Reid

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A

PRACTICAL TREATISE

ON

THE MANUFACTURE

OF

PORTLAND CEMENT;

BY

HENRY REID, C.E.

TO WHICH IS ADDED

A TRANSLATION OF M. A. LIPOWITZ'S WORK,

DESCRIBING A

NEW METHOD ADOPTED IN GERMANY OF MANUFACTURING
THAT CEMENT,

BY W. F. REID.

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PREFACE.

The following translated work on the manufacture of Portland Cement, as practised in Germany, shows evidence of the importance attached to the material in that country. Mr. Lipowitz gives the result of practical experience and also furnishes other data, of a valuable character, which, even to English manufacturers, may prove interesting if not instructive.

To England is due the credit of having first introduced the manufacture of Portland Cement on a large scale: her peculiarly advantageous position in having inexhaustible stores of the raw materials, in their cheapest and simplest conditions, coupled with the low price of fuel, enables this country to supply the article to every quarter of the globe.

France and Germany have hitherto been our principal customers; the careful attention bestowed on the application of Portland Cement, by the engineers and architects of these countries, has materially influenced its general improvement and consequent advancement.

English engineers and architects have until recently looked on this material with disfavour, from a belief in its unreliable and dangerous qualities; this distrust, from increasing experience, is gradually abating, and we may confidently look forward to an ultimately due appreciation of the many excellent qualities of this material, which will tend to increase its consumption at home and still further swell the now considerable item it forms in the list of the industrial exports of this country.

In placing these German results and experience before the engineering and architectural professions, as well as others interested in works of construction, I avail myself of the opportunity of describing the manufacture of Portland Cement as adopted in London and its neighbourhood. I am the more inclined to undertake this task from a feeling that much misapprehension continues to exist on the nature and composition of this Cement: some scientific authorities, otherwise safe and valuable guides, either misunderstand the importance of the subject or consider it too insignificant for their serious attention.

The recent extensive use of Portland Cement by the engineers of the Metropolitan Board of Works has led to much discussion in professional circles, tending to dissipate the fogs of prejudice and ignorance which have hitherto enveloped this important question of such primary value in the constructive art. The extensive works of the Main Drainage and Thames Embankments have enabled the engineers to introduce the best accessible materials, and they have with praiseworthy care and industry given great attention to Portland Cement, for the safe and reliable use of which material they have instituted and organized tests of undoubted value and excellence.

In describing the English system of making Portland Cement, I will confine myself more especially to the mode successfully carried on in the manufactories situated on the Rivers Thames and Medway. The plans, sections, and necessary details are of a practical and trustworthy character; they will differ from the German description, inasmuch as they only describe generally the nature of the process, at the same time embracing all necessary particulars that may be considered essential to a clear and useful understanding of the subject.

Portland Cement is now chemically described as a double silicate of Lime and Alumina, and possesses in an eminent degree the well-known property of hydraulicity, or capacity of setting and hardening under water. Indeed it may be familiarly described as an artificial improvement on the best hydraulic limes, with the additional excellent property of continuing good for a long period in any climate. Its manufacture was originally introduced about forty-four years ago, under a patent granted to J. Aspdin; but until within the last fifteen years the quantity made was comparatively limited, and might probably have continued so but for the intelligent appreciation of its merits by foreign engineers and architects. Large quantities of English Cement have been used in the construction of French harbours, docks, and fortifications; the early adoption by French engineers of this material is doubtless due to the great interest at all times displayed by them in the selection of suitable Limes and Cements for constructive purposes. The valuable researches in this direction of their eminent countrymen, Vicat, Berthier, and Treussart, cannot but have predisposed their minds to the investigation of a subject so brimful of interest and advantage.

Portland Cement is made from the deposits of chalks on the shores of the Rivers Thames and Medway mixed with alluvial clays from their estuaries and creeks; the simple nature of these ingredients render the manufacture of the Cements a comparatively easy operation, unless where gross carelessness permits an irregular mechanical admixture or manipulation of the several constituents. Much ignorance has been displayed in manufacturing this article, resulting, as may naturally be supposed, in much distrust and fear on the part of the engineer and architect, the reputation of the Cement being damaged in consequence. The larger manufactories that had supplied the French Government, and whose proprietors were necessarily controlled in the quality of the article by the rigorous tests of the French engineers, duly estimated the risks they had to encounter in contracting for such supplies; this necessity fortunately led to a full appreciation of the exigencies of their position, resulting in such improvements of the article that the limits of its excellence are now only controlled by its cost. More recently, the extensive operations carried on under the Metropolitan Board of Works have engendered a feeling of emulation to compete in supplying an article which shall successfully pass all the onerous conditions of the engineers, thereby proving that a good quality of Cement can be found when required.

In the somewhat censorious remarks, which Mr. Lipowitz considers it necessary to make regarding English Cement and its manufacturers, I will simply observe that a fair share of his reproof, in my opinion, should be borne by his countrymen; when excessive rivalry exists amongst merchants in supplying an imported article, like Cement, the tricks and evasions practised can only be successfully encountered by the vigilance of the consumer. Were rigid tests universally applied, adulterated or inferior Cement would cease to be made. No manufacturer would be found to risk the production of an article that could not find a market.

The tests organized by English engineers have now directed the manufacturer to the salient points of his commodity; Colonial engineers are now also insisting on equally stringent and rigorous conditions. This improved system of supervision will ultimately lead to great increase in the demand for an article possessing so many varied forms of application. Much attention is now being directed to the construction of houses and buildings with Portland Cement concrete; already large structures, such as sea and embankment walls, have been successfully built: indeed it is difficult to predict what may eventually be the uses to which so important a material may be applied. The unsolved problem of repairing our roads and streets (continuing to disgrace our scientific intelligence) may obtain its ultimate solution through the agency of Portland Cement; several experiments, partially successful, have already been made, but until those controlling our roads and thoroughfares dispel from their minds the heavy roller panacea, no immediate improvement can be expected in this direction.

Although the simple materials which in combination produce Portland Cement require but little dexterity in their manipulation, still, in the various processes which the ingredients undergo, a degree of intelligence is required from the workmen which unfortunately they do not always possess. The German process, on the contrary, indicates that much technical and scientific supervision is necessary to succeed in making a sound and serviceable article, capable of undergoing the tests of the chemist, engineer, or architect.

It is difficult to understand why so much apathy and indifference have been displayed, by our engineers and architects, in the treatment of the important question of Cement. Surely a subject of such primary necessity deserves proper consideration and investigation; that which engaged the serious attention of such men as Vitruvius, Smeaton, Pasley, and Vicat, cannot but be of interest to all connected with the constructive profession. Portland Cement has especially suffered from the inattention of the engineer and architect, who have unconsciously been instrumental in perpetuating errors in its preparation.

When the article was first made, in England, the original makers maintained an air of mystery in their operations, leading the public to believe that certain peculiarly gifted individuals were alone possessed with the necessary knowledge of the principle of manufacture. All such mystification and secrecy are happily exploded, and the business of a Cement manufacturer now depends for its success on the usual unavoidable conditions which regulate any other properly conducted commercial undertaking.

It will be my endeavour, in describing the English system of manufacturing Portland Cement, to follow as much as possible in the order which Mr. Lipowitz has adopted; there will be much dissimilarity in the various processes of manufactures described, yet they coincide in ultimate results.

Although desirous that sound and reliable information on this important subject should exist outside the manufacturing circle, I have no desire to find fault with any of those eminent manufacturers who have obtained a world-wide reputation for their Cements. A lengthened practical knowledge of the manufacture and application of Portland Cement induces me to undertake the present work, from a sincere desire to lay before the engineering and architectural professions information and experience which I trust will prove interesting and useful.

The plans and sections accompanying the English part of this work do not represent any existing manufactory, but are suggested as being the most advisable design which, in its uniformity and simplicity, will readily explain the various processes of manufacture.

HENRY REID.

London, *April*, 1868.

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THE

MANUFACTURE

OF

PORTLAND CEMENT.

CHAPTER I.

SELECTION OF SITE FOR MANUFACTORY.

In determining to erect works for the manufacture of Portland Cement, due regard to the convenient supply of the raw materials and fuel are elements of primary consideration. Mr. Lipowitz (German treatise, page 71) "does not recommend the construction of works unless they can command the supply of raw materials for twenty years at least." That period should be considered the very shortest in which the control of the raw materials should be secured. A manufactory depending so much on being supplied with materials of a cheap and bulky character for conversion into a commodity in itself of comparative small value, should be advantageously placed, not only for a time, but also at the cheapest possible rate for the supply of all the crude components required in the process.

The accessibility and cheapness of transit likewise deserves special attention. Even if the required materials are plentiful at a low price (unless your object be simply the supply of a limited local demand) the cost of carriage to the consumer is not to be disregarded; therefore, where practicable, the works may be erected at points on the sea-shore, on the banks of navigable rivers and canals, or connected by railways or their branches, so as to command conveyance at the cheapest rate. The more important manufactories in the neighbourhood of London are judiciously placed in this respect, and much of their success may be attributed to their excellent situation in commanding water-carriage to their principal points of consumption or shipment, at a cost of about 1*s.* 6*d.* per ton; their contiguity to the important Port of London also facilitates their shipping to foreign ports at low rates of freight.

It is not absolutely necessary that the works should be erected in any prescribed situation; but reasonable attention must be directed to the question of transit of all the materials, both raw and manufactured. I apprehend much difficulty would be met with in trying to obtain a site so favourably circumstanced as to combine all the essential requisites necessary to carry on successfully, and at the least possible cost, the business of a Cement Manufacturer.

To manufacture 100 casks of Cement per day, 240 tons, or thereabouts, of raw materials are required to be dealt with as under every week.

	TONS.
Chalk and Clay washed or otherwise mixed ..	240
Manufactured Materials shipped or delivered .	120
Fuel for Burning and Steam-power	40
Or a total of..	400

The above quantity of 400 tons is equal to upwards of 20,000 tons per annum, when the desired capacity of the Manufactory is constructed for 30,000 casks a-year; so that, to manufacture even this moderate quantity, a large weight requires handling or operating on. As the necessary quantity of Chalk forms about two-thirds of the whole of the raw materials, it is advisable to select a site where that article can be obtained at a cheap rate, having proper regard at the same time, however, to the chances of getting Coal and Clay at reasonable rates. In the London district, Chalk and Clay are readily procured at a minimum cost, and fuel, in the shape of coke from the gas-works in London, is usually purchased at a low price; so that a combination of more than ordinarily favourable circumstances places the London makers in an advantageous position for both purposes of manufacture and sale. Other producers of Portland Cement at Newcastle-on-Tyne, although deriving their supply of Chalk from the Thames (taken back as ballast by the coal-vessels), are enabled to compete with London makers in the foreign markets from the advantages possessed by them in having a command of cheap coals as well as a good port of shipment. I deem it necessary to direct attention to this subject to prevent the selection of an unsuitable situation being determined on for the erection of the manufactory, without due consideration of all the conditions necessary to success, and to show that there are other questions for deliberation besides that of a convenient supply of raw materials.

CHAPTER II.

RAW MATERIALS.

Chalk.

CHALK is a mineral so well known that it is not necessary to minutely describe its general features and characteristics. It forms, geologically, a large and important part of the eastern and southern counties of England, extending from Flamborough Head to Norwich; from thence south-west to Dorchester and nearly the whole southerly district, from a line drawn from Oxford through London to Margate, the latter surface alone exceeding four thousand square miles in extent. It is not found in Scotland, and only to a small extent in the north-east of Ireland. In France it extends from Calais, round Paris, to the mouth of the Seine. It also occurs in various parts of Germany, Denmark, and Russia.

The specific gravity of an ordinary specimen of chalk is 2·3 and contains by analysis:

Lime	56·5
Ca. Acid	43·0
Water	0·5

The chalk used in the manufacture of Portland Cement on the River Thames is obtained from the upper deposit, containing nodules of flints, and is generally described as the White Chalk. That used by the manufacturers on the banks of the Medway is obtained from the middle formation, containing considerable quantities of silicious matter, and is usually called the Gray Chalk.

The several deposits vary in density, differing in character according to their depth from the surface.

Clay.

The clay is procured from the alluvial deposits along the shores of the Rivers Thames and Medway and in the marshes adjoining, as well as in their creeks and inlets. The proper quality does not occur in large masses, and varies from a foot to three feet in depth. When fresh dug it is of a dark-blue colour, and feels smooth and greasy to the touch; in digging, the excavators require to exercise care in separating it from the sandy and ferruginous clays on which it rests, and also to reject all vegetable mould and fibre with which it is sometimes mixed. The marshes are generally covered at high water, and the mode of obtaining the clay is by barges which ground alongside the spot chosen for excavation. The selection of the clay is entrusted to men constantly employed for that purpose, who can be depended upon for their knowledge of its quality; this precaution is absolutely necessary to prevent the expense and loss should the clay be taken to the factory unsuitable for the purpose intended.

A fair analysis of the clay of a good and suitable quality is as follows (according to Feichtinger):—

Silica	68·45
Alumina..	11·64
Ca. Lime	0·75
Oxide of Iron..	14·80
Soda and Kali	4·0

The largest and most important cement-works are generally erected near the chalk-hills, and have an unlimited supply of that material at hand; the clay is, however, with few exceptions, brought from a distance, and costs on the average one shilling and sixpence per ton at the works.

Having secured the two materials solely employed in the neighbourhood of London for making the cement and satisfied himself as to their quality, the manufacturer will now have to exercise care and attention in their due and accurate manipulation.

CHAPTER III.

WASHING THE MATERIALS.

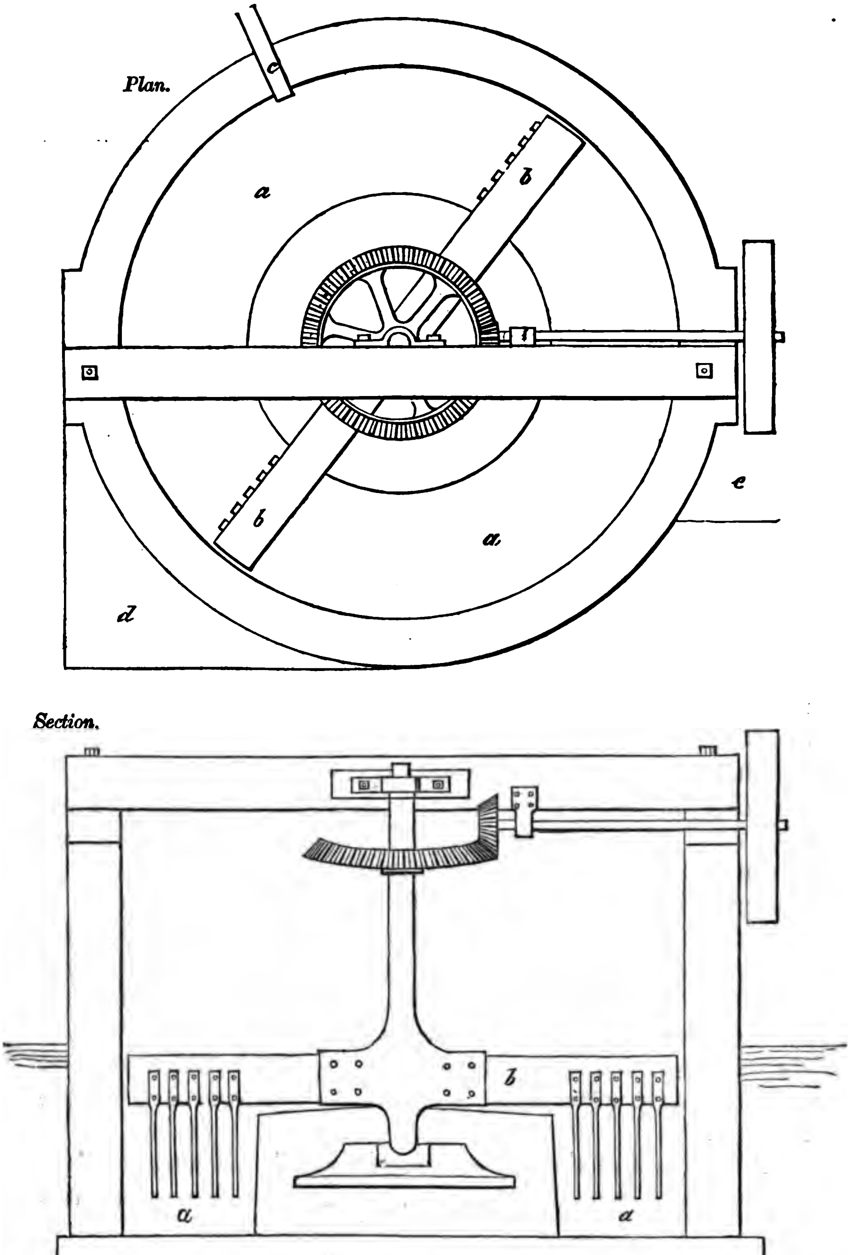
THE first process is what is technically called "washing," and consists of the proportionate and due admixture of the above-named materials; this is done in various ways according to the fancy or experience of the manufacturer. Edge-runners, harrows, and knives are all more or less successfully used. My experience inclines me to prefer the wash-mill of the following construction, as shown in Fig. 1ᵃ. It is, in my opinion, more economical, and, wherever I had an opportunity of doing so, I have erected it in preference to those of any other construction.

The wash-mill is circular, 18 feet in diameter, having a trough or channel *a*, from 3 to 4 feet wide and 4 feet deep, in which two sets of knives or dividers, fixed on the beam *b*, revolve at a speed of from ten to thirteen revolutions per minute; the trough is regularly supplied with a quantity of water, sufficient to keep the mixture to a consistency of thin cream when the whole is in a state of commotion, from the pipe *c*; the clay and chalk are thrown or tipped into the mill at the platform *d*, in the necessary and accurately ascertained proportions; at *e*, the trough is lowered from one foot to fifteen inches to permit the overflow of the mixed materials in solution, or intimate mechanical suspension, from which it passes by gravitation to the backs or reservoirs marked *A* on Plan, Plate IV. The adjustment of overflow is contingent on the speed of the mill and requires nicety of regulation so as to prevent the passage of undissolved particles of chalk or clay; it is sometimes necessary to place a finely perforated piece of zinc in front of this outlet, so as to ensure safety in this necessary part of the manufacture. Indeed, this initiatory operation of washing must be considered the most important one in the whole process of cement manufacture: if carelessness or ignorance permits an error to establish itself now, no perfection in any succeeding process can obliterate or rectify the mischief.

A wash-mill of the above description requires a power of eight horses to work it, and can be erected, including boiler, engine, and

WASH-MILL.

Fig. 1ᵃ.



machinery, ready for work, at a cost of from three to four hundred pounds. Such a mill is capable of washing from 40 to 50 tons of chalk and clay per day of 10 hours, at a cost of about 14*s.* per day, according to the value of fuel and labour of the locality.

The leading principle of this wash-mill (and what I believe to be its superiority over others) is, that in addition to the mechanical power of cutting by the action of the knives, great reduction of the materials is effected by attrition. The liquid (and much of the finer particles of the materials) is kept in a continual state of ebullition by the rotary wave in the trough. The wearing parts are the knives, which should be made of the best iron and steeled at the points. It is advisable to have a set always ready to put on the beam while the others are being repaired and lengthened, for the wear is considerable in consequence of the flints in the chalk and stones in the clay. The mill also requires cleaning out about once a month, so as to remove the fine flints, &c., which get concreted in the bottom.

To perform the amount of work above stated, three men are required regularly at the work, one of whom should be the leading man taking charge of the clay, and whose duty it is to see that each barrow of chalk is accurately marked or registered on the board fixed on the post of the mill for that purpose, before being tipped into the trough; and, whenever the proportion of chalk-barrows have been recorded, the leading man or ganger brings the barrow of clay to the mill, making a diagonal mark on the board across the number of barrows of chalk, showing thereby that the due proportions have passed into the mill. Barrows holding about one-fifth of a cubic yard are the best suited for this work; they should be filled level, never heaped. Too much importance cannot be attached to this part of the process, as the future success of all the other operations depends on the care that may be bestowed on the washing. If improperly mixed materials pass into the back, all the care and knowledge possible cannot remedy the evil. No after-manipulation can rectify a mistake committed in the washing. I therefore consider it necessary to point out thus minutely all the details of a process, in itself apparently simple, but if carelessly or improperly performed entails incalculable loss on the manufacturer, and which none but those practically acquainted with the business can fully appreciate or estimate.

The manufacturer's attention is here particularly directed to the acquirement of a reliable knowledge of the material with which he has to deal. If his works are situated within the circle of some proved chalk district, the established experience will guide him; but if otherwise, his first task will be to ascertain the lime, alumina, and silica value of the materials at his command.

Mr. Lipowitz (in pages 2, 3, and 4, German treatise) describes the simplest method of analysis; but for those wishing more comprehensive details I here copy from General Gilmore's treatise on limes, hydraulic cements, and mortars, the method of analyzing practised by the American chemists. I most willingly give this extract in full, as I consider it valuable to those who may from necessity or inclination desire to ascertain accurately the quality of the materials with which they have to deal. The process of analysis is quite exhaustive enough for any practical purpose, and is simple and easily performed.

QUALITATIVE EXAMINATION OF HYDRAULIC LIMESTONES.

Hydraulic limestones are characterized, as a class, by their fine-grained, compact, or granular texture, presenting a conchoidal fracture, yielding readily to a file or sharp-pointed instrument, and effervescing more or less freely, on the application of hydrochloric or nitric acids.

The prevailing colours are gray, bluish-gray, grayish-white, and drab, with intermediate shades.

The powdered mineral is more readily acted on by the acids than the massive form.

Hydraulic limestones will generally be found to contain *silica, alumina, oxide of iron, oxide of manganese, lime, magnesia, potash, soda,* with *carbonic, sulphuric, and phosphoric acids,* and occasionally some organic matter of a bituminous nature. As some of these may be absent, it will be necessary to ascertain the character of those present, before proceeding to an ultimate quantitative analysis.

For this purpose an unweighed portion of the mineral is reduced to a fine powder in an agate mortar, and digested in one measure of water for eight or ten hours, aided by the gentle heat of a sand-bath, and the solution is then filtered clear, and divided into so many equal portions in wine-glasses.

Nitrate of baryta added to one of these gives a white precipitate, which does not disappear on the addition of nitric or hydrochloric acid, and indicates the pressure of *sulphuric acid.*

By evaporating another portion to *dryness,* in a sand-bath, at a gentle heat, and igniting the residue, subsequent addition of hydrochloric acid, followed by diluting with an excess of water, will cause the *silica* to separate as a gelatinous hydrated precipitate.

If another portion be treated with pure water of ammonia, and gives a pure white gelatinous precipitate, it indicates the presence of *alumina* or *magnesia,* or both.

In this case hydrochloric acid must be added, until the precipitate is re-dissolved, and the solution rendered distinctly acid. If, on the addition of ammonia, the precipitate reappears undiminished in quantity, it contains *alumina* only; if it be distinctly less in quantity, we may infer the presence of both *magnesia and alumina;* but if no precipitate now appears, it contains *magnesia* only.

If the precipitate above by ammonia has more or less of a brown colour, the presence of *oxide of iron* or *manganese* may be inferred; but if after re-dissolving and adding ammonia as above, the brown colour disappears, it is due to the *oxide of manganese* only. Should the brown colour still continue, it is owing chiefly to the presence of *oxide of iron.*

If, after the addition of ammonia, the solution be filtered to remove the magnesia, alumina, the oxides of iron, and manganese, *oxalate of ammonia* be added to the filtrate, causing a white precipitate, it indicates the presence of *lime.*

If *oxalate of ammonia* be added, until all the lime be precipitated, and then filtered, and the filtrate be evaporated to dryness, and ignited to destroy the excess of oxalate of ammonia, the residue, if found to be soluble in water, indicates the presence of *potash* or *soda* or both.

If, upon treating the last solution with pure bi-chloride of platinum, no precipitate appears, we may infer the presence of *soda;* but if a yellow precipitate appears, *potash* is present in the solution.

The yellow precipitate of potash and platinum having been collected on a filter, the filter treated with sulphide of hydrogen, and again filtered, to separate the excess of bi-chloride of platinum, and then evaporated to dryness, a residue soluble in water remaining indicates the presence of *soda.*

Returning to one of the original wine-glass solutions, to which a portion of strong nitric acid must be added, if it be then dropped into a solution of *molybdate of ammonia*, and a yellow precipitate appears, it indicates the presence of *phosphoric acid.*

The presence of bituminous matter is shown by the odour or loss of weight upon igniting a specimen previously dried at 212° Fahrenheit.

QUANTITATIVE EXAMINATION OF HYDRAULIC LIMESTONES.

It is usual in conducting this process to ascertain—

1. The specific gravity. 2. The amount of hygrometric water. 3. The amount of phosphoric acid. 4. The amount of silica and insoluble matter. 5. The amount of alumina. 6. The amount of oxide of iron. 7. The amount of oxide of manganese. 8. The amount of carbonate of lime. 9. The amount of sulphuric acid. 10. The amount of potash and soda. 11. The amount of carbonate of magnesia.

The specific gravity of the specimen to be analyzed having been determined, a portion of the mineral is reduced to fine powder in an agate mortar, and a given quantity, say 50 grains, is placed in a platinum crucible previously counterpoised with its cover. The crucible and its contents are then to be placed in a steam-bath oven, and heated for two hours, when it is to be cooled in a receiver over sulphuric acid, and then quickly weighed. The loss in weight is the weight of the uncombined water.

The contents of the crucible must then be transferred to a beaker glass, and digested in strong nitric acid, to which a little hydrochloric acid has been added, for forty-eight hours, the action being favoured meantime by the gentle heat of a sand-bath.

At the termination of this process, the solution is to be filtered, an excess of molybdate of ammonia added to the filtrate, and the whole evaporated nearly to dryness.

During the process, the chlorine of the hydrochloric acid, aided by the excess of nitric acid, decomposes the ammonia of the molybdate of ammonia, and the molybdic acid goes down with the phosphoric acid, as *phospho-molybdate of ammonia*, in the form of a yellow precipitate, with the formula, $2\,(3\,NH_4\,O.\ PO_5) + 15\,(HO.\ 4Mo\ O_3)$. This precipitate is insoluble in water and in nitric acid. After diluting the mixture and giving it time to settle, the precipitate is collected on a filter, washed in pure cold water, and, while yet moist, dissolved in ammonia (the beaker glass being rinsed with the latter and added thereto).

From this solution in ammonia, sulphate of magnesia precipitates all the phosphoric acid as *ammonia phosphate of magnesia.* This is to be washed with dilute water of ammonia, collected on a filter, dried, ignited at low red-heat, and weighed,—the filter having been burnt and the ashes added to the rest.

Deducting the weight of the filter, every 100 grains of phosphate of magnesia thus obtained contain 64·06 grains of *phosphoric acid;* every 100 grains of phosphoric acid may represent 217·60 of phosphate of lime.

This determination of *phosphoric acid* being an *independent* process, the filtered solution left above is thrown away, and, as in the start, a new solution must be prepared.

Fifty grains of the same mineral, prepared and dried as before at 212°, are now to be dissolved in strong hydrochloric acid, the action being favoured by the gentle heat of a sand-bath for forty-eight hours, after which the solution is to be diluted with water, filtered,—and the *silica* and *insoluble silicates* washed, dried, ignited, and weighed, are recorded.

The filtered solution from the preceding is then precipitated by strong ammonia, and the precipitate, consisting of *alumina, oxide of iron,* and *phosphates,* after being well washed, is transferred while moist, filter included, into a strong solution of pure potash, which dissolves out the *alumina.*

This potash solution, filtered from the oxide of iron, &c., is rendered acid by the addition of hydrochloric acid, and the *alumina* is then thrown down by an excess of ammonia with a little sulphide of ammonium.

The precipitate thus obtained is washed with hot water, dried, ignited, and weighed. Deducting the weight of the filter, we record the absolute weight of the *alumina.*

The oxides of iron and manganese remaining from the potash solution, are dissolved from the filter in hydrochloric acid, the solution *carefully* neutralized by ammonia, and then, by the addition of succinate of ammonia, succinate of iron is precipitated.

Upon filtering this, and adding ammonia to withdraw the succinic acid, the residue is washed, dried, ignited, weighed, and the weight of the *oxide of iron* ascertained.

To the preceding filtrate, concentrated to a small bulk by evaporation, sulphide of ammonium is added, causing a precipitate of sulphide of manganese. The latter, collected on a filter, washed, dried, and *thoroughly roasted,* changes the sulphide into *oxide of manganese,* which is then weighed.

Return now to the first filtrate, caused by the addition of ammonia to the original acid solution, and which contains the lime, magnesia, and sulphuric acid simultaneously. With the processes described we precipitate the lime by *oxalate of ammonia*. Collect it after eight or ten hours' repose, on a filter, and weigh it; deducting the ashes of the filter, the weight of *carbonate of lime* is known. Every 100 grains contain 44 of lime.

The filtrate now contains a quantity of oxalate of ammonia, and ammoniacal salts, to decompose which, pure nitric acid is added in excess, and the filtrate evaporated to dryness. Re-dissolve the residue in hydrochloric acid, to which an excess of nitric acid has been added, and again evaporate to dryness. This dried residue of nitrates is now *drenched* with pure acetic acid, and then washed with water. Upon the addition of *acetate of barytes* to the solution, the *sulphuric acid* present is precipitated as *sulphate of barytes*, which is collected on a filter, dried, and weighed. Every 100 grains contain 34·31 of *sulphuric acid.*

The filtrate from the sulphate of barytes is now evaporated to dryness, and transferred by a little oxalic acid and water into a small porcelain crucible, in which it is heated, and again evaporated to dryness with an excess of pure oxalic acid, which changes the nitrates into oxalates.

The dried residuum thus obtained contains the alkalies and the magnesia, and must then be perfectly ignited, to change all the oxalates into carbonates. In order to separate the *alkalies* from the other ingredients in this last residuum, it is dissolved and thoroughly washed through a filter with water. The dissolved carbonates contained in the filtrate are changed into chlorides by the aid of a little hydrochloric acid, and then, evaporating the filtrate to dryness and igniting, the saline residue is weighed, and the weight of the alkaline *chlorides of potassium* and *sodium* recorded.

Re-dissolving the mixture of alkaline chlorides in a small quantity of water, a solution of bi-chloride of platinum is added, and the whole of the chloride of potassium present is changed into the double chloride of platinum and potassium, appearing as a yellow, insoluble precipitate.

Being evaporated by a gentle heat to near dryness, weak alcohol is added to dissolve the chloride of sodium, and any excess of the platinum salt which may be present. The yellow powder is collected on a filter, washed well with alcohol, dried, and weighed.

Every 100 grains indicate the presence of 19·31 of *potash*, or 30·51 of the *chloride of potassium.*

The weight of the chloride of potassium thus obtained, deducted from the weight of the mixed alkaline chlorides, gives the weight of the *chloride of sodium.*

Every 100 grains of the latter indicate the presence of 53·17 of soda in the limestone.

The *magnesia* which remains in the portion of the residuum which is insoluble in water, is now dissolved on the filter in diluted sulphuric acid, and after evaporating and igniting in a platinum crucible, is weighed as *sulphate of magnesia.*

Every 100 grains contain 53·33 of *magnesia;* 100 grains of *magnesia* indicate 210 of *carbonate of magnesia.*

It will be perceived by the foregoing process, that, with the exception of the moisture, organic matter, and *phosphoric acid,* which we estimated in a separate quantity of the limestone, all the ingredients have been determined from a single weighed portion, and thus a check over the whole is secured; for if the sum of the weights of all the ingredients varies much from the 50 grains of limestone used at the outset, it is proof of error in the process.

Should the amount of *silica* and *insoluble silicates* be large, they should be fused with three times their weight of carbonate of soda, for three or four hours, by which they may be brought into a soluble condition, and the solution treated as in the foregoing, and the sum of the weights ascertained.

As the following Table, No. 1, is the result of a series of analyses conducted by the above process, I think it advisable to place it here, as it contains six analyses of English and Scotch cement stones.

Table No. 2 consists of the analyses of various limestones in different parts of England and Wales.

A very simple method, recommended by Berthier, for an approximate analysis of limestone is given below.

In order to estimate the qualities of a calcareous stone as a limestone, it is sufficient to determine the quantities of clay and magnesia contained in it.

Pulverize the stone and pass the powder through a silken sieve; put ten grains of this powder into a capsule, and pour over it, a little at a time, muriatic acid, nitric acid, or vinegar diluted with a small quantity of water, agitating at the same time with a glass tube or small stick; discontinue adding the acid when it ceases to effervesce;

Table I.—ANALYSES OF VARIOUS CEMENT STONES.

Where obtained.	Carbonic Acid.	Potash.	Soda.	Silica, Clay, & insoluble Silicates.	Silica.	Alumina.	Oxide of Iron.	Peroxide of Iron.	Carbonate of Iron.	Carbonate of Lime.	Lime.	Carbonate of Magnesia.	Magnesia.	Sulphuric Acid.	Chloride of Potassium and Sodium.	Phosphates, &c.	Brown Oxide of Manganese.	Hygrometric Water lost at 212° F.	Water and loss.	Excess (−) or loss (+).	By whom analyzed.
Utica, Illinois	..	·62	·88	25·20	..	6·16	..	2·02	..	58·84	..	..	10·38	·48	..	..	..	·40	..	−4·98	Prof. E. C. Boynton
Sandusky, Ohio	..	·40	12·10	19·66	..	3·14	..	3·86	..	40·54	..	..	17·98	·72	..	..	..	·38	..	+1·22	Ditto.
Cumberland, Maryland	..	1·54	4·64	24·74	..	16·74	..	6·30	..	41·80	..	..	4·10	2·22	..	..	..	·60	..	2·68	Ditto.
Shepherdstown, Virginia	..	..	..	17·84	..	4·60	..	1·70	..	58·25	..	11·16	..	·74	3·26	..	..	·20	..	+2·25	Ditto.
From High Falls, Ulster, New York: Layer No. 9	..	..	..	18·52	..	2·18	..	1·86	..	43·30	..	26·04	..	1·96	4·24	..	..	·20	..	+1·70	Ditto.
Ditto „ 10	..	..	..	29·34	..	5·74	..	1·76	..	33·54	..	20·80	..	1·02	5·80	..	..	·16	..	+2·04	Ditto.
Ditto „ 11	..	..	..	39·74	..	6·00	..	1·44	..	30·74	..	14·48	..	·66	7·42	..	..	·24	..	− ·72	Ditto.
Ditto „ 12	..	..	..	19·64	..	7·52	..	2·38	..	30·72	..	35·10	..	·64	4·10	..	..	·18	..	− ·28	Ditto.
Ditto „ 13	..	..	..	26·00	..	4·64	..	1·86	..	28·48	..	32·86	..	1·18	4·72	..	..	·26	..	..	Ditto.
Ditto „ 14	..	..	..	28·08	..	5 72	..	5·38	..	43·32	..	14·52	..	1·60	2·78	..	..	·20	..	−1·60	Ditto.
Ditto „ 15	..	..	..	18·46	..	4·22	..	2·32	..	37·50	..	35·62	..	·20	1·68	..	..	1·40	..	−1·40	Ditto.
Ditto „ 16	..	..	..	27·70	..	2·34	..	1·26	..	46·00	..	17·76	..	·26	4·02	..	..	·22	..	+ ·44	Ditto.
Ditto „ 17	..	..	..	11·10	..	2·52	..	1·42	..	40·00	..	39·04	..	·22	4·06	..	..	·26	..	+1·38	Ditto.
Lawrenceville, Ulster County, New York	..	..	..	19·80	..	4·40	..	·76	..	33·90	..	34·06	..	·32	4·78	..	..	1·56	..	+ ·42	Ditto.
Akron, Erie County, New York	..	..	..	33·80	..	3·96	..	·88	..	35·60	..	19·26	..	·50	6·18	..	..	·14	..	− ·32	Ditto.
Points-aux-Roches, Lake Champulin	·0333 (potash and soda)			..	20·07	1·7 (alumina and oxide of iron)		..	..	53·3	..	22·6	..	..	..	..	..	..	1·666	..	Lt. Caleb Huse.
Near Hancock, Maryland	·3000 (potash and soda)			..	27·1	1·5 (alumina and oxide of iron)		..	..	65·0	..	5·3	..	..	..	..	..	..	·8	..	Ditto.
Vassy (France) cement	..	..	..	..	14·0	5·7	..	..	11·6	63·8	..	1·5	..	..	..	..	..	..	3·4	..	Not named.

TABLE I.—ANALYSES OF VARIOUS CEMENT STONES—*continued.*

WHERE OBTAINED.	Carbonic Acid.	Potash.	Soda.	Silica, Clay, & insoluble Silicates.	Silica.	Alumina.	Oxide of Iron.	Peroxide of Iron.	Carbonate of Iron.	Carbonate of Lime.	Lime.	Carbonate of Magnesia.	Magnesia.	Sulphuric Acid.	Chloride of Potassium and Sodium.	Phosphates, &c.	Brown Oxide of Manganese.	Hygrometric Water lost at 212° F.	Waterand loss.	Excess (−) or loss (+).	By whom analyzed.
Theil (France) limestone ..	36·28	..	..	..	14·90 (silica and alumina)			1·70 (oxide, peroxide and carbonate of iron)		..	45·63	..	·39	..	..	..	..	..	Water and bitumen. 1·10	..	Not named.
Theil (France) ditto when burnt	8·00	..	..	..	18·20	1·20		·80 (oxide, peroxide and carbonate of iron)		..	60·00	..	1·32	..	..	..	..	..	10·48	..	Ditto.
From Balcony Falls, Rockbridge County, Virginia (raw)	30·4	·120	..	..	34·22	7·800 (alumina and oxide of iron)		..	..	..	17·38	..	9·51	..	..	..	..	..	Water and organic matters. ·500	+ ·06	Ditto.
Ditto ditto (burnt)	..	..	..	..	49·53	11·288 (alumina and oxide of iron)		..	..	..	25·15	..	13·77	..	..	..	..	..	..	+ ·26	Ditto.
Calderwood (Scotland), cement-stone	34·30	..	..	..	8·80	3·40	..	Protoxide of iron. 10·20	..	..	30·24	..	6·76	..	..	2·66	..	..	3·64	+5·58	Prof. F. Penny.
Sheppy (England) stone, No. 1	31·00	..	..	..	18·00	..	5·25	..	..	..	30·20	..	·20	..	..	..	6·75	..	..	..	Not named.
Ditto ditto No. 2	29·00	..	..	..	17·75	..	6·00	..	..	..	35·00	..	·50	..	..	..	1·00	..	3·00	+1·06	Ditto.
Southend (England) cement-stone	29·77	..	..	..	12·00	..	8·80	..	..	..	34·08	..	1·52	..	..	..	..	..	..	+ ·33	Ditto.
Yorkshire Ditto ditto	31·00	..	..	..	24·00	..	1·31	..	..	..	30·50	..	1·04	..	..	..	..	..	..	+5·40	D.tto.
Harwich Ditto ditto	22·75	..	..	..	9·37	..	17·75	..	..	..	29·25	..	..	Sulphate of soda, &c. 7·50		..	..	..	3·87	..	Ditto.
Trass .. { Used by Genl. Treussart at Strasburg }	..	7·0	1·0	..	57·0	..	5·0	..	..	..	2·6	..	1·0	..	..	..	..	..	9·6	+ ·48	Berthier.
Pozzolana { Used by Genl. Treussart at Strasburg } ..	..	1·4	4·0	..	44·5	..	12·0	..	..	..	8·8	..	4·7	..	..	..	..	..	9·2	+ ·4	Ditto.
From Lockport, Niagara County, New York (burnt, rather old)	16·57	..	..	..	23·94	19·18 (alumina and oxide of iron)		..	..	..	40·31	..	..	..	..	..	..	..	..	..	.. ..

TABLE II.—ANALYSES OF VARIOUS LIMESTONES.

DESCRIPTION.	LOCALITY.	By whom analyzed.	Carbonic Acid.	Lime.	Carbonate of Lime.	Carbonate of Magnesia.	Iron Alumina.	Alumina.	Silica.	Bitumen.	Water and loss.	Oxide of Iron.	Residuum.	Iron and Clay.	Magnesia.	REMARKS.
Magnesian ..	Near York	Smithson Tennant	47·00	33·24	..	..	..	..	..	..	..	..	..	0·40	19·36	York Minster is built of this stone.
Ditto	Denton, ditto ..	Rev. J. Holme ..	..	..	63·0	30·0	..	2·25	..	..	0·25	..	..	..	..	
Ditto	Eldon	Sir H. Davy	..	..	52·0	45·2	1·1	..	..	..	..	..	1·7	..	..	
Ditto	Aycliffe	Ditto	..	..	45·9	44·6	1·57	..	..	..	..	..	2·8	..	..	
Ditto	Portishead, near Bristol..	Dr. Gilby	..	..	53·5	37·5	..	..	..	..	1·2	0·8	7·0	..	..	A conglomerate in contract with the new Red Sandstone.
Ditto	4 miles N.W. of Bristol..	Ditto	..	..	58·0	38·0	..	..	1·5		..	1·1	1·4	..	..	
Ditto	Bolsover, Derbyshire	Professors Daniell and Wheatstone	..	..	51·5	40·2	1·8	..	3·6	..	3·3	..	..	..	..	Analyzed for the Committee appointed to decide on the most suitable stone with which to build the Houses of Parliament.
Ditto	Huddlestone, Yorkshire	Ditto ditto	..	..	54·19	41·37	0·30	..	2·53	..	1·61	..	..	..	..	
Ditto	Roach Abbey, ditto	Ditto ditto	..	..	57·5	39·4	0·7	..	0·8	..	1·6	..	..	..	..	
Ditto	Park Nook, ditto ..	Ditto ditto	..	..	55·7	41·6	0·4	..	..	..	2·3	..	..	..	..	
Oolites	Ancaster, Lincolnshire	Ditto ditto	..	..	93·59	2·90	0·80	..	..	Trace.	2·71	..	..	..	..	
Ditto	Bath Box, Somerset	Ditto ditto	..	..	94·52	2·50	1·20	..	..	Trace.	1·78	..	..	..	..	
Ditto	Portland, Dorset ..	Ditto ditto	..	..	95·16	1·20	0·50	..	1·20	Trace.	1·94	..	..	..	..	
Ditto	Ketton, Rutlandshire	Ditto ditto	..	..	92·17	4·10	0·90	..	..	Trace.	2·83	..	..	..	..	
Ditto																
Shelly Oolite ..	Barnack, Northamptonshire	Ditto ditto	..	..	93·4	3·8	1·3	..	..	Trace.	1·5	..	..	..	..	
Ditto	Ham Hill, Somersetshire	Ditto ditto	..	..	79·3	5·2	8·3	..	4·7	Trace.	2·5	..	..	..	..	
Siliciferous ..	Chilmark, Wiltshire	Ditto ditto	..	..	79·0	3·7	2·0	..	10·4	Trace.	4·2	..	..	..	..	
Carboniferous..	Whiteford, Flintshire, N. Wales ..	Dr. Clarke	40·10	49·65	..	..	..	8·80	0·60	0·60	0·25	..	..	..	..	
Blue Lias ..	Holywell, ditto ..	Dr. J. Muspratt ..	..	..	71·55	1·35	..	3·52	20·1	..	0·5	2·21		Alkalies. 0·79	..	74·73 soluble, 25·27 insoluble in acids.

effervesce; then evaporate the solution with a gentle heat, until the whole is reduced to a pasty consistence; dilute it in about half. a litre of water, and filter it; the clay remains on the filter, and must be dried in the sun or by a fire, and weighed; or it will be better before weighing to calcine it to a red heat in an earthen or metal crucible. Pour very limpid lime-water into the solution, as much as to cause a precipitate; collect this precipitate, which is the magnesia, as quickly as possible upon a filter; wash it with pure water, calcine or otherwise dry it as much as possible, and then weigh it. If there be any iron or manganese in the solution, they will precipitate with the magnesia. It would be superfluous to attempt to separate these three substances from each other.

CHAPTER IV.

SAMPLING THE WASHED MATERIALS.

THE preceding Tables of Analyses will be useful to those who may require to make Portland Cement in any of the localities from which the specimens are taken; to enable them to do this, the dry process advocated by Mr. Lipowitz will have to be adopted.

If the materials required to be operated on are simple chalks and clays, analogous in character to those of the Rivers Thames and Medway, there will not be much difficulty in arriving at the proper mixture. The present and safest proportions are, provided both chalk and clay are selected free from sand, four parts of chalk from the Medway (gray), or three parts of Thames (white), with one of clay by measure.

These proportions are subject to modification, according to the state of the chalk and clay; the amount of water they absorb is variable. Chalk usually contains a minimum quantity of moisture (under a temperature of 100° F.) of 12½ %. The clay is also very moist, and on the average 30 % may be allowed for it. So that although the materials are in themselves simple, yet the fluctuating quantity of water they contain necessitates an ever-vigilant attention to the process of washing: whether you adopt a measure of capacity or weight this difficulty will be encountered, and must be met by a regular system of sampling of the mixed materials as they leave the wash-mill. Sampling, to ascertain result of proportions, should be considered by all Portland Cement manufacturers as an indispensable part of their operations. In some large works men are specially and solely employed for this purpose.

