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DEPARTMENT OF REGISTRATION AND EDUCATION
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DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

REPORT OF INVESTIGATIONS—NO. 49

A SUMMARY OF THE USES OF LIMESTONE AND DOLOMITE

BY

J. E. Lamar and H. B. Willman

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INTRODUCTION

This brief discussion of the uses of limestone and dolomite has been compiled to provide information for the Illinois stone industry in their search for new outlets for their products. It is by no means intended to be an exhaustive treatise on the subject but rather a summary to serve as a basis for the selection of those uses which seem to have promise. Such uses may then be studied further by consulting the publications in the list of references and by personal investigation and contact with potential consumers.

It should be emphasized that the processes involved in some of the uses of limestone and dolomite are highly technical and that, before any attempt is made to exploit stone for any given use, the technology of the particular use should be thoroughly investigated. Also the uniformity, extent, and availability of the raw material and the size and availability of the market should be carefully studied.

In some cases it has been difficult to distinguish between the uses of limestone and the uses of lime. However, if a consumer purchases raw stone, this is considered a use of limestone regardless of the fact that the consumer may subsequently convert the limestone to lime in his process of utilization.

Although the specifications presented are considered to be reasonably typical, considerable variations occur and, as a rule, each consumer has his own specifications. For some uses there has been lately an increased tightening of specifications, the details of which have not yet reached the literature. Furthermore specifications are often varied somewhat in order to permit the use of materials which are close at hand and available at low cost. It is felt that, in the main, the specifications given should be considered only as indicative of the general requirements which stone must meet. They will serve to indicate probable uses but investigation of the specifications of potential consumers should precede and govern any attempts to sell stone.

In general the uses of limestone and dolomite may be classified into two groups, "chemical uses" in which the chemical composition of limestone and dolomite is of prime importance, and "physical uses" in which the physical character of the stone is most important. For the former it is customary to draw chemical specifications and usually physical specifications as well, but specifications for the latter usually refer only to the physical properties.

In subsequent pages the uses described are arranged in alphabetical order for convenience regardless of whether they are primarily chemical or physical. However, it is generally possible to distinguish between chemical and physical uses by the fact that no chemical specifications are given for the latter.

It has not been possible in this report to adhere strictly to any specific definitions of limestone and dolomite because data have been drawn from a great many different sources in which, for the most part, no statements of usage are given. It is believed, however, that the following discussion will enable the reader to judge from the text how the terms are used in most cases.

The term "limestone" is often employed as a general term to describe rocks which are composed principally of calcium carbonate or calcium and magnesium carbonates. Limestones are subdivided, as a general rule, into three groups on the basis of chemical composition. In such a classification the term "limestone" is used specifically to designate those rocks which are composed dominantly of calcium carbonate and contain only small amounts of magnesium carbonate. The term "dolomite" is used to describe rocks composed principally of calcium and magnesium carbonates. A pure dolomite contains about 54 per cent calcium carbonate ($CaCO_3$) and 46 per cent magnesium carbonate ($MgCO_3$). However, no minimum limit is in common use for the amount of magnesium carbonate which must be present in a rock in order that it be called dolomite. The term has been applied to rocks which contain as low as 30 per cent magnesium carbonate. The terms "magnesium limestone", "magnesian limestone", or "dolomitic limestone" are often employed to describe rocks whose composition is intermediate between limestone and dolomite. The general relationship of these terms possibly is more evident as expressed below.

Limestone	Limestone—high in $CaCO_3$, low in $MgCO_3$
	Magnesium (magnesian) limestone—amounts of $CaCO_3$ and $MgCO_3$ intermediate between those in limestone and dolomite
	Dolomite—high in $MgCO_3$ as compared to a possible maximum $MgCO_3$ content of 46 per cent

A classification proposed by Hatmaker (*44*, p. 2)* and given below in tabulated form indicates in a general way the approximate composition limits in more or less common use for various kinds of limestone and dolomite.

* References are given on pages 45-48.

High-calcium limestone—
more than 95% $CaCO_3$ and
not more than 5% $MgCO_3$

Limestone—
less than 10% $MgCO_3$

Magnesium limestone—
10 to 40 or 45% $MgCO_3$
- Low-magnesium limestone—
10 to 20% $MgCO_3$
- High-magnesium limestone—
more than 20% $MgCO_3$

Dolomite—
more than 40 to 45% $MgCO_3$

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LIMESTONE PRODUCTION

In order to give a picture of the importance of the various uses of limestone and dolomite from the standpoint of quantity and value, the following tables showing production in the United States and in Illinois for 1935 are included.

Table 1.—Limestone Sold or Used by Producers in the United States and in Illinois in 1935 (*17*)

Use	United States			Illinois		
	Quantity (Short tons)	Value	Average Price (Per ton)	Quantity (Short tons)	Value	Average Price (Per ton)
Building stone—						
Rough construction	293,050	$ 310,878	$ 1.06	10,090	$ 31,126	$3.09
Rough architectural	a1,795,360	567,041	a0.32	...	...	...
Finished (cut and sawed)	a1,448,460	1,822,828	a1.26	...	...	...
Rubble	185,790	276,569	1.49	39,610	43,948	1.11
Riprap	1,982,250	1,890,625	0.95	214,220	213,880	1.00
Crushed stone—						
Concrete and road metal	30,151,790	26,354,559	0.87	2,965,050	2,106,582	0.71
Railroad ballast	3,623,500	2,525,949	0.70	389,650	257,572	0.66
Fluxing stone	12,191,660	7,902,717	0.65	336,240	175,567	0.52
Sugar factories	460,460	640,375	1.39	...	...	...
Glass factories	250,930	414,027	1.65	...	...	...
Paper mills	188,090	339,372	1.80	...	...	...
Agriculture	2,140,370	2,656,728	1.24	349,690	246,935	0.71
Other uses	5,788,110	4,967,097	0.86	82,800	141,709	1.71
Total	b57,492,760	$50,668,765		4,387,350	$3,217,319	

a Cubic feet; price per cubic foot.
b Approximate.

TABLE 2.—LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES FOR MISCELLANEOUS USES IN 1935 (*17*)[a]

Use	Short Tons	Value	Average Price Per Ton
Alkali works	4,090,980	$2,188,597	$0.53
Calcium carbide works	287,340	135,844	0.47
Coal-mine dusting	52,660	147,523	2.80
Filler (not whiting substitute)—			
Asphalt	152,040	363,163	2.39
Fertilizer	39,590	62,847	1.59
Other	55,850	223,893	4.01
Filter beds	49,860	52,672	1.06
Magnesia works (dolomite)	96,810	153,973	1.59
Mineral food	42,980	190,461	4.43
Mineral (rock) wool	96,940	81,905	0.84
Poultry grit	30,290	110,426	3.65
Road base	157,960	91,810	0.58
Roofing	9,820	8,919	0.91
Stucco, terrazzo, and artificial stone	18,810	73,824	3.92
Whiting substitute[b]	147,910	563,514	3.81
Other[c]	56,860	82,396	1.45
Unspecified	72,310	125,243	1.73
Total	5,549,010	$4,657,010	

a These uses are listed as "Other uses" in Table 1.
b Includes stone for filler for calcimine, pigments (paint), polishes, pottery, putty, rubber, targets, wallboard, and uses not specified.
c Includes stone for acid neutralization, bird gravel, carbolic acid, carbon dioxide, chemicals (unspecified), dust, dye works, explosives, landscaping, lime burning [raw stone sold to chemical and manufacturing plants (*11*)], mosaics, oil refining, pipe manufacturing, salt refining, spalls, studio snow, and waste rock.

USES OF LIMESTONE AND DOLOMITE

ABRASIVES

According to Goudge (*41,* p. 372), "soft limestone pulverized to a moderate degree of fineness is being used in a process similar to sand blasting for the cleaning of soft metal molds, and there are possibilities of it being used for the buffing and cleaning of metal preparatory to electroplating."