There are various modes of sampling adopted, but I consider the following a simple and safe one.

Take at regular intervals during the day a quantity of the semi-liquid overflowing from the wash-mill—say from 30 to 40 gallons at a time,—place it on the hot plates near the sample kiln *O*. This may be dried in four or five hours, according to the temperature of the plates. When dry enough it should be at once put into the sample-kiln and burnt; no time should be lost in doing this, so as to have the earliest evidence of the condition of the washing. The sample should be moderately well burnt, and when quite cool pounded in a mortar, from which it is sifted in a fine meshed sieve (of about 2000 meshes to the square inch). Make a sample from the powder with the least possible quantity of water, which divide into two circular pats, three or four inches in diameter and half an inch thick. Place one of them, when sufficiently set, into a basin of water, leaving the other in a dry place—the first with the object of proving the hydraulicity of the mixture, and the other the colour. After an interval of 24 hours, the samples should be carefully examined in a good light, and if the water-sample is free from cracks or fissures it may be passed as sound, or at least may be considered safely mixed with the proper proportion of carbonate of lime. If on examination the air or dry pat appears of a blue-gray colour, without any stains or brown specks, you may safely continue the proportions of chalk and clay represented by the duplicate samples. But if on the contrary the water-sample gives way, cracking and flying, as it is technically called, no time must be lost in reducing your measure of chalk or increasing the quantity of clay. Again, should the water-sample continue sound in appearance after 24 hours' immersion, having set quickly when being worked up into the pat, and the air-sample of a brown colour, you may consider the mixture over-clayed, and instant steps must be taken to alter the proportions.

The sampling should be entrusted to a reliable workman, who must keep a register of all his samples, marking each, when soft, with the date and distinguishing marks between water and air samples. No samples should be destroyed until after the lapse of a month, so that they may be frequently examined in case any exceptional phenomenon should be displayed in the interval. Sometimes, through carelessness or by allowing the knives to revolve at too high a speed, the particles of chalk are passed out of the mill in too large pieces, and consequently after being burnt become developed in the sample as slaked lime. This state of things should, however, be considered as very exceptional, and such a circumstance ought not to occur in any well-conducted manufactory.

CHAPTER V.

REVIEW OF THE TWO METHODS OF PREPARING THE RAW MATERIALS.

HAVING thus far described the English mode of preparing the raw materials, I will now proceed to compare that system with Mr. Lipowitz's, as practised in Germany.

By both processes a perfectly accurate admixture of the raw materials is indispensable, and therefore the manufacturer's attention is again specially directed to this point.

In using water for mechanically combining the materials, a considerable saving of power is effected. One objection, however, to this process is the loss of some of the soluble ingredients, when being decanted, by evaporation and absorption, as well as that portion which is drained off with the surplus water from the backs. Another difficulty met with is from the irregularity with which the various materials are precipitated from their water of solution. The necessity of washing the mixture in a very fluid state increases this difficulty, which is generally overcome—as far as possible, at least—by what the workmen call "luting the backs"—that is, agitating by means of a perforated board, attached to a long handle, the washed materials when first passed from the mill.

It is obvious that a considerable time must elapse before materials so treated are ready for further manipulation; and, unless some expensive means of dessication are resorted to, a period of from two to three months is required to prepare the materials for the next part of the process.

I should here remark that almost all chalks and clays are mixed with variable quantities of insoluble sand, and therefore this objectionable ingredient should not be allowed to get mixed with the other materials. It is sometimes necessary to make special arrangements to separate it from the washed mixture; some manufacturers even adopt mechanical agency for its minute distribution throughout the whole mass. My experience, however, leads me, by preference, to recommend its entire withdrawal or separation: this is readily effected, as the sand usually collects at the point of the back where the drain from the wash-mill is fixed. It should only be treated as waste, for, from careless washing, it frequently contains pieces of chalk too large to be beneficially affected by the subsequent chemical action in the kilns.

The primary object, in both methods, is the attainment of accurately and minutely mixed materials; this is accomplished by the one system through the agency of an expensive mechanical process, and in the other obtained with much more simple and less expensive machinery, greatly assisted by water as a solvent, acting mechanically as well as chemically.

The relative cost of the two processes differ widely, and is much in favour of the wet system. I should say that the expense of reducing and mixing the raw materials by Mr. Lipowitz's method cannot be less than 3*s.* per ton, under the most favourable circumstances, while by the washing operation it does not amount to one-third of that sum; so far, therefore, the advantage of mechanical cost is in favour of the English method, and I will now proceed to point out that in subsequent operations this superiority, in my opinion, is not maintained.

For the more ready illustration of the comparative merits of the two systems, I will assume that the same quantity is to be manufactured—namely, 100 casks per day, which is the capacity of the manufactory described by Mr. Lipowitz. This is equal to 20 tons, or thereabouts, according to its quality, of manufactured cement. As the washing process is only applicable when chalk or soft calcareous earth is to be used, I will assume therefore, for the purposes of comparison, that the dry method is adopted to treat or convert the same description of materials that are found and dealt with in the Rivers Thames and Medway.

By calcination, and after making due allowance for waste, there is a loss in weight of 50 per cent. between the raw materials put into the kiln and the result in manufactured cement obtained at the spouts of the horizontal millstones; so that to manufacture 100 casks per day, or 120 tons of marketable cement per week, 240 tons of raw materials are required; that quantity would suffice by the dry method after the chalk, &c., had been freed from its moisture by the action of heat in the drying kiln, as explained at page 17 of the German treatise. In the wet process, however, a much greater increase of weight is entailed from the necessity of mixing sufficient water with the raw materials to render the mixture fluid enough to flow into the backs or reservoirs; at least 400 tons of washed materials, including the absorbed water left after decantation, will be required to produce 120 tons of finished cement per week; it will be necessary, therefore, to provide cubical space large enough to contain 600 cubic yards of washed material in each week. I have already observed that an interval of two months, at least, is required to allow the materials to settle and dry, so that to meet the requirements of a manufactory of the above-described capacity an available space eight times that of one week's washing is necessary, or 4800 cubic yards; this would require a surface of nearly an acre if the backs were one yard deep; so great a surface is only obtainable where land is of comparatively small value.

The space therefore, under the conditions named in the above description, for the reception of one week's washing is an acre, and the weight to be dealt with 400 tons; whereas by the dry method an insignificant amount of room only is required, and the weight but 240 tons, in obtaining equivalent results. The necessity of delay in allowing the raw materials to settle and dry entails the great cost of space and in like manner adds to the weight. It should be observed that in the dry process from 30 to 35 per cent. of water is required to render the raw cement powder plastic (see page 32 of the German treatise). This amount of moisture being only applied for a temporary purpose, becomes evaporated or expelled by heat in the drying channels in a short time, and need not be further referred to in this comparison.

While therefore, by one method, the material washed is not available for further operation until an interval of two months has elapsed, by the other method, when ground dry, the further process may be continued and even perfected in the same day—obviously a great and important advantage, preventing thereby the necessity of locking up an amount of capital represented by the value of two months' washed materials; so that, notwithstanding the extra cost of grinding over that of the washing, there are other considerations in the question which, when duly estimated, may leave the balance in favour of the German system. [This matter will receive further comment in describing the subsequent stages of the manufacture.] One disadvantage, consequent on the necessity of occupying so large a surface, consists in the unavoidable expense incurred in manual labour by wheeling the washed material from the backs to the drying plates.

CHAPTER VI.

DESCRIPTION OF THE BACKS, OR RESERVOIRS.

THE selection of the site for the backs requires some consideration, as their position in relation to the mill and drying-plates is of the utmost consequence in the economy of the manufactory. The large amount of space required for this department of the manufacture necessitates an arrangement whereby they will not interfere with the accessibility to the wharf, or landing, for the unloading of the raw materials, and the subsequent shipment of the manufactured cement. Having this desirable condition in view, I placed the backs *A*, as shown in Plate IV., behind and, as far as possible, surrounding the kilns and drying-plates. The distance from the wash-mill is immaterial, for the outflow from it proceeds by gravitation to the several backs, by the descending drains or channels, represented in the plans and sections, Plate IV.

In some manufactories the backs are situated at a considerable height above the general level of the works; in such cases the washed material is thrown up by force-pumps, this disadvantage, however, being counterbalanced by an arrangement of the drying-plates, whereby the waste heat from the kilns is utilized.

As before described, a weekly quantity of 400 tons is required, to accommodate which a cubical space of 600 yards will be necessary; this would represent a superficial area of the same number of square yards, supposing the backs were constructed one yard deep; the suitable dimensions therefore (as shown on plan, Plate IV.) for each back is 90 ft. by 60 ft., and that multiplied again by 8 will give the total number of square feet for the whole back, or reservoir arrangement, capable of containing two months' work of the wash-mill, the other succeeding operations absorbing one week's washing, so that one back will be emptied and another filled, an arrangement of this kind is not necessarily an arbitrary one, as possibly, under certain circumstances, it may be more convenient to have two backs filling and two being emptied at one and the same time ; all these are matters of detail which may be fairly left to the intelligence of the manager or foreman of the works.

It is advisable to construct the walls of the backs with brickwork, or cement concrete, and the bottoms should be paved with either of these materials. By such a mode of construction the difficulty of mixing the washed stuff with clay, gravel, or other objectionable matter is avoided, and the first larger cost is soon repaid by the certainty of having the materials unmixed with the continually crumbling sides and bottoms of the backs if constructed with clay or gravel, or both.

Each back is provided with a sluice, at the point marked *a* on the plan, Plate IV., to regulate and facilitate the passage of superfluous water from the mixture; the opening or width of this sluice should be from 12 to 14 inches, having a frame with a groove on either side to receive the boards (6 inches broad and 1½ inch in thickness), which, when the back has been filled, are gradually removed as the materials settle to the bottom. In a well-arranged manufactory having a properly-balanced back-room space, and where therefore the necessity of "pushing the backs" does not exist, it is advisable to prevent the escape of any of the surplus water until it has become perfectly clear.

When the back is being filled, frequent "lutings," as the workmen term it, should be made, so as to mix the materials thoroughly in case they are irregularly precipitated; and so soon as this has been done, average samples must be made in the manner described at page 18, so that, independently of previous tests, or samples, evidence shall exist of the accuracy or reliability of the mixture before subjecting it to the succeeding and more expensive processes. Any expense or care bestowed at this stage of the manufacture will be amply repaid by an accurate knowledge of the condition and quality of the washed material. If error has, by negligence or ignorance, crept in at this stage of the manufacture, it is far better that its extent should be ascertained, when possibly within the reach of remedy, rather than at some more advanced process, when no ingenuity can prevent a loss or rectify the blunder. Many manufacturers continually suffer from an apathetic indifference to this most important safeguard of their business.

It is recommended, when a new factory is being established, to fill all the backs before commencing further operations; by such an arrangement the washed material is ready to be placed on the drying-plates, and as soon thereafter as possible converted into Cement; the subsequent regular operations of the wash-mill will maintain a continuous and uniform supply of the mixture.

During the summer months advantage may be taken of the weather to dry some of the stuff from the backs in the open air; this can be done by cutting it out with a spade or graft, and placing the pieces on the sides of the backs, or other convenient points; wheeling the materials in barrows to a distance is to be avoided. Material carefully dried in this manner is superior, in my opinion, to that dried on the plates by artificial heat. Mr. Lipowitz (German treatise, page 8) does not recommend this treatment, but his objection may only apply to the cement when made with other materials than chalk; I quite agree with him, however, that the raw material, after having been dried at a high temperature, deteriorates by subsequent exposure to a current of air. Another objection to such a practice is the increased expense incurred by moving the materials twice instead of once. In a manufacture where labour forms so conspicuous an item of the cost, all care should be devoted to prevent an undue and unnecessary repetition of any part of the process.

CHAPTER VII.

DRYING-PLATES AND COKING-OVENS.

When the washed materials in the backs has become sufficiently consolidated, it is wheeled in barrows on to the drying plates, situated between the backs and the kilns, where it is dried by the waste heat from the ovens for coking the coals used in burning the cement, shown on plan, Plate III., at *B*.

The most suitable position for the drying-plates and ovens is in close proximity to or adjoining the kilns, and between them and the backs, so as to reduce the price of wheeling to the lowest possible cost. Any departure from this arrangement must necessarily add to the expense of this department of the manufacture.

The ovens are built of substantial brick-work on a bed of good

Portland Cement concrete at least 2 ft. thick, as shown on Plate III., fig. 1. Each oven is built large enough to contain a ton of coals; its dimensions are 12 ft. long by 4 ft. wide and 3 ft. high. Those parts of the oven exposed to the action of the heat should be lined with best Newcastle or Stourbridge firebricks. There are four sets of ovens, each having five coking-chambers of the above size, and the heat from which is conveyed through a series of flues, under the drying-plates, to the several chimneys marked *b* on Plan, Plate III. As the temperature at and immediately adjacent to the ovens is very great, it is necessary to use firebricks over the ovens, and for twenty feet beyond them, for a covering as well as the sides of the flues. The flues for the remaining distance of their length may be covered with slabs or tiles made of cement and brick rubbish. I have found them durable and inexpensive, if carefully made. In some cement works, cast-iron plates are used for covering, but my experience leads me to object to their being used for that purpose; they soon get warped and burnt, allowing the escape of the heat, or, which is even more objectionable, permitting the material to run through and choke up the flues.

This part of the process is necessarily an expensive one, from the great wear and tear caused by the heat requiring to be constantly maintained at a high temperature; the daily covering of the plates with cool material causes an unequal contraction and expansion, resulting in early destruction of the best fire-resisting bricks or tiles. The width of the flues is variable, according to circumstances; I have for some years built them 4½ inches wide in the clear, with half-brick divisions, completely honeycombing the space under the plates, and absorbing nearly all the waste heat from the ovens. An objection to their use is the liability to choke from the accumulation of soot; unless careful and frequent attention is directed to this point, much loss will be incurred. If the flues are made wider the heat is more dispersed, and a large amount of it is wasted in entering the chimney when at too high a temperature. The chimneys should have dampers fixed in them for the purpose of regulating the draught and preventing as much as possible the escape of heat.

Having already shown that the different arrangements are judiciously proportioned to the requirements of the manufactory of a size or capacity named—that is to say, the mill is so constructed as to wash daily the quantity which can be conveniently made into cement throughout succeeding operations; the same

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degree of harmonious proportion is also necessary in regard to the plates. Four sets are arranged adjoining eight kilns (*C* on Plan, Plate III.), so that it will be necessary that on each working day a quantity of dried stuff (completely desiccated) equal to forty tons shall pass into the kilns, involving thereby the necessity of placing daily on the plates from the backs an equivalent moist quantity of eighty tons at least. Some degree of care will have to be exercised in arranging the wheeling from the backs so as to prevent a needless expenditure of labour. At this stage of the manufacture a striking advantage is apparent in favour of the dry system. By that method only forty tons are required at the forming machine (see page 30, German treatise), while at the parallel stage of the wet process the plates require a covering of eighty tons weight.

In covering the plates it is advisable to put on only as much stuff as can be taken off on the following day, and to enable this to be done the ovens will require loading or charging every twenty-four hours with a proper quantity of coal (not exceeding one ton) which, when converted into coke, will be sufficient to burn the stipulated daily quantity of cement. I am assuming in this calculation that no gas-coke is used in the manufactory, and the works are entirely dependent on the produce of the ovens for their daily wants—the fuel for the steam power alone excepted; such an arrangement does not necessarily preclude the use of gas-coke, which, if obtainable at an advantageous price, may be substituted for the coke made in the ovens. In that case it will be necessary, or at least advisable, to charge the ovens only every second day, and to do this most effectually the summer time should be selected for this change, as owing to the more favourable temperature of the season the required quantity of dried material may be relied on. As the most favourable time to buy coke is during the winter months, when the gas works are making the largest quantity of gas, it will be necessary to have a quantity stored at the cement works at hand when it may be required.

In the arrangement of drying-plates (which I have before referred to) for utilizing the waste heat from the kilns, the necessity for coking-ovens does not exist; this saving is, however, obtained at the sacrifice or rather additional cost, in a greater amount of drying space, and also extra kiln room. In the largest cement manufactory in England this principle has been successfully applied under most and unusually advantageous circumstances.

Unless where the physical conditions of the ground on which the manufactory is to be erected are favourable, I would not recommend the adoption of this system of heat utilization, because of the greatly increased cost required to carry it out thoroughly; at all events it is unsuitable for a factory of a working-power of 600 casks per week.

CHAPTER VIII.

STRIPPING THE DRYING-PLATES AND LOADING THE KILNS.

It is advisable to remove the material from the drying-plates (whenever dry enough to be put in the kiln), and to follow as speedily as possible with a fresh covering of moist stuff from the backs, so as to prevent waste of heat by exposure of the plates to the atmosphere. The best way to adjust this part of the process is to put on as much material only as the heat will effectually desiccate during the twenty-four hours; a thickness of eight or nine inches of dried stuff immediately over the ovens (where the heat is greatest), diminishing gradually to one or two inches in depth at the chimney. As a considerable quantity of steam and vapour is driven off by the heat in drying the material, necessary provision will have to be made for its free exit through the roof, or at the sides, and thereby prevent its return in a condensed state on the top of the stuff on the plates. In summer this precaution is not so necessary, but in winter, and during the continuance of damp weather, a careless attention to this apparently simple matter will considerably reduce the effective value of the drying-plates.

The object of placing the material from the back on the plates being to remove the water with which it is combined, and so prepare it for de-carbonization or burning, it is not necessary that more heat should be applied than will effect this purpose: in fact any excess will be injurious, as when too highly heated at this stage it becomes very brittle or rotten, and on being removed to the kiln crumbles into small pieces and dust, prejudiciously interfering with the draught of the kiln when burning. On the other hand care must be taken to prevent the material being put into the kiln when wet. Some cement burners consider a certain amount of moisture beneficial, as, in their opinion, it makes better cement. This may be so in a slight degree, as the steam mechanically facilitates the expulsion of the carbonic acid; that advantage, however, is more than counterbalanced by the extra cost in fuel, as well as increasing the weight to be raised when loading the stuff into the kiln; it is more economical to allow the material to remain on the plates until perfectly freed from its moisture, as there is always sufficient water in the fuel to realize all the advantages obtainable from steam while the kiln is burning.

As the above described mode of desiccating the mixed material previous to burning, is necessarily performed in a heated atmosphere, and much of the surface of the plates being in a red-hot state, the implements used for shifting the stuff require to be made of iron. The best and handiest form of vessel or utensil for holding the raw cement is that usually described as a scuttle, made of No. 20 gauge sheet charcoal iron, well riveted together, and strengthened at the top and bottom with iron hoop of 14 or 16 gauge; the best shape is 14 inches diameter at the bottom, widening to about 20 inches at the top, and 10 or 12 inches deep, having a handle at either side for convenience of lifting; they hold nearly half a bushel of stuff, and should be made of a suitable size, so that when filled, an able-bodied man can readily lift or move them about. The wear and tear of these implements form a considerable item of cost; it is advisable, therefore, to make and repair them on the premises: the smith, generally required in all cement works, will be able to manage this. Some of the men working on the plates are provided with wooden clogs to enable them to stand the heat when shovelling, and as this department of the work is the most difficult and trying, it is usual to pay the plate-men extra wages.

A comparison between the two methods at this point will be useful.

1st. The German, or dry system. The material ready prepared, in regular-sized cubes, as it comes from the forming machine (German treatise, page 33), is placed upon the frames on the waggon, requiring but little further attention until it reaches the endless kiln, where it is readily placed in position and burnt.

The expense in operating upon 40 tons of raw material from the room, where left by the grinding machinery, to the kiln is the value of five women's time, which might be estimated in England as worth ten shillings, being at the rate of two shillings a-day each. This would be equal to threepence per ton on the raw material, or sixpence a ton when de-carbonized. Add to this the cost of labour in placing the bricks in the kiln from the waggons, which we may estimate at twopence per ton, or supposing we put the whole cost from the grinding machinery to the kiln, including loading it, at ninepence per ton of manufactured cement, thereby making liberal allowance for any incidental extra expenses that may occur. Thus, then, ninepence per ton covers all cost of manipulation required for the transfer and preparation of the raw materials as left by the crushing and grinding machinery at No. 4, Plate II. (German treatise), until placed in the endless kiln. This is accomplished, too, without waste, leaving the bricks in a regular form and condition best suited for the economical application of the fuel required for de-carbonization, and still further effecting an important saving in the results from the kiln by the comparative absence of defectively burnt cement. This question will be more fully discussed when the relative merits of the kilns come to be considered.

2nd. English, or wet system.

The process, analogous to the crushing and grinding operation of the dry method, which by the agency of water as a solvent, aided mechanically by the knives of the wash-mill, effects the almost perfect admixture of the clay and chalk in a state of suspension, and is subsequently and tediously prepared for the kilns by the combined processes of decantation and evaporation. The much increased volume or space (consequent on this process which the raw materials occupy) entails the necessity of having a large open surface of back room for its reception and storage; this objection is still further aggravated when you consider the increased distance the material is necessarily sent, by gravitation or propulsion, from the kilns to which it must in a partially dried state be finally returned. I consider it necessary again to allude to this subject, as this very obvious disadvantage places the English method in an inferior position in comparison with the German one.

Under the most favourable circumstances the cost of labour per ton of manufactured cement expended in the process of emptying the backs, covering the drying-plates, and loading the kilns is from three to four shillings. Another extra item of cost is the considerable wear and tear of implements required, such as wheeling planks (or rails), barrows (or waggons), shovels, and scuttles.

In every condition of the weather and at all seasons the German method may be continuously worked, while by the other method considerable interruption must arise in inclement seasons, or during the prevalence of rain. The difference of space required, and the much increased rate and saving of time in converting the raw materials I have already adverted to in Chapter V., page 19.

CHAPTER IX.

DESCRIPTION OF KILNS AND MODE OF FILLING THEM.

KILNS for burning Portland Cement are of various circular forms, and much difference of opinion still exists as to which is the best. Many complicated designs, patented and unpatented, have from time to time appeared for the bewilderment and confusion of manufacturers, until at last their sheet-anchor of hope seems to hold fast to the but little modified original form. Each manufacturer exercises his own judgment, or rather he is more frequently influenced by his manager or workmen in the selection of shape and capacity of kiln for his work, and you will find, on an examination of the various manufactories in the neighbourhood of London, kilns varying in capacity from 10 to 70 tons. Where the waste heat is applied in drying the raw materials, the kilns are necessarily closed up, preventing the escape of heat otherwise than into the flues. Of course the necessary amount of atmospheric air required for combustion is admitted through the firebars at the bottom of the kiln when it is lighted up. The open kiln is more generally used, of the form shown by Fig. 2, Plate III.; it may be made of any reasonable size, but I have drawn this equal to a capacity of 30 tons burnt cement, as being most suitable for the size of manufactory now under description. The original kilns were comparatively small, with tapering domes of considerable height, giving great facilities for burning the cement quickly, with a small proportion of waste. The more recently built kilns are double the size, with slightly tapering sections and the domes nearly parallel. In large manufactories, where the available space is limited, an arrangement of this description of kiln may be permitted, but under ordinarily advantageous circumstances the most economical ones are those capable of burning 30 tons of manufactured cement.

The wear and tear of kilns is a heavy expense in the manufacture: they should at first be built strong and substantial, with due regard to the permanency of the structure; they should be lined with good firebricks; such lining ought not to be tied in or bonded with the other part of the brickwork, for when the contraction, caused by the great heat, takes place, the whole lining *en masse* should be enabled to slip down, and the spaces at the top of the firebrick lining filled in so as to prevent the heat from entering the common brickwork. In those kilns where this precaution has not been taken, and all the work bonded together, the cement frequently adheres to the sides, and in falling to the bottom, when being drawn or emptied, drags a portion of the kiln with it. The durability of the lining of the kilns is much increased by painting it with a semi-fluid mixture of the raw material from the back. This should be done each time before being filled, and all the joints and courses well stopped. This simple and cheap precaution materially increases the durability of the kiln.

As in lime-making, the object of burning is to set free the carbonic acid in combination with the materials, so also in manufacturing Portland Cement sufficient heat is required, not only for the same purpose, but also to facilitate the partial vitrifaction of the mixture. In the one process, dealing with a material the component and unvarying parts of which are accurately known, the kilnman's duty is comparatively easy; but a burner of Portland Cement has not only to regulate the amount of heat required, but he should also be intimately acquainted with the quality of the raw stuff, for if the mixture has a full proportion of chalk (without being absolutely dangerous) he will require to increase the amount of coke to enable him to burn the kiln effectually and profitably; if, on the other hand, an excess of clay has been washed, a much less quantity of fuel is required. An overdosed mixture of lime is difficult—nay, almost impossible—to be overburnt, but one over-clayed will be liable to fall into dust, with a moderate amount of firing. Should any carelessness have occurred in the washing, an intelligent and experienced burner will readily detect it in the kiln; and, unfortunately for the reputation of Portland Cement and its makers, this is too frequently the first intimation of an error when it is too late for rectification.

It is impossible to state any regular time which is required to burn a kiln, as so much depends on the mixture and the state of the draught. It is possible, and I have burned a 12-ton kiln in 10 hours under generally favourable circumstances, while I have also seen the same sized kiln as much as four days before being properly finished.

The principle of the cement kiln is intermittent, and consequently objectionable, as each time of loading it must be first heated, and, before it can again be drawn, must also cool. An enormous amount of caloric is thus absolutely wasted, and, as fuel forms an item of cost in manufacturing cement of between 20 and 30 per cent. of its present marketable value, any plan whereby this heavy charge could be reduced would be readily adopted by every manufacturer. Many attempts to establish a kiln on the perpetual system have been devised, but hitherto the desideratum of a perfectly unexceptionable running kiln is still unattained. If the cement was only required of 90 lbs. per bushel in weight, there would not be much difficulty in maintaining the fire in the kiln; but when you require a cement exceeding 110 lbs. per bushel, the difficulty is much increased, in consequence of the necessary clinkering of the contents of the kiln, to obtain that weight. I am of opinion that the improvements in our present form of kiln will be attained through the agency of an adaptation of the plan proposed by Mr. Lipowitz. It is not only a question of fuel, for the enormous cost of labour in filling the present kilns, as well as the great wear and tear attending their use, are equally serious objections requiring much consideration.

As in the previous arrangements of back room, and drying-plate accommodation, due regard is given to the proportionate extent of each, so also must the size of the kilns and their number be measured by the same rule. Not only should their position be convenient to the drying-plates, but accessibility to the mill for grinding is likewise an element of deliberation in planning the factory.

The cost of erecting a kiln to burn 30 tons of clinker (unground cement) would be from 120*l.* to 150*l.*, and the yearly outlay in repairs, including labour and materials, would be about 30*l.* This would be a yearly expense of 240*l.* for the eight kilns required to make 30,000 casks per annum according to the accompanying design.

The kilns are loaded in the following manner:—The movable iron bars (wrought-iron two inches square) are put in their proper position at the bottom of the kiln (see Fig. 2, Plate III.), on which is placed a few bundles of brushwood, on the top of which a sufficient quantity of large coke is put for the purpose of facilitating the lighting of the kiln; then alternate layers of coke and raw material are laid until the kiln is filled to the top. The quantity of fuel required is variable, and the accurate amount will be regulated by the judgment and experience of the burner. Great care must be taken, however, to have the raw stuff, as well as the coke, broken to a regular and uniform size, and every precaution is to be adopted in preventing the dust of the material and fine breeze of the coke from getting into the kiln; for, when it does, the draught and effective action of the burning is prejudicially interfered with.

The time required to burn a kiln varies, and no fixed rules can be laid down for guidance in that respect; the different qualities of the fuel and the raw material influence materially the results, some mixtures being more easily converted into cement than others; form and situation of kiln also contributing to the uncertainty of this operation. When, therefore, so much depends on chance in attaining satisfactory conclusions, there is much risk and difficulty in prescribing any fixed rule for the guidance of the cement-burner. The whole process, from beginning to end, partakes so much of the rule-of-thumb character, that any technical proposition for the more reasonable attainment of any one department of the process would meet with but little attention. I cannot, however, pass over the de-carbonizing process without adverting to the degree of heat necessary for that purpose. Much difference of opinion exists as to the heat required to de-carbonize limestone and cement; this difficulty is occasioned by the unreliable character of pyrometers, and other heat-measuring instruments. By experiments made with the thermo-electric pyrometer, it is found that pure limestone loses its carbonic acid by being heated for several hours at a temperature of 1300° to 1400° Fahrenheit, and by increasing that amount of heat the gas can proportionately be more rapidly evolved. Such a temperature would not, however, suffice when exerted under the disadvantageous conditions in which a Portland Cement kiln and its contents are placed; so much of the applied heat would necessarily be absorbed in warming the kiln and expelling the moisture from the fuel; the resistance also offered by the peculiar position of the contents occasioned by the mode of loading the kiln, which delays the expulsion of the gas. The contents being placed in alternate layers of coke and raw cement, it follows that the burning proceeds gradually, and, generally speaking, the bottom strata of the charge is burnt and ready for drawing before the upper portion is ignited. It is obvious, under such conditions, that the whole upper part of the charge is saturated or impregnated with the gases liberated from that underneath it, and the otherwise simple process of de-carbonization complicated, from the peculiar form of the kiln and the arrangement of its contents.

A Portland Cement kiln constructed on purely scientific principles would assume a form differing widely from any existing models. It is possible, indeed, that the circular and high form will be altogether abandoned, and one more resembling that recommended by Mr. Lipowitz adopted in its stead. When we consider the simple duty or work sought to be done through the agency of the kiln, we cannot help an expression of surprise that so unsuitable a form of kiln has been for so many years in use. No doubt the shape has been determined from the original lime-kiln, and any change in shape has not until now been considered advisable or even desirable.

The sole duty of the kiln is to expel the carbonic acid, and the heat necessary to effect this at the same time slightly vitrifies the whole mass. A more clumsy and unsuitable arrangement than the existing one for carrying out so simple an operation can hardly be conceived, and it is to be hoped that some more reasonable and speedy mode may be devised for the accomplishment of this undeniably important object.

I here give the result of several months' accurately-recorded tests of the quantity of fuel (twenty-four and forty-eight hours' coke made from Tanfield Moor coal) used in burning cement made with gray chalk and alluvial clay from the Medway: the fuel contained at least 20 per cent. in weight of moisture left after quenching the fire, when the coke was drawn red-hot from the ovens and the raw materials were perfectly dry, and carried direct to the kiln, without exposure to the air. The average capacity of the kilns was 14 tons (burnt cement), and their situation was open and exposed, being built on a marsh about six feet above high-water sea-level; the eye or grating of the kilns had a southerly aspect, without shelter of any kind.

In burning 1000 tons of cement, under the conditions above described, the cost of fuel was found to be equal to 7*s.* per ton. The cement was highly burnt, and weighed, on the average, 116 lbs. per bushel—a cement, therefore, of high tensile strength, and equal to any engineering test.

I merely mention these records with the view of giving an approximate idea of the fuel-cost for burning Portland Cement in a situation not by any means disadvantageously placed with regard to cost of coals or coke. The weight of the cement was considerably above the average, being therefore more costly to the manufacturer, and would command a higher market price where special quality was required. The average weight of a fair good useful cement is about 106 lbs. per bushel, the fuel to burn which would probably, under ordinarily favourable circumstances, cost about six shillings per ton.

Before leaving this part of the subject, I would direct attention to the most economical conditions regarding the kiln.

1st. Substantial construction of the best accessible materials.

2nd. Most suitable form, having regard to the situation of the works, and the duty required of it.

3rd. Position of the kiln to be regulated by the situation of the drying-plates and the grinding mill.

4th. Proper kiln sheds for drawing and storing, when necessary, the raw materials as they are taken from the kiln.

5th. The necessary amount of atmospheric air to be induced to enter the kiln at the fire grating, for the purpose of aiding combustion.

A reiteration of the above few simple points may prove useful in considering the question of kiln accommodation.

CHAPTER X.

DRAWING OR UNLOADING THE KILNS.

Owing to the peculiar form and construction of the kiln, it is not possible, during the process of de-carbonization to watch its contents and progress with any degree of accuracy or precision; and in the case of closed kilns, where their heat is utilized, this is practically impossible. In addition to this difficulty, there is also considerable danger attending the attempt to examine too closely the progress of the burning, as the inhalation of the carbonic acid gas would be attended with serious results. All the attention that can be usefully bestowed on the kilns is when the fire first appears at the top, which, if the kiln is working truly and has been judiciously loaded, will be in the centre. The burner should then see that the fire is checked, so as to prevent the too rapid burning of the fuel, and consequent waste in imperfectly burnt cement; frequently with a varying draught or during boisterous weather, much attention is required at this stage, and sometimes the most careful burner is unable to prevent loss.

The kiln, before the fire-bars are withdrawn, should be allowed to cool, and all the unduly burnt cement carefully picked by hand from off the top of the kiln, which may again be put on to the last cover of another kiln. The clinker is at once loaded into barrows or trucks, and taken to the grinding mill at Fig. 1, Plate III., where it is stored or hoisted at once into the hoppers of the mill-stones. Much attention should be given to picking out the pink (imperfectly burnt material, so called from its being generally of a reddish colour), for if any quantity of this dangerous stuff is allowed to be ground with the good cement, much injury is done to the cement, the peculiar nature of which will be hereafter more particularly referred to.

The clinker, when made from properly-mixed materials and carefully burnt, will be of a dark greenish-black colour, differing in density, or specific gravity, according to the amount of fuel used. The whole contents of the kiln will be found to have shrunk to nearly one-half of its original size when all the necessary conditions have been complied with. This large reduction of volume is occasioned principally by the space occupied by the coke or fuel, which was nearly one-third of the kiln space. The material itself has also shrunk considerably, and has lost in weight from 40 to 50 per cent. The contents of a well-burnt kiln should not be too much clinkered, and, on being drawn, easily filled into the barrows without the necessity of breaking it. If there has been an undue proportion of heat applied with some mixtures, a large amount of waste in the shape of dust will be the result. The dust ought not to be filled with the clinker, but put to one side and used about the works when required. This dust, when mixed with water, will be of a very objectionable colour when set, and wanting in strength when tested with the machine. It may be used for rough mortar (without being ground) for building or concrete about the works.

It will be found that when the kiln burns freely and quickly, a good mixture of the chalk and clay has been made; but, on the other hand, if the kiln burns slowly and much dust falls through the bars, it may be concluded that an undue proportion of clay has been used. It may take ten days during the summer, in hot weather, to burn a kiln of material imperfectly mixed with clay.

The usual appearance of the contents of the kiln (when burned) is dark, but as it is impossible almost, under existing circumstances, to have a uniformly perfect result, in consequence of the irregularity and variability of the draught, care must be exercised in selecting or rejecting the variously burnt material when being drawn. Generally speaking, when the due and proper amount of fuel has been used, and regardless of eccentricity in de-carbonization, the combined weight of the two qualities in a badly burnt kiln would equal that from one properly and fairly finished under the most favourable conditions—that is to say, the sum of yellow-coloured cement and that of the hard dark clinker added together, would equal in weight the contents from a kiln (having, of course, equal capacity and the same amount of raw material and fuel weighed into it) perfectly burned; showing that fuel under such circumstances is not absolutely wasted, but only imperfectly applied from generally uncontrollable causes. The yellow cement is not to be confounded with the pink before mentioned, as they differ greatly in their respective values—the former being cement of light specific weight, and the latter imperfectly burnt. One can be safely mixed, in grinding, with heavy clinker, but the other must be rejected and again passed into the kiln. An experienced workman can easily discriminate between the one and the other. The good yellow is bright in colour and light in weight, and the faulty pink is of a dirty-white colour and much heavier than the other, varying with the degree of heat to which it has been subjected.

In large manufactories an occasional lightly-burnt kiln is of little consequence, as the ground cement is put together in large quantities, and the homogeneous mixture is too perfectly combined to permit the chances of any bad effects, which under-burnt stuff might occasion. In small works, however, such opportunities will not occur for rectifying mistakes of this kind; so, great care is necessary in preventing loss from this cause. This is another good reason why kilns in factories should be of moderate size. A kiln of 80 tons capacity imperfectly burnt, where only 600 casks a-week were made, would be a matter of serious moment.

In every case it is advisable to avoid keeping the freshly-burnt cement unground, and therefore, as in the previous operations of the process, the grinding and crushing power should be so adjusted that this necessity may not aıise. When ground and properly stored, under favourable conditions, the cement improves in quality. This subject will, however, be more fully discussed when the qualities of pulverized cement come to be considered.

As Mr. Lipowitz does not enter into any very particular description of the results by his endless kiln (see page 37, German Treatise) beyond describing its nature and mode of action, I am unable, in consequence, to enter very fully into a comparison between the two methods at this stage. Without absolutely committing myself, in the absence of more particular information, to his system, I would remark that there are many apparent advantages possessed by the endless kiln, which by our high and expensive kilns are unattainable. Perfect control over combustion seems one of the most important; and the facilities for loading and unloading are also in the highest degree favourable. The advantage (claimed for the kiln by its inventor) of being able to watch its progress during the process of de-carbonization is in itself so useful and valuable a quality, that, if none other existed, that alone would be sufficient to claim for it the favourable consideration of the cement manufacturer.

CHAPTER XI.

GRINDING THE BURNT CEMENT.

THE contents of the kiln, when sufficiently cooled, are taken to the grinding-mill, placed in the hoppers of the horizontal mill-stones, and there finally pulverized into a powder suitable for the market.

By both methods the clinker (technical name of the burnt cement) is similar in character when leaving the kilns, and the subsequent pulverizing operations are common to the two systems —the one great object being the attainment of a cement sufficiently fine for general purposes of construction.

The various machinery used for this purpose differs in character, and comprise crushing-machines, edge-runners, rollers, crackers, &c., according to the practice of the neighbourhood or locality. In the London district, crushing-rollers are displacing edge-runners (vertical stones), from their supposed superiority. Hitherto but little serious attention has been given to this most important branch of Portland Cement manufacture. Where edge-runners have been formerly used, their abandonment has more frequently been the result of ignorance than from any reasonable objection to their principle or profitable performance. The nature and construction of this kind of machinery necessitates a degree of careful attention which it but seldom receives, resulting too frequently in loss and disappointment. The form and mechanical construction of edge-runners indicates a twofold action of crushing and reduction by abrasion or sliding. Where, therefore, due and economical results are expected, the conditions necessary to attain success must be scrupulously attended to. This kind of machine should be regarded simply as an intermedial one, receiving the material to be operated upon in a certain form, which, when subjected to its influence, will be passed on, improved in value, and rendered fit and suitable for a succeeding, and, it may be, a final process of pulverization. How much one hears of the uselessness of edge-runners, and how numerous are the failures ascribed to their unsuitability for grinding purposes; all these complaints and objections, however, appear to me about as unreasonable as it would be to expect to find a horse that would combine the threefold qualities of a dray, carriage, and racer; physiological or natural laws preventing the possibility of such a wonder in the one case, as mechanical laws as certainly precludes its attainment in the other. You cannot expect a simple machine like edge-runners to possess the properties of a stamping or breaking machine, a pulverizing and grinding machine, for assuredly if you do, the result will be deserved disappointment. It is better, therefore, to rest satisfied with the performance, from that or any other machine, of that which its form, construction, or principle indicates or promises.

The size of the lumps or pieces of cement, as drawn from the kilns, are so varied in form, that the most suitable machine for the first operation in reducing is assuredly the stone-breaking machine, for particulars of which see German treatise, page 18. This machine is specially adapted for breaking any kind of material from almost any size, and the uniformity of the results leave the materials operated upon peculiarly suitable for being further acted on by the edge-runners or vertical stones. The power required for a breaking machine suitable for this purpose would be about 3-horse power. A machine of this power would pass the materials from 3 to 4 inches in size, and would break 30 tons a-day; it would be more advisable, however, to reduce the power so as to prepare the exact quantity required by the edge-runners, and so render the operation from one machine to the other uninterrupted and continuous. A simple mechanical feeding arrangement could readily be devised to pass on the broken pieces from the breaking machine to the edge-runners, and from thence by elevation to the hoppers of the horizontal mill-stones, where it would be finally and perfectly pulverized. For further and more detailed particulars of the above machines, I would refer to the excellent description of them given by Mr. Lipowitz at page 24 of his treatise.

By the above suggested arrangement, the aggregate amount of power required for the three machines would be—

	Horse-power.
Stone-breaking Machine	3
Edge-runners	5
Horizontal Stones	8
Or a total of	16

A pair of 4 ft. 9 in. horizontal French burr stones properly dressed and in good level working order would easily grind the cement, when prepared by the other machines, at the rate of 20 tons per day by an expenditure of even less than 8-horse power. Thus you would have an economical result without over-taxing any one part of the mechanical arrangements; whereas, on the other hand, from motives of first economy, were you to adopt the system of grinding (as is now frequently done) by horizontal stones only simply preparing, and that very imperfectly, the materials by hand labour, you will certainly strain the machinery, imperfectly grind your cement, and attain these unsatisfactory results at a maximum cost of wear and tear as well as power. At least 16-horse power would be expended in performing that most imperfect operation. My experience is opposed to any adoption of this form of dealing with the burnt cement.

It will be necessary to have two pairs of mill-stones, so that, while one pair are being dressed, the grinding would go on without interruption. It is not requisite to have the other machines in duplicate, as their wearing parts only require repair or renewal at considerable intervals of time.

I do not, of course, insist on the above form or manner of arranging the grinding machinery to the exclusion of any improvements which may exist, or may hereafter be devised, for the better performance of this important branch of the manufacture; but having carefully studied this question, I am firmly convinced of the necessity of a much more common-sense system of grinding cement than the existing one.

Portland Cement manufacturers are quite conscious of the advantages of good grinding, and now, in my opinion, very unwisely object to a cement of high specific gravity from the great cost incurred in pulverizing it. In taking this position they evidently act inimically to their own and the cement's reputation. It is not a question of manufacturer's interest so much as one of public and general importance. Engineering experience, both English and foreign, of undeniably high authority, insists on the heavy cement, which, to receive and develop its full power and value, must necessarily be subjected to a pulverization resulting almost in a powder of impalpability. The question of extra cost in effecting this object is obviously one entirely between the manufacturer and consumer, and need not be discussed in a work of this description. While the engineer and architect demand a material of a certain quality and value, it is the duty of the producer to provide it, taking care at the same time to protect himself by charging a profitable and remunerative price. Engineers, while insisting on quality, are well aware that when any article is specially prepared, an extra price must be paid for it; when specifying first-class iron or steel, they do not expect to get it at the cost of common iron. There can be no doubt that, hereafter, when the due and sensible appreciation of the different qualities of Portland Cement come to be understood, that bulk at least will not be considered the test of value.

Before leaving the grinding question, I will briefly describe a small and simple machine used principally in America for preparing the ground cement for the mill-stones. It is called a cracker, and made of cast-iron, as shown on Figs. 4 and 5, Plate I., consisting essentially of a frustrum of a solid cone called the core, working concentrically within the inverted frustrum of a right hollow cone, both being provided on their adjacent surface with suitable grooves and flanges for breaking-up the stone as it passes down between them. The elements of the lower portions of both cones make a smaller angle with the common axis than those pertaining to the upper portions with a view to lessen the strain, and the effects of sudden shocks upon the machinery, by securing a more gradual reduction of the stone to the required size. These lower portions being subject to very rapid wearing, are made of chilled iron, and are moreover cast in separate pieces, in order that they may be replaced by new ones, as occasion requires. The greatest diameter of the core at the top, including the flanges, is 9 inches, at the bottom 5½ to 6 inches, and its height is 15 to 16 inches. The diameter of the shell, measured within the largest flanges, is 14 to 15 inches at the top, and 5½ to 6 inches at the bottom, a trifle greater than that of the core; its height is 16½ to 18 inches. One cracker of this size, working with a velocity of 80 to 85 revolutions per minute, is sufficient for a mill grinding 250 to 300 barrels per day of American Natural Cement, similar in character to the Roman Cement of this country made from the septaria of the London Clay. It prepares the stone of the size of a pea or hazel-nut, and one cracker will supply two pairs of horizontal mill-stones. As each barrel of American Cement weighs 300 lbs., this gives a daily quantity of from 34 to 40 tons; and I should say such a machine made somewhat stronger would prepare at least 20 tons of Portland Cement clinker for the mill-stones. The simplicity and cheapness of this so-called cracker recommends itself to the consideration of English manufacturers. A somewhat similar form of mill, called a conical mill, is used in this country, having French burr-stones working similarly within each other, but my experience does not lead me to advise their use for grinding any but soft and friable materials, and where no previous preparation or reduction is necessary. Where they have been used in grinding cement, failure has resulted from too high an estimate or promise of their capability. A *multum-in-parvo* millstone, for cement-grinding at least, is not a thing to be desired.