AGRICULTURAL LIMESTONE

Use.—Agricultural limestone or "agstone," as it is sometimes called, is applied to soil because it neutralizes soil acids and acid clays, converting the latter to calcium or magnesium clays; it releases plant food elements from some soil minerals; it supplies, according to whether limestone or dolomite is used, nutrients for plant use in the form of calcium or calcium and magnesium; it favors the growth of legumes and promotes their use of atmospheric nitrogen; it improves the type of decay of organic matter in the soil; it flocculates some clay soils; it converts toxic aluminum compounds which are soluble under acid conditions to insoluble compounds; and it may improve the tilth of the soil (*27; 48; 49; 66,* p. 88).

TABLE 3.—PRODUCTION OF LIME AND CEMENT IN 1935

	United States		Illinois	
	Quantity	Value	Quantity	Value
Portland cement (*13*, p. 1139)	76,741,570 bbl.	[a]$115,879,771	3,367,512 bbl.	[b]$4,613,491
Natural, masonry (natural), and puzzolan cements (*13*, p. 1158)	[c]1,006,064 bbl.	[d]1,428,611	(e)	(e)
Lime[f] (*16*, p. 1241)	2,987,133 short tons	21,748,655	117,602 short tons	878,746
Hydrated lime[f] (*16*, pp. 1241-42)	1,005,619 short tons	7,939,513	24,267 short tons	187,651

a Computed from the average factory value per bbl. of $1.51 for 1935.
b Computed from the average factory value per bbl. of $1.37 for 1935.
c 376 lb. barrels.
d Calculated from the average value of shipments of $1.42 per bbl. in 1935.
e Concealed; less than 3 producers.
f Sold or used by producers.

General chemical specifications.—The ability to counteract acidity or the neutralizing power of a limestone or dolomite depends on its content of calcium and magnesium carbonates and is commonly expressed as per cent "calcium carbonate equivalent," often abbreviated as C. C. E. The calcium carbonate equivalent is a measure of neutralizing ability in terms of calcium carbonate. As magnesium carbonate has a greater neutralizing value per unit weight than calcium carbonate, namely 1.19 times that of calcium carbonate, dolomites often show a calcium carbonate equivalent of more than 100 per cent. A calcium carbonate equivalent of roughly 109 per cent is the maximum obtainable with pure dolomite. Most of the agricultural limestones produced commercially vary between 90 and 100 per cent calcium carbonate equivalent. In general, rocks having a calcium carbonate equivalent of less than 85 per cent are not used for agricultural limestone unless stone having a higher calcium carbonate equivalent is not available.

General physical specifications.—Agricultural limestone usually passes a 4-mesh screen and ranges in size down to dust. Many producers make a more finely ground product. A "score card" for rating agricultural limestones on the basis of the sizes of the particles has been proposed by the Agricultural Experiment Station of the University of Illinois (*4*).

Remarks.—Both limestone and dolomite are used widely for correcting soil acidity and both are called "agstone" or "agricultural limestone."

ALKALIES

Use.—The sodium carbonate manufactured in the United States from sodium chloride (salt) is made exclusively by the Solvay or ammonia-soda process (*71*, p. 59). The Leblanc process is employed in England for making sodium carbonate from salt, but the use of this process is steadily decreasing. Both processes involve the use of limestone. In the Solvay process the limestone is dissociated to lime and carbon dioxide at the manufacturing plant. The carbon dioxide enters into the manufacture of the sodium carbonate. After the lime is hydrated it is employed to recover the ammonia involved in the process (*71*, pp. 59-60), and is used for causticizing the sodium carbonate to sodium hydroxide in the manufacture of the latter compound (*88*).

General chemical specifications.—The following specifications have been given: a high-calcium limestone (*52*, p. 253); limestone containing "over 93 per cent calcium carbonate, 3 to 5 per cent magnesium carbonate, and 2 to 3 per cent silica" (*72*, p. 264); calcium carbonate 90-99 per cent, silica, alumina, ferric oxide 0-3 per cent, magnesium carbonate 0-6 per cent (*47*, p. 52). It is believed that most American manufacturers would insist that silica not exceed 1 per cent (*88*).

General physical specifications.—The stone should be two to six inches in diameter (*47*, p. 56).

Remarks.—Caustic soda (NaOH) is made by treating sodium carbonate with milk of lime and also electrolytically from sodium chloride (*71*, pp. 88-89).

ALUMINUM OXIDE

Use.—Limestone is used in the manufacture of aluminum oxide by the Bayer process. The limestone is burned to lime which is used to make sodium hydroxide and this alkali in turn is employed to extract aluminum oxide from bauxite (*72*, p. 341). The aluminum oxide may be subsequently converted to aluminum or may be used directly for other industrial purposes.

General chemical specifications.—A high-calcium limestone containing over 97 per cent calcium carbonate and less than 1 per cent silica is used.

AMMONIA

Sales of limestone to ammonia works are reported but the use of the limestone is not specified. It may be converted to calcium carbide and used in this form in the cyanamide process of ammonia manufacture (*71*, p. 116), or it may be burned to lime and used for the recovery of ammonia from weak ammonia liquors (*69*).

ASPHALTIC COMPOUNDS

Although it is common practice in the United States to burn the acid sludge resulting from the refining of petroleum (*67*), some sludge is neutralized with lime or limestone and used as fuel oil and to a limited extent in road oils (*87*).

According to the English writer, Knibbs (*52*, p. 278), "The mixture of lime and sludge is like asphalt and it is used for making roofing materials and generally instead of asphalt," but it is believed that in the United States very little use has been made of the sludge for roofing material because of its staining properties (*87*).

AVIATION FIELDS, YARDS, PLAYGROUNDS, ETC.

Use.—Limestone or dolomite is used to surface aviation fields, tennis courts, yards, playgrounds, station platforms, and the like.

General physical specifications.—No generally adopted size specifications are known for stone for these purposes. Obviously stone for all such uses should have good weather resistance. Stone for aviation fields should be white to give it good visibility (*66*, p. 82). Stone for surfacing tennis courts probably should range in size from about ⅛ inch to dust so that it packs to a relatively dense mass, and it should have a high cementing value so that a firm surface results. For yards, playgrounds, etc., a clean, comparatively fine stone is often used.

It has been found (*74*) that for many surfacing purposes, such as those mentioned above, "Small amounts of ½-inch or even ¾-inch stone mixed with the finer sizes gives a better body to the mass of stone without in any way injuring its packing qualities or smooth surface. This feature is best appreciated in wet weather."

BAKING POWDERS (*71*, p. 130)

Use.—Monocalcium phosphate, a constituent of certain types of baking powders, is made by treating limestone or lime with purified acid.

General chemical specifications.—"Selected" hydrated lime or limestone is used. The limestone probably should be a high-calcium stone.

General physical specifications.—Probably ground or pulverized stone is used.

BUILDING STONE

Limestone and dolomite are used extensively for various building purposes and are produced as cut stone, ashlar, rough building stone, and rubble.

Cut Stone

The term "cut stone" includes all varieties of limestone or dolomite which are shaped to units of definite size, usually in accordance with detailed drawings (*10*, p. 23). The stone may be surfaced with any one of a number of finishes, including a polished finish, and is used for a wide variety of purposes including construction of walls, for sills, trimming, wainscoting, flooring, etc. Some of it is carved for decorative purposes. Those limestones and dolomites which take a good polish are classed commercially as marbles.

STONE FOR EXTERIOR USE

General physical specifications.—Cut stone for exterior use should possess good weather-resisting qualities, and should therefore be free from such substances as chert, ocher, clay, or shale inclusions. The stone should not contain mineral grains which upon weathering produce colored streaks and stains if such colorations are undesirable. In particular, the minerals pyrite and marcasite, which produce the yellow stain of iron rust, are undesirable in cut stone for many uses. Various strength tests have been devised for determining the suitability of different types of rock for construction purposes. However, it is likely that, so far as Illinois limestones and dolomites are concerned, those stones which successfully withstand weathering in natural outcrops and weathering tests (*81*, p. 44) will be found to be amply strong. Thiel and Dutton (*81*, pp. 38-48) have recently discussed tests of the physical properties of building stone.