Much diversity of opinion exists as to the required fineness of the powdered cement, and while the process adopted in attaining this object is attended with so much expense, it forms very naturally a subject of serious consideration to the manufacturer. French, German, and American engineers have given great attention to this question, while our own architects and engineers have not deemed the matter sufficiently important to require their special consideration. As an illustration of this subject, I may mention that a very small proportion of the Portland Cement made in this country will pass a No. 40 gauge (that is, 1600 perforations of the sieve to the square inch) without leaving a large percentage of residuum behind, whereas in America the engineers insist on 85 per cent. of the cement passing a No. 80 gauge (6400 meshes to the square inch). In Germany a No. 60 gauge (3600 meshes per square inch) is required, and in France much attention is given to this subject. As the American experience is confined to the natural cements of America, which are capable of much easier reduction than English Portland Cement, there is no absolute necessity for insisting on a quality finer than the 50 gauge as an average good cement. In carrying the degree of pulverization beyond a certain point, a large and disproportionate cost of both power and time is involved; this difficulty has been met by many suggestions to overcome the expense and delay consequent on a high degree of fineness. The most favourite attempts to meet this difficulty has been the introduction of fine wire bolts, but the large amount of wear and tear in renewing the sieving has rendered their use in every way inexpedient. Mr. Lipowitz requires a steel-wire netting of 4225 meshes to the square inch for the effectual pulverization of the raw material, and, I presume, also recommends a similar gauge for the burnt cement. When therefore the quality of fineness of the powdered cement forms so prominent a feature in its value, it behoves the manufacturer to direct his attention to this question, and to consider whether the existing machinery is adequate to attain this desideratum in the most effective manner and at the cheapest cost. The most vital ingredient of this question is one seldom thought of by the manufacturer, and certainly unknown to the engineer and architect—that is, in making heavy and valuable cement a large expenditure of fuel is incurred in obtaining an article of maximum specific gravity and consequent hardness, the full value of which cannot be realized but through the operation of maximum pulverization. This subject is worthy of a little further explanation. The contents of the kiln vary in hardness according to the degree of heat to which they may have been subjected, and accordingly represent different values in hardness and strength—the more valuable being of course that which is heaviest—thus their imperfect grinding leaves behind as a residuum the best cement, or allows it to mix with the mortar as so much sand, and possessing only its value as an adulterant or matrix for binding the mass together. How much better, therefore, would it be to obtain the fullest value of all preceding cost of manufacture in reducing to the finest powder the hardest particles of cement—for unquestionably the amount of cement rejected by even a No. 40 gauge sieve is so much loss not only in itself, but also additionally so from its being separated from the more lightly burnt or less valuable portion.

There is no further special attention required in the operation of grinding, but a few remarks may be useful in reference to the treatment of the cement when ground. In some manufactories it is the practice to fill the sacks and casks direct from the spouts of the millstones. This is a very objectionable custom, and can only be excused from a feeling of economy in saving the expense of filling the casks and sacks by hand. The cement should be taken from the millstones to a cool floor, and laid or spread in thin layers, carefully laying on each day's grinding for a week at least. By this means the whole becomes a thoroughly mixed homogeneous mass, and when filled into casks is of a uniform character, all qualities of the cement being thereby thoroughly mixed, and equal. This is not the case when filled into packages from the spout, as the run of cement through the hopper varies, as also does the clinker from the kilns, rendering it practically impossible to command a uniform material at any time. When the cement, therefore, is filled direct, it necessarily varies in quality, and much dissatisfaction is frequently occasioned thereby. By adopting the above mode of storing the cement, the quality is much improved, and the important advantage of regularity and evenness of quality is ensured. Some manufacturers as well as consumers of cement are under the impression that exposure to the atmosphere is detrimental, and it is very possible this erroneous notion took its rise from the care which was and is still necessary to protect Roman Cement from the influence of the air. The two cements differ so essentially in their main features and characteristics, that the management required to secure the good qualities of the one would prove pernicious to the other. For if there is one quality in Portland Cement more valuable than another, it is the property of retaining its power and value for an indefinite period of time. I have used Portland Cement which has lain for upwards of two years in a large covered building, exposed to the air without any attention or care, and found it good and without deterioration—in fact, equal to new cement. On large works, where suitable facilities exist, I would recommend that all Portland Cement should be exposed in a covered and weatherproof building for at least two months before being used. Such a mode of treatment would materially improve its quality, and on important works afford facilities for testing quality before being used. There is no advantage to be derived in keeping Portland Cement in casks, but, on the contrary, much damage is caused by unnecessarily retaining it in packages, especially if it has been filled direct from the millstones. The frictional warmth from the stones is very considerable, and the heat is retained in the cask for a long period, sometimes, indeed, causing considerable waste by a partial setting of the cement in cooling. When cement is intended for shipment abroad, the packages form an element of careful consideration; so much so that some merchants require iron casks, to ensure the safety of the cement in transit. The extra cost incurred is not altogether lost, as in some countries the iron casks are used in the shipment of oil and other commodities to this country. It is absolutely necessary to have sound packages for all foreign shipments, as even the best made casks do not always prevent loss in the ship's hold from the absorption by the cement of bilge water, &c. Cement is an article the low price of which does not ordinarily permit the payment of high freights, and in consequence it is generally treated as ballast, and is too generally placed at the bottom of the ship.

Mr. Lipowitz, at page 64 of the German treatise, complains of the bad quality of casks sent with cement from England: again I must plead, in extenuation of our shortcomings on this head, the great and incessant competition amongst German merchants, who too frequently receive imperfect packages from being less costly. A cask well made of sound old material is much better adapted for the carriage of cement than one made of new and unseasoned stuff; if both are filled direct from the mill-stones with hot cement, the old cask will be found the better package of the two.

CHAPTER XII.

TESTING THE CEMENT.

Having thus performed all the necessary manufacturing operations, it is now the duty of the manufacturer to ascertain the value of what he has made by a rigid series of tests, so that his cement may be proved in the works before being submitted to the engineer's trying ordeal where it is intended to be used.

Until within the last few years the manufacturer did not trouble himself with testing his cement, trusting that the ignorance or supineness of the consumer would enable his commodity to pass unchallenged. Recent advances in the knowledge of Portland Cement, by engineers especially, now renders such a loophole of escape from responsibility practically impossible. A manufacturer need not excuse himself from due attention to this matter by a plea of ignorance of the subject, for in all engineering works of importance the actual requirements of the cement is duly specified, and when contracting to supply cement, the maker must ensure its due acceptance by proving its quality at the works.

French engineers especially have for many years insisted upon tests of an onerous character, and English manufacturers have been benefited by the rigorous nature of these tests, for they have been instrumental in compelling attention to the quality and nature of the cement. The form and size of the briquette or brick submitted to the test has been uniform, if the mode has been sometimes eccentric and theoretical. A practical objection to the peculiar *modus operandi* presented itself to the Author when preparing a large quantity of cement for a French Government contract some years ago. It was necessary that the identical mode of testing should be adopted for the purpose of securing the acceptance of the cement by the French authorities; but it was found that a strict adherence to the prescribed form of test involved an expense quite inconsistent with the required conditions, and accordingly, to avoid and save the expense of cutting the brick, he devised the machine shown on Fig. 5, Plate II., for pressing the briquettes at one operation. This was found so convenient that it was constantly used in preparing the bricks for testing, and subsequently, when Mr. Grant decided on testing the Portland Cement to be used in the construction of the Southern Main Drainage Works of the Metropolis, he adopted this machine, which, in a somewhat improved form, continues to be used by all engineers and cement manufacturers who have any regard for the permanency of their construction or the reputation of their cements. On large works and even to a cement manufacturer, the cost of testing amounts to a considerable sum in the course of the year, and the adoption of the specified French system is only possible where a large quantity of cement of a first-class quality is required, in consequence of the great expense for labour in cutting the bricks. I have shown on Fig. 6 the plain bricks as used in France, and Fig. 7 represents the one generally adopted in England. Much care and nicety of handling is required to make these briquettes sound, as inattention to the proper degree of pressure and consistency of the mixed cement will lead to erroneous results when they are submitted to the testing machine. The necessity of at once putting the samples in water increases the liability to error, and too much attention cannot be given to this matter.

The difficulty which I met with in testing the cement according to the French practice also seems to have occurred to Mr. Lipowitz, who at page 60 of the German treatise gives his reason for the adoption of briquettes similar in form to those above described.

Engineers in all countries have given the subject of testing much attention and consideration; but, from a want of intelligent assistance and co-operation from the manufacturers, great delay and uncertainty has occurred in preventing the practical realization of a uniform standard of tests. Luckily, the comparative recent establishment of the Metropolitan Board of Works has given an impetus to the use of Portland Cement in the works of the London Main Drainage and Thames Embankment schemes, which its most sanguine advocates never presumed to predict, let alone realize. The popular character and constitution of this Board, invested with such plenary powers of administration and finance, offered unprecedented facilities to their engineers for the introduction or adoption of the best kinds of materials for the construction of those great and permanent works. Messrs. Bazalgette and Grant, when preparing the specification for the first section of the Southern Main Drainage Works, determined to use Portland Cement on a large scale—indeed, to an extent hitherto unknown in this country—and with a pertinacious boldness worthy of their character and profession, and notwithstanding the gloomy predictions or prophecies of interested manufacturers, have succeeded in the most satisfactory manner in establishing a system of tests well calculated to guide the engineer and architect in the safe and most effective use of this material.

In Mr. Grant's paper, read before the Institution of Civil Engineers on 12th December, 1865, the whole series of experiments and tests organized and conducted by him during a period of seven years, much valuable information is given fully corroborative of the easy possibility of obtaining Portland Cement even under the most stringent conditions of supply and vigilant control of quality.

The forms of mould or brick adopted by Mr. Grant, and the machine for pressing them, as also the steelyard, or breaking indicator, are shown on Plate II., Figs. 4, 5, and 7.

The simplicity and effectiveness of this mode of testing has commended itself to the engineering profession; and manufacturers, with few exceptions, now consider the machine and pressing apparatus as indispensable items of their machinery of manufacture. The adoption by the maker of cement of the means of testing may, it is to be hoped, ultimately lead to his guaranteeing the quality, which would obviously simplify and reduce the anxiety of the engineer when using the article. This culminating point of excellence, when reached, will create confidence and security to those who may require or wish to use the cement for simple purposes, and where the advantage of professional advice and guidance is unattainable or unnecessary.

In all forms and kinds of testing, the primary object is the attainment of a reliable knowledge of the peculiar properties of the cement, and the amount of confidence with which it may be used. Fortunately, the acquirement of this knowledge is free from complexity, and no one desirous of obtaining such information need hesitate in bestowing the necessary trouble or labour in reaching it. For the purpose of reducing this question to its simplest form, I will treat the test as one only requiring to know the amount of lime contained in the cement; that is to say, whether there exists an excess or otherwise of that constituent. The mode of sample tests, described at page 18, is a ready mode of reaching an approximate result for the manufacturer; but the builder requires and should know as speedily as possible the constructive value of the cement about to be used by him. This knowledge is only to be reached in a moderate space of time by the hydraulic or water test, and as far as it goes will safely guide the consumer in using a cement free from dangerous qualities; it will not, however, indicate in so short a time its exact value or measure of strength. A cement can be proved by this process to be free from a dangerous or excessive mixture of lime, and therefore in a condition to be safely used; yet it must only be considered as a mode of testing to be tolerated in exceptional and peculiar cases, the exigency of which can alone be the excuse for such an imperfect system.

French experience and practice has perhaps given the largest amount of attention to this question, and I will therefore first explain the mode of testing adopted by some French engineers.

M. Vicat introduced the needle penetrating test to prove the relative hardness of the cement. The machine used for this purpose was similar to that shown by Fig. 3, Plate II., and was used as follows: The measure of penetration was effected by the impact produced from the point of a steel needle impelled by a falling body. The needle, which is slightly conical, or tapering towards the point, is truncated at right angles to the axis, so as to give a diameter at the lower end of one-twelfth of an inch. It protrudes from a socket in the lower extremity of a vertical rod or spindle, to which it is firmly secured by means of a thumbscrew. To the upper extremity of the spindle is attached a diagonal scale of steel, accurately graduated to tenths, hundredths, and thousandths of an inch, and provided with a horizontal index, firmly fixed to the framework of the instrument. The absolute penetration of the needle is obtained by taking the difference between the index readings before and after impact. The falling body is a hollow metal cylinder, weighing one pound, of which the exterior diameter is about equal to the length. This cylinder, in its descent, passes freely over the spindle, and strikes upon a shoulder attached just above the screw.

The trial of the needle was adopted as the most ready means of measuring the relative hardness of several mixtures of pure mortar and cement without sand. Nothing further than this information was at first expected. General Treussart objected to the use of the needle, from the impossibility of accurately measuring the amount of penetration, and the partial hardening of the cement or mortar being greatest at the surface. Both of these objections could be met by an accurately constructed instrument or apparatus, acting only on prisms or bricks of cement or first-rate hydraulic limes. This mode of testing is, however, considered too theoretical, and is not, therefore, recommended for practical purposes. This instrument is still used by some French engineers, and a short reference to it is considered advisable.

The more onerous and common tests practised in France are those requiring a certain tensile value in fluctuating periods of time; the first of which, *viz.* a breaking-weight of 480 lbs. after fourteen days' submersion in the sea, is sometimes enough to prove the value, provided the cement is accurately made; if otherwise, the second and succeeding tests frequently break down, and fall short of the conditions required. Some English manufacturers have, to their cost, unfortunately experienced the very great responsibilities attending a contract to supply Portland Cement to government works in France. These tests are the result of civil and military engineering experience in France, whose engineers have most industriously prosecuted the subject, and the tests now in use in

England have been based on French practice. For information as to the modes adopted in Germany, the reader is referred to the German treatise, chap. xxvii., p. 55.

It may be considered an indisputable necessity that all tests or examinations of cement should precede, and not follow, their use. What satisfaction would arise from the after-knowledge that your house or your bridge had been put together with faulty cement, which sooner or later would tend to its destruction? For it must not be forgotten that in certain conditions of the atmosphere, the development of imperfections spreads over a considerable space of time. Hence the absolute necessity of the water or hydraulic test. In discussing the subject of testing, it is to be understood that the necessary remarks and observations apply only to testing, for—

1st. Solidity or tensile strength;

2nd. Relative solidity, or resistance to fracture;

3rd. Reactive solidity, or crushing power.

Comparative, frigorific, and age tests are more or less fanciful in character, and do not possess much practical value. A slight allusion, however, to them may prove attractive to some.

Comparative tests, as more particularly practised in Germany, consist of testing the cement against its equivalent cube of building brick or stone. No standard value can be attached to tests of this kind, from the fluctuating quality of both bricks and stone. That country aims at excellence in the manufacture of its bricks, and is so successful in this direction, that those familiar with the general character and quality of that article in Germany will not be surprised at the results arrived at, as described by Mr. Lipowitz in his chapter on testing cement before referred to. To attempt a comparison between the stock bricks of London and Portland Cement is too absurd for serious consideration.

In the table, page 60, where results of comparative tests are given, the variable character of the strength of bricks is strongly illustrative of this subject. It is there shown that a brick made of neat cement is nearly as strong as the best vitrified Staffordshire blue brick, and certainly the hardest brick made or used in this country. Age will ultimately increase the strength of the Portland Cement brick, while the value of the blue brick will remain stationary, or probably retrogressive. When first introducing the Staffordshire brick in the Main Drainage Works, much objection was raised by practical men to the difficulty of effecting a perfect or lasting junction between so hard and non-absorbent a material with cement. The result has been most satisfactory, not only in the sewer works, but more recently in numerous wall-copings and railway station platform-edgings.

The frigorific test is one seldom applied, or even thought of, although it does commend itself in countries where great extremes of temperature exist, and where it is important to ascertain the frost-resisting properties of any kind of building material. The usual preparation for this purpose is a cold saturated solution of sulphate of soda warmed to the boiling point, in which is suspended for half-an-hour the sample under test. Then pour the liquid, free of sediment, into a flat vessel, and suspend the sample over it in a cool place under ground. When efflorescences appear on the brick it must be dipped in the solution, say three or four times a day for about a week; at the end of which time the quantity of earthy sediment in the vessel, collected on a filter and weighed, will indicate the effect to be expected from frost on the same sample. The brick under trial might also be of such a form that its strength could be tested before and after subjection to the above process. In our moderate and temperate climate such refinement of testing is unnecessary, but in northern latitudes, where a range of 100° or 120° Fahr. is indicated, such precaution as the above-described process may not be considered superfluous.

The age test of durability is one necessarily of a speculative character, and partakes too much of the fortune-telling element to demand grave consideration in a work of this kind. The extent of our Portland Cement experience covers a space of half a century, and considering the difficulties surrounding its introduction and first manufacture, it is surprising to what perfection it has already attained. Iron, brick, stone, and timber suffer more or less from atmospheric and climatal action. Iron, unless constantly coated with protoxide paint, becomes oxidized to an injurious and even dangerous extent. Bricks, as they may be hard or soft, deteriorate in a prejudicial degree. Stone of the best selected varieties but too significantly, in London at least, point out and caution us against its indiscriminate use. Timber, even when subjected to any of the numerous preparations for the arrest of decay, is too untrustworthy a material for general use, and can and should only be used where unavoidable. In all the above materials the maximum amount of their constructive value is obtained at first, and no subsequent improvement is ever or can possibly be realized. On the other hand, Portland Cement does not reach its greatest strength until years after it has been used; indeed our knowledge is still imperfect as to the ultimate range of improvement it may attain. The tables in pages 53, 54, and 55 enlighten us as to its progressive advance, and all this attained without preservative preparations of any kind. Iron requires protoxide paints, bricks and stone must be subjected to indurating solutions, and timber protected against decay by some chemical preservative more remarkable for its promise than its performance. No preparation, on the other hand, is required for Portland Cement; indeed, any coating of paint excluding the air would act prejudicially, and retard the crystallization of the setting process. In the air, in the water, and in fact under all imaginable circumstances, the possibility of using with success this material forms one of the greatest recommendations in its favour. Even its present standard of value may be increased in combination with some of the soluble silicates of soda or potash. There has been already some advance in this direction; but a combination of this kind should only be attempted where the cement can be obtained of an undeniably excellent quality and strength. No free lime should be present, or injurious action will arise and cause disappointment. I shall now proceed to discuss the relative values of cements, and will draw largely on Mr. Grant's valuable tables for illustrating the subject.

CHAPTER XIII.

EXPERIMENTS ON THE CONSTRUCTIVE VALUE OF PORTLAND CEMENT, AND THE USES TO WHICH IT IS APPLIED.

As Mr. Grant's tests and specifications for using Portland Cement are now being generally adopted by engineers, I here extract from his paper the particulars thereof:—

"The whole of the cement to be used in these works (Southern High Level Sewer), and referred to in this specification, is to be Portland Cement, of the very best quality, ground extremely fine, weighing not less than one hundred and ten pounds to the striked bushel, and capable of maintaining a breaking-weight of four hundred pounds on an area $1\frac{1}{2}$ inch square, equal to $2\frac{1}{4}$ square inches, seven days after being made in an iron mould, of the form and dimensions shown on drawing, and immersed six of these days in water."

The moulds above referred to were made of bell-metal, having a sectional area at the breaking-point of $1\frac{1}{2}$ inch $\times$ $1\frac{1}{2}$ inch $= 2\frac{1}{4}$ square inches, with templates of thin iron, the exact size of the mould, the bricks or briquettes being afterwards, and in a short time, pressed out by the machine referred to at page 46. The whole process of testing was entrusted to a special workman, under the control of the superintending clerks of works, to whom only was permitted access to the testing-houses; so that every precaution was taken to stamp the tests with truth and impartiality, and prevent the possibility of tampering with the samples.

Mr. Grant, in speaking of his experience at the date of his paper (12th December, 1865), says:—

"No difficulty was found in training an ordinary workman to test the cement by means of these machines, and after using during the last six years more than 70,000 tons of Portland Cement, which has been submitted to about fifteen thousand tests, it can be confidently asserted that none of an inferior or dangerous character has been employed in any part of the works in question."

Again, in speaking of the cost attending the testing of the cement, an objection which had been raised, Mr. Grant says:—

"In all works of magnitude, engineers and architects should insist upon the cement being thoroughly tested before being used. To do so no great expense need be incurred; for the first cost of one of the machines is about £50, and the annual charge for labour about £80. The whole expense of testing the cement used in these works, which extend over a distance of eighteen miles in length, and cost upwards of £1,250,000, has only been about five farthings per ton of cement,—an utterly insignificant cost when compared with the great advantages gained in quality and soundness of work."

Fortunately for the reputation of Portland Cement, Mr. Grant did not confine his tests and experiments to the simple requirements of the works under his charge; but extended them in different branches of investigation, which have resulted in valuable information. Thus, in a series of nine hundred and sixty experiments, with cement weighing 112 lbs. to the bushel, gauged neat and with three varieties of sand, the following surprising results were obtained:—

NEAT CEMENT.

	lbs.
1 week	445·
1 month	679·9
3 months	877·9
6 „	978·7
9 „	995·9
12 „	1075·7

So that the cement more than doubled in strength in twelve months.

When mixed with equal proportions of clean sharp Thames sand, the following results took place:—

	lbs.		Per Cent. of the Strength of Neat Cement.
1 week	97·0	=	21·8
1 month	309·3	=	44·5
3 months	367·0	=	41·8
6 „	546·8	=	55·9
9 „	607·8	=	61·3
12 „	700·3	=	65·1

The above table shows a considerable lower strength than in the previous experiments, but still indicating the progressive value developed by time.

The next table, using the same kind of sand and in the proportion of two of sand to one of Portland Cement, we have as follows:—

	lbs.		Per Cent. of the Strength of Neat Cement.
1 week	52·5	=	11·80
1 month	123·5	=	18·16
3 months	254·5	=	29·00
6 „	425·1	=	43·46
9 „	431·5	=	43·33
12 „	458·5	=	42·62

Still showing a periodical increase in value.

Again, when the same quality of sand was increased to the proportion of three to one of Portland Cement, we have:—

	lbs.		Per Cent. of the Strength of Neat Cement.
1 week	27·0	=	6·07
1 month	58·0	=	8·53
3 months	135·5	=	15·43
6 „	232·4	=	23·74
12 „	320·6	=	29·90

When a proportion of four of the same sand with one of Portland Cement was used, the following was the result:—

	lbs.
1 month	32·5
3 months	109·0
6 „	157·0
12 „	221·0

And again, with five of sand to one of cement, the breaking-weights were:—

	lbs.
1 month	21·
3 months	88·5
6 „	95·5
12 „	122·3

All corroborating each other as to the progressive and continuous improvement in value of the cements.

The above tests may be considered as possessing more than ordinary value, from the fact of their having been made regardless of any manufacturing question or with any trade object.

Mr. Grant again, with the view of ascertaining the time or age at which neat cement and a mixture of it with sand attains its maximum strength, instituted a series of three hundred experiments to spread over ten years, and as less than three years of that time had run, we only are furnished with the following. A cement of higher specific gravity, *viz.* 123 lbs. per bushel, was here used, and when mixed neat, broke thus:—

	lbs.
1 week	817·1
1 month	935·8
3 months	1055·9
6 „	1176·6
9 „	1219·5
12 „	1229·7
2 years	1324·9

The same cement, when mixed with an equal proportion of Thames sand, broke at the following weights:—

	lbs.		Per Cent. of Neat Cement.
1 week	353·2	=	40·78
1 month	452·5	=	48·35
3 months	547·5	=	51·85
6 „	640·3	=	54·42
9 „	692·4	=	56·77
12 „	716·6	=	58·27
2 years	790·3	=	59·65

The proportionate strength of cement and sand increases, it will be perceived, between three months and twelve months, at the rate of two per cent. every three months, but in the course of the second year only 1·38 per cent. per annum.

Another interesting series of two hundred and twenty-five experiments, made with cement gauged neat, and kept for periods varying from seven days to twelve months: first, in water; secondly, out of water, indoors; and thirdly, out of water, exposed to the action of the weather. At the end of twelve months the results are respectively as 1099, 827·4, and 719·6; that is to say, the cement, which was kept out of water indoors attained only 75·29 per cent. of the strength of that which was kept in water; while that which was out of water, and exposed out of doors, acquired only 65·48 per cent. As there are considerable variations in the apparent strength at different ages, if the averages are taken, they are as 100, 80·64, and 76·8. Cement allowed to set under water seems, from these experiments, to gain in strength from twenty-four to thirty per cent.

The above results and Mr. Grant's conclusions are in conformity with the experience of Smeaton, Vicat, and other eminent engineers, who found that good hydraulic limes and cements improve in water to a much greater extent than when used in building on land. The reason for this will be considered when we discuss the theory of cement setting and the influence of weather upon it.

Mr. Grant, in reference to the size and form of brick, says:—"The adoption of this particular size was to some extent obligatory, from its being the only known form in use." It is fortunate that this form is still adhered to, notwithstanding the many suggested alterations. We have every prospect of seeing an established system of uniform tests for Portland Cement; for a too-eager straining for theoretical perfection would stultify the good effects such uniformity secures, for many of the objectors to the Metropolitan Board of Works test entirely lose sight of the necessary practical nature of the mode of testing, and those by whom it is conducted. It is not a test to be made in an office, or conducted by scientifically-educated men, but of necessity one performed out of doors, and entrusted to men of ordinary intelligence and probably uneducated.

As evidence of the kind of opposition offered to Mr. Grant and his specification, the following may be said in illustration of this subject. It should be stated, in case previous reference to this matter may not have been sufficiently clear, that the test in question substantially consists of three leading ingredients.

1st. A twofold measure of specific weight and volume or capacity, *i.e.* "*110 lbs. to the striked bushel.*"

One would naturally suppose that so clear and intelligible a proposition would satisfy the most scrupulous searcher after practical perfection. Yet, notwithstanding its simplicity, it met with opposition from an engineer of eminence and standing, who endeavoured to prove the unsuitability of such a test. In arguing the position he had assumed, he said:—

"A quantity of cement was poured into a bushel measure by a man accustomed to the work, and struck off level. It then weighed 107 lbs., exclusive of the weight of the measure. Then another portion of the same cement was poured slowly out of the sack down an inclined board into the bushel measure, and it then weighed only 97 lbs.; he then had it shaken down in the measure and the weight then got up to 132 lbs. When it was found, therefore, with the same measure of capacity and with the same materials there could be a variation of from 97 lbs. to 132 lbs., he could not help thinking, if a test of gravity could be obtained which was not liable to those variations, it would be a very desirable thing. Until the mode of ascertaining the weight was altered, so as not to be affected by the question as to whether in the trial the cement was more or less compact in the measure, he thought that the stipulation as to weight, though the manufacturers did not wish to have any more tests imposed, should be combined with that of sifting, so as to ensure the fine grinding of the cements, as, if this were not done, he thought the requirement as to weight was liable to act as a premium for coarse grinding. In reference to this, he would state that he had sifted, through a sieve with 900 holes to the square inch, a certain portion of the cement, which weighed, as before stated, when very carefully put into the measure, 97 lbs., and when put in in the ordinary way weighed 107 lbs. to the bushel. Those portions which would not go through the sieve were then poured into the bushel measure with the same care as that which made the unsifted weigh, as previously stated, only 97 lbs. With this care, the coarse weighed as much as 101 lbs., and when shaken down hard into the measure, 144 lbs.; whereas the unsifted cement weighed, as before stated, only 132 lbs. He then took by themselves the fine particles which had passed through the sieve, and they then weighed only 98 lbs. as against 97 lbs., and when shaken, 130 lbs. as against 132 lbs. for the mixed and 144 lbs. for the coarse. He gathered from this that weight, as ascertained by pouring the material into a measure, was liable to extremely variable results, even when the greatest care was taken; and further, that, unless it was accompanied by the test of sifting, there might, and probably would, be badly-ground cement present in the mass."

It will be seen from the above extract, that it is possible to fill a measure in different ways, so as to obtain varying results. The same rule is also applicable to other substances besides cement. Flour, sugar, tea, &c., would equally break down under such rigidity of test, without practically destroying the value of the measure of capacity that might be used. Again, a piece of cloth would measure a yard by the ordinary method, and a different result obtained either by expanding or contracting the material, as the fancy of the experimenter or theorist might dictate. All this ingenuity and its results are therefore not likely to damage this the first element of the test, even if this criticism upon it had not been made.

2nd. The second stage of the test is that it shall remain under water for six days before being submitted to the—

3rd, or tensile test, of a value equal to 400 lbs. on an area of 2¼ square inches.

The necessity of this triple test strikingly illustrates the care required in using Portland Cement; for unless the cement passes in every stage, there is no reliability as to its quality. The 1st, or weight, could readily be met by an inferior, heavy, over-clayed material, that would also remain good under water for the prescribed time, and yet be found utterly deficient in tensile strength.

In the early initiatory experiments, very unsatisfactory results were obtained. Mr. Grant, on this subject, says: "The importance of having the cement finely ground was shown very early in these experiments; and there can be no doubt that much of the difference in these first results is attributable to the several samples varying greatly in this respect."

There is a remarkable uniformity in the results of the later experiments made by Mr. Grant, which is quite conclusive as to the extra value of heavy cement. In a summarized Table of Experiments spread over four years, made indiscriminately out of a total quantity of upwards of 300,000 bushels, the breaking-weights were as follows:—

Average weight per bushel. lbs.	Tensile strain on 2·25 sq. inches. lbs.	Average weight per bushel. lbs.	Tensile strain on 2·25 sq. inches. lbs.
106	472	119	777
107	592	120	732
108	650	121	705
109	646	122	716
110	708	123	673
111	693	124	819
112	687	125	816
113	701	126	657
114	699	127	864
115	705	128	916
116	768	129	920
117	718	130	914
118	644		

If attention had been given to the different quality of the fineness of the cement, it is just possible that the variations from the progressive increase of strength would have been accounted for from imperfect pulverization. It is conclusively shown by the above Table, based on a lengthened experience spreading over a considerable period and with a practical object, that an increase in weight of twenty-four pounds to the bushel nearly doubles the tensile breaking-value of the cement.

In another Table of Experiments made with fresh and sea water, the following results are given:—

The cement weighed 121 lbs. per bushel.

Age of Bricks.	Fresh Water. Average Breaking-Tests. lbs.	Salt Water. Average Breaking-Tests. lbs.
7 days	922	943
14 „	1062	1056
21 „	1138	1147
28 „	1123	1203
2 months	1175	1341
3 „	1256	1368
4 „	1320	1464
5 „	1327	1353

The whole of the above tables and experiments were made with reference to the tensile strength; and I will conclude my gleanings from Mr. Grant's paper with the following Tables of Experiments on the compression of Portland Cement, Bricks, &c.:—

TABLE of 178 Experiments on the Compression of Portland Cement Bricks: size, 9" × 4"·25 × 2"·75 = 105·18 cubic inches surface submitted to pressure being 9" × 4·25 = 38·25 square inches.

1860 and 1861.

	Average Crushing weight. Tons.	Age of Bricks.
Neat Portland Cement	65	3 months
1 vol. Cement, 1 vol. Sand	43	,,
1 vol. ,, 2 vol. ,, ...	34	,,
1 vol. ,, 3 vol. ,, ...	24	,,
1 vol. ,, 4 vol. ,, ...	23	,,
1 vol. ,, 5 vol. ,, ...	16	,,
Neat Cement	92	6 months
1 vol. Cement, 1 vol. Sand	59	,,
1 vol. ,, 2 vol. ,, ...	47	,,
1 vol. ,, 3 vol. ,, ...	37	,,
1 vol. ,, 4 vol. ,, ...	31	,,
1 vol. ,, 5 vol. ,, ...	26	,,
Neat Cement	102	9 months
1 vol. Cement, 1 vol. Sand	78	,,
1 vol. ,, 2 vol. ,, ...	62	,,
1 vol. ,, 3 vol. ,, ...	41	,,
1 vol. ,, 4 vol. ,, ...	38	,,
1 vol. ,, 5 vol. ,, ...	29	,,

The following Table shows Experiments on various Bricks and different kinds of Stone:—

1859 and 1860.

	Cubic contents.	Surface exposed.	Average Crushing weight Tons.
Red Brick, Oldham	113·66	39·33	40
Medway Gualt Brick.. ..	111·37	40·50	17
Ditto, pressed	105·30	..	48
Stafford Blue Brick	117·18	27·9	50
Red Machine Brick	105.94	37·8	28
Fireclay Brick	87·12	34·85	65
Wortley Blue Brick	95·94	34·76	72

—	Cubic contents.	Surface exposed.	Average Crushing weight. Tons.
Portland Stone on the bed ..	109.83	39·94	47
Ditto against the bed	109·83	39·94	43
Bramley Fall Stone on the bed	109.83	39·94	91
Ditto against the bed	109·83	39·94	52
Yorkshire Landing on the bed	105·27	38·28	96
Ditto against the bed	105·27	38·28	100

On examining the various results, it will be found that Portland Cement bricks, even at nine months old, exceed in value or resistance to compression some of the best natural and artificial building materials of the country. These satisfactory conclusions, arrived at through the agency of most carefully conducted experiments, have, instead of satisfactorily and for all time setting at rest the great intrinsic value of Portland Cement as a constructive material, been the means of inducing one of the manufacturers to ask (at the discussion created by the reading of Mr. Grant's paper at the Institution of Civil Engineers), "Where, then, was the practical use of having a cement stronger than the material which had to be joined together? If the stone decayed, what were the joints good for?" It is to be hoped that this advocate for levelling downwards will not find many adherents in these progressive times. Much of the clamour against heavy cement is caused by its slowness in setting, and doubtless great waste and loss is occasioned by many using this quality of cement for purposes to which it is unsuited. Ignorance on the part of the builder prevents his testing it before being used, and its unfitness for his special purpose is not known until after the damage has been caused and beyond remedy.

Fortunately, the above Tables conclusively prove that the value of Portland Cement must be measured by its weight, and that the limit of its excellence is controlled only by the value of fuel used in its manufacture and the amount of mechanical agency which may be applied in its subsequent pulverization. The striking evidence furnished by these Tables of the superiority of bricks made of Portland Cement may hereafter lead to the consideration of the practicability of substituting them for the worthless stock-bricks now so universally used.

One remarkable feature prominently exemplified in these results of experiments is the uniformity of value according to the quality of cement used,—indeed, almost approaching in character to a formula for the guidance of engineers and architects.

Much misconception exists as to the limit of safety in burning the cement. It is argued that the insistance by the engineer of extremely heavy cements involves the risk of destroying it by overburning, and that as weight can only be reached by an excessive dose of lime, the risk was too great to run by specifying a cement of, say, 120 lbs. weight per bushel. Such a cement, they say, contains an excess of lime, which on being mixed with water becomes developed as free lime, and consequently blows, to the injury or destruction of the work in which it is used. The advocates of these objections cannot possibly understand the peculiar nature of the chemical effect of decarbonization in the kilns, or they would know that the very safety of an overcharged mixture of lime depends on its being overburnt; that is to say, it is possible to extinguish the evil tendency of a moderately overdosed lime-mixture by excessive burning, say, up to 120 lbs. per bushel; while if only burnt to 100 lbs. per bushel, the full influence of the excess of lime would be too surely developed and felt. That a heavy cement possesses less energy than a light cement in setting is beyond question; but to say that it destroys that essential property is erroneous. Mr. Druce, the engineer in charge of the Dover Harbour Works, speaking on this subject, advances the weight of his authority in favour of cement of 124 lbs. to the bushel. "He apprehended that it was the ultimate strength of cement, and not that at its earlier or intermediate stages, which concerned engineers." The same gentleman, in speaking of the interested opposition of some manufacturers, who asserted that a cement of 104 lbs. weight per bushel was preferable to one of a higher specific gravity, said:—"The light cement of 104 lbs. had the property of quick setting, and showed good results in the first instance, but it arrived at its state of ultimate hardness at a comparatively early period; while heavier cements showed moderate results at the earlier stages, but continued the process of hardening at a rate much more in proportion to their ages; the period of arriving at their ultimate hardness being also much longer, as shown by Mr. Grant's Tables. The results of 400 experiments made by himself on each of these classes of cements satisfactorily proved the superiority of heavy cements, and that the inference sought to be established was entirely fallacious. These results had been fully borne out in practice on the works at Dover, by the quality of the concrete blocks, and in other ways; and the contractors were so satisfied that it was to their own interest to use heavy cements, that they now declined to receive any but that above-named (124 lbs. per bushel). They had lately executed a most important work, which was one of the large detached forts in the deep water of Plymouth Sound; and from using only the highly-manufactured cement, they had lost but three blocks during the whole time of the contract. . . . The strength of cement might be reduced to any extent that was desired, and economically so, by increasing the proportions of sand employed; and as for a long time past the price of heavy and light cements in the markets had been much the same, there was a considerable saving in using the heavy cement with the larger proportion of sand that it would take. At the same time it must be admitted that greater weight meant nothing less than higher manufacture, and that heavy cement was worth a higher price. The natural conclusion was, that the light cement, from the great demand for it, was commanding a higher price than it deserved. The difficulty with Portland Cement now was that it could not be depended upon. . . . . It was almost a matter of necessity that it should undergo a course of tedious tests before assurance could be obtained that the cement would not 'blow' in the work; and this bar to its use would remain until the makers adopted the course pursued in other manufactures, which was, to aim at every possible improvement in quality, with the certainty of a good article always commanding its value in the market."

The above valuable testimony to the merits of Portland Cement, and also to the carelessness of its makers, may ultimately prove beneficial to its reputation.

Another authority, Mr. Coode, says:—"He quite agreed that probably Portland Cement would be used much more extensively than it was at present. Hitherto this cement had been rather dreaded. He was so satisfied with it that he had, some twelve months since, specified for the construction of a pier facing the German Ocean, and exposed to the 'fetch' of a sea from 191 to 200 miles, the whole of which, from the foundation-courses upward, was to be of Portland Cement concrete blocks, the face of the work, both seaward and towards the harbour, being of the same material; and he believed it would prove, both in point of strength and durability, to be equal to any ordinary building stone. In point of cost, it involved the question of building the pier in that material, or not at all, for if the pier had been faced with stone, the expense would have been beyond the funds at the disposal of the authorities of the harbour in question. He was led, in a great measure, to adopt that material in the face of the work from having seen the result of the action of the sea upon a pier at Hartlepool. In the year 1856 a pier was projected in Hartlepool Bay, which was stopped somewhat abruptly by Act of Parliament, and the work was left with the bare ends, both of the face-stones and concrete blocks in the hearting, stepped back in the ordinary way. He examined it after seven years' exposure to the action of the sea, and he found that the arrises of the Portland Cement blocks, though they were not of first-class quality, were quite as sharp as those of the Bramley Fall stone with which the pier was faced. He had the authority of Mr. James May for saying that the experience of more than fourteen years at Alderney had shown that the blocks of concrete made with Portland Cement indurated with time rather than disintegrated. This seemed to be a reason for making experiments upon the relative strength of concrete made with Portland Cement and different proportions of shingle and sand. He would also observe that, amongst all the experiments made with that cement, he was not aware of any having been made with reference to its resistance to the action of attrition or abrasion. That was a quality which Portland Cement possessed in a remarkable degree, and experiments in that direction might be worth the attention of manufacturers, and would, he anticipated, exhibit some extraordinary results, which would be very useful and encourage the larger use of the material. Sea-walls or piers faced with concrete blocks, and exposed to heavy seas, would not only have to resist the shock of the waves, but also the severe test of the attrition due to the moving sand and shingle, which were always found to tell considerably upon such works at the ground-line in shallow water, and this was one of the greatest enemies to contend against in works so founded.

"With regard to the export of Portland Cement, the best and cheapest mode of conveyance on long voyages was by packing it in wrought-iron tanks, measuring about four feet each way, as a convenient size, instead of in casks. Thus protected, it always arrived at its destination in first-rate condition. He had on several occasions sent cement in that way to some harbour works he was executing without a contractor in South Africa. It resisted all moisture and damp on the voyage, whether from leakage of the vessel or any other cause, and the iron tanks had been sold in the colony, generally for the same money, and in some cases even for more, than they had cost in this country."

Much doubt exists in the minds of some engineers as to the practicability of using Portland Cement concrete in still and running water.

Mr. Kinniple in replying to Mr. Grant, who had said that "Portland Cement concrete, made in the proportions of one of cement to eight of ballast in some cases, and of one to six in others, had been extensively used for the foundation of the river-wall, piers of reservoir, and foundations generally, at Crossness and Deptford, with the most perfect success," states his experience and says:—"Now to have obtained such perfect success, it must have been absolutely necessary to have kept the entire works clear of water, for it was not possible to get concrete under water, whether quiet or not, if it was thrown in dry immediately after mixing. He had ascertained that in only one inch of quiet water, concrete made in the proportions of three to one was endangered by the working out of the silicate, or the best of the cement, from the ballast; those silicates resembled slime on the surface, and with the slightest motion in a run of water were lost. In concreting an outer apron just inside a coffer-dam at low water, he had used Portland Cement concrete, in the proportions of four of ballast to one of cement. It was all put in at the same time, in the same manner, with the same cement and ballast, and by the same men, and was allowed to remain in quiet water for three months; when he had again occasion to examine it, the concrete nearest the abutments was sound and hard, but in the centre, or rather in the part last closed in, it was quite soft; in fact it was ballast, with a mere fraction of cement retained in it. This was executed in about two inches of quiet water, and had to be removed for the insertion of fresh concrete. To avoid this for the future, he had resolved that all Portland Cement concrete should be mixed on the surface, and allowed to set for several hours; the length of time for setting to be in proportion to the quantity of the cement used, and when set to be used in a crumbled condition. By experiments he found that he was able to retain nearly the whole of the cement without any loss as to strength."

In the above practical observations there is much valuable information, which indicates a thorough appreciation of the essential properties of Portland Cement. At the same time the treatment of the concrete as recommended by Mr. Kinniple, could not safely be entrusted to the ordinary workman, unless directed or controlled by intelligent supervision. If a cement of a light specific gravity (say 104 lbs. per bushel) was used in the manner indicated, it would be necessary to place it in position within half an hour after being mixed, or the concrete would be worthless; on the other hand, any heavier cements ranging from 114 lbs. to 120 lbs. per bushel might safely be left at varying periods of from four to twelve hours without danger from the carelessness or ignorance of the workman. Mr. Grant's experience had reference more particularly to the deposit of large quantities of concrete within coffer-dams, or at all events free from the injurious action of running water. The large works in concrete executed by him in the foundations of the Crossness pumping-station and the Southern Thames embankment-wall afford striking evidence of the suitability of that material for such works. The concrete was gauged in the ordinary way and immediately wheeled to position and tipped, the water from springs and the river having been kept under by pumping. Where it is inexpedient or impossible to aid the execution of this description of work by the assistance of coffer-dams it will be preferable to make blocks of concrete and thereby ensure against wash or waste of the cement by water.

Sir Charles Fox alludes to his own experience in overcoming successfully the placing of Portland Cement concrete in moving water. He says:—

"In forming the foundation of the Rochester Bridge, the cylinders were sunk 42 feet below the bed of the river (Medway). Being a tidal river, there was in those cylinders a good deal of what the workmen call 'breathing.' In other words, the water rose about a foot at the bottom of the cylinder, and then receded, and continued to rise and fall, as it was supposed, by simple momentum. It was found that as a consequence all the cement in the concrete, when placed at the bottom of the cylinder, was washed out, and came to the surface, so that for nine or ten inches at the bottom only ballast remained. The difficulty was got over in the following manner:—A quantity of concrete having been prepared, a piece of stout canvas sail-cloth, such as was used for hose-pipes, was cut one foot larger in diameter than the bottom of the cylinder, to which it was well fitted all round; and when covered with about two feet of concrete, it held down the water until the remaining concrete was deposited safely upon it. In that case Portland Cement was used. The same plan was adopted with all the cylinders for those foundations."

Mr. Rawlinson, an eminent practical authority, says:—"There was one application of Portland Cement not generally known, *viz.:* its use, when of good quality, under water by the aid of a diver. He had used it to make a joint between iron and iron, under a 90-feet head of water, with perfect success, to keep out a quicksand. No other means had enabled him to master that quicksand. He had occasion to sink a well where there was a quicksand at a depth of 90 feet, overlaid by a thick bed of marl and underlaid by new red sandstone rock. A first well was sunk in the ordinary manner, by miners of the district, and, being an utter failure after two years' work, was abandoned. The second well was sunk within 30 feet of the same site, by 7-feet cylinders, which were sunk without pumping, and lowered by working inside till they rested on the new red sandstone rock; but the dip of the rock was at such an angle that the 7-feet cylinders could not be made to bed into its surface. He then worked with drills in the sandstone rock, by placing a second cylinder inside the first, with a cast-iron diaphragm bottom, having a 2-feet hole in the centre for the passage of the boring tool; but the difficulty was to make the joint between the two cylinders tight. The ordinary iron cement of iron borings and sal-ammoniac would not set, but washed out. He then sent down pure, stiffly-made Portland Cement in buckets; this was put in place by divers, and set perfectly, where it had remained for three or four years, though exposed to a severe strain by the constant pumping. To close the joint round the bore-pipe passed through the diaphragm, Portland Cement concrete was used, sent down also in 90 feet of water, spread out and placed by a diver."