In general it is desirable that deposits intended to serve as a source of cut stone be composed of relatively thick strata free from numerous joints and chert nodules or other hard masses. It is often desirable that the stone be "free working," that is, that it split with approximately equal ease in all directions.

Much valuable data regarding the weather resistance of a building stone may be obtained from a study of the effects of the weather on outcrops of the stone and on actual installations in buildings. When such information is not available, or when supplementary data are desired, freezing and thawing tests or accelerated-soundness tests are sometimes performed and are helpful in predicting the probable reaction of a stone to weathering. However, no generally accepted limits for the desired weather resistance of a good building stone as measured by these weathering tests have been established.

STONE FOR INTERIOR USE

General physical specifications.—Stone for interior use is usually finished with a smoothed or a polished surface. An attractive color is important in polished stone used for decoration. Floor tile should also have an attractive color and be resistant to abrasion. Any stone subject to frequent washing should be free from pyrite and clay partings as these sometimes cause failure.

Stone used in large units for interior masonry should have roughly the same properties as stone used for exterior masonry, except that the interior stone need not be as weather resistant.

Deposits of limestone or dolomite which are to serve as a source of interior stone should have about the same characteristics as those for exterior stone. However, some relatively thin deposits may be of commercial importance if the stone is sufficiently attractive or unique from the standpoint of color, texture, etc. Black marbles are an example.

Interior stone should be free from chert nodules or other localized impurities which affect the ease of cutting. Colorful stone is much in demand.

ASHLAR

Use.—Ashlar consists of "small rectangular blocks of stone having sawed, planed, or rock-face surfaces, contrasted with cut blocks which are accurately sized and surface tooled" (*10*, p. 24). Ashlar is used for the construction of the walls of houses and other buildings.

General physical specifications. — Ashlar for exterior or interior use should have roughly the same qualities as cut stone. However, deposits which are to serve as a source of ashlar, especially stone that is to be split to size rather than sawed, need not be in as heavy beds as cut stone; a deposit consisting of 2- to 12-inch beds may be desirable. Likewise rather frequent natural joints in the deposit may be an aid to quarrying.

Rough Building Stone

Use.—Rough building stone "consists of rock-faced masses of various shapes and sizes" (*10*, p. 25). It is used for houses, chimneys, basements, public buildings, bridges, fences, and walls (*10*, p. 25).

General physical specifications.—The physical specifications are the same as for ashlar.

Rubble

Use.—The term "rubble" is generally applied to irregular stone fragments having one good face (*10*, p. 25). Rubble is used for basements, exterior walls, etc., and in the form of comparatively thin slabs as a stone veneer, especially for frame houses.

General physical specifications.—Rubble should have good weather resistance and at least one face with an attractive color. Chert, clay, or pyrite partings should be avoided because they tend to reduce weather resistance. Stain-producing impurities such as pyrite and marcasite grains should be avoided if a stain-marked wall is objectionable. Usually a relatively thin-bedded deposit is easiest to work for rubble. If the rubble is to be used for veneer, a deposit composed of layers roughly 1 to 4 inches thick is commonly desirable. The surfaces of the bedding planes in such a deposit should have an attractive color.

BULB GROWING

The sale of limestone for bulb growing is reported (*23*). The limestone probably should have an attractive color and be in small chips.

CALCIUM CARBIDE

Use.—Limestone is sold for making lime which is used in the manufacture of calcium carbide. The process of manufacture involves fusing the lime with coke in an electric-arc furnace (*60*).

General chemical specifications.—Goudge (*40*, p. 46) recommends an extremely pure limestone with a phosphorus content less than 0.01 per cent, magnesia less than 2 per cent, and silica less than 3 per cent. Riegel (*71*, p. 273) states that no phosphates, or almost none, should be present and that the limestone should be free from magnesium carbonate. Mantell (*60*) specifies limestone containing at least 97 per cent calcium carbonate and quotes from Bingham the following maximum quantities of impurities permissible: magnesia 0.5 per cent, alumina and ferric oxide 0.5 per cent, phosphorus 0.004 per cent, silica 1.2 per cent, sulphur traces only. The data given regarding phosphorus content are subject to revision as recent developments in the process of manufacturing calcium carbide now permit the use of limestone with a considerably higher phosphorus content (*43*).