The above very interesting example of the successful application of Portland Cement, under such unusually difficult circumstances, is very satisfactory indeed.

Mr. B. P. Brereton, who has had opportunities of using Portland Cement very largely in still water, says:—

"In 1848, when Portland Cement was first thought of for foundations, inside of cylinders, the late Mr. Brunel was engaged in building a bridge across the Thames at Windsor. It was at that time stated that Portland Cement answered well, used in the proportion of one part of cement to ten parts or twelve parts of gravel, and in that way formed an economical mode of filling up foundations in the water. In putting it in through water, it was not considered prudent to try it in those proportions, but it was tried with one part of cement to nine parts of ballast. The cylinders were sunk through the gravel without pumping, and they became full of water through the bottom, and under the sides. Through that water the concrete was passed, after being properly mixed, and it set well and hard in eight days or ten days. The result of the first experiment was surprising. On pumping out the water there was, on the top of the concrete, a thin layer of slime and matter, which led to the expectation that the cement had been washed out of the concrete in its deposition, and for satisfaction on that point the concrete was carefully examined. It had set very hard, and on drilling nearly three feet into the concrete, no amount of drilling, consistent with reason, could make any further impression. This proved that the slime was due to only a very small portion of the cement that had been washed out, and that the great bulk of it remained in the concrete; the proportions were afterwards increased to one to six. The result of the experiments led to the use of that concrete very largely in subsequent bridges, and it was deposited in depths even of from 50 feet to 70 feet, without the least attempt at pumping. When sufficient concrete had been deposited to balance the water pressure, and when, after ten days or a fortnight, it had set, the water was pumped out of the cylinders, and the remainder was filled in with concrete of the ordinary kind."

"Those instances were sufficient to prove that concrete was good for all purposes so required of it. Those foundations, which had been built sixteen years or eighteen years, showed no symptom of failure. With regard to the setting properties of this cement, when used with sea sand, or otherwise, he had found the use of sea sand and salt water perfectly satisfactory, both with Portland Cement and Lias Lime; but there was no question as to its setting being rather retarded by that course. A few weeks ago, at some works in Wales on which he was engaged, in a tide-way, he mixed cement used with sea sand and salt water, but it did not set quickly enough. He then tried the blown sand, taken from the hills, not wet, and mixed with fresh water, and the cement set satisfactorily; whereas if the sand was saturated with salt water it took a longer time to set. At Windsor, with a depth of 12 feet to 18 feet, the concrete was lowered in bags holding about 1¼ yard at a time, and it was discharged at the bottom. The same plan was adopted elsewhere in deeper water, upon a larger scale, but a different disengaging apparatus was used."

Mr. Hawkshaw said, "He had used Portland Cement in a tide-way, and had not experienced any difficulty in so using it. Neither had he experienced difficulty in using concrete blocks in similar situations. As to the setting of concrete in water, he had passed it by means of boxes through 70 feet of water, and with the usual precautions it succeeded. In Italy he had seen sea-walls built in 20 feet of water, without passing the concrete to the bottom in boxes. Nothing more was done than to mark the outline of the wall, by piles boarded on the sides. It was mixed very rapidly, and a large number of men and boys were employed to carry it away in small quantities and throw it where it was to be deposited. Extensive sea-walls were built in the Mediterranean in that way.

"There could be no doubt that within his own experience, the manufacture of Portland Cement had been greatly improved, and it could now be relied on to an extent which could not have been done formerly. He had so much confidence in it, that he was now commencing a large harbour on the Dutch coast at the mouth of the Amsterdam Canal, the piers of which were to be carried out a mile and a quarter into the sea, and he proposed to build them of blocks of concrete, made with shingle and Portland Cement. He agreed that these blocks, when well made, appeared to retain their forms and preserve their surfaces, equal to those of any stone which was used for these purposes.

"The difficulty in using sand and cement arose from the fact that blocks so composed took a long time before they could be handled. The fact that no shingle was to be found on the coast of Holland had caused his attention to be directed to the use of sand alone for hearting or internal blocks. Since he had visited the Suez Canal he had been informed that there was some idea of making the piers at Port Said of blocks of sand and cement only, and, no doubt, where there was time to wait till these blocks became hard, they would be suitable for portions of the work. Portland Cement had the remarkable quality that it indurated to a higher extent in water than in air. That was in itself a great advantage in sea-works. One thing which gave him confidence in adopting concrete blocks so extensively as he had done, was what he noticed some years ago at ports on the Mediterranean. He endeavoured to ascertain the age of some concrete blocks which he saw in an old pier at one of those ports, not built, but thrown in as *pierre perdue*, and, as far as he could make out, those blocks had been made about one hundred years. They were not perfect in form, but they had not been made with the care with which blocks were made at the present time for works of that kind."

After such unanimous testimony from engineers so distinguished in their profession, it will be unwise for manufacturers of Portland Cement to continue any resistance or opposition to the demand for heavy and good cement, which it is quite evident some engineers better understand than many of the makers; the time has gone past for the *ipse dixit* of the manufacturer to impose a cement of indifferent or doubtful quality, simply because it had been made at an old-established manufactory; something more than this kind of reputation will be required for a maker to hold his ground amongst engineers who have given the question of Portland Cement the necessary attention. Progress in the use of this material is due more to the intelligence of the consumer than to the wisdom or common sense of the manufacturer. Hitherto a first-class cement was only obtainable under the pressure of the engineer. Voluntary action on the part of those most interested has not yet been exhibited. If Mr. Grant had listened to some manufacturers, the Board of Works test would not have been instituted.

Having by the above quotations shown that, under peculiar and varying circumstances, Portland Cement has in every case successfully accomplished what was required of it, and in no instance mentioned has failure resulted from its use, I will still further extract a few facts from the important discussion which followed the reading of Mr. Grant's paper, on the use of Portland Cement for making large concrete blocks.

Mr. J. F. Bateman on this subject said :—"He would state the mode of construction adopted by Mr. Stoney for the Ballast Board at Dublin for quay-walls at that port. The ordinary quay-walls were of concrete, formed of one part of Portland Cement to ten parts of the gravel of the Liffey. The crushing power, at three mouths, was 16 tons to the square foot, and this concrete was made at a cost of from 10*s*. 6*d*. to 10*s*. 8*d*. per cubic yard when set, exclusive of the cost of plant. It was not set in blocks, but was deposited between planks, in the ordinary way of making concrete walls. Owing to the success of these walls, Mr. Stoney had undertaken the formation of concrete blocks on a larger scale than, he believed, had been hitherto attempted in the building of a wall 24 feet below low water, without coffer-dams. These blocks were made 23 feet upon the base, 26 feet deep, and 10 feet upon the face, weighing 330 tons each. They were built on a strong platform formed upon the shore to carry this enormous weight, and were allowed to remain as long as was necessary to harden before they were removed. They were then floated to their destination and lowered to the base previously prepared for them, under a large diving-bell 20 feet square. The cost of these blocks, formed of one part of Portland Cement to six parts of the gravel of the Liffey, and faced with granite, was estimated at 16*s.* per cubic yard exclusive of plant, and 18*s.* with plant. In fine weather they might be laid on an average of one block at every tide; but by supposing that only one block could be laid every other day, or 150 blocks in the course of the year, they would form a wall 1500 feet long, at a cost which was a mere bagatelle compared with other modes of construction involving the use of coffer-dams. It was about ten months since he investigated the question, and he could not report what had been done since. He could, however, speak with confidence as to the stability, strength, and apparent durability of the walls already constructed,—those in which the composition was one of Portland Cement to ten parts of the gravel of the Liffey."

Sir Charles Hartley said:—"Harbours of Refuge were being constructed at Biarritz and St. Jean de Luz, situated on the rocky sea-board between the mouths of the Adour and Bidassoa, and consequently at the very head of the Bay of Biscay, a position peculiarly exposed to the fury of Atlantic gales from the N.W. The rise and fall of the tide at this part of the coast varied from 3 mètres to 5 mètres. At Biarritz the works were carried on under great difficulties, owing to its being without a safe haven for the shelter of small craft, to the number of detached rocks, to the great depth of the sea close in shore, and to the presence of an almost incessant ground-swell even at times of perfect calm. This unfavourable condition of things obliged M. Daguenet, the engineer in charge, to advance the new jetty from the mainland to its full height at once, by pitching large blocks of béton into the sea from a temporary waggon-road. The blocks used had a cube of 33 tons each, and were composed of Portland Cement, stone, and sand, in the proportions of 1 part of cement to 2 parts of sand and 3 parts of broken stones. After being made they were allowed to remain three months to harden, and were then conveyed in waggons to the tip-head.

"At St. Jean de Luz the proximity of a small tidal harbour rendered the formation of a new jetty (this work, like the Biarritz jetty, is intended to have a length of about 300 mètres, founded at an average depth of 24 feet below high-water mark) a much easier task, for under its shelter blocks were made on the shore, between high-water and low-water mark, and from one month to two months afterwards, according to the season, were taken to the jetty by a couple of pontoons, and quickly lowered into place. The blocks measured 4 mètres by 2½ mètres and 2 mètres in their sides, and weighed 44 tons. They were begun and completely finished during the ebb of a single tide, and the boards which then encased them were removed within 24 hours afterwards. The proportions of these blocks were 1 of Portland Cement, 2½ of sand, and 3 of stones. They set much sooner, and supported more sand than the Biarritz blocks, in consequence of their frequent immersion in water, immediately after being built; and they were not liable to fracture when deposited, on account of the employment of pontoons. The jetty, above the level of ordinary low-water, was entirely constructed of very small rubble—faced with ashlar rarely more than 3 feet cube—set in Roman cement, or rather in the quick-setting Spanish cement, which very nearly resembled it, and which after being used half-an-hour was capable of resisting the heaviest seas. This appeared to be a skilful application of two cements, differing widely in their respective qualities, and however much the durability of a quick-setting cement might be questioned, its success in the meantime at St. Jean de Luz, where it was employed under trying circumstances, was undoubted.

"With regard to the relative value of cement and pozzolana, he might state that Italian engineers, as a general rule, preferred the latter, principally on the ground that it had stood the test of centuries, whereas they contended that cement for sea-works was still on its trial. They argued, moreover, that béton formed of pozzolana was infinitely cheaper in Italy than béton composed of the cements of France or of England; and, in support of this assertion, they might have quoted the fact that pozzolana blocks only cost from 20 francs to 28 francs a cubic mètre, at almost any part of the Italian sea-board, whilst a wall built at Genoa, with the Valentine cement of France, had cost 45 francs; the blocks used at Biarritz, and made of Portland Cement, 40 francs; and the

Cherbourg blocks, made also of Portland Cement, as much as 55 francs per cubic mètre: the cost of materials, labour, and immersion, being included in each case.

"The choice of a cement, or of pozzolana as a substitute for it, depended so much on the character of the work to be executed and on its geographical position, that the greatest merit would ever be due to those who selected the materials of construction best adapted to the exigencies of the situation. Thus it might be found that pozzolana was superior to cement, where, as in Italy, the former was plentiful and cheap, and the latter scarce and dear; that Portland Cement was more suitable than pozzolana wherever there was a constant wash of the sea to contend with, or where, as at Biarritz, great tenacity was required; and that a very quick-setting cement was best where, as at St. Jean de Luz, the construction of a temporary coffer-dam or casing was impossible. He believed, as a rule, foreign engineers were bolder in their concrete works than English engineers had been hitherto; and he fully agreed with those who predicted a much larger use of English cements, and especially of Portland Cement."

The practice thus described by Sir Charles Hartley, of jointing with Roman or other quick-setting cement is usually adopted by English engineers under similar circumstances. Mr. Grant, when constructing a portion of the Main Drainage works through the Woolwich Marshes, had to contend with a large flow of water from springs. He overcame the difficulty by the use of *freshly-burnt* Roman Cement concrete, which set within half-an-hour, and thus enabled the bricklayers to continue the building of the sewer without interruption. Mr. Hawkshaw, in alluding to the laying of concrete blocks, said:—"In positions where the water was rough, he took the precaution of immediately pointing the surface-joints with Medina Cement, which set very rapidly."

The choice of the engineer has hitherto been only between a heavy good artificial Portland Cement and the natural Roman or Medina Cements, as it is not to be supposed that they were aware of the possibility of obtaining a Portland Cement of quick-setting properties. A cement of the same specific gravity as the ordinary Roman or Medina Cement (about 80 lbs. to the bushel) would set equally quick, with the additional useful property of keeping good for a much longer period of time; or it is even possible to hasten the setting of heavy Portland Cement by the addition of a chemical ingredient without prejudice to its ultimate hardening.

The above somewhat lengthened extracts from Mr. Grant's paper is intended to show that for massive sea-walls and works of a similar character cement concrete has been extensively used by engineers in all parts of the world. The satisfactory results of the most eminent engineering experience is conclusive as to its suitability; and wherever doubt or anxiety has been felt, it was from fear of the quality of the cement itself—no hesitation on the part of the engineer to use it in blocks of from 330 tons or less.

With reference to the cost of concrete in bulk and in blocks, it will of course depend on the neighbourhood or locality. In addition to the above information of the cost of concrete and blocks at Dublin, and at several places in France, I here give Mr. Grant's Table of Experiments made to ascertain the cost of a cubic yard of Portland Cement mortar, with varying proportions of cement, sand, and water used. This Table will readily enable any one to estimate the cost for themselves, which will of course be regulated by the price of the materials at the place of consumption. The weight of cement per bushel is not given—an element to be considered in such a question—but it may be safely assumed as having been not less than 112 lbs. per bushel:—

Proportion of Cement and Sand.	First Series.	Bushels.	Second Series.	Bushels.
1 to 1 ..	Cement ..	12¼	Cement ..	13
	Sand ..	12¼	Sand ..	13
		24½		26
	with 56 gals. water.		with 48 gals. water.	
1 to 2 ..	Cement ..	8¼	Cement ..	8½
	Sand ..	16½	Sand ..	17
		24¾		25½
	with 44 gals. water.		with 36 gals. water.	
1 to 3 ..	Cement ..	6½	Cement ..	6¼
	Sand ..	19½	Sand ..	18¾
		26		25
	with 46 gals. water.		with 28½ gals. water.	

Proportion of Cement and Sand.		Bushels.		Bushels.
1 to 4 ..	Cement ..	5¼	Cement ..	5
	Sand ..	21	Sand ..	20
		26¼		25
	with 47 gals. water.		with 38 gals. water.	
1 to 5 ..	Cement ..	4¼	Cement ..	4⅛
	Sand ..	21¼	Sand ..	20⅝
		25½		24¾
	with 51 gals. water.		with 34 gals. water.	

These experiments show the possibility of mixing up a cubic yard of mortar with very fluctuating quantities of water. The three ingredients of cement, sand, and water may be considered as uniform in quality, and therefore not in themselves influencing materially the result. It may be safely assumed that the greatest amount of care was exercised in the conduct of these experiments, and the result clearly indicates the necessity of accurate manipulation in the preparation of cement mortar. As a rule, the less quantity of water you can use the better; the only limit will be found in the objection of the bricklayer and mason, or their labourers, to the greater difficulty in handling or using a stiff mortar. Different qualities of sand have a material bearing on the question of mortar. Clean washed Thames river sand is mainly the result of the disintegration or reduction by attrition of flints, and substantially consists of fine particles of that mineral, and not therefore equal in quality to sands obtained from the oolitic or limestone beds on the western coast of England. Sand to be most useful in a mortar should have porosity enough to fully absorb the moisture from the cement. A singularly favourable application of Portland Cement in combination with chippings from Bath and Anston stones was practised by Mr. Buckwell in the manufacture of his patent Granita Breccia stone, some years ago. He made paving-slabs, drain-pipes, and segmental parts of sewer drains in a most ingenious and effective manner by mixing certain proportions of Portland Cement and stone chippings. The mode by which he accomplished certainly most satisfactory results was by the use of the best obtainable quality of cement—140 lbs. per bushel when possible—mixed with the smallest and sometimes almost inappreciable quantity of water, through the fine rose of a watering-can. The mixture of cement and chippings was first made in bunks, or large mortar boards, with sufficient water to prevent the dusting of the cement. It was then shovelled into the moulds made of cast-iron, bolted firmly together, and the materials rammed with iron rammers. The result obtained by this method of percussion from the impingement of the rammers or beaters was most satisfactory, especially where the matrix used was chippings of oolite stones and a proportion of sand of the same material. In using flints or gravel in the same manner, less successful results were obtained. The durability of the paving-slabs or stones made by this process was satisfactorily tested by a portion of it having been laid down on the footpath of the south side of King William Street, City, where it remained, subject to the incessant wear of the traffic of that great thoroughfare, for nearly fourteen years. During that period the York paving, on either side of the experimental portion, had been renewed more than once. The necessity for the removal of these Granita Breccia slabs did not seem apparent, for if they had been relaid by reversing the surfaces, there is no doubt that another dozen years' wear could have been obtained from them. These results were arrived at by the simple and expensive agency of manual labour; had the adaptation of machinery, contemplated by the inventor, been perfected and practically applied to this manufacture, the consequently reduced cost would have commanded for it a position amongst building materials which its merits doubtlessly deserved.

CHAPTER XIV.

MODE OF USING THE CEMENT.

Next in importance to the quality of the cement is the manner or mode by which the materials are mixed together. In ordinary building operations of moderate extent, the practice of mixing by hand may be tolerated; but when works of great magnitude are to be executed, the necessity of some more sensible and perfect means of amalgamation of the sand and cement is required. For mortar, a machine used by the designer, M. Greyveldinger, on the works connected with the drainage of the Boulevard de Sevastopol, Paris, is shown on Plate I., Fig. 1. It consists of a hopper of sheet-iron, *A*, closed at the bottom by a disc, *B*, surmounted with a cone, *C*. The disc and cone receive a rapid rotary motion by means of the cog-wheel *D*. The hopper is provided with a rectangular opening, *E*, of nearly eight inches in width, and of which the height can be varied at pleasure by means of a sheet-iron, controlled by a ratchet and cog-wheel, *F*. Below the hopper is a cylindrical spout, *G*, containing a revolving screw, to the core of which iron points are attached at regular intervals. Jets of water, regulated at pleasure by hand by means of the stop-cock *K*, are let into the funnel *J*, at the bottom, through a hose leading to a reservoir of water.

The dry ingredients of the mortar having first been roughly mixed with a shovel, and, if necessary, passed through a screen, are introduced into the hopper. The rotation of the disc and cone completes the incorporation of the dry materials, and imparts to them a centrifugal motion which ensures a constant flow from the opening *E*, into the funnel *J*, where they receive the requisite supply of water, and pass into the spout *G*. The motion of the screw carries the mortar to the other end of the spout, completes the mixture, and discharges it into barrows or buckets placed to receive it. M. Greyveldinger had four buckets arranged on a revolving platform *M*. By means of the crank *N*, the buckets are passed under the opening in the spout, and thus filled in succession without wasting the mortar or arresting the motion of the machine.

At the Boulevard de Sevastopol, Paris, motion was derived from a one-half horse-power engine, by means of a belt working on the drum, *O*.

There were required to tend the machine eight labourers, to measure the materials, fill the hopper, take away the mortar, &c., one intelligent foreman to regulate the opening in the hopper and the supply of water, and one engineer. The average daily expense, exclusive of wear and tear, is as follows:—

Nine men at three francs each ..	=	Fr. 27
One engineer		4
Coal		2
Or a daily cost of ..		Fr. 33 = £1. 6*s*. 5*d*.

A machine of the above size was capable of turning out about 38 cubic yards of mortar per day of ten hours.

This mill will answer for the quickest-setting cements, as only eight seconds of time elapse after the mixture receives the water before the mortar is discharged into the buckets.

Extensive operations requiring large quantities of mortar should be provided with a machine similar in construction to the one above described. In such works as the Main Drainage of London a mortar-mixing machine might have been employed with great advantage: if not singly, at all events in conjunction with a mortar-box and cart, similar to that shown by Figs. 1 and 2, Plate II.

This description of cart and box has been successfully used for a considerable time in the United States of America; more especially in executing the extensive works at Fort Warren, where the superintending engineers consider it very suitable and useful. In dock, harbour, or embankment operations, where it would be more convenient to establish the mortar-house or shed at the point where the cement and sand were delivered, a mortar-cart would be very serviceable. Indeed in all large works the preparation of mortar should be under the immediate control of the engineer. A notable instance of the success of this plan is furnished at the Liverpool Docks, where Mr. Hartley prepared the mortar, even purchasing the raw limestone, burning and mixing it with sand, and when mixed in the mortar mill sold to the contractor at a price per cubic yard.

French engineers, generally speaking, are responsible for the quality of the cement, and, especially for Government works, purchase direct from the manufacturers.

The German engineers also are responsible for the quality of cements supplied to their works.

CHAPTER XV.

APPLICATION OF CEMENT IN CONNECTION WITH MARINE ARCHITECTURE.

In addition to the numerous and varied uses to which Portland Cement is applied by the civil engineer in the construction of works of magnitude, visible progress is also apparent in its adoption for structures of less importance though equally useful. The marine engineer has for a long time used it in considerable quantities to prevent oxidization in the holds of iron vessels. Mr. Scott Russell said, "Portland Cement had been extensively used in the insides of ships, to preserve the iron from corrosion; and after eighteen years' use, he had seen Portland Cement dug out of an iron ship, when the red-lead, paint, and the skin of the iron were as sound as on the day they were put there." The successful internal use of the cement has led to the application of it externally by Captain Cowper Coles, C.B.

Captain Cowper Coles, C.B., has invented a method for preserving ships' bottoms by the application of Portland Cement. It has been successfully used on two vessels (the 'Tamar' and coal vessel No. 145) at Portsmouth Harbour; on the former, during a period of two years, and on the latter for two years, with great satisfaction. While other parts of the ships which were coated with anti-fouling paints required scraping and renovating six times during the above-named periods; the surface covered with the cement only had to be scrubbed, involving but little cost of time or labour.

The first experiment made was on the wooden sheathing of the 'Royal Sovereign,' on which the cement was put on the 10th of August, 1864; and on the 27th June following the officers of Portsmouth Dockyard reported that:—

"A patch of cement, on the plan of Captain Coles, R.N., was also placed on the starboard side of the teak sheathing, about midships, 6 feet long, extending from the upper to the lower part of the sheathing, protected round the edges by a coat of teak. This cement is now in very good condition, being only slightly indented, apparently by being struck by boats above the water. The weed on this cement is somewhat longer than on the adjacent parts of the sheathing, but no appearance of any barnacles or corraline formation is apparent thereon.

"As this experiment appears satisfactory, it is submitted whether a more extended trial of it would not be desirable."

A subsequent experiment was made on an iron coal-vessel (No. 145, Portsmouth Dockyard). She was launched November 15th, 1864, and on being docked in February, 1865, an examination proved that "the Portland Cement placed over the thin iron plate and within the wood frame have small portions of the cement broken off on the upper edge, and the surface of the cement coated with slime and very fine grass in the neighbourhood of the water line. The small portions broken off were merely on the surface, and had not in any instance bared the iron."

In the above experiments, the cement was painted with various anti-fouling mixtures for experimental purposes. The other portions of the vessel were coated only with anti-fouling compounds, and had to be scraped and re-coated before being undocked. In November, 1865, she was again docked, when the cement was found in the same state of preservation as before.

The official report, dated November 24th, 1865, says:—"The patch of cement put on by Captain Coles, R.N., is still firm and hard; and on cutting away a portion to obtain a view of the thin sheet iron behind, it was found perfectly dry and free from rust.

"1st. To the cleanliness and good preservation of the iron under and in direct contact with the cement, although it had been in the water one year, I would beg to call particular attention.

"2nd. That on a plate of the thin sheet-iron, to which the cement is attached, being removed, the bottom underneath was found free from oxidization. Water had found its way behind the cement, between the thin sheet of iron and the bottom, but Hay's glue, with which the bottom beneath this thin plate was coated, had protected it from corrosion."

Captain Coles does not claim for his invention the property of preventing absolute fouling of ships' bottoms. He says, "I protect the bottom with a coating of cement, which being in no way liable to be removed by oxidization, will enable you to clean the ship's bottom when these anti-fouling mixtures lose their power of preventing the growth of vegetation and barnacles, as effectually as though they were coppered; and it yet remains to be proved whether the cement, without any paint over it, is not the best, leaving it to the energy of the captain to hog and clean his ship's bottom whenever opportunity admits of it."

The method adopted by Captain Coles for applying cement to ships' bottoms is as follows:—

1st. Thin iron plates, about $\frac{1}{32}$nd of an inch in thickness, are prepared by having rectangular holes, from one to two inches apart, punched in them in such a manner that only three sides of the rectangle being cut, it does not become severed from the plate, but still forms part and parcel of the same, hanging on by its fourth side. The plates are then fixed to the ship's bottom proper, by means of small screws, so arranged that every square foot of iron plate would have five screws to fix it, one at each of the four corners and one in the centre, although in reality only two screws for each square foot would have to be accounted for, as regards weight and total number of screw-holes. For instance, a vessel with 22,680 square feet surface of bottom requires but 45,663 screw-holes if arranged in the above manner. The screws have conical heads, are $\frac{5}{16}$th of an inch in diameter, and need not enter the plates of the iron hull proper more than one-eighth of an inch. The ship's bottom may first be paid over with any paint, varnish, glue, or anti-corrosive mixtures that may be prepared. When the plates are on, the small rectangular portion at each hole is turned up at an angle of about 45°; thus forming small tongues, and affording a firm hold for the cement, which is plastered on about half-an-inch thick, in the usual manner of plastering a wall.

2nd. The screws for this method are tapped into vessels' bottoms the same as described in the first method, but may be further apart. Over these screws is wire netting of about one inch or three-quarter inch mesh, when a washer with a slot in it is slipped in between the wire and the head of the screw, which when tightened to the required extent, holds the wire netting tightly to the ship's bottom; and having thus cased the ship's bottom with a wire netting, it is ready to be plastered with cement, which will be found to adhere so strongly to the wire, that when thoroughly set and hard it requires a cold chisel to remove it.

3rd. The ship's bottom may be covered with wood sheathing, one inch thick. Into the wood are driven small nails, at about an angle of 45°, a quarter of an inch being left protruding; over this the cement is plastered, as before described.

4th. The ship's bottom may be dressed with a cold chisel, like a stirrup iron, producing a rough surface with under-cut projections, and thus enabling the cement to adhere. This mode may be found particularly useful, when used in combination with the three previous modes, for such small parts of the vessel as are difficult to get at; but for large surfaces it is not to be recommended.

If the system of coating ships with cement should be generally adopted, I propose to prepare the plates for building before they are put on the ships, by rolling them with studs or ribs; the ribs should be about a quarter of an inch high, one-sixteenth of an inch thick, and about two inches apart. These ribs should be well burred with a cold chisel and hammer, to give the cement a good hold. Rivet heads need not be cut off, but should be left in their rough hammered state; this will tend to make them much more durable, and at the same time assist in holding on the cement. In fact, instead of making a ship's bottom as smooth as possible, it should be made rough and then the cement applied, which can be faced up to any smoothness required. The expense of putting the cement on a vessel, prepared for it when building, will be small, in comparison with those which have to be prepared for it after they are built.

Captain Coles has also furnished the following information and particulars as to the cost of coating vessels' bottoms with cement, and the estimated loss by displacement when so treated:—

ESTIMATED LOSS by DISPLACEMENT, when COATING a SHIP of 3765 tons measurement. Total area of ship's bottom to be coated, 22,680 square feet; ditto immersed, 21,500 square feet.

BY FIRST METHOD.

	Tons.
Weight placed in ship's bottom	77·42
Displacement due to $\frac{5}{8}$ of cement and $\frac{1}{16}$ thin plates ..	36·85
Total loss of displacement	40·57

SECOND METHOD.

Weight of wire netting, &c., placed on ship's bottom .	57·62
Displacement due to $\frac{5}{8}$ thickness	32·00
Total loss of displacement	25·62

THIRD METHOD.

Weight of wood and nails placed on ship's bottom ..	88·00
Displacement due to $1\frac{5}{8}$ inch thickness	86·00
Total loss of displacement	2·00

LOSS OF DISPLACEMENTS.

According to first method	40·57
" second "	25·62
" third "	2·00

The expense of first putting on this cement by mechanical means may appear large; it is, however, less than the expense of coppering, and when once done no further expense would be entailed, as it would last for years.

From the experience I have gained by various experiments I have made in a small way, as well as putting it on the mortar float 34, 'Royal Sovereign,' and 'Tamar,' I hope eventually much to reduce the cost.

Estimated Cost for Coating a Ship of 3755 tons. Area of ship's bottom, 21,500 square feet. Draught of water forward, 21 feet 9 inches; aft, 23 feet 3 inches. Length of ship's side at water-line, 245 × 2 = 490 feet. Supposing cement to be carried 2 feet above the water-line, then the total area to be coated will be 21,500 × (2 × 490) = 22,480 square feet. Number of holes, 45,663.

	£	s.	d.
Cost of labour for drilling and tapping, at 3*d.* per hole	570	15	9
Cost of 317½ gross screws, at 2*s.* 6*d.* per gross	39	13	9
317½ gross of thin iron washers for fixing wire netting, at 2*s.* per gross	31	15	0
Cost of 2520 square yards of wire netting, at 1*s.* 3½*d.*	162	15	0
304 casks cement, used at the rate of four casks to 300 square feet, at 10*s.* 6*d.* per cask ..	159	12	0
Cost of plastering, at the rate of 300 square feet, at 30*s.*	112	0	0
Docking and undocking	100	0	0
	£1176	11	6

The advantages to be derived by such a mode of preserving ships' bottoms from the injurious effects of barnacles and other obstructive formations tending to retard a vessel's speed, seems from the above particulars very great. The cost appears, however, much beyond what is really necessary for such a purpose. Indeed it amounts, according to the above calculation, to upwards of one shilling per square foot.

Of all the methods described by Captain Coles the fourth one appears the most economical, and would also prove, by careful attention to the quality and treatment of the cement, the most advantageous.

The preparation of the iron in building new ships, so as to leave a serrated or rough surface, would in itself prove a sufficient preparation for the reception of the cement. In such a case, the cost would not really amount to one-third of the price above-named. Hitherto our experience of Portland Cement in contact or combination with iron, has been limited; but after the testimony of Mr. Rawlinson, described at page 67, the further use of cement in connection with that metal, may be prosecuted with fair chances of success. When such a combination is desirable, or necessary, it should be remembered that no previous preparation of oil or other paints is required—on the contrary, such a preliminary coating would conduce to the weakening of the cement, or at least prevent its full value being realized in contact with the iron. An experiment made for Messrs. Hemans and Hassard by Mr. Webster, the contractor, proves indisputably the possibility of forming a lasting and perfect junction of the two materials. A portion of wrought-iron tube, 3 ft. 6 in. in diameter, made from the ordinary plate-iron —thick and rivetted, was interiorly coated at two operations with neat Portland Cement, and after eighteen months the tube or pipe so treated continues to exhibit a perfectly lined pipe, possessing the valuable property of being used as a conductor of water without the possibility of oxidization. The experiment was designedly made to ascertain the capacity or value of Portland Cement for coating wrought or cast iron pipes for the conveyance of water. Its success adds another item to the increasing list of the useful purposes to which Portland Cement may be applied.

CHAPTER XVI.

SUITABILITY OF CEMENT CONCRETE FOR HOUSES, &c.

In the earlier period of Portland Cement manufacture, the aim of the makers was more specially directed to the production of a cement for the engineer's particular use. The quantity consumed by architects was small in comparison with that required for engineering works; hence the indifference of builders as to its use for houses and similar works of construction: when used it was ordinarily employed as a substitute for stone dressings and other details of ornamentation. Its employment in substantial construction was seldom entertained. A better knowledge of its properties and value, however, has gradually led to its use in combination with other materials in a concrete form for building, dwelling, and other houses. Several systems of building by the application of Portland Cement and other materials are in use in this country, and much attention has more recently been given to the same question in France, Germany, and the United States of America. Public interest is directed more especially to the construction of dwellings for the labouring classes, whose cottages have been for so long a disgrace to our civilization. Many causes have operated in perpetuating a state of things far from satisfactory, and the introduction of concrete as a substitute for brick and stone will, it is to be hoped, accelerate the improvement of our working population through the agency of improved house or cottage accommodation.

The advantages which this system of concrete block buildings offer are so apparent that it is almost superfluous to discuss it here, as the future success of such kind of buildings must necessarily depend on the quality of the cement used and the dexterity or care in mixing the materials.

During almost every age of the world's history, man's dwelling-place has, for obvious reasons, been composed of the rude materials in the neighbourhood of his abode. When man ceased or changed from his nomadic life to one of settled occupation or enjoyment, he naturally availed himself of that which cost him least labour to construct his house. So we are familiar with many varieties of primitive structures, from the lake dwellings to the dub *béton* or clay hut; progressing onward again from that stage of structural condition to the composite Babylonian brick of mud and straw, and so on through Roman history of magnificence and splendour to our own times. In the Babylonian and Roman periods, when a dominant race held the masses under a state of bondage or slavery, works of magnitude and great architectural pretensions were created, not so much for the people's comfort as to gratify the selfishness or vanity of the prevailing ruler. Happily in this age no such gratification requires indulgence, and the comfort of the people form a prominent element in all discussions affecting a civilized country's welfare. In any suggestion for the amelioration of our labour, the first consideration naturally turns upon the personal comfort of the people. Advanced agricultural science has unfortunately recognized the comforts of the beast in preference to the man, and too striking evidence exists of the folly of such a system. To the credit of some landed proprietors, no such claim is now acknowledged, and praiseworthy efforts are vigorously at work to remedy a mistake too long permitted to exist.

A prominent difficulty surrounding this subject is the first cost, naturally leading to the ultimate one of profit. The isolated instances where comfortable cottages exist, built regardless of the cost and return for outlay, should not influence us in discussing this question of the day. A man possessing the necessary feeling of independence, would not willingly inhabit a dwelling given him gratuitously: the workhouse is not a congenial subject in the thoughts or minds of our labouring classes. The workmen, or those dependent on him, should neither be housed, clothed, or fed at the public expense, and no right-minded man would accept such a permanent state of things: encourage his self-respect and independence by the possession of a home which he might call his own, or at least occupy with the knowledge that his landlord received as rent remuneration for his outlay in the cost of its erection.

There are several so-called systems of concrete construction, from the old mortar and gravel mixture to the more recently prosecuted one of Portland Cement, in varying proportions with gravel or shingle; of the latter, successful results have been arrived at under the auspices and patronage of his Imperial Majesty the Emperor of the French. Visitors to the late Paris Exhibition had opportunities of convincing themselves of the value and advantages of this particular mode of construction. In England there are several examples on a moderate scale of a similar kind, but the desired and necessary support to ensure success in a novelty like this does not yet seem forthcoming, to give the system sufficient impetus for its general or even moderate application. It is possible that owing to the interested opposition of builders, obstructions are offered to the introduction of a system of building which, while materially improving our dwellings, would doubtlessly reduce the amount of their work and profits. Again, reasonable objection may be made to the monolithic nature of the operation and its consequent imperfections; but as regards cost, comfort, and durability, no exception can possibly be taken to such a system of structure.

The advocates of the specially adapted machines for the speedy erection of concrete buildings, in their enthusiasm for employing their peculiar method, invariably lose sight of the permanent character of the work itself. It is not a quickly raised structure that is wanted or desired, but one that, when built, shall endure. The mechanical excellency of the machine does not necessarily guarantee that the materials it is used for, to form and shape, are unexceptionable in quality or free from blemish. Attention is invited to this branch of the question, with the view of avoiding a too hasty adoption of any one system without regarding the more primary one of quality of materials.

If the full measure of success or usefulness in the erection of concrete houses is to be attained, it will be when special and due regard or attention has been given to the following conditions.

1st. Quality of the Portland Cement and the materials with which it is intended to be combined. It may be safely assumed that *every locality* commands the material to form the matrix, and *none are beyond* the influence of a cement supply. Enough has been said in these pages to guide any ordinary intelligence in the acquirement of a safe and good Portland Cement, and a few observations as to the quality of the sand, gravel, or shingle, &c., with which it is to be mixed may not be considered out of place.

The durability of the material is an essential element for consideration, for however good the cement may be, the matrix itself is really the portion which will eventually have to stand the greatest strain. A rotten or friable material is therefore to be avoided, unless where unavoidable, and in that case only in combination with a large proportion of the cement, so as to neutralize, as far as possible, any tendency to weakness. Sand, where a choice exists, should be as rough and coarse as possible, and that made by the various natural or physical influences from sandstone, limestone, or other similar rocky formations, is to be preferred over those from flints, porphyritic or volcanic rocks. The former sands or shingle are more porous than the latter, and consequently better able to absorb the soluble silicates of the cement when being mixed.

For this reason, therefore, it is not advisable to have the sand, gravel, or shingle too fully saturated with water; if this is so, the matrix is unable to imbibe the fluid portion of the mixture, and consequently it is thrown off as waste from the concrete. This observation equally applies to the mischievous practice of overwetting bricks in building with cement mortar. A dry brick is objectionable enough, but when saturation is carried to excess, equally faulty results ensue. In districts where clay abounds, with sand and gravel scarce, unless broken rock or other suitable shingle is obtainable, the clay must first be burnt in conical heaps with coal or wood as fuel. The quality and hardness of the ballast thus obtained will depend much on the nature of the clay operated ever, a degree of refined manipulation is more essential, so as to ensure satisfactory results in the stability of the work when walls of considerable height are required, having large surfaces exposed to the changeableness of climate; if these walls are constructed hurriedly with doubtful materials in a slovenly manner, there is much likelihood that a disappointment and loss will follow. For these reasons, therefore, it is more expedient, for small buildings especially, to adopt the use of blocks of any convenient size, according to the taste or convenience of the builder—a useful size is 1′ 6″ × 9″ × 4½″, so that where necessary they may bond with common bricks without the necessity of cutting. A block of these dimensions is equal in cubical capacity to eight ordinary building bricks, and will of course when placed be equivalent to that number laid in the work. The size is suitable, and not too heavy for one man to lift, carry, and lay in position.

The manufacture of such blocks is possible and recommended where one or two small cottages only are required to be built. The moulds should be made of cast-iron, and the concrete well rammed into them in as dry a state as is consistent with the proper requirements of the material, for too small a quantity of water would be quite as injurious as an excess; again, that would be materially influenced by the amount of percussion applied by the impingement of the rammer. The rammer should be as heavy as can conveniently be used, and should be of wrought-iron, having a flat face rectangular in form, so that the corners of the mould may be well filled, and thereby ensure a good sharp arris to the blocks. The manufacture of blocks of the above description is not difficult, and may readily be done by the most ordinary labourer in any part of the country. A degree of supervision would be necessary to ensure the proper quality and admixture of the materials. It will be necessary to make a considerable quantity of blocks before beginning to build, so that when the mason or bricklayer commences operation no delay in his work will arise. The first cost of the moulds will, in comparison with the extent of work, bear an excessive proportion of the expense; but this difficulty would disappear where a quantity of cottages were required in one district; or even if this should not be the case for a long period, they can be kept without loss, or perhaps re-sold to other parties who may be building similar structures. It is unnecessary here to describe more fully the possibility of making any kind or form of block which in even the simplest cottage will be required, such as chimney shafts, smoke or ventilating flues, door jambs, arch bricks, &c., &c.; these requirements will readily occur to those engaged in the operation of building, and as they will be the best judges of what is wanted, it is superfluous to dictate designs or forms that could not by possibility be generally applicable. For country cottages of moderate pretensions and extent, it is quite possible to construct the whole roof, ceilings, and floors entirely of Portland Cement concrete, aided by a small quantity of iron, at a very moderate cost indeed, with the additional advantages, not possessed by the ordinary buildings, of stability of construction and comfort to its inmates.

That the amount of skilled labour required to build a small cottage suited to the requirements of an agricultural workman's family is not very great, as is shown by the following extract from a useful little periodical, 'The Cottage Gardener,' describing in the year 1851 a specially cheap kind of labourer's cottage which was built at Enville, near Ongar, in Essex, by Mr. Clay, assisted by a skilful farm labourer, and cost only 10*l*. "It is a building, three rooms in length, erected at the corner of a meadow, on a spare nook which could not well be turned to any other profitable purpose; and it is a leading feature in it, that with the exception of the deal boards for the doors and the glass for the windows, the whole of the materials have been produced on the farm. The walls are built of 'clay lumps'—that is, clay worked in the same manner as for bricks, moulded into lumps, twenty inches long, seven deep, and ten wide, and well dried in the sun in the heat of summer. These are laid with the same material, just as if building with bricks and mortar, and when plastered over on both sides, and thoroughly dried, form a wall exceedingly hard and firm, which no cold or damp can penetrate. The roof is shaped with poles cut from a wood on the farm, the place of thatched laths being supplied with straight sticks; over this an excellent coating of thatch is neatly laid, and the inside is plastered and whitewashed. The windows, which are of ample size for a cottage, are formed of large panes, a bar passing down the centre; and the transverse supports are of lead, so that the expense of a regular window frame is saved; and as a further proof of the extent to which economy is carried, the door is made folding, and the half being thus light, swings on gudgeons, by which the outlay for hinges is spared. The floor is composed of a sort of concrete, made of brick, earth, and fine sand; and the chimney, which contains a cozy enclosed corner for the labourer at night, is built of clay lumps. An extra window in the shape of a cross, studded with fragments of coloured glass, has been introduced by the taste of the architect into the end of the bedroom, and answers the double purpose of furnishing light and ornament. The whole length of the building is 32 feet; width, 12 feet; height of walls inside, about 8 feet; and to the canopy of the roof, 11 feet. The size of the sitting room is 10 feet by 12 feet; bedroom, 11 feet by 10 feet; kitchen, 9 feet by 10 feet. We come now to the actual cost. The following were the figures furnished to us, and which we tested by the statements of the man by whom the work was done:—

	£	s.	d.
Making 300 clay lumps, @ 3*s.* 6*d.* ℔ 100 ..	1	8	0
Laying ditto, @ 2*s.* 6*d.* ℔ 100	1	0	0
Thatching	1	16	6
Glass for windows and glazing	0	11	0
Wood for doors and window frames	1	1	0
Rough wood for rafters and thatching laths..	0	10	0
Nails and forming roof	0	12	0
Claying inside and whitewashing	1	0	0
Chimney pots..	0	12	0
Making a total of	£8	10	6

"Thus it will be seen that Mr. Clay, unlike most architects, has completed his building for less than the estimate; and we think if the 1*l.* 9*s.* 6*d.* were laid out in preparing some other material for the floor—for the idea of a clay floor does not strike us very pleasantly—it would remedy the only thing about the cottage we are disposed to find fault with. The house was furnished and occupied when we visited it, being let, we believe, to a person on the farm at fourpence a week, which yields good interest for the outlay; and Mr. Clay assured us he could readily let it if disposed at 45*s.* per annum."

The building of the above class of cottage is not recommended, but merely mentioned for the purpose of assisting to simplify a question of much importance, and to show that the same amount and kind of labour could be as successfully applied to the construction of a concrete cottage, the comfort and durability of which would be immeasurably superior to the one now described. Concrete floors and ceilings could also be substituted for those of clay and wood; and a roof made in the manner described by Mr. Lipowitz in the German treatise at page 66, would render a cottage so built convenient and comfortable. As an investment for a moderate outlay of capital there can be no question of its eligibility, for such a cottage could be built of Portland Cement concrete with much superior fittings to those at Enville for a sum under 50*l*., and in some favourably-circumstanced localities at even much less than that.

For larger building operations, the use of machinery for mixing the concrete is advisable, so as to reduce this cost of the operation and an improvement in quality. Many machines are in use for this purpose, but for simplicity and effectiveness the following machine is highly recommended:—

It consists of a cylinder 13 feet in length, 4 feet in diameter, open at both ends, and revolving on its axis at the rate of from fifteen to twenty revolutions per minute. It is inclined to the horizon at an angle of from six to eight degrees. The materials are thrown from a barrow into a hopper, from which they pass into the upper or higher end of the cylinder. The mixing or incorporation of the materials is produced by the rotation of the cylinders, from the lower end of which the concrete falls into the barrows or carts placed there to receive it, or in the case of block making, direct into the moulds. Motion to this simple machine is obtained by passing a driving belt or strap round its exterior diameter, without the necessity of cog-wheels or pulleys. The inner surface of the cylinder is coated with sheet-iron. Such a machine is capable of mixing upwards of 100 cubic yards of concrete in ten hours. A machine of this description commends itself for its simplicity and economy of first cost. It would not be advisable to use one of a smaller size, as thirteen feet is as short a length as could be used, having regard to the due and proper admixture of the materials. There are numerous machines of more or less complexity, which have been used in many large engineering works, but they are unsuitable for application to the purposes of house building; indeed, the expense of such machines preclude their use for any but extensive public and important works.

A work of this description would be incomplete without some allusion to the several apparatus used and recommended for building concrete walls. In the United States of America an apparatus has been devised by Mr. E. E. Clarke, of New Haven, Connecticut, for the erection of concrete houses, which has been pronounced both convenient and satisfactory, while it leaves nothing to be desired on the score of simplicity and economy. It consists essentially of a wooden clamp, the upright or vertical arms of which can readily be adjusted by means of traverse screws, to any required thickness of wall. These arms support the planking which determines the thickness of the wall, and are attached, one fixed and the other movable, to a horizontal brace. When in use the entire apparatus is kept in position by securing this brace to some fixed point of support.

In carrying up the walls of a building, these points of support are provided in the inside, being vertical posts secured to the ground, in the first instance by braces, and afterwards to the flooring joists of the upper stories. Fig. 2, Plate I., represents this apparatus in position for laying a hollow concrete wall, not intended to be furred on the inside. The hollow is secured by means of a movable plank, called a core, a trifle thinner on the lower than the upper edge, so that it can be moved after the concrete is rammed around it. The ties between the inner and the outer walls may be common bricks, and these are placed under the "core" in each of its positions as the building progresses. The "core" is notched on the lower edge, so as to fit down upon the ties flush with their lower beds. Fig. 3, Plate I., represents a side view of the "core." The width of the hollow should be from two to three inches, the thickness of the inner wall from four to five inches, and that of the outer wall ten inches and upwards, as determined to give the requisite strength. The hollow is sometimes placed in the centre of the wall, a practice which may be admissible in buildings not intended for residences. For these latter, when a thickness of five inches for the inner wall is exceeded, it should be furred for plastering, to prevent the condensation of moisture.

The apparatus in common use on the continent of Europe, and in some portions of South America, in constructing pisé work, would answer in forming walls of concrete, and would besides be less expensive, and perhaps more easy of adjustment than that above described. It consists simply of a boxing of planks, kept in place by upright posts on the exteriors, at suitable distances apart, say four to five feet. The lower ends of the posts are mortised and keyed into horizontal pieces called futtocks, which reach entirely through the wall and are withdrawn, and the holes filled up, after the box is filled with the pisé or concrete, and a new course is to be commenced. The upper ends of the post may be kept in position by similar cross-pieces, but the more common practice is to confine them by lashings of rope or cord, tightened or loosened at pleasure by a stick used as a lever for twisting up the lashings. The wall may be made hollow by a core in the manner previously described.

A short description of the mode of preparing clay or earth for pisé work may not be considered out of place here.

Pisé work is formed of clay or earth rammed in layers. The best and most suitable material is clay containing small gravel, and of a consistency capable of being dug with a spade. The clay should first be perfectly beaten up and screened so as to reject stones exceeding the size of a hazel nut; it is then moistened to such a consistency as when placed under water it will not crumble to pieces. The material thus prepared is rammed in layers of from three to four inches thick, care being taken not to carry up the walls too rapidly, so as to prevent injury to the lower portion from the weight of the superincumbent mass. Except in very dry climates walls so constructed should have an exterior coating of plaster, to prevent their being injured by rain; when so treated the walls should be thoroughly dried.

Many examples of cottages built of a kind of pisé exist in some parts of Somersetshire, and the mud-huts of Ireland resemble pretty much this mode of construction. The variability of our climate, however, is unsuitable for this kind of work, and their existence can only be tolerated under very exceptional circumstances; it is only on a poverty-stricken soil, owned by a helpless or indifferent landlord, who by force of circumstances or inclination rests contented with a growth of human wretchedness, which our laws are alike helpless to check or control.

In France especially, considerable attention has been given to the construction of every variety and form of monolithic building works, by the application of "Béton Aggloméŕés Système Coignet." This preparation essentially consists of a mixture, in varying proportions, of river-sand, powder-slaked hydraulic lime, and Portland Cement.

During the winter of 1866, the author had an opportunity of observing the construction from this material of several arches, 18 feet span, under the stair approach from Westminster Bridge to the southern embankment of the Thames. The works were executed, by permission of the Metropolitan Board of Works, for the purpose of testing the cost and efficiency of buildings so constructed. M. Coignet, the engineer and inventor of the system, controlled and superintended the work, which was performed by French workmen. The materials for the work were carefully selected, and consisted of river-sand, blue-lias lime, and Portland Cement. The first operation consisted of reducing the lime to a fine powder by slaking with water; afterwards the fine particles of lime were sifted through a wire sieve of upwards of one thousand meshes to the square inch. This part of the process is an expensive one, not only as regards the labour employed, but also from the resulting waste of the lime rejected by the sieve. The lime so treated is then put with the sand and Portland Cement into a specially-constructed pug-mill, or triturating-machine (the mixture being first slightly wetted by water, poured from a can through a fine rose). The first run or two is put back into the mill, from its being, as a matter of course, imperfectly mixed. (The leading workman intelligently conducting the whole process and controlling personally the supply of water.) When the material thus treated emerges from the machine it is thoroughly mixed, and has the appearance of moist sand, quite granular to the touch, showing no indication of the cementitious and indurating properties which it possesses. From the mill it is wheeled in barrows to the building, and there carefully laid in layers of about six inches deep, each layer being well and steadily rammed with wooden rammers, the small and scarcely appreciable quantity of water with which the preparation is mixed permitting the setting of the mass in a very short period of time, and enabling the centres to be struck within a few days. Notwithstanding the unfavourable season during the time this work was executed and the occurrence of several nights' sharp frost, the work was not materially retarded or injured. The precaution, however, was adopted during the severest frost of covering the work with tarpaulins.

The above experiments and other subsequent sewer constructions confirmed the inventor's statement of its suitability for such purposes; but the cost in comparison with Portland Cement concrete was so disproportionate, that the engineers of the Board of Works abandoned all intention of using it. Portland Cement concrete cost on the works where the experiments were made from eleven to thirteen shillings per cube yard, while that of the Béton Agglomérés cost more than double that sum, according to the amount of Portland Cement it contained. In appearance this material resembles Ransome's patent silticeous stone, and attains a high degree of hardness. It is possible to make this agglomerate without any admixture of Portland Cement; but there is no doubt that when so treated it will fall far short in value, and unless containing a large proportion of that material its profitable application for building purposes would be very questionable. Indeed, if we analyze the cost of the preparation of this material, it will be found that the lime ingredient forms a large item in its cost; so much so, that it would be more preferable to use an increased quantity of Portland Cement, and thereby simplify the whole process of preparation. Portland Cement and good sand treated similarly would produce an artificial stone of great value; and it is with the view of showing what can be attained by the intelligent manipulation of the simplest materials that allusion is here made to the "Béton Aggloméres Système Coignet."

Previously to 1864 M. Coignet had constructed a total length of 30,000 mètres (nearly twenty English miles), under the city of Paris, of sewers of different sizes and forms. The composition of the mixture used for that purpose consisted of "river-sand, of good quality, 5 cubic mètres; hydraulic lime, slaked in powder, 1 cubic mètre; heavy Paris Cement (considered as equivalent to Portland Cement), 250 kilogrammes." This work was executed at a saving of about 20 per cent. compared with masonry, as certified by M. Belgrand, engineer-in-chief of the water-supply and sewers of the city of Paris.

Constructions of various kinds have likewise been made by M. Coignet; and, among others, bridges of considerable span erected. It is doubtful whether arches so constructed are safe where any amount of moving weights is passed over them. The vibration caused by the percussive action of carriage-wheels being quickly rolled over bridges so built must prove injurious and liable to cause fracture in the structure. In bridge-building of concrete or any other similar conglomerate, the arch should be constructed of blocks made of the required geometrical form, thereby realizing the whole strength and safety of the principle of the arch. All other parts, such as piers, abutments, spandrills, and parapets, can be made of concrete in any of the ways referred to or described.

Tall's patent apparatus for constructing walls of houses, &c., has met with much favour, and several buildings in different parts of the country have been erected by its aid. There is some resemblance between this apparatus and that described in page 94, as used in America, and where solid concrete walls are preferred to blocks of the same material, the assistance of such apparatus is recommended.

Having thus far described the various systems and modes of construction by the agency of Portland Cement, it will be well to conclude this part of the subject by some allusion to the reasons which influence an investigation of this kind, and lead to the conclusions and recommendations submitted by the author.

The primary considerations in all building operations must essentially be that of safety. This embraces a wide range of subsidiary questions which more or less surround the main one. Lime-mortar has for many ages been acknowledged as the only means of joining the stone or bricks used in the erection of buildings of every kind. The search after and resulting discovery of cement possessing the capacity of setting under water is a comparatively modern discovery. Smeaton, in 1756, when experimenting on hydraulic limes to ascertain the best and quickest for hardening under water, for the purposes of the Eddystone Lighthouse, decided, after most patient investigation, on using Aberthaw lime mixed with pozzolana from Civita Vecchia, near Rome.

It is very questionable if the ultimate strength of this mixture would be equal to the lime by itself; his object, however, was accomplished by introducing the portion of pozzolana as a vehicle of quick-setting energy to the lime, much in the same way and for the same reason that painters mix their colours with driers. That eminent engineer put much value on the quantity of iron contained in the amalgamation he used with so much success, and therefore concluded that the essential quality of a good hydraulic lime was the amount of ferruginous matter it contained. The accuracy of this conclusion is rendered doubtful by more modern experience, and although the analysis of a good specimen of Portland Cement contains from 5 % to 6 % of oxyde of iron, its hydraulicity would not be impaired or destroyed by its absence.

The old proverb that "Lime at the age of a hundred years is but a child" is beyond question, and we are too familiar in this age of pulling down with dusty evidence of this indisputable fact. In the year 1822 General Treussart, in demolishing one of the bastions in the citadel of Strasbourg, found the lime as soft in the inside as the day it was made. The bastion had been constructed by Vauban in 1666, so that the mortar was 156 years old. In pulling down a pillar, nine feet in diameter, in the church of St. Peter at Berlin, which had been built eighty years, the mortar in the interior was quite soft; and an examination of any of our oldest buildings in this country will too fully prove that the mortar only hardens externally, and the amount of induration is very superficial indeed. With this knowledge the question very naturally arises, Why continue to use a material like lime, which does not and cannot harden even during the period of our longest leases? Is it more expensive than lime-mortar? Are its properties not yet sufficiently known, and can it not yet be used with confidence and safety?

The second question as to cost is readily answered in the negative, and the best authority that can be cited in confirmation thereof is Mr. Bazalgette, who said, "In many cases Portland Cement would bear admixture with sand, so as to enable it to compete in price with common mortar, and secure greater strength in the work at the same expenditure." Again, in combating the manufacturer's argument (see page 61):—"Then it had been argued, that if the cement was stronger than the material which it had to unite, it was not surprising that the manufacturer should be unwilling to raise the standard of quality; but he had yet to learn that any cement had been obtained which was *too good*. When that pitch was arrived at it could readily be diluted with a larger amount of sand, and its cost and its strength reduced at pleasure. It was the engineer's duty to raise the standard of quality, and when it had fairly been determined what was the best material, it would always command its price in the market, and that would determine the question, which was the most marketable article to produce."

It will be difficult to find more valuable testimony as to cost and quality of Portland Cement. The engineer-in-chief responsible to the country for the due execution of the most important sanitary and domestic works of this age, has considered the question of cement worthy his careful attention.

Even to the ordinary observer there cannot be much difficulty in arriving at the same conclusion. Most of us are familiar with the common method of preparing lime-mortar for building purposes; the operation is constantly going on, and perhaps its very frequency prevents careful observation of the process. The lime is generally delivered at the works "alive and fresh" from the kilns, when the operation of "killing" it is speedily commenced. This part of the *modus operandi* is usually entrusted to the least intelligent labourer on the job, who sets about with buckets of water to slake the lime; after this reduction is effected it is then carefully covered with sand, in any proportion and regardless of quantity or quality, in fact a kind of shroud is placed around it, fitting accompaniment in its altered condition, bereft of active energy. The next stage is screening, when it is ready for the succeeding process of mixing, for which again large quantities of water are required. The batch of mortar is thus prepared and considered by some practical men to improve by keeping. It is cut or dug down from this heap as required, and used with due care in laying bricks and stones for building purposes. It is impossible to understand why such an irrational mode of mortar preparation has been through all ages permitted to exist, and against such strong and conclusive evidence of its unsuitability, both as regards expense and quality of work. It is true that after some time the external surface of the mortar-joints indicate a slight degree of induration, due to the absorption by the mortar of the carbonic acid gas from the atmosphere; this is, however, so infinitesimal in quantity, that it may be compared to a thin coat of varnish on a wall. Under such circumstances the value derived from lime-mortar is very small, and the amount of discomfort and loss it entails is very great; many a careful housewife is puzzled at the amount of dust continually floating in and around her dwelling, in winter and summer, always demanding her most careful attention, without awakening in her mind any suggestion for the solution of the mystery. It is readily found, however, in the walls containing so large a proportion of fine mortar-dust, which the vibration caused by occupation shakes down and disseminates through every nook and cranny of the house; not only damaging our furniture and garments, but the less palpable particles also absorbed into our bodies through the agency of the lungs. Dust in fact everywhere! Shut up your house, hermetically seal your windows and doors, and still you will find dust! The very atmosphere in its mechanical power of compression brings it down, and the wind-force or thunder-reverberation detaches the incohesive mixture used as mortar. And we might go farther even than this, and assume that if all natural causes were suspended in bringing about the inconveniences above named, nevertheless the consequences from such an almost impossible state of things would still arise from the very traffic of our streets—our cabs, carts, and carriages assist in making our homes uncomfortable, and may be in some cases unsafe.

We are sometimes startled at accidents caused by a hurriedly built house tumbling to the ground. Our travelling comfort much disquieted by an occasional account of the sudden annihilation of some new railway arch or viaduct, constructed with telegraphic dispatch. All such casualties traceable to the primary cause, "bad mortar!!" Even the building of carefully constructed chimney shafts is frequently rendered imperfect or insecure by the irregular drying of the mortar with which it is built. Many of us are familiar with distorted and fantastic shafts, ludicrous imitations of the leaning Tower of Pisa, and only awaiting some elemental influence to spread destruction and death around. The highly ingenious operation, performed some years ago, in sawing back a distorted chimney shaft at Glasgow, would not have been necessary if the chimney had been built with Portland Cement mortar. Under any circumstances its independent and unaided power of setting quickly is one of the most valuable properties it possesses.

On the other hand, let us consider what would follow if Portland Cement were used in place of lime for mortar. Firstly, an important saving would arise in the cost, in addition to the other manifold advantages which would necessarily follow. Instead of using an inert and useless material, one would be substituted possessing active qualities of high value. Instead of having lime bulky in quantity and weak or worthless in quality, and imperfectly and ignorantly manipulated, we would have a material possessing the required and essential qualities of cheapness of first cost and economy in construction. The cement and sand could even be supplied to the builders in the required proportions accurately mixed, and only requiring the aid of water to render it suitable for the bricklayer or mason. Surely this would be a more rational method of securing stability of construction, and without the ignorant intervention of a common mortar-mixing labourer.

Buildings constructed of Portland Cement concrete possess the valuable property of resisting or deadening sound—a desirable advantage under certain circumstances.

If our military authorities were to consider and bring into practical operation the building of barracks and cottages for our soldiers, it would materially benefit the men, by affording them interesting occupation, with the object of improving their own comfort and health. There is no encampment occupied by our soldiers without the means of carrying out any scheme of this kind with great public advantage.

CHAPTER XVII.

THE IMPROVEMENT OF ROADS, STREETS, ETC., BY THE AGENCY OF PORTLAND CEMENT.

In any country where an advanced state of civilization demands roads of a superior kind, much attention is naturally directed to the best and cheapest materials for their construction. New countries, whose prosperity depends on the state of intercommunication which links the most remote localities together, now rely on the modern system of railways for aid in opening up and developing their resources. The parent state, naturally anxious for the welfare of its offspring, stretches out its hand with the necessary help for the pioneering assistance, leaving it ultimately to complete that which its fostering care had begun. Visible advance under such circumstances must necessarily be slow and tardy, and, except as under the exceptionally favourable circumstances with which India has been provided with railway accommodation, no very successful results have been obtained. The giant efforts of America in binding together remote and isolated territories by railways, securing thereby the peopling and cultivation of her rich and inexhaustible virgin soils by the aid of Europe's redundant population, is striking evidence of the advantages derived from good means of transit.

Arterial communication, whether it consists of roads or railways, and however well it may be arranged or defined, still leaves the important question of subsidiary channels of intercourse unsettled. The plentifulness or scarcity of the materials for road construction will naturally affect the prosperity of any district, whether belonging to an old country or a new one. The more advanced communities will also feel the baneful influence of a costly system of road making. The great centre, London, has gone through all the different phases of road and street improvement, and notwithstanding the vast sums of money expended in the search after an ultimatum of perfection, that much-to-be-desired goal has not yet been reached.

The latest novelty in this direction is the application of Portland Cement, in conjunction with other materials, for the improvement of the surface of streets and thoroughfares, by Mr. Joseph Mitchell, lately general inspector of roads and bridges in the Northern counties of Scotland. An official post of so much importance naturally qualifies its holder to lay claim to a position of authority in all matters bearing on the question of road making.

Mr. Mitchell's pamphlet on this sbuject contains much information of a practical character, and in introducing this question, he says, "The wear and tear of an ordinary macadamized road, and consequently its cost of maintenance, are very great. The explanation appears from experiments, which show that a cubic yard of macadamized stone, when well pressed down in a box with a capacity of 27 cubic feet, contains 11 cubic feet of vacuities; and that a roadway covered with 12 inches of metal, before it is consolidated into a smooth and useful surface, has a large portion of its stones crushed into small particles, and that more than one-third of its dimensions consist of mud and sand. When heavy rains occur, combined with heavy traffic, disintegration of the stones in such a roadway takes place, and quantities of mud are generated in proportion to the amount of traffic."

The improvement consists in filling up the vacuities above described with Portland Cement grout, so as to form a concrete binding the whole mass firmly together, and impervious to water.

Mr. Mitchell, in speaking of the wear and tear, says:—" Every one must have noticed the tear and wear of the causeway stones in an ordinary street pavement, and the irregularities of the surface of the streets, after six or twelve months' traffic. Granite and other stones of the hardest quality appear to give way under the weight of the traffic. The explanation of this waste may be found in the ordinary mode of constructing street pavement. The stones are laid on a bed of loose sand some 2 or 3 inches deep above the soil, and are then beaten down into an approximately even, but really irregular surface. They are laid three-fourths of an inch to $1\frac{1}{2}$ inch apart, and the intervals between them are filled up with sand (which is soon reduced to mud). Thus, each stone is insulated, and made to rest on a yielding surface.

"In a street so constructed, the ends of the causeway stones are found, after twelve months' traffic, to be worn down from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. This arises from the percussion of the wheels of carts and carriages falling from the centre of one stone on to the joint of the two adjoining, which, being on a yielding surface and the wheels striking on the ends, sink a little from the pressure. When a stone has sunk bodily from $\frac{1}{2}$ inch to an inch, or when a little hollow occurs in the pavement of the street, it will commonly be found that the adjoining stones are much worn, the hollow on the surface increasing the force and effect of the percussion of the wheels. The greater the hollow the greater is the tear and wear from the strokes of the wheels."

Mr. Mitchell then proceeds to describe the new method of street paving which he proposes.

"In the new mode of constructing street pavement which I have proposed, there is first laid down a bed of cement concrete 3 inches deep (gravel may be used instead of macadamized stone, where abundant and cheaper), and to the requisite convexity in the cross-section. This concrete quickly consolidates, and entirely excludes moisture or water from below.

"On this foundation, the paving stones, 5 inches deep and 3 inches wide (a width of 3 inches gives a better hold to the horses' feet than a width of 4 or 4½ inches, which are the common sizes), are built, and when brought to a perfect form, the joints are filled with cement grout. When the whole is consolidated, it forms a surface perfectly immovable by traffic and impervious to moisture. The wear and tear of the stones arise from the attrition of the traffic only. If the causeway be well made there should be no irregularities on the surface; when such irregularities exist, they are due to defective workmanship.

"Three experiments have been made to test the merits of the new or concrete road, and two to test the merits of the new form of causeway.

"The first trial road and pavement was laid down in Inverness early in 1865. They have been under traffic for upwards of two years, being passed over by the whole goods traffic of the Highland Railway. The road is now perfectly sound, and it has required no repairs, whereas the macadamized roadway adjoining it has constantly required repairs, and is now full of irregularities and ruts.

"The second trial new road was laid in London. As it was important that this plan of road-making should be subjected to the test of severe traffic on some of the London thoroughfares, I applied to, and obtained permission from, the Right Hon. William Cowper, Chief Commissioner of Works, to lay down 100 yards of it in length by 35 feet in width on the Mall in St. James's Park, at the foot of the Green Park. The whole traffic between the district of Regent Street, Piccadilly, Pall Mall, Buckingham Gate, and the Victoria station, passes along this route, which is apparently subjected to as heavy traffic as any thoroughfare in London.

"Subsequently this road proved a failure, the surface breaking up under the traffic. My explanation of the failure (which was very puzzling at first) is as follows:—The roadway at each end of the experiment was macadamized at the time the experiment was made, and the contractor's men who were crushing the macadamized road with a heavy roller of from 3 to 4 tons weight, were inadvertently permitted by the person in charge to pass their heavy roller from end to end, continuously, over the experiment before it had properly consolidated. The crystalline structure of the cement was injured by this, and in consequence the *surface* yielded to the incessant cab traffic and the month of continuous rain to which it was immediately thereafter exposed. The surface was repaired by the trustees, by a coating of 2 inches of macadamized stone, which was rapidly ground down on the hard concrete by passing vehicles. As the bottom was entire and consolidated, had a coating of 2 or 3 inches of new concrete been laid down, with the required time to consolidate, it would have answered all the purposes contemplated, but the surveyor deemed it his duty to remove the concrete surface entirely, which was only done at great trouble by means of levers and iron crow-bars. The experiment was certainly a failure; but in attempts of realizing new conceptions, it is in the nature of things that there must be repeated failures before success is reached.

"The third experiment was made in Edinburgh, and has in my opinion proved very satisfactory and useful. A length of 150 feet of concrete road by 45 feet in breadth, and a similar extent of street pavement, were laid down last summer at George IV.'s Bridge, where the traffic is heavy and continuous. One-half of the street was laid down with concrete at a time, and the traffic was rigidly kept off that part for a month; the other half was then laid down. The whole roadway has since been under traffic for twelve months, and has proved perfectly sound and immovable, not a stone turning up all that time. After the road had consolidated, and had been under traffic during the winter, it was observed that some small hollows had shown themselves at the joinings along the centre of the roadway, and arose from our inexperience in laying down the concrete, and will in future be avoided. These hollows were cut out, and made up with new concrete, and opened for traffic in a week. The result has been that the surface is now perfectly smooth and regular.

"The street pavement on the south side of the concrete was then laid down on a bed of cement concrete 3 inches deep. The cement concrete was permitted to consolidate for about ten days, and thereafter the pavement was built on it with cement mortar; and when the stones were regularly set, the joints were filled up with cement grout.

"The pavement has also been perfectly successful, the water running off it as from a foot pavement, leaving no mud; and the only wearing of the surface is from the attrition of the traffic.

"It has been stated that the noise of vehicles on the pavement is greater than on the ordinary pavement. I do not consider it greater. The blows arising from the irregularities on the ordinary pavement are noisy, as well as destructive to the road and to carriages; but the noise on the concrete pavement, though not greater, is different, it having more of a ringing sound, like that of a street bound up with frost.

"In point of wear and tear and freedom from mud and dust, this street pavement has many undoubted advantages over that now in common use, particularly where there is heavy traffic; but I anticipate that a road consisting of a good body of concrete should supersede even this species of street pavement."

The fairness with which Mr. Mitchell places his experience in connection with cement concrete is creditable to his candour. The failure in St. James's Park might very reasonably be placed to a somewhat defective knowledge of Portland Cement and its peculiar properties. For such a purpose, the very heaviest and therefore the slowest setting quality of cement should have been used, and a period of three months would not have been too long a time to enable the perfect crystallization of the cement to have taken place. Again the passing heavy roller, even if all the ohter circumstances had been favourable, would tend to neutralize any good effects of the best Portland Cement ever made. The two years' experience of the trial road at Inverness, over which the traffic to and from the station of the Highland Railway passed, seems satisfactory. The Edinburgh experiment appears to be conclusive as to the practicability of making roads and pavements with Portland Cement concrete. Mr. Mitchell reported to the Edinburgh Road Trustees on this subject, and as the following extract from his report to their secretary enters fully into the cost and particulars of the Edinburgh trial, it is here given:—

"The concrete road cost 6*s*. 8*d*., and the paved road 17*s*., per square yard. A sum of 1*s*. 8*d*. per square yard was incurred for excavating and removing the materials of the old road and for watching; but I calculate that the value of the old materials would go to meet these outlays. The small experiment that has been made, however, is not a good criterion of the cost. In a work on a large scale the cost ought to be less.

"The advantages offered by this mode of construction on a road under heavy traffic, as far as our experience has gone, are:—

"First. *Diminished wear and tear.*—The general surface is apparently not worn in twelve months more than *one-eighth of an inch.*

"Second. *Superior cleanliness.*—The road is almost wholly free from mud and dust.

"Third. *Diminished cost and annoyance from repairs.*—The road has required little or no repairs for twelve months. It requires no scraping or watering, and its maintenance is almost nominal, while the coatings, scrapings, and waterings of a macadamized road under similar traffic in Edinburgh, cannot be done under 1*s*. to 1*s*. 6*d*. per square yard, besides the great inconvenience and discomfort they cause to the public.

The original cost of a macadamized road 9 inches deep, which, before it is consolidated, is crushed into 6 inches of available material, is about 2*s*. per square yard, or say somewhat less than one-third of the concrete road. In London where the metal is 20*s*. the cubic yard, instead of 6*s*. as in Edinburgh, and where the cement is cheaper, the cost of a road of 9 inches of metal will nearly amount to the cost of a concrete road. It thus appears that the cost of the concrete road will be proportionally less, and its advantages proportionally greater, in London and towns similarly situated than in Edinburgh.

"The cost of the concrete pavement, which is 17*s*. per square yard, is higher than it should be, as the stone was procured from Aberdeen instead of the neighbourhood of Edinburgh, and gravel would have served for the concrete bottom quite as well as the more expensive macadamized stone."

Mr. Mitchell does not appear to overstate the cost of London roads in his comparison with Edinburgh prices. There is one important element omitted in his consideration of this question, however, which materially affects the result; namely, the great difference between the loads passing over London streets and those in Edinburgh or Inverness. The animals also drawing these load differ materially. A London dray-horse and the horses used in Scotland for draught purposes are very different kinds of beasts. The waggons and carts also vary in weight and size. It is a very common thing to see loads of coals, &c., exceeding six tons in weight, drawn along London streets by four horses—a weight of this kind moved or being drawn by such horses is the most searching test which any form or description of road could be submitted to. The great wear and tear to London streets is principally occasioned by the amount of iron from horses' feet and carriage and waggon wheels, which is continually acting percussively like so many hammers wielded by heavy and strong arms. Improved road surface would doubtlessly lead to a reduction in the weight of horses' shoes and wheel-tires—followed as a necessary consequence by a cheapening of the cost of locomotion.

Messrs. Wylie and Smith, engineers in Edinburgh, made experiments which show that the trial road laid down by Mr. Mitchell in Edinburgh possesses the additional advantages of enabling loads to be drawn at a much less cost in tractive power. These gentlemen found by experiments that in consequence of the superior evenness and solidity of the new road, a waggon of two tons weight ascending a gradient of 1 in 80 required a traction of 70 lbs., while on a common macadamized road the same weight required a traction of 140 lbs. On a road with wheel-tracks through new metal, 340 lbs. were required; and on a road newly covered with metal, 560 lbs. All the gradients were 1 in 80.

These experiments bring out in striking light the great advantages of a smooth surface for a roadway over a rough and uneven one; in fact, the amount of traction over a newly-metalled road is eight times that on a smooth cement concrete surface. Much of that waste of power is doubtlessly spent in pressing down the materials or metal to a sufficiently concrete form, and until that has been thoroughly effected, not only will a large percentage of the tractive power be dissipated in that direction, but also in the manufacture of sand and dust, from the attrition of the horses' shoes and carriage-wheels. Any suggestion in the use of new materials, whereby the one or the other of these disadvantages will be removed or reduced, deserves serious and attentive consideration.

It is unfortunate that Mr. Mitchell had not another opportunity of testing the value of his new method of road making in some other part of London. That concrete so used attains great hardness has been fully proved by Mr. Grant, who, when making the new Southwark Street, prepared a bed of Portland Cement concrete, on which he laid the granite paving-stones. This roadway when first opened for public traffic was unquestionably the best piece of street in or around the Metropolis. Shortly after the street was dedicated to public use, and possessing all the advantages which high scientific ability had succeeded in securing for it, such as the arrangements for the economical and efficient laying of gas and water pipes, in addition to the sewers, well-formed carriage and foot pavements, some of the water or gas companies set to work and broke up the roadway to lay down their pipes. It is supposed, however, that the men employed in this work of vandalism "caught a Tartar" in the concrete. They required very different tools than those to which they are usually accustomed for pipe laying. The public have not been favoured with a statement of the iron and steel cost attending this unnecessary work of destruction. Until the Legislature interferes to prevent the possibility of a recurrence of such proceedings on the part of the powerful gas and water companies, it will be hopeless to prescribe or attempt any form of concrete road for London or its suburbs.

Mr. Mitchell, after stating all the advantages to be derived from Portland Cement concrete roads, observes, however, "That the entire efficiency of this mode of road making depends on the quality of the cement, which should be the best Portland Cement, tested to bear a tensile strain of 500 to 600 lbs. on a bar 1½ inch square. Time after the road is made is a great element of efficiency, as the hardness of the concrete gradually doubles in the course of twelve months; but further experiments are necessary to determine the precise time the road should be left for consolidation before it is opened for traffic: a month I found quite sufficient in Edinburgh."

Although the plan of applying Portland Cement concrete in the construction of streets has been thus prominently brought forward through the trials and experiments of Mr. Mitchell, it is not by any means its first application for such a purpose. In Germany and Holland it has been similarly used for many years; and also in England in making garden and other paths; the trial of "Granita Breccia" pavement, described at page 76, and on the terrace at Lewisham, in Kent, referred to by Mr. Grant in his paper.

Having thus described the interesting and satisfactory experiments made by Mr. Mitchell, we will now shortly consider how far the mode of applying the cement on that gentleman's plan is consistent with the largest amount of value, which may or should be derived from the application of Portland Cement for such a purpose.

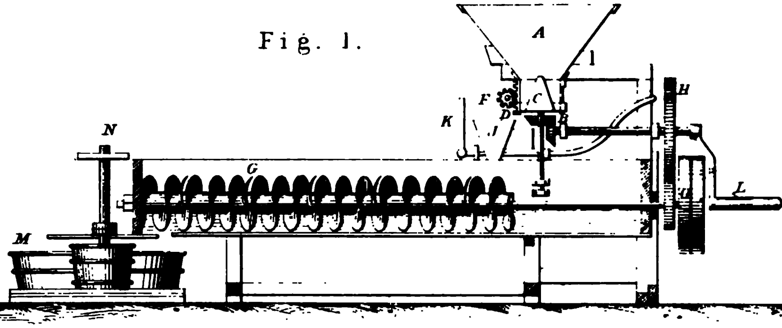
The numerous experiments quoted in illustration of the absolute necessity of time to develop the essential quality of a good Portland Cement, clearly indicates that the mode of application adopted by Mr. Mitchell is not the most advantageous one. If therefore the utmost value is to be extracted from this material in forming roads or streets, it must be through some such means as that already described at page 75. Blocks of any required form or size could be manufactured under the most favourable conditions and acquire before being used the requisite hardness, so as to ensure the full measure of strength when laid. This is the more necessary, as in populous districts—London and other large towns especially—it would be practically impossible to interfere with public traffic to the extent required for such a purpose. Those who have witnessed the re-laying of the paving-stones on London Bridge can well understand the difficulty of interfering with the traffic of a public thoroughfare. Yet notwithstanding the magnitude of this traffic and the great difficulties necessarily surrounding the execution of its repair or renewal, the author would not consider the engineer a visionary who would undertake to re-lay the whole extent of London Bridge in fourteen days, with a previously prepared roadway that would, when finished, be much better than the present one and possess many advantages to which it can lay no claim.

The walks in our public parks and places of amusement might, by a very small present outlay, be rendered for the future a source of comfort to our people and a great saving to the public purse.

If we become wise enough to prevent the dust in our houses, we should not pause at the stoppage of the same public enemy in our streets and footpaths; in short, mend our ways.

MORTAR MIXING MACHINE.

Fig. 1.



APPARATUS FOR BUILDING CONCRETE WALLS.

Fig. 2.

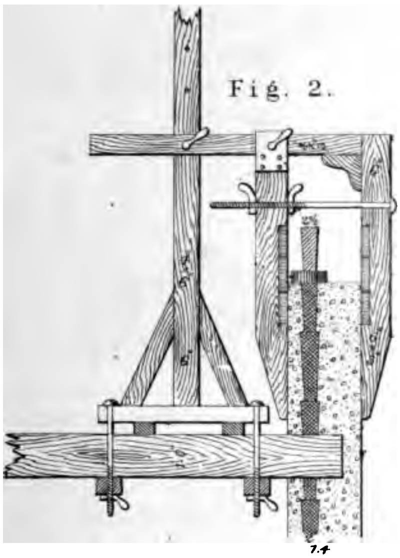


Fig. 3.

AMERICAN CRACKER.

Fig. 4.

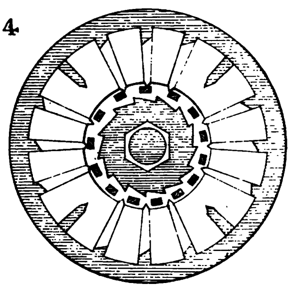
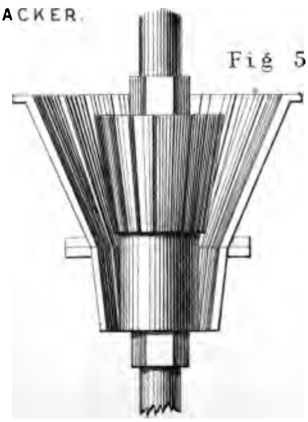


Fig 5.



Newbery & Alexander

E & F. N. Spon, 48, Charing Cross, London.

MORTAR BOX & CART.

Fig. 1.

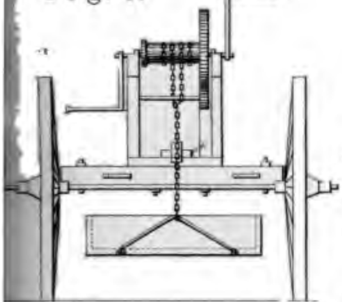
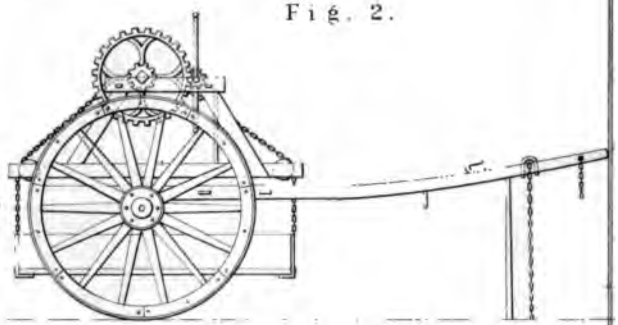


Fig. 2.



M. VICAT'S NEEDLE TESTING MACHINE.

Fig. 3.

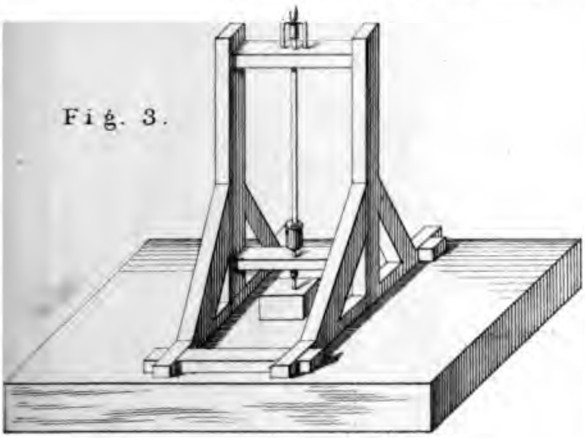


Fig. 6.

Fig. 7.

M^R GRANT'S TESTING MACHINE.

Fig. 4.

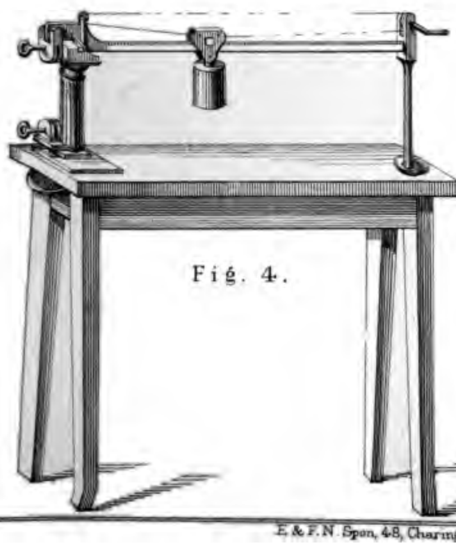
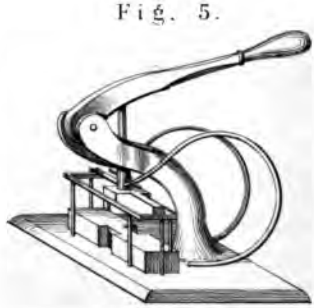


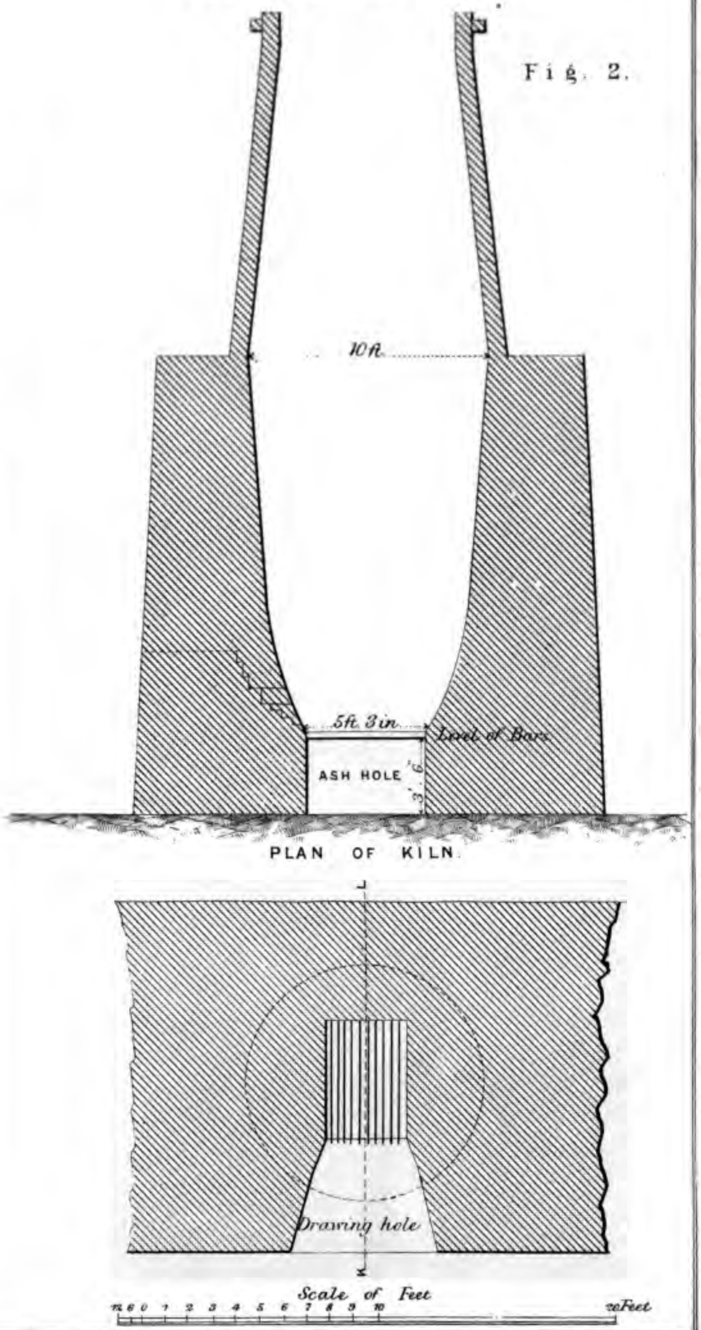
Fig. 5.



Newbery & Alexander lith. 43, Castle St. Holb.
E. & F. N. Spon, 48, Charing Cross, London.

SECTION OF KILN THRO'. K.L.

Fig. 2.



Norbery & Alexander, lith. 63 Castle St. Holborn.

THE

PRACTICAL MANUFACTURE

OF

PORTLAND CEMENT.

By A. LIPOWITZ.

TRANSLATED BY W. F. REID.

THE

PRACTICAL MANUFACTURE

OF

PORTLAND CEMENT:

WITH

A PLAN AND DESCRIPTION OF A CHEAPLY CONSTRUCTED

ENDLESS KILN

FOR BURNING

BRICKS, POTTERY, CHALK, AND PORTLAND CEMENT.

By A. LIPOWITZ,

CHEMIST AND TECHNICHOLOGIST.

TRANSLATED BY W. F. REID.

With Three Maps and Twenty-five Woodcuts.

LONDON:

E. & F. N. SPON, 48, CHARING CROSS.

1868.

PREFACE.

THE contents of this book were not originally intended for publication; but its object was to give some Contractors, who intended erecting Cement Works under my supervision, an idea or estimate of the cost. This was the origin of the present work, the contents of which are the result of personal experience and practice.

I have endeavoured to maintain a practical position throughout; and for that reason have not mentioned those men who for the last fifty years have contributed by their scientific labours to the practical development of the manufacture of Cement.

I must, however, express my esteem for those scientific men who were my guides, such as Vicat, Kuhlmann, Berthier, Brongniart, Malagutti, Von Fuchs, Bunsen, August Winckler, Dr. Feichtinger, E. Fremy, C. Vernier, Sainte-Claire-Deville, Dr. Artus, Dr. Elsner, Professors R. Böttcher, J. Otto, P. Schaffhäutel, Pettenkofer, Dr. W. Held, Mangon, Professor Bischof, Prince of Schönaich-Carolath Nöggerath, Dr. Mohr, and others. At page 5 I have told what assistance I received from Cement Makers.

In the work itself I have mentioned much which is generally included in the Preface.

With regard to the Endless Kiln, which is equally important to Brick, Lime, and Cement Manufacturers, I have described the manner of working the raw clay in a heated state, and of drying the bricks and tiles formed of it regardless of the weather.

The Plans, Sections, and Description of the Machinery are according to their capabilities and size.

I have not entered into the cost and particulars of the Endless Kiln, as Architects will have to be guided in this matter by the nature of the locality, extent of works, and the price of materials and their accessibility.

A. LIPOWITZ.

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THE

PRACTICAL MANUFACTURE

OF

PORTLAND CEMENT.

CHAPTER I.

RAW MATERIALS FOR THE MANUFACTURE OF CEMENT IN GENERAL.

THE manufacture of Portland Cement is possible wherever chalk, marl, clays, zeolithic and felsparry stones, volcanic formations, &c., exist in sufficient quantity or can be cheaply procured. Chalk is the most important ingredient in Portland Cement, for which can partially be substituted magnesia (dolomite chalk); then follow the clays, which contain silica, corundum (Adamantine spar), and generally oxides of iron; then the clay iron-stones; and lastly, kali or natron (soda), or both together, which determine the chemical composition of cement. All other constituents, such as chlorite, compositions of fluor, and sulphuric acid, are as unimportant as the carbonic acid and water, of all of which substances there is a very small percentage.

All materials containing the above constituents are found upon the surface of the earth in every formation, but not always fit for use, and their chemical composition rarely coincides. Raw materials are most suitable for cement making when their simple constituents have already become partially united, and when, in their original position, they have been exposed to the weather and the action of water. Whole or partial melting or incrustation, coarse or fine-grained crystalline texture, a greater or less degree of hardness, give raw materials very different properties; so that, although they are sometimes identical in chemical composition, they, nevertheless, possess different values for cement making, and therefore require different treatment and proportions.

Such being the case, it is difficult to describe exactly the most desirable materials for cement making, for the manufacturer will always use the materials most accessible at the cheapest cost. As in most localities, there is but a limited choice of materials; the manufacturer, if he is not himself a chemist, should employ one to analyze his materials. To do this, several pieces should be taken indiscriminately from the bulk, pounded and the powder analyzed.

The analysis should be exact, at least within one-half per cent., and must determine the quantities of chalk (Ca.), silica (Si.), clay (Al.), magnesia (Mg.), kali (K.), natron (Na.), oxides of iron (Fe.), carbonic acid (C_2.), sulphuric acid (S_3.), water (Aq.), and sand, which might occur accidentally.

It is not absolutely necessary that these analyses should always be made, but only when new and unknown materials are to be used.

When analyses of any particular material are made, it is advisable to compare the qualities of each quantity or load; chalk especially requires comparison, as the several layers or strata vary in density and hardness, and consequently the weight of each volume differs considerably.

CHAPTER II.

ANALYSIS OF CHALKS AND LIMESTONES.

For this purpose you should have a stock of pure nitric acid, of which one cubic centimètre shows 0·050 grammes of carbonate of lime. The method of distilling this acid (which may be obtained at any respectable chemical works) is fully described in Mohr's 'Handbook on Distillation,' vol. i., page 69.

Experiment.—Take two grammes of powdered chalk which has been previously dried, mix it in a vessel with a little water, and add the acid until the last drop turns litmus red; or add more acid, and then distil the whole with a solution of natron. (See Mohr, vol. i., page 69.)

Example 1.—Two grammes of limestone from Teplitz, in Bohemia, required 30 cubic centimètres of acid. As 40 cubic centimètres of acid decompose 2·0 grammes of pure carbonate of lime, the simple proportion is—

$$40 : 2 = 30 : x$$

$$x = \frac{2 \times 30}{40} = 1{\cdot}5 \text{ gramme carb. of lime;}$$

or,

$$2 : 1{\cdot}5 = 100 : x$$

$$x = 75\,\%$$

Example 2.—If the two grammes of chalk are mixed with 35 cubic centimètres of acid, and are therefore sour, they must be mixed with natron solution; five cubic centimètres of this solution are necessary, and 30 cubic centimètres of acid, as before, are absorbed, which shows that there is 75 % of pure carbonate of lime.

If the vessel is put aside for a short time the insoluble part will settle down. If it is required to know how much of the sediment is soluble in muriatic acid, mix it with the same and warm the whole; pour off the liquid and wash the sediment with distilled water; then dry it in the vessel in a sand-bath. Now weigh the vessel, and the surplus will represent that part of the chalk which is insoluble in acid. If you subtract this from the weight of the carbonate of lime, you get the weight of those parts of the chalk which are soluble in acid only.

This simple experiment is sufficient to determine the amount of chalk necessary to make the correct mixture for cement.

CHAPTER III.

ANALYSIS OF OTHER MATERIALS.

THESE include the remains from the analysis of the chalk, as also clays, phonolite, products resembling duckstone, iron-stone, and such like compounds.

Experiment 1.—Into a previously weighed vessel, put exactly 10 grammes of the substance or material which has been previously dried at a temperature of 100° centigrade. Mix it with muriatic acid and evaporate the whole in a sand-bath. It is then mixed with distilled water, filtered and weighed. That which is left may be considered silicious earth and clay.

Experiment 2.—The liquid, which has passed through the filter, and which contains all the soluble matter of the 10 grammes is then treated with ammonia. Oxide of iron and clay are then precipitated, and must be filtered and dried.

Experiment 3.—The liquid filtered from No. 2 is mixed with ammoniacal oxalic acid, then filtered, and the sediment, after it has been subjected to a red heat, may be regarded as carbonate of lime.

Experiment 4.—Magnesia is extracted from the liquid remaining from No. 3 as phosphoric ammoniacal-talc-earth by the addition of phosphoric natron. The sediment when collected in a small filter, washed with ammoniacal water and heated to a blood-heat, is pyro-phosphoric magnesia, 100 parts of which are equal to 36·64 parts of pure magnesia.

Experiment 5.—Of the alkalies which play such an important part in the setting of lime, only that part is of importance to the manufacturer, which is contained in the raw materials or mixed with chalk. Take 50 grammes of burnt substance and pound them in a porcelain mortar with distilled water. If the mixture hardens, add carbonic acid. Pour off the liquid and purify the remainder, which must be mixed with carbonic acid. Then evaporate the whole without filtering. Mix the sediment with a little water, filter and evaporate in a weighed vessel. The surplus weight consists of carbonate of natron and kali, with traces of chloride of natrium. One cubic centimètre of acid represents 0·047 gramme of kali or 0·031 gramme of natron.

Without committing a grave error, every cubic centimètre of acid may be reckoned equal to 0·04 gramme of alkalies.

Analyses are useful and instructive; but the production of good cement depends much also upon the technical knowledge of the manufacturer.

As before stated, very little chemical knowledge is requisite to determine the amounts of chalk, clay, &c., necessary for the composition of cement. The physical nature of the raw materials frequently requires different treatment, which the practical man can alone determine. This is the reason why so much cement made in Germany some years ago was worthless, although made according to chemical rules and principles. Great care was bestowed on the quality of the materials, while their manipulation was neglected or carelessly managed.

In the course of the practical part of my description of cement, I shall find opportunity to describe the imperfections of former cements, imperfections which even now occur.

Some manufacturers are fully cognizant of their errors, but are unable to remedy them from the want of means to construct new works and machinery. Therefore the cement manufactories of Germany, which have existed for about sixteen years and are twenty-five in number, have been conducted with great secrecy in order to hide their faults. Of course every new and novel invention requires outlay for its development, and whoever thinks of monopolizing it by secrecy will commit a great error, especially when the assistance and advice of others are required for its success.

The practical man requires only a look or a hint to understand what is wanted, and even chemistry must be subordinate to a perfect knowledge of the combination of the raw materials. Manufacturers whose works require large capital need not fear competition. No one will compete unless sure of a market and a profit. Competition in this case is advantageous, it improves the quality of the article and thereby increases the demand.

A commodity so cheap as Portland Cement can only be made within limited circles, and within the reach of economical transit. Besides, the raw materials vary in different localities, and their cost of carriage precludes the possibility of their being brought from any great distance.

In Stettin, for example, three manufactories were erected, all of which have succeeded. It would, therefore, be more advantageous for cement manufacturers to form a society, in which each could communicate his practical knowledge. Trials of new machines, kilns, and other things could be made at one place at a trifling cost when distributed among a number, and all would profit by the result. Many useless and profitless schemes of a ludicrous character might thereby be avoided.

After this digression I will return to the manufacture of cement.

CHAPTER IV.

THE PROPORTIONS IN WHICH THE RAW MATERIALS SHOULD BE MIXED, AND THEIR TREATMENT BEFORE BEING BURNED.

In the table at the end of this section are the analyses of some specially good cements, and the different natural products used in their manufacture.

These analyses confirm what I have already stated, namely, that the chief components of cements are:—

Chalk	from	50	to	65	%
Silica	„	10	„	25	„
Corundum ..	„	5	„	10	„
Oxides of Iron..	„	4	„	10	„
Magnesia.. ..	„	1	„	4	„
Kali and Natron	„	$\frac{3}{4}$	„	4	„
Carbonic Acid..	„	$\frac{1}{2}$	„	3	„
Sulphuric Acid.	„	$\frac{1}{2}$	„	2	„

If, therefore, the chemical components of the raw materials are known, it is easy to reckon the proportion of the samples, like the following practical example.

The materials are:—

	Ca.	Si.	Al.	K.	Fe.	Mg.	Aq.	Na.
Musselchalk of the Rhine ..	83·9	10·	1·5	—	1·5	1·6	1·5	—
Clay from Grenzhausen	0·61	68·20	20·	2·35	1·78	0·25	6·39	—
Brown iron-stone from the Lahn	—	—	—	—	50·5	—	9·	10·

The chalk contains, in round numbers, 84 % of pure carbonate of lime; these represent:—

$100 : 56 = 84 : x. \quad x = \frac{56 \times 84}{100} = 47 \cdot 04\%$ burnt lime. See No. 22 in table page.

If you require to make samples of cement of 55 % chalk, then an addition to the 47 % Ca. in the limestone would be necessary of:—

$55 : 45 = 47 : x. \quad x = \frac{45 \times 47}{55} = 38 \cdot 45$ parts in order to make 85 parts of cement.

As the chalk already contains 13% of hydrates, namely, 10% Si. 1·5% Al. and 1·5% Fe., they must be subtracted from 38·45%, or say in round numbers 39%, and if clay alone is added, 26 of it will be required. But as the clay contains 68·26% Si. 20% Al. 1·78% Fe., or about 90% hydrates,

$9 : 100 = 26\ x. \quad x = \frac{26 \times 100}{90} = 28 \cdot 88$ parts would have to be mixed with 100 parts of musselchalk.

The above sample would give a very light-coloured cement, as the Rhenish clays generally burn white. In order to make a cement of a greyish-green colour, make a second sample, and take the corresponding amount of brown iron-stone (limonite), 4½ parts of the oxide of iron contained in the limonite are necessary, in order to introduce 5% of oxide of iron into the 80–85 parts of the second sample. These 4½ parts are contained in 8·1 parts of limonite after it has been deprived of its water, and must be subtracted from 28·88 parts of clay. For the second sample, therefore, are necessary 100 parts of musselchalk, 20 parts of clay, and 8·1 parts of limonite.

As there is a very small portion of kali in these two first samples, a third sample must be made like No. 2, with the addition of one part of calcined soda of 90% standard purity.

The samples are mixed, formed, and burned, as described in Chapter VI. If burnt properly, the quality improves from 1 to 3.

I do not recommend the introduction of alkalies into cement in the form of kali or natron combined with chlor, unless peculiar circumstances render it necessary. Experience has taught me that all cements containing chlor alkalies suffer most from the effects of the weather, especially when combinations of magnesium occur in them. This is not the case with kryolite, which I consider a very good substitute for soda or potash.

The following relates to chalks, for they are the principal ingredients in all cements. Limestone, marls, &c., which leave 10% insoluble parts, when exposed to the action of muriatic acid, produce tolerable hydraulic limes. If, on the contrary, they leave from 20 to 25% of sediments, they will not slake after burning without first being powdered, after which process, however, they sometimes produce the best hydraulic lime, in many of its properties resembling Portland Cement.

The above shows that all additions are to be made according to the chemical properties of the chalk, in order to produce the best hydraulic limes, Roman or Portland Cement.

By comparing the analyses given in the following Tables, and by numerous experiments, I have found that the proportions of the materials differ very considerably.

All natural hydraulic and dolomitic chalks, as well as marl, &c., are formed out of other stones, not only by heat, but also by water and steam, or even water alone. Their hydraulicity, that is, their faculty of hardening under water, when burned, is increased when they contain soluble and strong alkalies. By following the course of nature I have arrived at important results.

If clay containing silica or iron is mixed with caustic, or even carbonate of lime, with the addition of cold water, and then dried, a much less intimate mixture is formed than if the water were heated to 100° centigrade. If the two mixtures, with hot and cold water, are burned and treated in the same manner, there is a perceptible difference in the quality of the cement. This difference is still greater, if $\frac{3}{4}$ or 2% of calcined soda is added to the hot water, and if the bricks are dried by artificial means. The cement must be mixed with from 30 to 35% of water. The bricks are then more porous, dry easier, and are not so brittle as those made with less water. This is the reason why small bricks burnt with charcoal or coke produce better cement than when burnt on a large scale. Practical examples confirm this. In a cement factory, the material was dried upon burning coke. It was afterwards exposed to a draught of air, and the cement produced from it was of a bad quality. Another manufactory, which was conducted on the wet system, could only produce a serviceable cement when it ceased to dry in the air, and began to use heated platforms.

NATURAL PRODUCTS.

Nos	Substances analyzed and by whom.	Ca.	Si.	Al.	K.	Na.	Fe.	Mg.	Ca.	Sa.	Aq.	Notes.
1	Puzzolana (Pulvis puteolanus)	2·8	44·5	15·0	1·4	4·1	12·0	4·7	..	..	9·2	
2	Santorin	2·36	68·5	13·3	3·13	4·71	5·5	..	..	..	1·45	
3	Trachyttuffe Duckstone, or Trass, from Brothal, near Andernach	5·4	49·	19·	0·37	3·56	12·34	2·42	..	..	7·65	Called Trass when ground, 56·86 % soluble in acids, 42·98 % insoluble.
4	The same {45·59 % Sol. in acids / 35·79 % Insoluble} ..	1·24	53·	18·2	4·17	3·73	3·56	1·6	..	..	12.6	With traces of phosphoric acid and chlor.
5	Trachyte, variable, chiefly composed of Felspar	2·2	65·5	20·0	9 to 11·5	..	3·0	1·6	..	..	2·	Porphyric trachyt at Konigswinter. Found spongy at Drachenfels and Wolkenburg.
6	Phonolith from Marienburg	2·0	56·6	17·0	9·56	2·66	4·0	1·69	..	..	5·0	37·46 % soluble in acids.
7	Phonolith from Whisterschau	0·6	54·0	24·0	4·24	9·21	1·2	1·37	..	..	3·2	Traces of titan and manganese, 48·97 % soluble in acids.
8	Felspar, common (Orthoclas)	2·	64·	20·	14·	..	..	..	..	..	..	
9	Felspar, glassy	..	68·	15·	14·5	..	0·5	..	..	..	..	
10	Albite (Natron Felspar)	..	69·	19·4	..	11·6	..	..	..	..	..	
11	Clays from Nassau, by Bensdorff, 47·40 sand	0·48	75·44	17·09	0·52	..	1·13	0·31	..	..	4·71	The fatty clays melted before the blow-pipe. The Rhenish clays burn white, are of different colours, very tough and plastic, and infusible in the Porcelain furnace.
12	Clays from Hillscheid, in Nassau, 58·95 sand	0·35	77·03	14·06	1·26	..	1·35	0·47	..	..	5·17	
13	Clay, at 100°, by Baurbach, 16·20 sand	0·36	62·78	25·48	2·51	..	1·25	0·47	..	..	6·65	
14	Clay, by Grenzhausen, 29·63 sand ..	0·61	68·28	20·	2·35	..	1·78	0·52	..	..	6·39	
15	Clay, Si., added after Fresenius, by Eberhahn, 18·29 % sand	1·08	64·8	24·47	0·29	..	1·72	0·87	..	..	6·72	

NATURAL PRODUCTS—*continued.*

Nos.	Substances analyzed and by whom.	Ca.	Si.	Al.	K.	Na.	Fe.	Mg.	Cl.	Sa.	Aq.	Notes.
16	Thonniern (septarien), English, according to Berthier	Ca. C. 65·8	18·0	6·6	omitted.		Fe. C. 6·0	..	..	..	1·2	Besides 0·5 Mg. C. and 1·6 Mn. C.
17	Thonniern from Boulogne, according to Drapier	61·6	15·0	4·8	..	..	Fe. 0·6	..	..	..	6·6	
18	Bavarian hydraulic lime (marl from the Tegernsee)	52·1	20 8	3·3	1·0	0·25	3·20	3·05	..	..	..	76·78 % soluble in acids. 21·82 % insoluble.
19	Limestone, from Krienberge, near Rudersdorf	Ca. C. 67·8 ..	.. 15·57	.. 4·18	omitted. ..	 ..	3·3 1·13	Mg. C. 5·6 ..	.. ..	.. ..	.. ..	Of no use as plaster.
20	Marl, from Perlmoos, near Kuffstein ..	Ca. C. 70·64 ..	.. 15·92	2·86 3·08	.. 0·55	.. 0·82	2·58 1·40	Mg. C. 1·02 ..	.. ..	.. ..	.. ..	78·23 % soluble in acids. 21·77 % insoluble in acids.
21	Oyster and mussel shells	Ca. 98·6	..	0·2	..	..	..	..	..	..	..	0·5 organic substances, 1·2 Ca. P.
22	Marble, or pure carb. of lime	56·2	..	..	..	..	..	..	43·8	..	..	
23	Magnesian limestone, from Amlwch, North Wales, by Professor G. Calvert	Ca. C. 21·4	5·58	2·07	..	..	Fe. C. 8·76	Mg. C. 61·15	..	..	1·10	From Carigerat, makes hydraulic cement.
24	Ditto Ditto Ditto	21·4	5·58	2·07	..	..	Fe. C. 8·76	Mg. C. 61·15	..	..	1·10	From Portgyfor, makes hydraulic cement (dolomite).
25	Ditto Ditto Ditto	72·2	2·70		..	..	3·21	15·86	..	..	6·0	From Hellsmouth, makes stucco.
26	Pure dolomite	Ca. C. 54·3	..	..	..	..	..	Mg. C. 45·7	..	..	..	
27	Kryolite from Greenland	..	..	Al. 13·07	..	Na. 33·35	..	..	..	..	..	53·58 Fl.

NATURAL PRODUCTS—*continued.*

No.	Substances analyzed, and by whom.	Ca.	Si.	Al.	K.	Na.	Fe.	Mg.	Cl.	Sa.	Aq.	NOTES.
28	Oxyhydrate of iron, brown iron-stone in all varieties, fibrous, thick, then yellow and brown clay iron-stones, and bog iron, as well as clayey sphærosiderite	..	20 to 60% (Si. and Al.)		..	..	20 to 89%	..	..	..	to 18%	From 0 to 10% M. From 0 to 10% D.
29	Clay from Eberhahn, at Vallender, on the Rhine, lowest part of coal formation	0·04	Sand. 17·79 32·18	.. 37·95	.. 3·	.. ..	.. 0·95	.. 0·11	.. ..	.. ..	.. ..	This clay is very liquid and tenacious. 10·02 loss and water. Costs 45*s.* per 1000 pieces of 10 lbs. each.
30	Clay from Muhlheim, between Coblentz and Andernach, also lowest part of coal formation	0·16	Sand. 12·41 47·78	.. 35·36	.. 1·24	.. ..	.. 2·69	.. 0·7	.. ..	.. ..	.. ..	11·72 loss and water. Costs 36*s.* to 45*s.* per 1000.
31	Natural cement-stone from Mittlesteine, Co. Glatz, in Silesia, very hard ..	56·83	Sol. 2·15	mk. Fe. 4·302	0·83 (K. and Na.)		..	Carb. 12·44	..	0·65	3·02	18·63% insoluble sediments.
32	Medway clay, according to Feichtinger	0·75	68·45	11·64	1·90	2·10	14·80	..	..	..	..	Used for most London cements.
33	Septarien clay from Wildau, 80 to 100 ft. thick, at Freienwalde and neighbourhood, according to Dr. Bardeleben	5·00	52·16	13·05	5·31	..	8·27	3·13	5·22	0·40	4·86	2·26% phosphoric acid.
34	Fatty green clay at Kieferstädtel, near Gleiwitz, by Dr. Bardeleben	1·26	57·09	17·8	3·64	..	7·87	1·72	..	0·08	8·6	2·05% phosphoric acid.

CEMENTS.

Nos.	Substances, and by whom analysed.	Ca.	Si.	Al.	K.	Na.	Fe.	Mg.	Cs.	Ss.	Aq.	Notes.
1	English Roman cement	40·4	13·6	9·9	0·36	..	With clay, 21	2·4	..	..	..	
2	Same from Hamburg (Faist)	41·8	19·2	9·0	0·37	..	With clay, 22	0·8	..	..	..	
3	English Portland cement (A. Hopfgarten, 1849)	54·1	22·2	7·7	1·1	1·6	5·3	..	2·1	..	1·0	
4	English Portland cement (Faist, 1852)	60·4	22·2	6·4	0·73	..	6·69	..	..	..	..	
5	Portland cement (Winkler, 1852) ..	62·23	22·2	4·0	..	..	1·92	..	3·2	..	..	
6	Portland cement (Knauss, 1855) ..	57·0	15·9	6·5	1·0	0·2	4·5	2·5	2·6	..	0·4	Soluble components.
		..	0·5	..	..	..	0·3		Quartz 9·8%		..	Insoluble components.
7	Portland cement, from St. Leger, France (4 parts chalk, 1 part clay), (Berthier)	84·0	10·	5·	..	..	1·	..	..	..	..	Before burning.
		74·6	..	23·8	..	..	1·6	..	..	..	..	After burning.
8	Portland cement (Pettenkofer)	54·1	22·2	7·7	1·1	1·66	5·30	0·75	..	..	..	
9	Portland cement, from the Bonn Mining Company, 1864	57·1	23·2	9·2	0·58	0·70	5·12	1·32	1·9	0·64	..	
10	Portland cement, from Perlmoos (Kufstein)	55·78	22·5	8·9	0·75	1·06	6·05	1·62	1·46	1·85	..	
11	Cement made of Burnt Mittlesteine Stone (Justus Fuchs)	45·63	12·13 sol.	18·26	1·04 (K. and Na.)		4·02	8·46	2·67	2·01	0·95	2·86% insoluble sediments. This cement requires a great deal of water, and must not be used directly it is mixed.

CHAPTER V.

THE THEORY OF THE FORMATION OF CEMENT.

I HERE give a short description of the formation of Cement, which I have copied from an article contained in the periodical on Mines and Foundries, for last year (1867).

The Prince of Schönaich-Carolath, in Tarnowitz, in an article called "The Theory of Portland Cement," is of opinion that the best clays for cements are those which contain iron up to 10 or 15 % in the form of iron-oxydule. The author considers the English Medway clay, the clay from Wildau, and the clay from Kieferstädtel, near Gleiwitz, as the most suitable clays for the manufacture of cement. These clays represent, according to the author, corundum, iron-oxydule, and alkali-silicates, which, when mixed with chalk, melt easily, before the lime becomes caustic, and surround each particle of lime with a vitreous covering, like a small bubble. These thin bubbles show under the microscope the flaky structure of most cements. Many cements do not appear flaky under the microscope, and yet possess all the properties of good cement. In this case it is thought that the clay, &c., melted when the carbonic acid was being expelled from the chalk, and so prevented the formation of the bubbles. If the process of melting be carried too far, the whole silicate is slacked, and a lime-glass is formed, with an insufficient quantity of caustic lime. It then loses its porosity, as well as its hydraulic qualities.

I perfectly agree with the author in all but one point. I consider the formation of cement dependent on the proportions of the raw materials, their intimate admixture, and partial combination before being burnt. The combination of the cement before burning is effected by the heat necessary for drying it, which caustifies the alkalies or combinations of alkalies. According to my ideas, clay containing iron-oxydule facilitates the clinkering of the cement, although this form of iron is not absolutely necessary for the production of good serviceable cement.

Clay from the delta of the Nile, as well as two sorts from the delta of the Rhine, when mixed with chalk from the tertiary basin of Mayence, produce good cements, although the greater part of the iron contained in them is in the form of oxides.

Three sorts of clay from Thüringen, of which one contained a greenish-grey iron-oxydule, the second contained a chocolate-coloured, and the third a red oxide of iron, when mixed with chalk, &c., formed good cements. If clays are fatty, compact, and not sandy, like the clays of Holland, which the Dutch use to make their celebrated bricks, they are, according to the preceding analyses and treatment, generally fit for cement making.

CHAPTER VI.

ON SAMPLES.

If the results of the burning of the samples are to resemble those of the burning in large kilns, the circumstances of the burning must be the same. This induced me to apply the principle of my endless kiln to sample kilns. I should now remark that all parts of the kiln exposed to heat should be lined with fire-bricks.

Fig. 1.

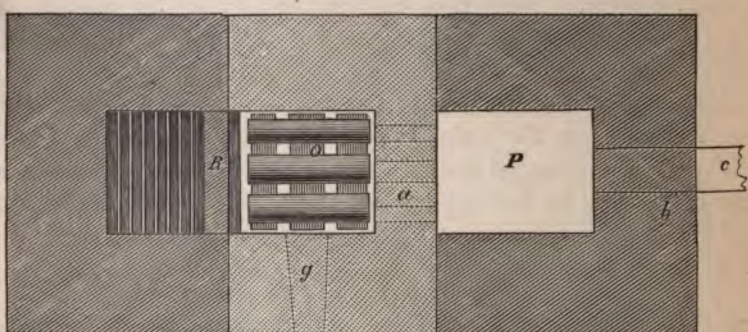


Fig. 2.

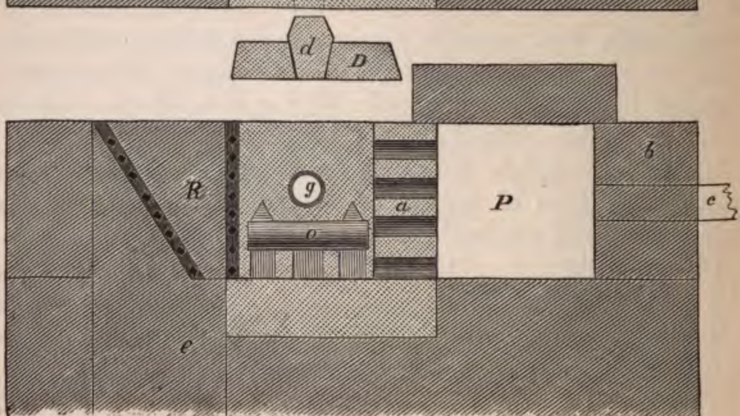


Fig. 1 is a ground plan of the sample kiln. Fig. 2, a longitudinal section of the same to a scale of one-eighth of the full size.

The fuel is put between the two grates *R* (the vertical grate or bars of the kiln should be provided with rods of burnt porcelain clay), the samples or bricks of cement are put behind the vertical grate of the oven *o;* the kiln is then closed with the cover *D*, and plastered with fire-clay. Behind the kiln is a space, *P*, divided from the other part by a perforated wall of fire-clay, three inches thick. The space *P* is hermetically closed, and, at the farther end of the whole, a pipe, *c*, is introduced, which leads to the shaft or ventilator. The action of the kiln is as follows:—

When the fire in the grate begins to burn, the whole heat of it goes through *o* into *P*, towards the ventilator; the greatest heat is in *o*, where it can be increased by the introduction of fuel through the opening *d* in the cover *D*, or by increased ventilation. In one side of the oven, *o*, a sheet of mica, *g*, is introduced, through which the contents of the oven may be watched; *e* is the ash-pit.

This sample kiln of my construction, which also represents the principle of the large endless kiln, renders it possible to make scientific and practical experiments and observations.

The experience thus obtained may be applied to the large endless kiln.

1st. The value of different fuels may be accurately determined. It is only necessary to introduce between the kiln and the ventilator a serpentine tube or pipe, immersed in water. The heat engendered in the kiln and the temperature of the water represent the worth of the fuel.

2ndly. The adaptability of all kinds of fuel for the purposes of burning cement, chalks, bricks, &c., can be ascertained.

3rdly. The amount of heat may be regulated to any degree, by the quicker or slower rotation of the ventilator (from 600 to 2000 revolutions per minute).

4thly. The proper degree of heat can be accurately determined by the colour of the material while burning, and the time required to burn it.

5thly. The space required to burn certain quantities of cement or chalk can be with accuracy determined.

In order to work this kiln, a ventilator of the smallest size may be used, costing about 2*l.*

Ventilators are of primary importance in my system of making cement, and in the endless kiln. I will therefore suppose that the principle of the ventilator is known to my readers, but not its practical application for suction or blowing, which I have explained in Figs. 21 and 22, page 45, their prices, and where and from whom obtainable.

CHAPTER VII.

SAMPLE BRICKS.

THE sample bricks are formed of the raw materials mixed in certain proportions with hot water, as has already been described.

The raw cement powder must pass through a sieve 65 meshes to a lineal inch, or 4225 per square inch; the same size is also applicable to the cylindrical sieves on a larger scale.

It is unwise to use a coarser sieve—for instance, one with 50 or 55 meshes to the lineal inch. The finer the raw materials are powdered, the better will be the cement.

The mixture is formed in moulds of tin, provided with pieces of wood for pushing out the material when dry. The best forms are 2½ inches wide, 6 inches long, and triangular, circular, or oblong, △ ○ ▭, so that the various samples may be distinguished after being burned. The samples are then placed in the kiln, one above the other, with intervals between, as shown in Figs. 1 and 2.

CHAPTER VIII.

PRACTICAL PREPARATION OF CEMENT.

a. THE dry method. Under this term is understood the treatment of the chalk, clay, and other materials when they are powdered in a dry state and then mixed with water. The other is called:—

b. The wet method, when soft chalk or marl is mixed with water, with the addition of clay and the other ingredients. When they have been intimately mixed, the whole is conducted into reservoirs or backs, where it settles down, and the superfluous water is drained off.

The latter method has the advantage of requiring less mechanical power, and the various substances are finely mixed with little difficulty. But it has the disadvantage that chalk, clay, and ironstone settle in the backs according to their several specific gravities, and are in consequence imperfectly mixed. Besides, those portions which are soluble in water are either drained away with it or filter into the ground.

I prefer the dry method if the mixture is heated before being formed, and if the materials are finely powdered. I tender the following advice to cement-makers who practise the wet method, or who possess soft marl, chalk, and clay. This method, after the water has been drained off, produces a mixture fit to be formed, and then dried, after its chemical properties have been accurately ascertained.

It is obvious that the wet method is not applicable to limestone, clay iron-stone, and phonolite. When these latter materials are used, they must be first passed between a pair of rollers, and then put into the horizontal mill. They are then treated as I have described.

CHAPTER IX.

DRYING THE CHALK.

All solid chalks and marls must first be heated to 100° centigrade, in order to dry them, otherwise they would be difficult to powder and sift. The manner of drying them is very simple. A square building is constructed (Plate II., No. 1) of fire-bricks. It can either be arched or open at the top. If open, it should be covered by a slate roof some height above it. In one end is a door, two feet six inches wide and about five feet high, through which the chalk is introduced. Along one side are arched holes, one foot wide and one foot six inches high, for the fires. The whole building is filled loosely with chalk, so that spaces are left through which, when the fires are lighted, the hot air rises and dries the chalk. When the chalk has been put in, the door is closed with stones and plastered with clay. When the contents are dried, the door is opened and they are taken out. This process is repeated as often as dry chalk is required. The dry chalk is then mixed in certain proportions, according to weight, with the other materials and then ground. It is also advisable to dry these other materials.

CHAPTER X.

BREAKING AND PULVERIZING MATERIALS.

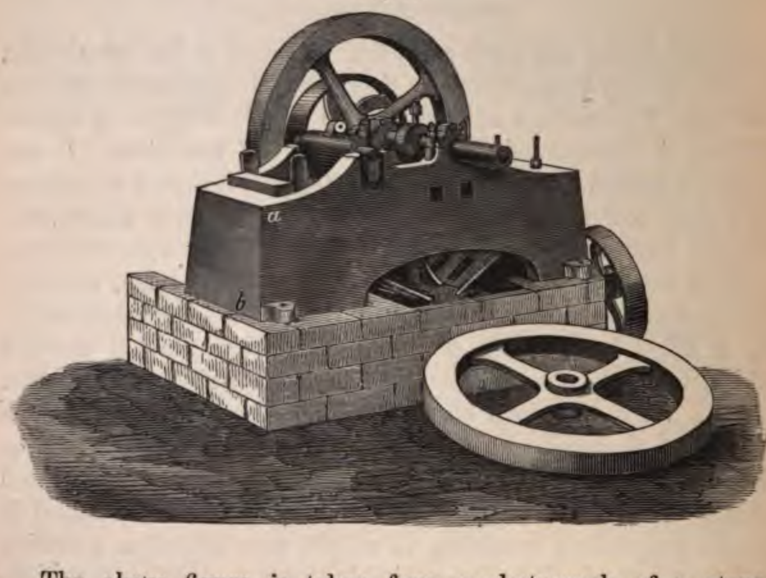
As already mentioned, all materials must first be brought into the form of a fine powder. As one machine or apparatus is incapable of performing this work, machines of different construction are required, which accomplish this gradually.

According to my own experience, I can recommend the following machines:—

A, The stone-breaking machine. The first machine of this kind was exhibited by Blake, an American, at the London Exhibition of 1862, after which time it was improved upon and made by several engineers in England and Germany.

Although this curious machine, which resembles a large iron mouth, was originally intended for breaking stones for roads, yet it was soon discovered that it produced too much dust and fine pieces for that purpose. For this reason in was employed or used in gypsum, soda, and other mills, and for the crushing of stones for mines, furnaces, &c.

Fig. 3.



The above figure is taken from a photograph of a stone-breaking machine made by Sievers & Co., at Kalk, near Deutz.

In order to give a better view of it, the fly and strap wheels are removed. The whole is very massive, and is constructed of cast and wrought iron. *a* represents a movable plate, which, when the machinery is in motion, opens about 28°. The strong side of the machine forms the second plate. The movable plate is set in motion by means of wheels and knee-joints in communication with the fly-wheel, and crushes all stones thrown into the opening. The broken materials fall out below at *b*. Both plates are covered with teeth. Blunt and shallow teeth are preferable to deep and sharp ones. The distance between the plates may be regulated to the required size; and in order to save labour in raising the broken fragments, a tramway is placed or laid under *b*, on which a truck or waggon is put to receive the broken materials as they fall from the machine.

This machine is sold by various firms. I have had experience of those made by Sievers & Co., as well as those from the Georg-Marien foundry, in Osnabrüch, and of Schwartzkopff, in Berlin.

A machine of the above description can be purchased of Sievers & Co., in Kalk, near Deutz, for the sum of 60*l.*; it is called a No. 1 machine, and can crush from 25 to 30 tons of raw materials per day in pieces three inches square or less.

I prefer a stone-breaking machine, when kept in good working condition, to rollers which have hitherto been used, especially for crushing the clinker (burnt cement). The cement-breaking rollers made by Messrs. Möller, of Kupferhammer, near Brackwede, in Westphalia, cost about 54*l.*, and are capable of breaking or crushing from 15 to 20 tons of moderately hard Bielefield cement-stone in 12 hours. Two-horse power is required for this machine.

B, Edge-runners (vertical mill). This mill is represented in Figs. 4 and 5 (p. 20), at a scale of $\frac{1}{48}$ of the real size. I prefer the stones 5 ft. 6 in. in diameter and 1 ft. 6 in. broad on the face. When constructed of iron, the outside rim should be at least six inches thick; but I consider them better when made of some hard stone, such as porphyry or granite. Hard lava-stones can also be used; but I think those of Niedermendiger (near Andernach) too soft for this purpose.

The four or six arms or spokes should be strong, and the intervening spaces filled up with heavy stones and cement. I saw in Limburg, at the cement works of Heyn Brothers, cast-iron edge-runners containing the sand with which they had been moulded

Fig. 4.

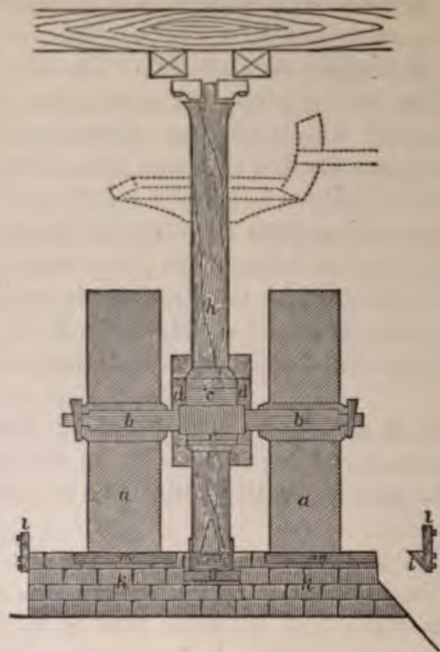
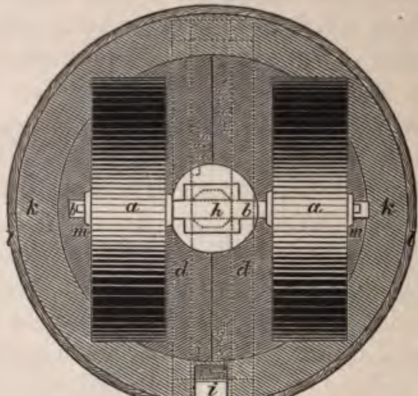


Fig. 5.



and without spokes. They should not weigh less than three or four tons.

I have carefully observed the wearing of stones in cement manufactories, more especially those made of cast-iron, and found them worn unevenly—some in the middle and others at the sides.

I attribute this to their being badly fixed; for when the stones were truly horizontal, and not too distant from the vertical shaft, they wore evenly on the surfaces, and their faces continued level. There is certainly one advantage possessed by the iron runners over the stone ones; that is, the facility of renewing them; and if the works are near an iron foundry, where this can be cheaply and expeditiously done, iron runners may be considered equal to stone ones.

The work required from the edge-runners is much simplified when the materials received from the stone-breaking machine do not exceed the size of a walnut; and I recommend a short cylindrical sieve to be fixed for the purpose of regulating the size.

The construction of the edge-runners or vertical mill is shown Figs. 4, 5, 6 and 7. All parts should be strongly constructed. The shaft, *b b*, on which the stones, *a a*, are fixed (one farther apart than the other), can be moved up or down in the vertical shaft, *h*, so that the stones may act on thicker or thinner layers of materials as required.

The bottom, *m m* (Figs. 4 and 5), is constructed of cast-iron plates, 4 or 5 in. thick, or stones (as may be considered most advantageous). A rim, *l l*, six or eight inches high, made of wood and bound with hoop-iron, surrounds the whole.

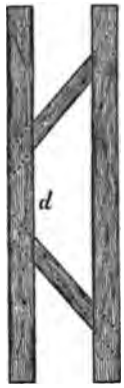
If the material to be crushed is of a uniform size, the work of the stones is easy, and their wear and tear insignificant, besides which they perform a larger amount of work; their construction might in that case be slighter.

This reminds me of some manufactories where pieces of cement, &c., as large as a child's head are thrown into the mill; the stones jump over these, and can neither break them nor touch the smaller pieces lying between. Stones so treated do little work, at an enormous waste of power. In feeding the mill, the materials should be either put in near the shaft or at the side.

It is bad economy to exact too much work from one machine; it is preferable to have several machines, one following the other, and thereby save power.

The stones, as already mentioned, are placed at irregular distances from the shaft—say about one-quarter or one-third of their breadth or face of difference—so that they may not follow in each other's track. Two scrapers are fastened into a wooden frame—Fig. 6 from above, Fig. 7 from the side, Fig. 8 from the front.

Fig. 7. Fig. 6.



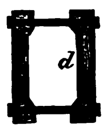


Fig. 8.

One of these scrapers throws the materials from one side under the stones, the other takes it away permanently from the other side and pushes it into a groove in the bottom, Figs. 4 and 5; both scrapers are fastened by screws, so that they may be made to perform their work equally. If instead of one scraper two are used, Fig. 6, *e e*, the one stands before the other, so that only a fourth of the width of the stones is scraped at once, which is much more advantageous. In this case, two scrapers, *f f*, are fixed, one behind each stone; one throws the materials to the other, when it is pushed out of the mill. *e e* and *f f*, in Fig. 6, represent the sockets into which the scrapers are screwed.

Edge-runners so arranged will perform miracles, and set at rest the objections frequently urged against them.

If a frame of iron is used for fastening the scrapers, it should be fixed so as to press against steel springs, or pieces of india-rubber. When the scrapers catch they are generally broken, and the whole machine deranged; this cannot occur if the materials are first reduced by the stone-breaker to pieces the size of a walnut.

The action of the stones being of a twofold kind—that is, rolling and rubbing, the pressure only acts on the larger pieces of material, and therefore the speed at which they rotate should never exceed twelve revolutions per minute. If the speed is greater, the centrifugal force pushes the stones towards the ends of the shaft, injures their fastenings, and causes them to leap over the larger pieces without crushing them.

It is to be remembered, as a matter of course, that all working parts of the mill are to be well and regularly lubricated.

The mill is to be driven from the main shaft by a strap or belt. I prefer using straps where the machine is not over-taxed, for they cause less interruption and give an easier motion.

Many mills have their supply and removal of materials most carelessly performed, and I have convinced myself that much improvement can be effected in this respect. I do not refer to those mills in which the materials are left for a certain time, and are then removed by a scraper lowered for that purpose; this, in my opinion, is the most imperfect mode of using them. In some factories the horizontal shaft is composed of two pieces, which admits of each stone being raised or lowered separately; this arrangement is advantageous, if the chief shaft is not weakened by it.

Sievers and Co. charge for a mill, with iron runners complete, the whole weighing about 22,500 lbs., at 18*s.* per 100 lbs. Each runner, filled with masonry, weighs from 3 to 4 tons.

The opening in the bottom of the mill leads in a sloping direction into a cylindrical sieve, 3 feet long by 1 foot 6 inches wide, made of perforated sheets of steel, the holes of which are from a sixth to a quarter of an inch in diameter. Perforated sheets of steel, weighing 1¼ lb. per square foot, can be had from Sievers and Co. at 7*d.* per lb. The sheets measure 4 feet long by 2 feet wide, and can be perforated to order.

In Fig. 5 the stones are seen from above.

Fig. 4 represents a vertical section of the mill in the direction of the shaft *b*, on which the stones or cast-iron cylinders, *a a*, are fastened. The shaft, *b*, can be raised or lowered in the thick part of the shaft *h* in the slit *c*. On this thick part of the chief shaft rests the frame *d d*, which is represented on Fig. 6, seen from above. In this frame, *e e* are the sockets in which the scrapers are screwed. These are situated nearest the chief shaft, and push the materials which enter at *g* under the stones. The scrapers fastened in the sockets, *f f*, force the pulverized material into the groove *i*, Figs. 4 and 5, whence it falls into the cylindrical sieve, *S* and *S'*, Plate II.

Fig. 7 gives a side view of the frame.

Fig. 8 shows how the frame is bolted together at its junction with the chief shaft.

k k, in Figs. 4 and 5, is the solid brick-work foundation.

l l, in Figs. 4 and 5, represents the wooden margin or rim bound with iron.

m m, in Figs 4 and 5, is the bottom of the mill.

If the operation of crushing has been well performed, or rather if the crushing of the materials has progressed favourably, they will, for the greater part, pass through the sieve into a worm situated below, which sends it on till it reaches the elevator, by which it is raised to the fine cylindrical sieves situated in the upper story or flat of the mill.

These two sieves, of which a transverse section is given in Plate III., are 9 feet long, and from 2 to 2½ feet wide, and are covered on all sides with steel-wire netting of 4225 meshes to the square inch. Iron-wire netting does not last half so long as steel.

The sieves are enclosed in wooden cases, which have small doors in the sides. It would be superfluous to describe this arrangement, as every machinist is well acquainted with it. Figs. 9 and 10 represent it.

Fig. 9 shows the cylindrical sieve and its case, as seen from above, and the point from which it is fed or supplied, *c*, which lies to one side. The sifted materials, which are about the size of a

Fig. 9.

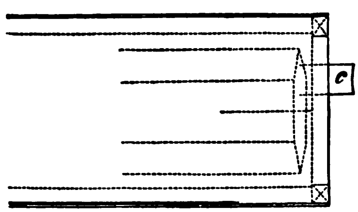
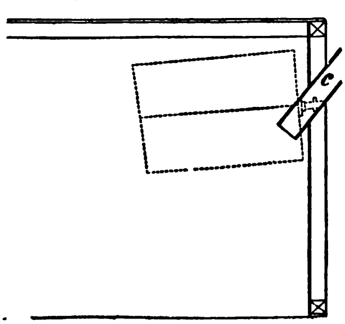


Fig. 10.



pea, and are about one-half of the material crushed in the mill, fall from the end of the sieve through a wooden channel into the horizontal mills.

CHAPTER XI.

IRON HORIZONTAL MILLS.

Figs. 11, 12, 13, and 14 represent a horizontal mill to a scale of $\frac{1}{30}$ of its full size.

A complete mill, made of iron, without the stones, including frame, case, hopper, pritchells, mill-bills, driving-wheels, and screws for adjusting the stones, costs from 45*l.* to 60*l.*

The horizontal mills are situated in the works at No. 3, Plate II. Those marked *M* are for grinding the raw materials, and those marked *M′* are for grinding the cement.

Fig. 11. is an elevation of the mill viewed from the strap or driving side. *A* is the hopper, which is fastened to the case *B* by three supports, *a a*. At the bottom of the hopper, in the eye of the millstone, is fixed an iron tube, *C*, which can be raised or lowered by the lever and screw *D*.

The case B is made of sheet-iron, and provided with handles for convenience of raising. Each spout discharges into the worms *TT′*, Plate II.

Fig. 12 shows a vertical section of the mill: *E* is the runner, and *F* the bedstone; *G* the spindle; *H* a cross-bar, with three arms; the tube *C* can be placed in the required position by the adjusting screw *D*, Fig. 11.

Fig. 13 is a horizontal plan in the direction of the shaft, and shows the machinery or mechanical arrangement for raising the spindle, that is, the runner to which it is fixed by four bolts of at least $1\frac{1}{2}$ in. in diameter.

The circular iron hoppers receive the materials from the floor above, and are so adjusted that no more will pass than the stones can grind.

The eyes of millstones are generally made too small: it has been proved that the process of grinding is performed only by about a quarter of the millstone. It is therefore advisable to make the eye larger, especially for stones, cement, &c. If the diameter of the millstone is 4 ft., the eye should be 1 ft. 4 in.

Fig. 12.

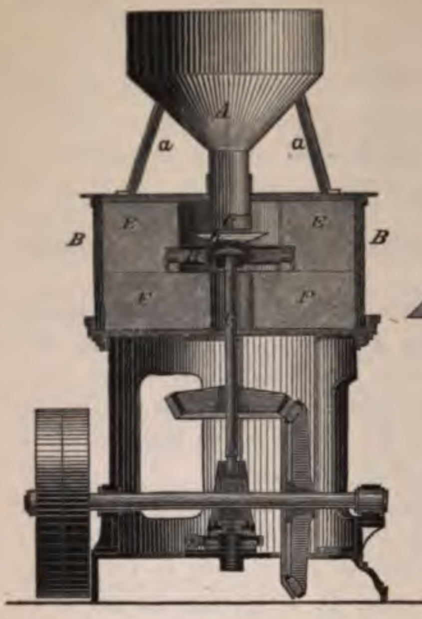


Fig. 11.

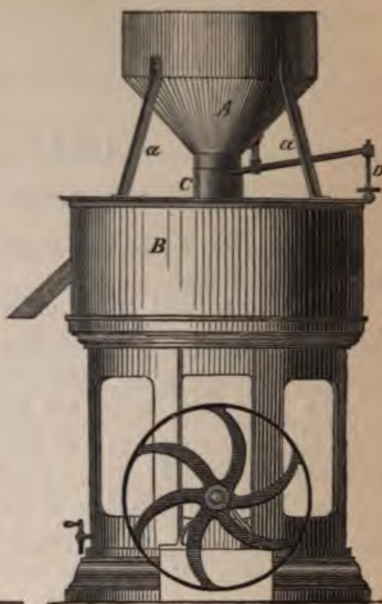
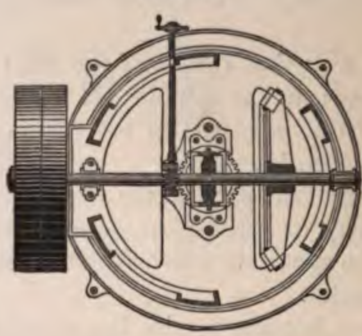


Fig. 13.



CHAPTER XII.

MILLSTONES, AND WHERE OBTAINED.

THE hardest quality of stones must be selected for grinding the cement. For grinding the raw materials (which are never so hard as the burnt cement) the hard lava-stones from the quarries of Neidermendig, near Andernach, may be used. Sal. Landau, in Cologne, and Francis Xavier Michel, in Andernach, furnish these stones. The latter supplies the hardest kind of Neidermendig stones at the following prices:—

One stone, 4 ft. 9½ in. diam.,	1 ft. 4 in. deep	..	£6 0 0
" 4 ft. 5½ in. "	1 ft. 3 in. deep	..	£4 14 0

and smaller stones in proportion.

The German stones are too soft to grind the burnt cement, which may be proved by rubbing a piece of clinker against them, when they will be found to be scratched. The best French stones are from Dordogne and Marne. Some of the Belgian stones are also suitable, and may be purchased of good quality from the firm of Roger Filsit & Co., in Laferté-sous-Jouarre, at the undermentioned prices:—

4 ft. 10 in. diameter	£38 15 0
3 ft. 3 in. "	£18 15 0

Quartz-sandstone and granite stones may be obtained of Widow J. Bungholzer, at Perg, in Upper Austria, 4 ft. 2 in. in diameter, at the price of £6 each. Joseph Oser, at Krems, in Lower Austria, sells compound stones, of a species of volcanic quartz, which are said to be very good. Krawinkel, in Gotha, makes millstones of very hard pale-red porphyry, containing pieces of quartz as big as peas. Their cost is as under:—

3 ft. diameter,	6*s.*	per inch in thickness.
4 ft. "	10*s.* 6*d.*	" "

Similar stones can also be had at Neckarzeltingen, in Wurtemburg. The French millstones put together by Albert Jüngst, in Dresden, are said to be good; and I have heard of them having been sent from that place to the Rhine.

If you have an opportunity of choosing stones, select each of a pair of different degrees of hardness. The runner, having the hardest work, should be of lava, &c., and the bed-stone may be made of granite or quartz-sandstone; but it is always safest to have the best French stones for both bed-stone and runner, or at least French runner and granite bed-stone.

French burr stones are seldom made in one piece, because large lava stones have different degrees of hardness, and are very expensive when of a large size, although better for cement grinding. It is usual to make French stones in several pieces, carefully selected, which are joined together with the best cement and then bound round with a band of hoop-iron. I should recommend all stones to be built in this way.

The dressing of the cement stones must be deeper than that used for flour or corn mills. At the eye the furrows should be made from $\frac{3}{8}$ to $\frac{1}{2}$ an inch deep, and on the margin or skirt from $\frac{3}{16}$ to $\frac{6}{16}$ deep. The regulation of this, however, depends pretty much on the velocity of rotation, the hardness of the material to be ground, the degree of fineness when it is introduced into the mill, and the quality of the millstones. With a little attention, the breadth, depth, and distance of the furrows or grooves may soon be determined.

CHAPTER XIII.

TACKLE FOR RAISING THE STONES.

All the horizontal mills being in one building are readily accessible, and I would recommend the machine of Carsten Waltjen, in Bremen, as being most useful for changing or moving the stones. It is in the form of a horseshoe upon wheels, the stone by this means can be readily wheeled to the place required; this mode is much preferable to cranes, which take up much space and are not easily managed.

CHAPTER XIV.

ROTATORY SPEED OF THE STONES.

The circumference or periphery of the stones should move about 25 or 28 feet per second. According to this rule, stones of 3 ft. 6 in. diameter would make 150 revolutions, and 4 ft. stones 130 revolutions per minute; but practically stones of 3 ft. 6 in. should not exceed 130 per minute, and those of 4 ft. diameter 120 per minute.

According to very accurate experiments, stones 3 ft. 6 in. in diameter require four-horse power, provided all parts of the machinery are carefully lubricated and the stones truly parallel. If the stones are well dressed, from 10 to 12 tons of crushed burnt cement in pieces the size of a pea may be ground to the finest powder in 20 hours.

I would here observe, that the millstones should be placed from 2 ft. 6 in. to 3 feet above the ground, and that each mill should have a fast and loose pulley.

Any intelligent machinist or millwright is familiar with all other details, and would have no difficulty in erecting a mill if you provide a solid foundation.

The necessary machines required for the manufacture of one hundred casks of cement a-day would be—

1 stone-breaking machine,

1 vertical mill,

3 horizontal mills for the raw materials, and an equal number for grinding the burnt cement.

Although the raw materials are softer and consequently more easily ground than burnt cement, still it is advisable to have the number of machines mentioned.

From each mill a covered shoot leads to the endless worm *TT'*, Plate II., which carries the ground material onwards till it mixes with that coming from the edge-runners, the mixture then falls into the pit at the end, *EE'*, of the worms, out of which it is raised by the elevators to the cylindrical sieves in the upper floor; from these sieves it can descend through inclined shoots into the places 4 and 7, Plate III.

CHAPTER XV.

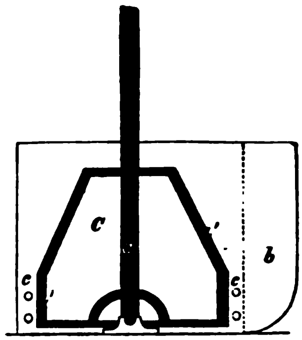
GRINDING THE RAW MATERIALS.

As I have previously stated, the raw materials must be mixed by weight, or according to measures corresponding with fixed weights. They should never be mixed in large quantities, to ensure their being more intimately incorporated in the breaking-machine, the vertical mill, the worm, and the horizontal mill.

Great care must be taken in the mixing of the raw materials.

The operation of mixing the raw materials in the stone-breaking frame a' a' by its revolutions causes the insoluble particles to mix with the liquid. In the place where the liquid is taken out there is a space b, so that the stirring apparatus is never interfered with. In the inside, close to the side of the vat, a tube, c c, is wormed round twice, at one end of which steam enters, and escapes condensed at the other. This arrangement serves to keep the contents of the vat warm. Fig. 17 shows a plan of the whole; the letters are identical with Fig. 16.

Fig. 16.



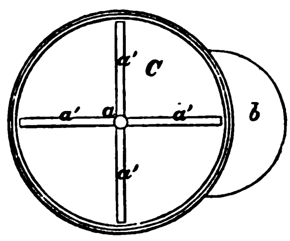


Fig. 17.

CHAPTER XVIII.

FILLING THE VAT.

There is placed on the side of the vat a graduated scale, showing its capacity in quarts or gallons, as may be most convenient. It is filled with water by a pipe and tap leading from the main cistern in the works.

Experience informs us that 100 parts of raw cement powder require from 30 to 35 parts of water, in order to make cement-powder plastic. Add to every 100 parts of water (which is enough to form 300 parts of cement-powder) from 2¼ to 6 parts of calcined soda and 6 lbs. of freshly burnt and slaked chalk. The machine is then set in motion and the whole intimately mixed.

CHAPTER XIX.

MOULDING BRICKS AND DRYING-PLATES.

INTO the forming-machine are put alternately one measure of powdered cement and one measure of the liquid from the vat till it is full, the shaft being in motion. When first the machine is filled, the materials are not always intimately mixed, in which case they should be returned to the machine. This part of the work should be performed by women only. One woman stands behind the forming-machine and places the drying-boards, which are ten inches broad and as long as the platform, under the opening of the mould. The strip of cement which exudes or comes out at the bottom of the cylinder falls upon the board, at the same time pushing it forward. During this process another girl cuts it into regular pieces five inches broad with a piece of wire fastened on a cane bow. When one board is filled, the same girl removes it and places it, with the help of another woman, upon the iron drying-waggon.

The forming-machine is filled by a woman and a girl. The girl fills a measure with cement powder and hands it to the woman, who throws it into the machine, and then adds a corresponding measure from the liquid in the vat. From time to time she scrapes the sides of the cylinder and the upper knives, so that the mass may mix equally.

It is evident that these five women must be constantly at work, in order to keep up with the machinery. This part of the process should not be done by piecework, for in that case it is liable to be performed carelessly.

Some people may think that a mechanical arrangement might be introduced to put the powder and liquid regularly into the cylinder; but I have convinced myself, by numerous experiments, that such an arrangement is not so suitable as the plan I have described.

As the plastic strip of cement is warm on leaving the machine, its exterior soon dries, and it may then be lifted by hand.

The drying-plates should be made of iron, on account of the considerable heat to which they are exposed. They are 4 feet long and 10 inches broad, and consist of a frame of strong angle iron, across which, at equal intervals, are fastened bars of half-inch round iron. In order to make the whole more complete and compact, two pieces of band-iron should be fastened diagonally underneath.

The weight of one of these plates or frames is about 15 or 16 lbs., and assuming the cement strip to weigh 60 lbs., a weight of nearly 80 lbs. has to be lifted from the platform and placed on the drying-waggon. This is done by the two girls. The girl who is not engaged at the platform divides the half-dried bricks from each other, and directly a drying-waggon is filled, she pushes it into the drying-channel.

That iron frames are better than sheets of iron for drying is evident; but as about 500 of them are required, weighing altogether about 4 tons, their cost is considerable. They, however, wear much better than wooden ones, and even when worn out are worth something as old iron. Instead of those frames, perforated sheets of iron may be used, weighing about 3 lbs. to the square foot, as represented in Fig. 18, to a scale of $\frac{1}{16}$ the natural size. Corrugated sheets of iron may also be used, as shown in Fig. 19, which represents a tranverse section of a sheet with a brick lying upon it.

Fig. 18.

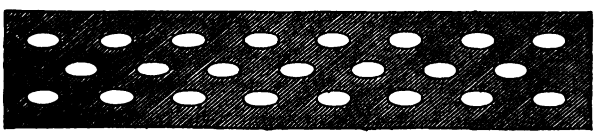
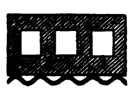


Fig. 19.



Drying the bricks upon perforated or corrugated sheets has the advantage that they do not break so readily as when dried upon frames. The higher price of corrugated and perforated sheets is compensated for by their being less in weight.

In order to prevent the frames, plates, or corrugated sheets from rusting, they should be rubbed from time to time with a rag dipped in linseed oil.

CHAPTER XX.

DRYING THE BRICKS.

The bricks when formed are placed upon the drying-waggons, which are then pushed by the women into the drying-channels, Plates II. and III. The drying-channels, which are heated by the fires from the steam-boiler flues and the endless kiln, are described in another part of this book. Each channel is 60 feet in length, and can hold twelve or thirteen waggons, 4 feet 6 inches long. Each waggon has six stages, the lowest of which is 9 inches above the rails; and as each stage holds three drying-plates, upon which are twenty-seven bricks, the waggon therefore contains or holds one hundred and sixty-two bricks.

When the bricks are dried, they shrink to about one-half of their original size, and then weigh about 4 lbs. each, so that the canal, when full, contains more than two thousand bricks, weighing 4 tons. From the mouth of the channel a tramway leads to the endless kiln. Another return channel declines from the kiln to the forming-machine, down which descend the empty waggons to be used again.

This method of drying is one great advantage of my system of manufacture. Other works have extensive drying-houses, built at great cost, requiring a larger outlay of labour and time to do an equal amount of work, besides the loss sustained by breakage of the bricks. Other works again have extensive covered drying-plates, at one end of which there are numerous ovens, and at the other a chimney-shaft from 100 to 120 feet high, in order to cause a draught through the numerous flues. My system utilizes the heat, which in other manufactories escapes through the chimneys. I can dry equally fast in winter as in summer, and am therefore independent of the seasons and temperature, as well as the dry or wet state of the atmosphere.

CHAPTER XXI.

DRYING-CHANNELS AND WAGGONS.

PLATE II. shows a ground plan of the drying-channels and the return channel for the empty waggons. The former have an inclination from the forming-machine towards the kiln of about $\frac{1}{60}$th of an inch per foot. The inclination of the return channel is in the contrary direction, as the arrows in the plan indicate. The waggons when filled advance by means of their own weight or impetus, and require but little extraneous help.

The channels have at each end tightly fitting doors, which should be made of wood covered with zinc. Besides these, there should be external doors made of wood with felt nailed round the edges, which fit against the edge of the brickwork or masonry, where they can be fastened.

The hot air, which is exhausted from the boilers by the two ventilators in the upper story, Plate III., passes through the channel *e*, Plate II., and then enters the drying-channels. Dampers are so arranged that the hot air can enter the channels *A* or *B* by the openings *d* and *d'*.

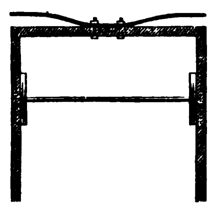
For example, if *A* is being loaded, the end next the forming-machine remains open to admit the waggons: the second channel has been already filled and closed at both ends. The hot air enters at *d'* and is drawn out of *c'*, Plate II., laden with moisture, by the exhausters. Therefore while one channel is being filled, the other is drying. This goes on as long as necessary, and as many bricks are dried as the forming-machine can supply. The openings *c* and *c'* in the arched roof of each channel unite and form the channel *c''*, Plate III., each of which has a closely fitting damper, so that the hot air, laden with moisture, can be drawn out of *A* or *B*.

The common channel *c''* is continued, as is shown in the section, Plate III., to the ventilators, and may be made of thin sheet-iron. From the ventilator, No. 19, the hot and damp air can pass through a chimney; or, in winter, it can be used for warming rooms. G. Einbech, at Burg, near Magdeburg, manufactures galvanized pipes for conveying hot air or steam. At Berlin, in the fringe factory of Louis Friedberg, there is a warming apparatus with 1055 feet of five-inch pipe, which costs one shilling and threepence per foot.

The bricks are generally quite dry when they come out of the drying-channels. If under certain circumstances this should not be the case, they are sure to be firm enough to be put into the endless kiln.

The drying-waggons now remain to be described. They are constructed entirely of wrought iron, with the exception of the eight-inch wheels, which are of cast iron, and made so as to fit all tramways on the works. Every waggon has six stages, six inches apart, each of which contains three drying-plates. The waggons are so made that they can enter the channels, which are 3 feet broad and about 4 feet high, without impediment. Every waggon can be pushed backwards or forwards. In order to prevent jerks, springs of cast steel may be fastened before and behind each waggon, as represented in Fig. 20, to a scale of $\frac{1}{34}$th of the natural size.

Fig. 20.



The frame of the waggon should be strengthened by diagonal pieces of angle iron, so that the plates may be easily pushed into it. As they are very liable to rust in the damp and hot air, they should be coated with coal-tar or asphalte, and should be rubbed at intervals with linseed oil, like the drying-plates.

CHAPTER XXII.

THE ENDLESS KILN AND MODE OF BURNING THE CEMENT.

With one exception, every manufactory in Germany burns the cement in cylindrical kilns 50 feet high and 10 feet in diameter. These kilns are filled up with alternate layers of raw cement, coke, coal, or, better still, Bohemian browncoal, and then set on fire. The holes by which they have been filled are closed up and the draught regulated by means of dampers. They burn for about three days, and are allowed to cool from five to eight days. They are then drawn or emptied, and the imperfectly burnt pieces separated from the clinker, which is then taken to be ground.

Even an inexperienced person can see at a glance what an enormous amount of time and labour are wasted in filling these high kilns, what fuel is lost in heating them every time, and what great expense is incurred in their construction. Independently of this, they require a great deal of management and care while burning.

All these disadvantages and expenses are obviated by my endless kiln. For five years I have studied and observed the so-called "ring-kilns" of Hoffman & Licht (described in Otto's 'Handbook on the Rational Practice of Agriculture,' 5th edition), and have convinced myself by experiment of their utility and the small quantity of fuel they consume; and at the same time I have tried to discover and remedy their faults and imperfections.

I construct the ring-kilns in a manner which does not mar their original qualities, but, on the contrary, offers the following advantages:—

1. Instead of building the kiln of a circular form, I build it oblong. This gives a greater degree of solidity at a smaller cost of construction, and as the chambers are close together, they only require a thin partition-wall.

2. My system dispenses with the so-called smoke-chambers and the high chimney-shaft, which are such disadvantages in Hoffman's kilns; for, in order to enable the chimney to draw, the air entering it should have a temperature of between 150° or 200° centigrade, which amount of heat is altogether lost.

3. The slits in Hoffman's kilns, which weaken the arches considerably, are not required in my kiln. These most important advantages, as well as the simplicity of its construction, render it peculiarly applicable wherever machine power is used.

4. My kiln may be built on a hill, in a valley, or below the surface of the earth.

I will assume that the principle of the endless kiln is understood by the reader. The more work a given amount of fuel performs, and the more heat that is utilized from the gaseous productions of combustion, as well as from the burning materials of the cement, the more perfect is the system. I will now proceed to describe my kiln according to the drawings. The measures or dimensions are exactly in accordance with the given scales.

Every kiln or oven should have for foundation an impervious stratum isolating it from the earth. The most suitable material is concrete and lime mixed with brick-dust or ashes. For ordinary purposes these materials are sufficient, but where springs or standing water exist, a layer of bricks in cement or slabs of asphalte may be used, as shown by the black line in the drawing. A cheap substitute for asphalte is wood cement. See Chapter XXX., On the Application of Cement.

Hoffman's kilns are much injured by damp.

The ordinary moisture from the earth has no injurious influence on my ovens, as the process of exhaustion by the ventilator does not permit any interruption to take place, and a little steam is rather beneficial and assists the calcination of the cement. As the actual construction of the kiln should be entrusted to an experienced engineer or architect, I purposely abstain from all but the necessary details of description.

Plate I. is a top view of a portion of the kiln, showing the "heating holes," *a a a*. The divisions of the kilns are represented by dotted lines. The second portion gives a view of the floor of the kiln. On the floor are marked the places which are to be left open, so that the fuel can pass through the stokeholes to *a' a' a'*, which should be in free and open communication with each other. The doorways, *b b*, leading from the outside to each division, are also represented. The middle of the strong outer walls may be filled in with cheap masonry or rubble, *c*, which can be better seen in the transverse section on the same plate. Each kiln has at both ends, where the fire turns, two divisions, and can have any number of chambers along the sides. I consider sixteen or eighteen chambers as the most convenient number for the whole kiln.

Plate II. represents the complete kiln seen from above, with sixteen divisions.

I have given the thickness of the wall along the middle of the kiln at three feet, but two feet thick would be ample. All parts which come in direct contact with the fire should be constructed of fire-bricks.

The chambers are separated by the pillars, *e e*, in the middle, and by the buttresses, *e' e'*, in the walls, Plate I. The pillar, *e*, in the middle rises about half the height of the division, and then throws out arches, *f f*, to both sides.

The cold air enters at one door and circulates to the division which is on fire. On its way it passes over those chambers which have burnt out, absorbing their heat in its progress. This heated air increases the temperature of the burning materials through which it passes, and entering the next compartment, it heats the contents sometimes to a blood heat. In order that this may be performed thoroughly, the door leading to the next compartment is hermetically closed. The fire then enters the channel *g*. Of course all outward openings and fire channels up to this point must have been previously closed.

The doors of the kiln are closed on the inside with fire-bricks, which should be plastered with infusible clay or loam; then boards are slid into the grooves shown on the section of a door of the kiln and the interval or space between them and the barricade of bricks is filled with ashes, sand, or any other incombustible non-conductor of heat.

From each compartment the fire or smoke channel, *g*, leads to the principal flue, *G*, which is situated on one side of the kiln, and leads to the receptacle of the exhauster.

The wall which ends the compartment can be made of any cheap material. If peat is procurable, the wall may be constructed of it. It may be rendered air-tight by mixing water with the peat to the consistency of paste, with which the wall is to be plastered on both sides. If peat cannot be obtained, pieces of board may be used and plastered with clay or slurry. Experience will soon determine the most convenient material for this purpose. If these barricades are made of a combustible material, they will only require to be overturned at the proper time through the stoke-holes, and then serve as fuel.

Behind, where the cold air enters, any number of holes may be open; but in front, up to the partition-wall, there must only be one smoke-channel, *g*, open.

This one flue is then exhausted by the ventilator, and draws off all the air, gases, and smoke of the preceding compartments.

Each compartment shown in Plate I. contains about 1200 cubic feet of space; a large quantity of air containing oxygen is therefore required. This quantity is so arranged that it can consume the fuel quickly or slowly, as may be required.

When the divisions are filled with cement-bricks dried in the channel, about 40 lbs. of coal, or from 80 to 100 lbs. of wood or peat, are consumed per hour. Each pound of wood or peat requires for combustion 120 cubic feet of air per hour, or 12,000 cubic feet for the whole quantity of 100 lbs.

The half-metrical ventilators (exhausters) manufactured by C. Schiele, at Frankfort-on-the-Maine, while making 2126 revolutions per minute, draws about 160,000 cubic feet per hour, or thirteen times more than required. The exhausters may therefore revolve at a much less velocity—say, for instance, 1583 a minute, which would draw 90,000 cubic feet of air, a quantity more than seven times enough to finish the combustion. Further details are given in the chapter on Ventilators.

It is unimportant whether the air enters the ventilators hot or cold; on the contrary, it is rather an advantage if it is in the latter state, when it has communicated its warmth to the bricks already put into the following compartments.

That an immense saving of fuel is effected, is beyond dispute; more especially when you recollect that the air must enter chimney-shafts at a temperature of from 200° to 300° centigrade, in order to cause a good draught. This caloric is absolutely lost in the chimney.

Each flue, *g*, which ends in the great flue, *G*, must be closed with a valve, *h*, when not in use. These valves are semi-spheres of cast-iron, fitting into holes in iron plates which divide them from the great flue, *G*. They can be closed by means of bars of iron fastened to them, which can be kept in the right position by iron pegs.

Although it is evident that all parts in connection with the ventilators should fit accurately, yet a few slits are of little importance, as the exhauster always draws more air than is necessary for combustion.

Every kiln should be covered with a roof, which may be constructed of the cheapest and most accessible material, as it only serves to keep out the snow and rain. In most cases a common wood roof, or one of wood-cement, may be used. Cast-iron pillars, resting on masonry (Plates I., II., and III.), support the roof. I would not use wooden posts on any account. Therefore I have represented on Plate I. the iron details necessary for the construction of the roof.

Fig. *a*, Plate I., represents a transverse section of a pillar, with its base or socket. The latter has a surface of one square foot, and is $\frac{3}{4}$ of an inch thick. The pillar itself, which is cast like a cross, is four inches in diameter, and each rib or web half-an-inch thick. Each pillar weighs 17 lbs., including the sockets for the wood, &c.

b b shows two views of the pillars resting on the outer masonry or brickwork, with the wooden parts of the roof. *e e* represent those pillars which rest on the kiln itself, and support pieces of the roof on both sides.

In winter or autumn, or when the weather is rainy or stormy, a weather boarding round the kiln is necessary, and it may remain in all seasons of the year, if care be taken to ensure efficient ventilation in summer. It should be constructed of boards fastened to the pillars: the best place to do this is at the angles by bolts and screws.

It is superfluous for me to further describe the particulars of construction, for every architect can best judge for himself. So much will depend on locality and cost of materials, that any suggestions as to prices or costs cannot generally apply.

Much discussion has arisen regarding Hoffman and Licht's endless ring-kilns; and at every meeting of the Brickmakers' Society since 1865, remarks have been made in reference to them. In this kiln, worked by a chimney divided in the middle, the size of the compartments is limited by the height and draught of the shaft; for, as already mentioned, the air must be heated to a high temperature before entering the chimney.

As regards the system of exhaustion, it is evident that the ventilators will perform their work if all doors and chambers are hermetically closed. The weather has no influence on the burning of the kiln. Of course there is a limit to the size of the compartments even by this method; but it can be easily reckoned. It is only necessary to ascertain the quantity of air drawn into the kiln, and the temperature of the compartment and its adjacent one. In summer there will be a larger quantity of air required than in autumn or winter.

The full advantages of the kiln are not realized with less than twelve or eighteen compartments; with a smaller number, the heated air is dissipated. The size of the kiln will necessarily be regulated by the requirements of the manufacturer, who will be the best judge as to the quantities of bricks, lime, or cement required to be burnt in the year, and can regulate the dimensions of his kiln accordingly.

I hope these explanations of the Endless Kiln, with the help of the drawings, will enable any one to understand its principle and advantages.

It is evident that any degree of heat may be produced by regulating the draught; a red, or even a white heat may be obtained by increasing the quantity of air. In burning cement, the regulation of the heat is of the utmost importance, and all other kilns now used have no provision made for this desirable purpose.

Cement when burnt at too low a temperature contains caustic lime, which when mixed with water gives out considerable heat. It hardens quickly in the air, but does not do so under water. Cement of this character, if used in building, will twist and distort the walls; and when over-burnt, is converted into silicates, forming a clinker without binding qualities, and crumbling to powder on exposure to the air.

The most important operation in the whole process of manufacture is that of burning; although even that, however accurately performed, will not convert a carelessly manipulated raw material into a good cement.

I have still to describe the manner of closing the stokeholes. Cast-iron lids are lowered from the top of the kiln on ledges made to fit; they are then plastered with clay or slurry. About six of these lids should have holes in the middle, in which a sheet of mica can be fixed, in order to observe the heat and progress of the fire, as already mentioned in describing the sample kiln.

It is often very difficult to light one of Hoffman and Licht's kilns, in consequence of the cold and damp air, which is not readily induced to ascend the shaft. This never occurs with my kiln; and it is peculiarly suitable for burning lime and cement, as the carbonic acid is removed at once.

Any one can perceive that the endless kiln is capable of useful and profitable adaptation in the hands of a skilful and attentive burner. Accurate rules cannot be laid down for its management, as the fuel and materials vary so much in their character; but generally speaking, the burner should know—

1. To what temperature the materials must be heated.

2. The time required to burn each compartment, especially those at the end of the kiln.

3. How much and how often the fuel should be put into the stokeholes.

4. How many chambers he can heat or dry in advance of the burning.

5. He must work punctually and regularly; and to enable him to do this, a clock should be placed on the top of the oven, striking every quarter of an hour.

6. Which doors and stokeholes he must open, in order to cool the burnt cement quickly.

7. How often he must clean the flues.

8. The rate of speed of the ventilator most suitable for burning.

9. That the combustion has finished when the contents of the oven sink to a certain point.

10. How to determine, from the first few burnings, which arrangements of the bricks are most advantageous, so that the draught is not stopped, nor too little cement put into each compartment.

CHAPTER XXIII.

VENTILATORS.

THESE are bellows, consisting of a kind of paddle-wheel fastened on a shaft, the whole enclosed in a tightly fitting case. The air (gas, steam, &c.) which is to be drawn out, enters into holes on each side of the case, out of which it is driven by the centrifugal force through openings on the outside.

Figs. 21 and 22 give a side and top view of a ventilator.

Fig. 21 shows the chamber, *c*, which sucks the air out of the channel *a*. Fig. 22 gives a top view of both chambers, *c c*. The air sucked through these chambers is expelled by the channel *b*.

Ventilators have been introduced into Germany chiefly through the exertions of Mr. C. Schiele, of Frankfort-on-the-Maine, who has materially improved their construction.

The following is his description of those machines made at his factory:—

"One and the same ventilator may be used with equal success for blowing or sucking, and the openings can be turned in any direction. The bottom, which does not require a very solid foundation, may be screwed into the wall, floor, or ceiling, without influencing the draught. When they are ordered, the position in which they are required to stand should be mentioned, so that they may be arranged accordingly before packing. The blowing and sucking holes are provided with flanges in order to connect them with tubes. Only one strap is necessary to drive them; but for the sake of convenience two strap wheels are fastened into each ventilator, so that it may be turned from either side. In order to

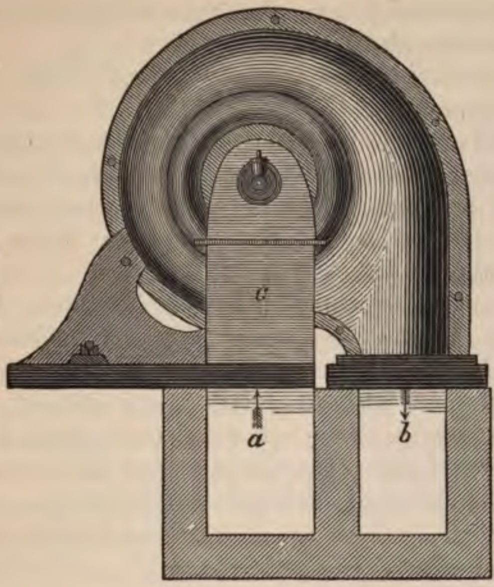


Fig. 21.

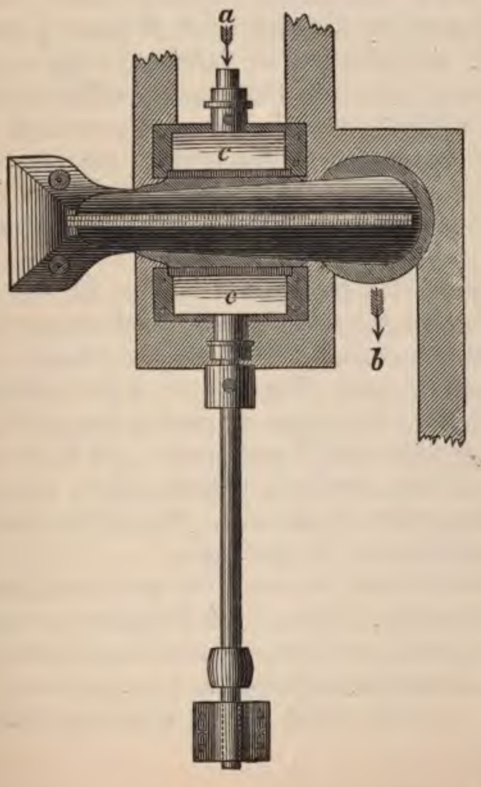


Fig. 22.

drive quickly or slowly, these wheels are of different dimensions; and two straps may also be used at once.

"Economical oil-feeders are supplied with them, in order to lubricate them properly.

"All ventilators furnished by me work without any perceptible noise. No other kind of ventilators resemble them in this respect, not even my first ones, which obtained prizes at the Paris and London Exhibitions, and which have often been imperfectly imitated by other manufacturers.

"These ventilators require a less motive power, for a given amount of work, than any others. This is by reason of the harmony of their form and the nature of the stream of air set in motion, and the care taken to prevent jarring and concussion.

"The construction of the new ventilators is particularly simple and strong, so that they can rotate at a great velocity without fear of breaking, for the strap would give way before the ventilator.

"The suction openings are protected against the falling in of substances and other similar accidents.

"In the whole construction only those metals are used which have been proved, by the experience of many years, to be the most perfect. All imitations are deficient in this respect.

"Much may be done by the proper position of the ventilators. I am ready, without extra charge, to communicate the result of many years' experience in England to the purchasers of my ventilators. A guarantee for the perfect working of the ventilators can only be given when they are erected under special supervision."

In the ventilator represented in Fig. 22, the shaft is considerably longer on the side where the small strap-wheel is fixed.

The shaft should always be lengthened when the ventilator is used for hot-air or gases. For instance, if the ventilator is placed behind the fire of a boiler, the air passing through it has a temperature of from 250° to 400° centigrade. Air so hot, when mixed with ashes and dust, renders it difficult to keep the ventilator well oiled, and soon destroys the iron. The driving-strap would also suffer if placed too near the ventilator.

These reasons have prevented the use of ventilators for steam-engines and hot fires. If the air can be cooled down to 70° or 100° centigrade it ceases to injure the machine, especially if the shaft upon which the strap-wheel is fastened, is lengthened.

The air may be cooled by the following simple means: it should be passed, before entering the ventilator, through a long channel, or an apparatus like that described for the sample kiln. This consists of a series of tubes placed in water, through which the hot air is drawn. The water is thus very often raised to the boiling point, and can be profitably used for many purposes.

It has been proved by practice, that when ventilators are properly used, from 30 % to 50 % fuel is saved or can be utilized, which is the same thing.

Ventilators are recommended for drying rooms for clothes, wool, grain, &c., or for heating large quantities of water for bathing or washing establishments. I have seen the fire of a brewing vat, from which the hot air and smoke were drawn through a ventilator, turned by a man. By this means from 30 % to 40 % fuel was saved. The hot air, after passing through the ventilator, heated water in a wooden vat provided with serpentine tubes, after which it retained a heat of from 70° to 100° centigrade, and was used in winter for heating the rooms.

I have already mentioned the amount of air necessary for the combustion of one pound of coal, wood, or peat.

The following Table gives full particulars of Schiele's ventilators —their prices and capabilities.

The only explanation necessary is that the given size is that of the fan, which is about half the size of the ventilator.

The number of horse-power indicates the strength necessary to attain a certain velocity. The pressure of the air ejected from the ventilator may be ascertained by a double glass tube in the form of the letter U, open at both ends and about one-third full of water, quicksilver, or, better still, coloured glycerine. This tube can be fastened by an extension of one of the ends, and by means of a perforated cork into a hole in the ventilator or the channel leading from it. The height of the liquid in the farther tube shows the pressure of the compressed air in the ventilator or channel.

Under the head of ventilation, drying, &c., the quantity of air is given in cubic mètres which passes through the ventilator. This quantity of air diminishes if it meets with any resistance, which would be the case if the mouth of the ventilator were narrowed or contracted.

I also give the results of experiments made with one of Schiele's ventilators, half-a-mètre in diameter, on the 31st December, 1865, at a temperature of 2° Reaumur. These give the amount of air furnished by different pressures :—

VENTILATORS.

Diameters of the Fan.	Prices at Frankfort.	Produces Wind.										Diameter (in Centimètres) of the	
		Water Pressure 15 to 25 Centimètres.			Water Pressure 30 to 40 Centimètres.			Air for Ventilating, Drying, &c.					
		For	With	H. P.	For Melting of	With	H. P.	Cub. Mètre per min. direct.	Cub. Mètre per min. induced.*	With	H. P.	Double Strap Wheels	Opening
	£ s. d.												
⅛th mètre	1 10 0	1 Forging	.. ..	⅛	.. ..	..	..	5	20	..	..	.. ..	..
¼ ,,	3 9 0	5 at	4000 Rev.	¼	15 Cwt. Iron	6000	1	25	100	3000	1	5 and 6·25	12·5
½ ,,	8 15 0	20 3 Centim.	2000 per	2	60 per	3000	4	100	400	1500	4	10 and 12·5	25
1 ,,	25 13 0	80	1000 min.	7	240 Hour.	1500	12	400	1600	750	16	20 and 25	50

Weights about 60, 100, 450, and 1500 pounds. For less work the rotatory velocity and motive power are smaller, and for more work they must be increased. The case should be double the size of the fan every way. A piece of wood across the bottom is all that is necessary for packing it.

---

* *i.e.*, when the ventilator blows into a pipe.

These experiments were made at the new Gas-works of the Frankfort-on-Maine Gas Company in order to test the meter of a new gasometer, which weighed about 35 tons, and contained about 106,940 cubic feet.

Numbers of the Trials.	Width of the Opening of the Ventilators in Millimètres.	Number of Revolutions per Minute.	Pressure of the Air in Millimètres.		Air forced into the Receiver in five minutes in Cubic Mètres.
			In the Ventilator.	In the Receiver.	
1	245	2126	92	66	257·17
2	245	1583	77	66	168·33
3	126	2126	188	66	141·21
4	126	1583	124	66	78·32
5	62	2126	202	66	39·28
6	62	1583	135	66	22·44

If these results are applied to the endless kiln, it is evident that a half-metrical ventilator, with a two-horse power, and making 2000 revolutions per minute, can draw through the kiln thirteen times more air than is required. The velocity may therefore be diminished by employing a larger strap or driving-wheel.

I have, as shown in Plate II., No. 18, placed the exhauster, or ventilator, of the endless kiln on a channel in communication with the drying channel. This exhauster also acts as bellows. The hot air enters the ventilator at a heat of from 50° to 60° centigrade, and is so impregnated with moisture as to be totally unsuitable for drying purposes. In this case it can be driven away into the open air instead of the drying channel. What is mostly used for drying in the drying channels is the hot air coming from the boiler fires. Although this air also contains steam, yet its temperature is so high that it is able to absorb a great deal more, and consequently able to dry the cement bricks. The ashes and particles of dust contained in this air are deposited in the channels through which it passes, and part of the soot settles in the drying channels. When, therefore, the air enters the two half-metrical ventilators, its temperature is much lowered, and contains moisture and very little smoke.

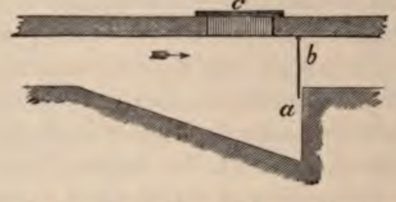
I may here mention that the two ventilators should be so placed as to suck or exhaust the air out of the drying channels, and not so that one ventilator sucks the air which has already passed through the other, for in that case much less effective work would be performed.

The channels leading to as well as from the ventilators should have all their corners rounded off, as angular or sharp corners cause the ventilator to jerk, and thereby increase the friction and retard the movement of the air.

In the book entitled 'Annual Review and Progress of Mechanical Technology,' by Dr. Hermann Grothe, Berlin, 1867, Julius Springer, are two figures of a ventilator, distinctly showing the rounded corners of the channels.

I have already spoken about the extension of the fan spindle, and I recommend it wherever warm air is used. If the channel from the fire to the ventilator should be too short, so that the ashes and dust enter the latter, I have found it a very good plan to make depressions in the bottom of the channel. Fig. 23 represents their form.

Fig. 23.



Close to the depression *a* is a fringe of movable brass wires, which is stretched across the channel, and against which the ashes strike and fall into the pit. Sieves are of no use, as they so soon get stopped up, and iron ones do not answer, as they oxidize so quickly. *C* is a manhole for cleaning the channel.

The work which a ventilator performs depends on its size and the velocity with which the spindle rotates.

Two half-metrical ventilators require the same power as a one-metrical one; but I consider it more advantageous to have the two, as only one need be worked if less air is required.

I must here remark that I do not specially recommend Schiele's ventilators as the only perfect and serviceable ones; but as they were the ones with which the experiments were made, I have only referred to them.

Many other firms make ventilators on the same principle, but of different construction, which are used for a variety of purposes—for instance, to free rooms of dwelling-houses, mines, shafts, and fermenting rooms of bad air, vapour, and gases, to supply them with fresh air, and also to cool malt, &c.

Ventilators of different construction are used as bellows for forges, cupolas, and glass furnaces, for drying clothes and for many other purposes.

The application of ventilators for drying wet fuel is described by me in the 'Farmers' Report' (September, 1867).

CHAPTER XXIV.

GRINDING THE CEMENT.

Having given all the requisite information regarding the raw materials, I have now only to describe the grinding of the burnt cement or clinker. I have already mentioned that the same number of mills are necessary for grinding the cement as are used in pulverizing the raw materials. The clinker is first put into a stone-breaking machine, then into a vertical mill, and lastly into a horizontal mill, where it is ground to an impalpable powder.

The finer the cement is ground the better. The cement should not be packed in casks directly it leaves the mill, as is erroneously done in most manufactories. On the contrary, it should fall from the mill through the inclined shoot into the room No. 7, Plates II. and III., where it spreads itself in layers. When it has lain (sweated) here a few days it should be weighed into casks and packed firmly by means of shaking. This room has over the drying channel an inclined shoot, so that when a sliding door is opened the whole room can be emptied. The space No. 7, Plates II. and III., should be divided into two compartments, one of which should be emptied while the other is being filled.

If the cement is to be kept some time, it should be put into large and perfectly dry rooms, as in No. 7. When this is done, only the surface of the cement is injured by the dampness of the air and carbonic acid, and that in so slight a degree that the quality of the cement is not injured.

If the cement is kept in casks or sacks, it suffers much more.

Many manufacturers have shaking machines, in order to shake down the cement in the casks, but they are quite superfluous, as the work can be performed by hand.

CHAPTER XXV.

ERECTION OF THE STEAM-ENGINE, ETC.

In order to work the different machines a steam-engine of 60-horse power is necessary. I would recommend one of Woolf's engines of the above power, as they only consume two kilogrammes of good coal per horse-power in the hour.

The above power of 60 horses is distributed as follows:—

1. Two vertical mills,	8 H.P. each,	equal to	16 H.P.
2. Two stone-breaking machines,	2 „	„	4 „
3. Six horizontal mills,	5 „	„	30 „
4. Worms, elevators, and sieves ..	.. ..	.. .. ..	2 „
5. Three half-metrical ventilators	.. ..	.. ..	8 „
6. Forming-machine and vat	.. .. ..	.. ..	3 „
		Or a total of	63 H.P.

The amount of power required being rather over-stated, and as the machines are seldom all working together, the 60-horse power engine will be sufficient to produce from eighty to one hundred casks of cement in the twenty-four hours.

Plate II. represents a ground plan of the chief building, and Plate III. shows a section of the factory through the line *x z*. The building is so arranged and divided that the raw materials can be prepared on the one side and the burnt cement on the other. *L* represents the position of the stone-breaker for the raw materials, *K* the vertical mill or edge-runner in connection with it, *S* the sieve, *T* the worm leading to the elevator *E*, *MMM* the three horizontal mills for the raw materials, *T* the worms leading from these mills to the elevator *E*. In order to grind the burnt cement an equal number of machines is necessary, which are placed opposite to the others. All the horizontal mills are in one room, but all the other operations are conducted in different rooms.

The room in which the forming-machine *A*, with the platform *B* and the vat *C* are, should be carefully separated from the other part of the factory by well-fitting doors and windows, as the steam generated in it would otherwise injure the manufactured cement. The section through the line *x z* shows that the forming-room is lower than the other parts of the building. Three channels open into this room, namely, two drying channels and the return channel for empty waggons.

Plate II., No. 17, represents a ground plan of the chimney, which should be at least 90 or 100 feet high and of suitable form. It communicates with the boilers (three in number) by means of the channels $a' a' a'$. When the dampers $b b b$ and b' are opened and b^2 shut, the draught ascends the chimney. When the chimney-damper, No. 17, b', is closed and b^2 opened, the draught goes through the ventilators, No. 19, Plate III., into one of the drying-channels.

It may seem inconsistent to recommend a chimney-shaft after what I have said in favour of the ventilators; but the following reasons will show that it is indispensable.

First.—Without a chimney the ventilators (No. 19, Plate III.) would have to be moved by some other force while the boilers' fires were being lighted up. Manual or horse labour would be insufficient, and the small steam-engine placed in No. 14, Plate II., would alone be capable of performing this work; but even then there must be some arrangement for moving the main shaft, as well as a communication with the small engine: this arrangement would be as costly as the erection of a chimney.

Secondly.—All machines are liable to accident and derangement, against which all possible precautions should be taken. If, for example, an accident happens to the ventilators, or if the drying channels cannot be used, no interruption in the manufacture would arise if a chimney was erected.

CHAPTER XXVI.

RECAPITULATION OF THE WHOLE PROCESS, WITH A DESCRIPTION OF THE PLAN.

Plates II. and III.

No. 0 is the shed for the raw materials, and only requires to be slightly built. It contains the clay and ironstones, the burnt chalk, soda, and, if there is room, a portion of the limestone or chalk, which can be drying. From No. 0 the raw material, as shown by the arrows, goes to No. 1, where the chalk is dried. It then passes in to No. 2, to the stone-breaker, *L*, the edge-runners, *K*, and the horizontal mills, No. 3, *M M M*. When the pulverized material has been sifted, it descends into No. 4. In No. 5, the raw cement is formed by *A B*, and the bricks pass through the drying channels, by the tramway, to the kiln, from which they are returned, when burnt, in the directions marked by the arrows, to the stone-breaker, *L'*, and the edge-runners, *K'*, in the room No. 6; from which they pass into the horizontal mills, *M' M' M'*, No. 3, to be finally ground. The powder is then stored in the room No. 7, and packed in casks above the drying channel, Plate III.

The building is not continued on Plate II., next to Nos. 5 and 7. At these two points two extensions might be made; one for finished cement, and the other would be suitable for an office, &c.

The cooperage and wood and hoop stores should be built at some distance, on account of the danger from fire. It should, however, be so situated that it may be sufficiently near the main shaft in case power may be required at any time to make casks by machinery.

No. 10 is the engine-house, in which is erected the chief steam-engine, and from which proceeds the main driving-shaft, lying above the floor of the upper story. This house is 60 feet long, and leads to the end of the room No. 3, where there is a communication between it and the forming-machine and the vat in No. 5.

In No. 11 are fixed the three boilers, *a a a*, which are connected with one another by the flues *a' a' a'*, each of which can be closed separately, and all of which lead through *e e* to the drying channel.

The ventilator, No. 18, Plate II., which works the endless kiln, must at the beginning be worked by the small steam-engine in No. 14, and until the large engine is started. This small engine is necessary, because the endless kilns are at work during the night, when the machinery is at rest. It should be of about 10-horse power, and if the works should be enlarged, it can always be kept at work.

In No. 15 is the boiler for the small engine, which requires a chimney, *f*, about 50 feet high, which also serves for the smithy at No. 16.

On Plate II. the building containing the rooms Nos. 14, 15, and 16 is represented as having a separate chimney, *f*, for the boiler of the small steam-engine in No. 15, and for the smithy, No. 16. In order, however, to economize space and expense, this building can be erected as shown by the dotted lines. These arrangements render the chimney, *f*, unnecessary, as the shaft, No. 17, is sufficient for all; the communications are also shorter, and all the motive power being in close proximity to each other, is more advantageously controlled.

CHAPTER XXVII.

PROPERTIES OF GOOD CEMENT AND MODE OF TESTING THEM.

Some may consider that the following details are unnecessarily explicit; but I am of opinion that to understand and manufacture a commodity, its qualities and peculiarities cannot be too well known or understood.

Building materials generally, but Portland Cement especially, are subjected to rigorous tests by architects and builders. There is an impression that English cement is better than that made in Germany; but this is not so. At the end of this work I have described the state and condition of English cement arriving in Germany. On account of this prejudice, the cement made at the large manufactory in Stettin (the first works, I believe, in Germany) was accurately tested by Professor J. Manger, of Berlin. The result, published in 1860, proved the superiority of the cement made at Stettin.

Every manufacturer should convince himself of the quality of cement, so that he may be able to guarantee it.

The following are the essential properties of good Portland Cement:—

Colour.

Portland Cement is in most cases greenish-grey, simply because the English cements are generally of that colour; this is not absolutely necessary, for many German cements, superior to English, are of a pale red stone-colour. This is partly caused by the treatment of the cement while burning, for if, during the process of clinkering, too much air is admitted, the iron contained in the mixture is too much oxidized. But as the public taste is in favour of the greenish-grey tint, the manufacturer should direct his attention to the fabrication of a cement of that colour.

Weights of Cement.

Portland Cements vary considerably in weight in consequence of the various places where they are made. One cubic mètre weighs from 1226 to 1375 kilogrammes, and one cubic foot is equal to 76 or 85 lbs.

In comparing the weights of equal volumes of cement due attention must be directed to the manner in which the several measures have been filled and the fineness of the cement. Coarsely-ground cement weighs heavier than that finely ground. The weight of cement, therefore, cannot be relied on as a test of quality.

Casks filled according to the English method weigh about 187½ kilogrammes, and measure one-seventh of a cubic mètre, so that seven casks may be reckoned equal to one cubic mètre.

The specific gravity of quartz-sand is from 2·6 to 2·8, and the specific gravity of pure Portland Cement from 2·5 to 2·65.

Affinity for Water.

Good cement requires but little water to make good mortar.

To 100 volumes of cement 44 volumes of water are generally added. If the mixture requires a greater quantity than that proportion, considerable heat will be developed, indicating thereby that the cement contains free or caustic lime. If, on the contrary, it requires less water, it is a sign that it has been over-burnt, too old, or already overcharged with water or carbonic acid. Good cement mortars require, according to Professor J. Manger—

1	volume cement..	..		0·44	vol. water,	gives	0·91	vol. mortar.
1	ditto	and 1	vol. sand	0·66	ditto	„	1·83	ditto.
1	ditto	„ 2	ditto	0·88	ditto	„	2·87	ditto.
1	ditto	„ 3	ditto	1·20	ditto	„	3·80	ditto.
1	ditto	„ 4	ditto	1·65	ditto	„	5·01	ditto.

It is evident from the above that if less sand is added, the volume of mortar is diminished, as the cement fills up the pores; but if more sand is added, the volume of mortar is increased, because the interstices are filled with water. Experience has also shown that cements containing a small amount of sand must be kept wet for a longer period.

Cements contain after consolidation from ten to twelve per cent. of water, which may be regarded as chemically combined, for it does not evaporate at an ordinary temperature; they have then a specific gravity of from 2·60 to 2·67, which is equal to the heaviest quartz. V. Fuchs compares cement with the zeoliths, which have a specific gravity of 2·1 to 2·3, while their hardness of 5 to 5·5 agrees with that of cement.

Those cements which when set absorb the least quantity of water are considered the best, and their mixtures with sand are proportionately good.

Water-tightness of Set Cement.

The quality possessed by cement of hardening under water, and its imperviousness, as well as its cheapness, render it invaluable as a building material. Of course pure cement possesses these qualities in the highest degree, and diminish in proportion to the amount of sand added.

In certain important hydraulic works the cement of a particular factory has been selected by reason of its water-tightness and density. Some years ago, when the harbour of Havre was being constructed, the following experiments were made to test the water-tightness of cement. Cylinders 0·10 millimètre in diameter, and 0·15 millimètre in height, were constructed of cement. Above and below, metal covers, open in the middle, were screwed on. The upper cover communicated with a tube 5 mètres high, which could be filled with water. When the experiments had been made, the English cements of White and Son, and J. F. Knight, were preferred to the French cements made under the direction of Vicat.

Heating of Cement when mixed with Water.

When cements are mixed with too much water, the particles are suspended, and they lose all cohesion.

The amount of heat engendered by mixing water and cement is a pretty fair test of quality. Good cements, when mixed with water, produce a very slight degree of warmth, never exceeding 30° centigrade, especially when mixed with two parts of sand. Cements giving a slightly perceptible warmth are not to be rejected, as they set under water, increasing in hardness. But cements giving a high degree of heat, when slaked, indicate an excess of lime which injuriously affects the cementation of the mortar. Cements of this character harden quickly, are easily acted on by water, and fall to pieces or crack when placed therein. The superfluous lime prevents the particles, ready to form a silicate, from uniting, just as if too much water had been used. If cement containing too much lime is used as mortar, part of the superfluous lime is slaked afterwards, and the brickwork is displaced. I knew a cement manufactory in Germany, managed by an Englishman, which suffered much from having made cement of this sort. The fault was not discovered until the Englishman was dismissed.

Cement must not therefore swell after use, neither should it crack or fly. It is most important that manufacturers should be able to detect these faults.

The following is a very good way to test the swelling of cement:—

Take pieces of large glass tubes or lamp glasses, the sides of which must not be too thick, about 5 or 6 centimètres long, and about 3 centimètres in diameter. Make an incision or cut down the whole length, and then fill the tube with cement mortar. If the cement is good, the tube does not open; but if containing too much lime, the opening increases.

Cement sometimes contracts after setting, causing cracks in mouldings, &c. The reason of this might also be a superfluity of lime, only in this case finely distributed in the cement, which slacks as soon as the cement sets, producing a mixture of cement and slaked lime, the latter shrinking when the mortar dries.

In order to ascertain this properly, put upon a slate pure cement and cement mixed with sand. In a few days after it has laid alternately in air of 30° centigrade and cold water, this defect will develop itself.

Hardness.

The degree of hardness which cement acquires under water as well as in the open air is rightly regarded as a criterion of its quality.

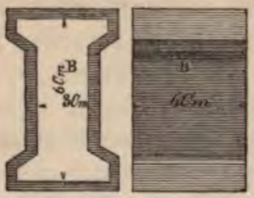
With a little practice the hardness of different cements can be easily ascertained.

Mix pure cement, or cement and sand in certain proportions, with the necessary amount of water, and after it has remained 24 hours in the air and 14 days under water, it should be dried and tested. When two pieces are rubbed together, the softer cement is more rubbed than the harder one.

Solidity.

The hardness determines the solidity of cement. The absolute, the relative, and the re-active solidity of cement can be determined in the same way that building materials are tested.

Fig. 24.



For this purpose procure forms of cast-iron like Fig. 24, 3 centimètres deep in the middle, 6 centimètres broad, and 6 centimètres long. They should have projections made on each side to receive clamps of iron.

Fig. 25.

A second form, Fig. 25, also made of cast-iron, is for moulding pieces of cement 12 centimètres long, 6 centimètres broad, and 3 centimètres thick. Both forms are represented at about one-fourth of the natural size.

In these moulds pieces of pure cement and cement mixed with four parts of sand are formed. The sand must be of the same degree of fineness and quite dry when mixed. When set the pieces of cement are pressed out of the moulds with templates of wood, and allowed to remain 24 hours in the open air and several weeks in water, which must be changed at intervals. The experiments can be made with wet or dry bricks, but they then have different degrees of solidity.

The proper testing of the solidity of cement is of great importance to the manufacturer, as he can ascertain the relative value of his make in comparison with others.

1. The absolute solidity is the resistance which a material of a given thickness offers to fracture. The might or force required to break it is called the degree of solidity. But this force is never used in practice, therefore a degree of safety is usually given,

which is generally about one-sixth of the degree of solidity. The duty of determining the degree of safety, however, rests with the consumer, the manufacturer only requiring to ascertain the degree of solidity.

The lower the amount of degree of safety required by the architect, renders the manufacturer's guarantee of the degree of solidity proportionately less onerous.

In determining the degree of solidity, each cement manufacturer should employ the best building material in his neighbourhood. Bricks are especially suitable, and should be of the same size (after being burnt) as the pieces of cement, Figs. 24 and 25, and made of the best clay fairly burnt. The pieces of cement are suspended by a hook at one end, and at the other is a clamp to which is fastened a scale or box filled with sand.

First-rate bricks require about 900 lbs. to break them. Bricks made of good pure cement require $\frac{1}{20}$ to $\frac{1}{24}$ less weight for their fracture; of course, if sand is mixed with the cement the breaking weight is much less.

It is somewhat remarkable that all cement bricks of one sort break at a nearly uniform weight. This is not the case, however, with clay bricks, which vary considerably in their breaking weights.

Trials made at Havre of the absolute solidity of different cements, proved the superiority of the English over the French cements.

These trials were made with bricks composed of one part cement and two parts of sand, in each end of which, after they have been dried, two incisions are made. In the two upper slits a tongue of metal was fitted, which held the brick, and in the bottom ones another tongue was introduced, to which was hung a box loaded (with weights or sand), until the cement gave way, by which means the absolute solidity was ascertained.

My experience proved the difficulty in making those incisions accurately; many of the briquettes were fractured in cutting, rendered the tests unreliable and inaccurate. I therefore prefer moulding the bricks with projections, and so obviate the necessity of cutting out the incisions.

It is also useful to ascertain the degrees of solidity of other building materials in the locality of the works, such as gypsum, common mortar, &c.

2. The relative solidity. The resistance which one body

opposes to another in its efforts to break through it is called the relative solidity.

In order to determine this, place two of the largest size briquettes (Fig. 25) with one centimètre of each end supported, leaving ten centimètres hollow underneath. Then apply a vertical weight on the middle of the bricks until they break.

Burnt bricks require a breaking weight of at least 50 lbs. to break them, which would therefore be their degree of solidity.

Cement-bricks break at a weight of from 46 to 48 lbs.

In practice the degree of safety is considered as about one-fourth of the degree of solidity.

3. The re-active solidity. The resistance which a body offers to crushing is called the re-active solidity. This solidity is of great importance in all building materials, as they have to bear the greatest weight in the direction of their vertical section.

The test of re-active solidity is almost superfluous if the relative and absolute solidity has been already determined. On the other hand, in almost every case the re-active solidity determines the collective name "solidity" of a building material, as it is the chief quality necessary for the construction of solid masonry or brick-work, and by means of which the amount of vertical and lateral pressure a building material can bear is ascertained. It is difficult to place so large a weight so as to exert accurate vertical pressure on the comparatively small surface of the brick.

A cubic centimètre of a good clay-brick requires upwards of 300 lbs. weight to crush it. A whole building brick, therefore, requires an enormous crushing weight, difficult of equal distribution over so limited a surface.

The degree of safety for building materials generally, including Portland Cement, is estimated at one-tenth of the re-active solidity. If therefore the applied weight is inaccurately distributed, a much smaller degree of solidity might be assigned to a material than it really possesses. For this reason the relative solidity is now generally determined by the agency of an hydraulic press, whereby any amount of pressure may be equally distributed, and the result accurately indicated.

Every manufacturer has not, however, this hydraulic press at his command, and cannot therefore determine the re-active solidity in so simple and accurate a manner; those, however, who do not mind going to this expense will find much convenience in using it. A small one would give a pressure of 3000 lbs. to a square inch. The cubes subjected to pressure should always be placed between two pieces of oak, free from knots, and rather smaller than the surfaces of the cubes to be operated on.

Durability of Cement.

It is somewhat difficult to ascertain the durability of modern substances, as manufacturers occupy themselves principally in producing cheaply, and pay little attention to experiments on durability. We know very well that a modern coat does not last so long as if it were made of cloth as manufactured forty years ago, yet we prefer it by reason of its fineness of texture and the lowness of its price. We can ascertain the quality of a pane of glass in regard to its clearness, transparency, polish, &c., but we cannot tell how long it will last before getting dull or assuming iridescent colours.

It is not improbable that a good Portland Cement may last for tens or even hundreds of years; but we cannot prove this, as our experience and observations only embrace a period of fifty years.

We do not know what other agents besides air and water may effect cement in the course of time, nor can we tell whether all cements are equally durable.

This last idea forcibly occurred to me ten years ago, when a cement produced by a German house was used successfully in laying pipes at a distillery. Another cement procured in the following year from the same manufactory and used for the same purpose fell to pieces in a few weeks.

This induced me to make experiments, which I do not consider conclusive, but which may serve to prevent similar occurrences, and may also give the manufacturer a hint how to conduct experiments in this respect.

These experiments served principally to determine the influence of warm and salt water, and of the air at different temperatures. In this manner I tried to concentrate the influence of time.

My experiments were comparative ones, as they served for practical purposes, in order to determine which kind of cement should be used for a certain purpose.

1. I immersed set pieces of cement in water containing 15 % of common salt, in which I kept them for weeks at a temperature of 30° centigrade.

2. The same pieces were then dried in the sun and again immersed in the solution.

3. I also made experiments with cement in the winter of 1856–57, by exposing it in a wet state to the frost, and then immersing it in hot water, and *vice versâ.*

Some German cements stood these superficial trials very well, others rather badly, and the English cement worst of all.

CHAPTER XXVIII.

RECAPITULATION OF THE TESTING OF CEMENT AND PRACTICAL ADVICE TO MANUFACTURERS.

It is not to be expected that all these experiments can be made daily, but every manufacturer should be well acquainted with the nature of the tests, and be able to compare his cement with the productions of other manufactories. The best time for experimenting is at the commencement of the manufacture, when the workmen are unaccustomed to their work, with more spare time on their hands, and when the kiln is being burnt more carefully and slowly. Every manufacturer should make good use of the time when the kiln is being built, &c., by trying numerous samples in the sample kiln, and subjecting the cement thus made to all the before-mentioned tests. If the manufacturer understands the routine, he can readily determine what burnings he ought to test. When the true proportions have been ascertained and the raw materials sufficiently pulverized, the chief remaining condition is accuracy in burning.

At the commencement, samples should be taken from each division of the kiln. If the cement is not sufficiently burnt it should be returned to the kiln, and if over-burnt, mixed in small quantities with good cement.

If the manufacturer is acquainted with the properties of good cement, he can easily, by a few simple experiments, apportion or manipulate his materials so as to imitate them. He must also acquire the following knowledge:—

1st. The degree of heat produced when the cement is mixed with water, and the strength with which it holds two building-bricks together.

2ndly. Whether the cement expands or contracts.

3rdly. The strength when mixed with four parts of sand.

I here give an extract from the Erbkamshen periodical on 'Architecture,' 1860, vols. x. and xii., written by the Prussian Inspector of Buildings, J. Manger, on the subject of English cement. This short extract tends to enhance the value of our manufactures, and now having at command a home supply, the use of this article is greatly on the increase.

Mr. J. Manger says, "The English cements are very liable to destruction, and are also very easily adulterated. The greater portion of it arrives in sacks instead of casks, after having lain in the hold of ships exposed to damp air and sometimes even water. When it is landed the spoilt cement is seldom separated from the good, but is pounded together sometimes with an addition of powdered ashes, metal dross, and sand. Even when packed in casks the cement seldom remains good. The casks are frequently irregular in size, and are mostly old ones, having been previously used for other purposes; they are generally made of old boards instead of new staves, and when so made are never water-tight.

The great competition amongst manufacturers in England causes the cement to be sold at a low price, and in consequence they cannot afford new casks, neither for the same reason can they export the best cement. This is proved by the fact that cement intended for exportation is much cheaper on board ship than that which is used in London.

As the cement sent from England is so bad that it cannot be sold there, it is better to procure it from German manufactories, as there is otherwise no certainty of its being pure and unadulterated.

CHAPTER XXIX.

SUBSTITUTION OF EXISTING WATER-POWER FOR STEAM.

If there is sufficient water-power to work a brick or cement manufactory there must be special arrangements for warming the forming-machine and the vat, as well as the drying channels. There are two ways of doing this. The first, which is also the cheapest, consists of an arched oven, from which the hot air goes directly to the drying channel through flues like *e e*, Plate II. A second flue, made of 2 or 3 in. cast-iron tube, leads directly into the case of the forming-machine, Fig. 14 at *d*. The hot air then passes through *e* into the tube *c c* of the vat, Fig. 16. If it be then too warm to enter the ventilator, which should be a quarter of a mètre large, it can be used for other purposes.

The second method of obtaining heat is more costly, and also more complicated.

Procure a small boiler, and expose 30 or 40 feet of its surface to the fire. From the top of the boiler lead one tube to the forming-machine and another to the vat. The hot air from the boiler-fire goes into the drying channels as in the first method.

I have already stated that the air drawn from the endless kiln by the ventilator (No. 18, Plate II) is not suitable for drying purposes.

CHAPTER XXX.

ON THE APPLICATION OF CEMENT.

THE use of cement has considerably increased during the last thirteen years, and it is now used for a great variety of purposes for which it was not formerly employed. I cannot in this paper mention all the purposes for which it is applicable, they are generally known, and therefore mentioned in the price lists of most cement manufactories.

Cement manufacturers seldom make articles of their own cement, but when they do so, it is only gutters, sinks, tiles, waterpipes, &c. The manufacturer should leave the construction of these articles to the consumer.

But it is otherwise if by novel or different treatment the cement can be converted into another product.

The firm of Charles Samuel Häusler, at Hirshberg, in Silesia, produces, under the name of Häusler's wood-cement, a black pitchy substance, which remains solid at a moderate temperature, but melts when heated, forming a liquid tenacious mass. It is not in reality a chemical compound, but a homogeneous mixture.

With this mass roofs are made, and called by the name of wood-cement roofs. The inventor, now unfortunately dead, made a roof of this sort over his wine-store twenty-six years ago, which, if I mistake not, is now in the same condition that it was then, and has not required any repairs.

All necessary details for the construction of these roofs are given in the price lists of the firm; there are also articles on them by Dr. Robert Schmidt, in Dingler's Polytechnical Journal, vol. clxx., pages 338–447, and the Polyt. Centralblatt, 1864, page 518, with illustrations.

I can only give a superficial account of their construction. The roofs must have an inclination of at least three-quarters of an inch per foot, and covered with wood one inch thick resting on beams or rafters not more than two feet three inches apart.

The whole is first covered with fine dry sand, upon which is placed strong brown paper. The molten mixture is then spread upon it with a tar brush. Four layers of paper are laid on in this way, each one being covered or painted with the mixture. Sifted ashes are then strewn over it. Afterwards, and when the zinc edges round the borders and chimneys are finished, sifted gravel, to a depth of from one to one-and-a-half inch, is spread over the whole.

This mode of roofing has been in use, during the last fifteen years, in Silesia, Saxony, and Upper and Lower Sausitz, and now continues rapidly to spread into other districts both north and west.

Mr. C. Rabitz, architect of Berlin, built a wood-cement roof on the back part of his house, six years ago, upon which is a garden. That gentleman obtained a prize at an exhibition of model roofs in Paris.

These kinds of roofs possess the following advantages:

1. They are as cheap as felt roofs (which only last ten years and are continually requiring repair).

2. Great simplicity of construction.

3. Are very durable and are not cracked by the sun, like the felt and asphalte roofs. The gravel intercepts the sun's rays and the tough cement does not give way.

4. They are cool in summer, and, being bad heat-conductors, are also warm in winter.

5. They cannot catch fire from the outside, and therefore may be considered fire-proof.

6. They may be covered with earth and used as gardens without injury.

The above advantages, coupled with the fact of their having been tested for upwards of twenty years, is calculated to lead to their extensive use. Should this be so, considerable quantities of wood-cement will be required.

As every good wood-cement may be made of the best Portland Cement mixed with coal or wood tar and a little sulphur, I advise all cement manufacturers to make and sell it. My reasons for such advice are the following:

1. Consumers cannot make it in small quantities by reason of its inflammability.

2. Freshly ground cement is most suitable.

3. It is improved by keeping and re-melting.

4. Cement makers can therefore manufacture it more cheaply than anyone else.

It is made as follows:

The tar is heated in a large iron boiler with a flat bottom, having its diameter somewhat larger than its depth, in which a stirrer, like that described in Fig. 14, revolves, mixing up the cement and sulphur which are sifted in. To each hundredweight of cement put one pound of powdered sulphur. These materials must be added carefully to prevent overflow of the boiler.

The mixture of cement and sulphur is added to the tar so long as it remains liquid enough to flow. The mixture is then drawn off through a pipe fixed in the side, and packed in suitable casks.

From 160 to 190 lbs. of best cement is mixed with 100 lbs. of coal-tar, according to its quality.

Dr. Hirzel, in the 'German Illustrated News' of 1861, page 85, describes the composition of Häusler's wood-cement as consisting of sulphur, india-rubber, pitch, and soot—a curious mixture, which is sold at fifteen shillings per cwt., and suitable paper at from thirty-four to thirty-nine shillings per cwt. But I find a cheaper quality of paper good enough for the purpose.

Ninety pounds of Häusler's cement and eighteen pounds of paper are required to cover one square rod of roof.

For the proportions given above I am indebted to Mr. Martini, director of a cement manufactory at Mariaschein, where I saw a roof which had been erected three years, and looked as good as new. Mr. Martini used only cement and tar; but I find it advantageous to add a small quantity of sulphur, which renders the mixture tougher. The freshest cement that can be obtained should be used.

Mr. Martini has favoured me with the following directions for constructing wood-cement roofs.

Description of Covering for all kinds of Buildings with Flat Roofs made with Wood-cement.

Samuel Häusler's wood-cement roofs have been much used of late, and are remarkable for their cheapness, simplicity of construction, and protection against fire.

I have had many opportunities of convincing myself of the value and adaptability of this kind of roofing, and have found by numerous experiments that a mixture of tar with cement forms a material equal in every respect to Samuel Häusler's, with the advantage of not being so liable to melt or drop in very hot weather. It requires similar manipulation to Häusler's.

The following directions will be amply sufficient:—

1. The inclination of the framework of the roof (which must have an even surface) should be at the rate of from one-half to three-quarters of an inch per foot. The rafters or joists should not be more than 2 ft. 3 in. apart, so as to give sufficient strength. As the rafters rest on the side-walls, a comparatively small quantity of timber is required. Boards of an inch or an inch-and-a-quarter thick are fastened or nailed on the rafters, and should be dovetailed. These are then covered with a layer of sand a quarter or half an inch thick, in order to produce an even surface.

2. Strong brown paper, in continuous rolls and as broad as possible, is then laid upon it, so that each length overlaps the other by about four inches. When the whole or a large part has thus been covered with paper, the mixture is put into a cauldron, in the proportion of a hundred pounds of tar to one hundred and eighty pounds of Portland cement. Care must be taken to heat the tar gently, and to mix the cement with it gradually, in order to prevent its boiling over. This mixture of tar and cement (wood-cement) must then be laid as hot as possible on the paper with a tar-brush. The next layer of paper is then laid upon it, and smoothed with a light wooden roller. In this way the whole roof must be covered. In order to break the joints of the paper, begin the second layer with half the breadth and proceed as before. The third and fourth layers are in like manner laid with alternate layers of wood-cement and brown paper.

The last layer must be carefully covered with the cement, and then strewed with sifted ashes to the thickness of a quarter of an inch. Next to the gutter is a board, covered with zinc and projecting about two inches. It should be laid on after the second layer has been completed, so as to be covered by the third and fourth. If there are any chimneys projecting through the roof, they should be surrounded with zinc immediately after the first layer has been finished and before the gravel is strewn upon it. This zinc should rise six inches up the sides of the chimneys and three inches upon the roof; the upper edges should be bent, so as to be let into the joints of the brickwork, where they should be carefully fixed with cement. By this means any water that may run down the outsides of the chimneys is diverted to the roof.

3. The whole is then finished with a coating of sifted gravel containing about one-third of dry loam, truly levelled with rakes and scrapers.

This work should not be attempted in rainy or frosty weather.

The workmen should wear very light boots, or better still, none at all, and should always stand on thin boards when working at the roof.

The advantages of this system of roofing are:—

1. A smaller quantity of wood is used.

2. The roof being flat gives more room in the upper floors of the house.

3. It is more convenient for constructing garrets.

4. Protection from external fire, and affords easy access to firemen.

5. If properly constructed, these roofs never require repair.

Several roofs at Hirschberg, in the Reisengebirge, constructed on this principle, are now twenty-two years old, and have never been repaired.

A square foot of this roofing, without the woodwork and including the labour, costs about $1\frac{1}{3}d.$, and Mr. C. Purkert, in Teplitz, guarantees roofs made under his superintendence.

CHAPTER XXXI.

MEASURES AND WEIGHTS.

In the absence of a universal system of weights and measures, it is necessary to adopt and use local weights and measures.

All civilized nations should unite in forming one uniform system. The French mètre-system, which has already been adopted by several countries on account of its simplicity, is the most appropriate. So long as no general system exists, every technical book should contain a table of the different weights and measures.

The following is a table of the weights and measures of the principal countries:—

1. One Prussian foot is equal to	0·966 Paris foot.
„ „ „	1·039 English or Russian foot.
„ „ „	0·993 Austrian foot.
„ „ „	0·314 mètre.
2. One French mètre is equal to	443·295 Parisian lines.
„ „ „	39·370 Eng. or Rus. inches.
„ „ „	3·281 Eng. or Rus. feet.
„ „ „	38·234 Prussian inches.
„ „ „	3·186 Prussian feet.
„ „ „	3·163 Austrian foot.
„ „ „	36·941 Parisian inches.
3. One Parisian foot is equal to	1·035 Prussian foot.
„ „ „	1·065 Eng. or Rus. foot.
„ „ „	1·028 Austrian foot.
„ „ „	0·325 mètre.
4. One English or Russian foot is equal to	0·938 Parisian foot.
„ „ „	0·971 Prussian foot.
„ „ „	0·964 Austrian foot.
„ „ „	0·305 mètre.
5. One Prussian cubic foot is equal to	0·901 Parisian cubic foot.
„ „ „	1·091 Eng. or Rus. cubic foot.
„ „ „	0·978 Austrian cubic foot.
„ „ „	0·031 cubic mètre.
6. One German pound is equal to	0·5 kilogramme. 500 gramme.
„ „ „	1·340 pound Troy.
„ „ „	1·103 pound Avoirdupois.
„ „ „	0·892 Austrian pound.
7. One litre is equal to	0·001 cubic mètre. 1 cubic decimètre.
1,000 grammes are equal to	1 kilogramme at 4° centigrade.
„ „ „	55·893 Prussian cubic inches.
„ „ „	0·873 Prussian quart.

CHAPTER XXXII.

COST OF THE ERECTION OF A MANUFACTORY TO PRODUCE 30,000 CASKS OF CEMENT PER ANNUM.

THE description of my method and the extent of the manufactory is for the production of 100 casks per day, or 30,000 casks per annum of 300 working days. The minimum capacity of a cement manufactory should be from ten to fifteen thousand casks per annum, and I do not recommend the construction of works unless they can command the supply of raw materials for twenty years at least.

The necessary buildings, including endless kiln, factory buildings, sheds, &c., are represented on the plan, Plate II. The exact cost of these buildings would, of course, be regulated by their situation.

In Holland, for instance, the cost of buildings, with all necessary foundations, &c., exceeded the price of machinery, which would seldom be the case in Germany.

Many manufactories built near navigable rivers, or canals, and railways, were constructed on too limited a scale, and their subsequent necessary enlargement costs considerable sums of money.

Those, therefore, building new works should so arrange that, hereafter, any required extension could be conveniently and profitably made; and the steam-power at first should, with that ultimate view, be greatly in excess. A 60 or 30 horse power engine might be worked at the rate of 20-horse power without waste. The boiler-power may only be up to what is required, leaving room for further boilers when required. Space should also be left for horizontal mills, ventilators, &c. The space also on both sides of the kiln should be kept clear in case a second kiln may be wanted or a shed for fuel.

Estimate of the Cost of Machinery and Iron for a Manufactory capable of producing 30,000 *Casks per annum.*

	£	s.
1. One Woolf steam-engine, 60-horse power ..	1200	0
2. Three wrought-iron boilers, each having a heating surface of 360 square feet, and tested to a pressure of 60 lbs., with grates, doors, register and other fittings, weighing 25 tons, at 24s. per cwt.	600	0
Carried forward	£1800	0

	£	s.
Brought forward	1800	0
3. One feed-pump, Giffard's injector as an auxiliary feeding apparatus, with pumps and all steam and water pipes, weighing altogether about 2 tons 10 cwt.	126	0
4. 13 tons 10 cwt. of shafting with couplings, bearings, and pulleys, 4 cast-iron pillars with tops, clutch boxes and screws, at 26s. per cwt. ..	351	0
5. Two stone breakers complete, about 50 cwt. ..	123	0
6. Two complete vertical mills or edge-runners, including erection—22 tons 10 cwt. at 19s. ..	427	0
7. Two endless iron worms, 10 and 23 feet long with elevation 16 feet high, and spindles and fixing screws	84	0
8. No. 7, ditto ditto ditto	84	0
9. Two small cylindrical sieves, at 75s. each	7	10
10. Two large ditto with steel wire netting and driving wheels, at 27*l*. each ..	54	0
11. Six iron horizontal mills, at 43*l*. each	258	0
12. Six pairs of French stones, at 29*l*. each	174	0
13. One waggon for moving stones	30	0
14. One iron forming-machine	60	0
15. One mixing-machine	38	0
16. Three half-metrical ventilators, with extra shafts, at 12*l*. each	36	0
17. Wire communication	15	0
18. One steam-engine of 10-horse power, with boiler and fittings	239	0
19. Two hundred and twenty square feet of driving-strap, mostly double	45	0
20. Two thousand lineal feet of rails, weighing about 10 lbs. per yard—about 5*l*. per ton	26	0
One thousand sleepers with nails	21	0
Labour in fixing the above	5	0
21. Thirty iron waggons, at 3*l*. 14s. each	111	0
22. Sixteen semi-spherical dampers, with perforated plates—30 cwt. at 15s. per cwt.	22	10
23. One hundred and eighty lids for the stoke-holes and six covers—50 cwt. at 10s.	25	0
Carried forward	£4162	0

	£	s.
Brought forward	4162	0
24. Trucks and waggons	15	0
25. Four hundred and fifty iron drying-plates—about 68 cwt. at 18*s*.	61	0
26. Fittings for smithy	23	0
27. Fittings for carpenter's shop	23	0
28. Laboratory fittings	23	0
29. Add 10% for erection and transport from the different places to the site	375	0
Total cost	£4682	0

The above estimate does not include the cost of buildings, and gives the maximum price for each article.

In a neighbourhood where machine and iron works are plentiful, many of the items would be much reduced. One of Woolf's high-pressure engines of 60-horse power, with expansion and condensing gear, is reckoned at 1200*l*., but it may also be had for 900*l*.

Where fuel is cheap, two high-pressure steam-engines may be substituted for Woolf's engine. Part of the exhaust-steam can be used for heating the forming-machine and vat, while the remainder could be condensed in suitable tanks.

CHAPTER XXXIII.

YEARLY COST OF RAW MATERIALS, AND WORKING EXPENSES IN PRODUCING 30,000 CASKS PER ANNUM.

Cost.

1. Raw materials, including chalk, clay, clay-ironstone, soda, &c.—9000 tons at 7*s*. ..	£3150
2. 1500 tons of coal—say 16*s*. per ton	1200
3. 40 labourers' time	1200
4. 30,000 casks, at 1*s*. 3*d*. each	1875
5. Expenses, repairs, oil and lighting, carriage, travellers' expenses, &c.	1005
Carried forward	£8430

Brought forward	£8,430
6. Five per cent. on the outlay of—say 9000*l*.	450
7. Ten per cent., as a redemption fund for the outlay	900
	£9,780

Income.

30,000 casks of cement, sold at 9*s*. each ..	13,500
Leaving a nett profit of	£3,720

or more than 40 % on the outlay.

The above estimate of the working expenses, as well as the price of the raw materials, will of course vary in different localities; one manufactory may be more favourably circumstanced with regard to the raw materials and fuel than another. The facilities and cost of transit also diffr; and again, the manufactured article will sell better at one place than another. Loss by negligence of workmen is another question not to be lost sight of. All these things, duly considered and appreciated, render the nett profits of a cement manufactory more frequently under than at 40 %.

The greatly increased price of wood for staves has added materially to the cost of casks. Where in some places they cost formerly 2*s*. 6*d*. to 2*s*. 9*d*. each, they cannot now be had under 3*s*. 6*d*., or even more.

But when we consider that many manufactories, notwithstanding losses at first starting, made a clear profit of between 20 and 28 % on the outlay, we may feel satisfied that works constructed on my system would make a much larger profit, or be enabled to sell the cement at a lower price.

CHAPTER XXXIV.

ON THE PREPARATION OF CLAY OR LOAM FOR THE MANUFACTURE OF BUILDING-BRICKS, WITH THE APPLICATION OF WARMTH, AND GREAT SAVING OF DRYING SPACE.

About sixteen years ago I was asked by a brick manufacturer, who used a kind of marl clay which had to be exposed to the air for more than a year before it was fit for use, whether this tedious and costly process could not be performed in a cheaper and more expeditious manner.

I have already given the result of experiments; namely, that under the influence of water and heat a more intimate combination of the constituent parts of the clays or chalks is effected.

If a freshly dug clay, which is generally exposed to the air some time before it is fit for the manufacture of bricks, is mixed with enough water to render it plastic, and then heated to about 70° centigrade, and while still hot moulded in a brick-making machine (drain-pipe press, Schlyckeisen's brick machine), the following results take place:—

1. The hot brick when it leaves the machine at once evaporates the greater part of the water necessary for plasticity.

2. The bricks, tile, &c., do not shrink, twist, or crack. The reason of this is probably because the water evaporates equally at all points, especially when the bricks rest on perforated or corrugated plates.

3. Bricks, pipes, or other shapes, can be lifted by hand in a few minutes after leaving the machine, and can then be piled one upon the other.

4. Of course drain-pipes, perforated bricks, or other goods having thin sides, are almost dry before they cool, which is not so in the case of common bricks.

5. Goods or objects made according to my method can, when cool, be placed in drying-rooms of any temperature without warping or cracking.

6. Experience has shown that clay treated in this manner shrinks less during the process of burning than that which has been mixed cold.

7. The internal moisture evaporates more rapidly through the innumerable cracks, invisible to the naked eye, which are found on the outer surface.

8. Clay, loam, &c., can be used directly it is dug, provided it has a temperature of at least 70° centigrade on leaving the moulding machine.

9. In a few hours' time freshly dug clay or loam when so moulded and treated can be placed in the kiln and burnt.

The advantages offered by my process are incalculable, as every brick and pottery manufacturer will perceive. To those possessing endless kilns of my construction, or even one of Hoffman and Lichts, my process will be fully appreciated, as in wet seasons it is often impossible to get the requisite number of bricks ready for burning.

As already stated, the clay acquires two properties by being mixed warm, namely, it gets as well mixed as if it had been exposed to the air a long time, and the bricks so made dry quickly without cracking.

Four years ago I wished to take a patent out for my method of working clay, but found a similar process had been patented in England in 1862. The English machine is unsuitable and complicated.

The heating of plastic clay can be performed in various ways, but two conditions are indispensable.

The plastic mass of clay must be heated to a temperature of boiling water; during the heating the clay must be intimately mixed.

These conditions are not difficult of fulfilment in the laboratory; but when you come to deal with hundreds of tons daily, much ingenuity and care are required to succeed.

Sixteen years ago, I found much difficulty in filling one of Whitehead's drain-pipe machines with hot plastic clay.

This was first done by machinery, three years ago, thus: an inclined cylinder of iron was constructed, in the middle of which a worm (screw) was fixed on a spindle. At the upper end of this cylinder the clay was introduced through a hopper, and steam from the steam-engine entered at the lower end.

I had not leisure to watch these experiments, but their results were very different and contrary.

Similar experiments made with a smaller apparatus in the laboratory convinced me of the difficulty of warming clay by bringing it in direct contact with steam. The strips of clay cut by the screw condensed the steam on their surface and made them slippery, preventing them uniting, and make the burnt bricks appear striped or twisted like striped agate. This result induced me to treat the raw clay in a similar manner to the raw cement. The clay, in as small particles as possible, was measured into the forming-machine, Fig. 14, and with each measure was put a sufficient quantity of water to render the clay plastic. The machine was then set in motion, and after the first strip had been returned to the machine, a solid strip of equally mixed clay came out at *A*, Fig. 14.

When lime which had been slacked in the air or marl-lime were added to the clay, it formed, as in the above instance, a mixture of equal quality, which dried in a few minutes after leaving the machine.

The clay after it has passed through the forming-machine might be put into other machines, such as those of Sachsenberg Brothers, of Rosslau, on the Elbe, or of Hertel, of Nienburg, on the Saale, in either of which it could be still more intimately mixed, only there ought to be arrangements for heating the rollers, so that the bricks, &c., might leave the machine in as hot a state as possible.

I consider the mixing of the clay in a warm state as one of the most important conditions of brickmaking, especially where endless kilns are used, as the bricks can be made and dried in any weather.

One advantage of my method is that you may dispense with drying sheds, and consequently realize a large saving in the cost of transporting the wet bricks.

The difficulty of drying large bricks was experienced centuries ago. In Holland, for instance, the smallest bricks are made, because the damp sea-air is more favourable for drying small bricks. Small bricks require more labour and fuel to make them, and when used for masonry or building they require more mortar than large ones.

I here give an approximate estimate founded on my system of forming bricks and drying them by means of drying channels.

A manufactory calculated to produce twenty thousand bricks per day, or four millions per annum of 200 working days, when solely dependent upon sheds for drying, seldom produce the four millions, and when done, at a great expense for labour.

If, on the contrary, four or five drying channels are constructed, each of which would hold four tons of bricks, which, according to their size or specific gravity, weigh from three to four tons per thousand, 20,000 bricks weighing from 70 to 80 tons can be dried in twenty-four hours, so that they may then be placed in an endless kiln and burnt at once.

I have made the above calculation highly unfavourable for the drying, as, with proper treatment, bricks can be sufficiently dried in three hours.

I was induced to offer these few remarks on brickmaking from the fitness of the endless kiln for such a purpose, and hope that it may induce brick manufacturers to experiment on the subject, for which purpose I will gladly help them with my advice.

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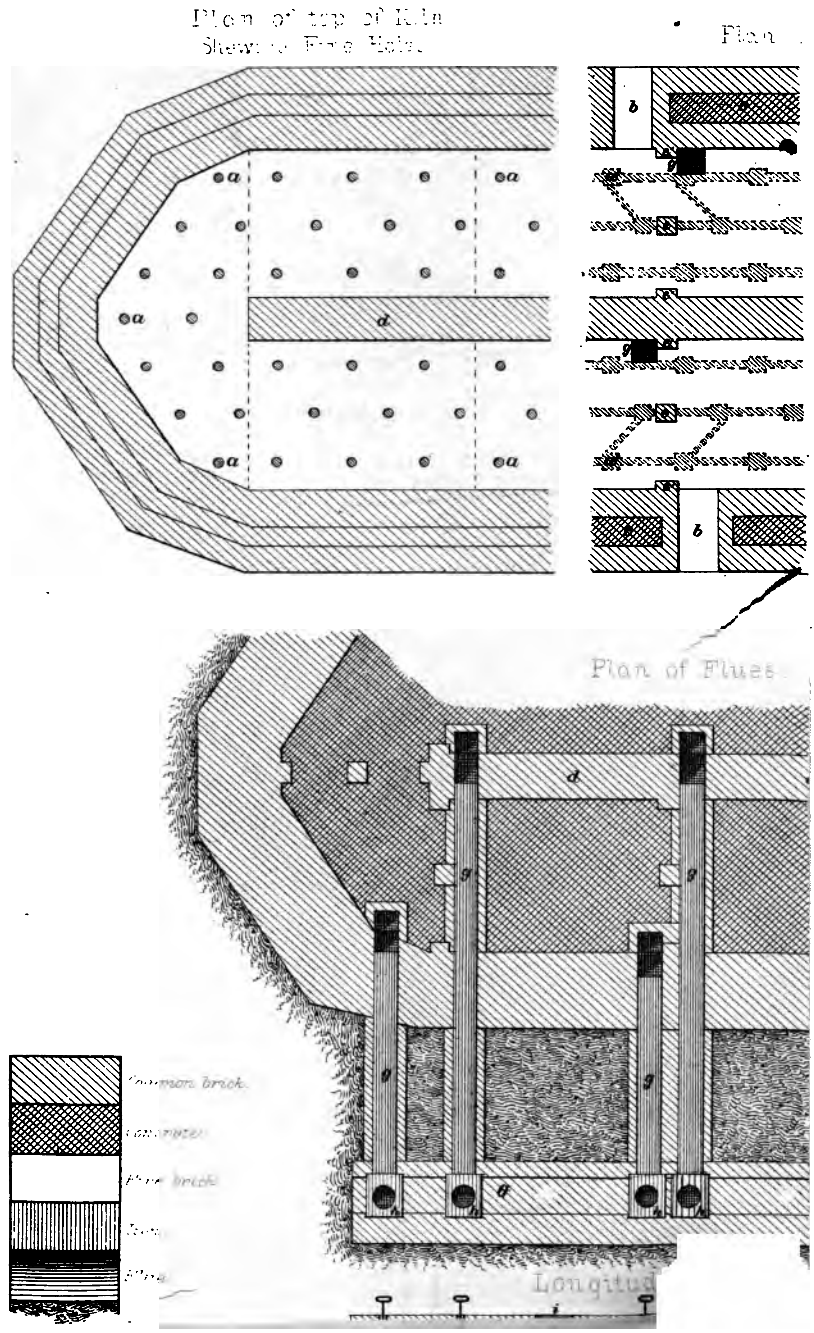
Plan of top of Kiln
Shewing Fire Holes
Plan
Plan of Flues
Common brick
Fire brick
Longitud

Plate II.

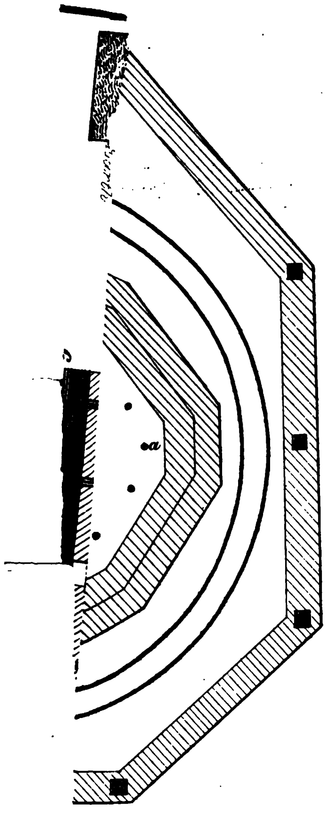

Plate III.