General physical specifications.—Lime burned from the limestone must "have mechanical strength without a tendency to crumble into dust" (*60*).

Remarks.—About two tons of limestone are used in making one ton of calcium carbide (*40*, p. 46).

CALCIUM NITRATE

Calcium nitrate (*52*, p. 259) is made by treating limestone with nitric acid. The nitrate is used in the manufacture of explosives, matches, pyrotechnics, and fertilizers. A high-calcium limestone is required.

CARBON DIOXIDE

Use.—The burning of limestone to lime is estimated to have supplied 40 per cent of the carbon dioxide of commerce in 1934 (*46*, p. 850). Some carbon dioxide is also produced in the manufacture of epsom salts from dolomite (see Epsom Salts). The production of carbon dioxide for the beverage trade by treating pulverized marble with acid is reported (*103*).

General chemical and physical specifications.—The specifications are the same as for stone for lime.

Remarks.—Carbon dioxide is sold in either the liquid or solid form and is used for a great many purposes among which are refrigeration, manufacture of explosives, food preservatives, manufacture of chemicals, in fire extinguishers, and for the carbonation of beverages (*46*, pp. 855-856).

CESSPOOL STONE

The sale of limestone for cesspool stone is reported (*23*). This is doubtless a use of building stone, probably rough building stone or rubble.

CONCRETE AGGREGATE

Use.—Crushed limestone or dolomite is mixed with cement or bitumen to make concrete. Cement concrete is used for the construction of roads, buildings, and other structures, and bituminous concrete is used principally for roads.

CEMENT CONCRETE

General physical specifications.—Specifications for crushed stone to be used as an aggregate in cement concrete vary, but in general include a minimum per cent of wear or French coefficient and require that the stone withstand without failure a specified number of cycles of the accelerated-soundness test, sometimes known as "the sodium sulphate test," or repeated freezing and thawing. The aggregate may be required to have a certain crushing strength but usually most limestone or dolomite aggregates have ample strength. Tests of crushing strength are generally made on the concrete rather than the aggregate. The Illinois Division of Highways specifies that the per cent of wear of stone for concrete aggregate to be used in State highways and bridges shall not exceed 7 per cent and that the stone "shall pass the sodium sulphate accelerated-soundness test, except that aggregates failing in the accelerated-soundness test may be used if they pass a satisfactory freezing and thawing test" (*105,* p. 318).

Various materials are considered undesirable in concrete aggregate. Specifications of the Illinois Division of Highways regarding these materials follow (*105,* p. 318):

The maximum amount of any one of the deleterious substances given below shall not exceed the following percentage by weight:

	Per cent
Removed by decantation	0.5
Shale	1.0
Coal	1.0
Clay lumps	0.5
Shells	1.0
Soft fragments	5.0
Other local deleterious substances such as alkali, friable, thin, elongated, or laminated pieces	3.0

The maximum amount of any combination of the deleterious substances listed above, together with material which fails to comply with soundness specifications should not exceed 5 per cent by weight.

BITUMINOUS CONCRETE

General physical specifications.—Crushed stone for use in the base course of bituminous concrete pavements, according to the American Association of State Highway Officials (*92,* pp. 25-26), should consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or distintegrated pieces. It should have a percentage of wear of not more than 6 and a toughness of not less than 6. It is specified that the coarse aggregate be of either (a) the No. 4 to 1-inch size or (b) the No. 4 to 2-inch size, be well graded between these limits, and conform to the following requirements:

(a) No. 4 to 1-inch size:

Passing	*Per cent*
1½-inch sieve	100
1-inch sieve	90-100
½-inch sieve	25-60
No. 4 sieve	0-10

(b) No. 4 to 2-inch size:

Passing	
2½-inch sieve	100
2-inch sieve	95-100
1-inch sieve	35-70
½-inch sieve	10-30
No. 4 sieve	0-5

The American Association of State Highway Officials (*92,* p. 31) specifies that crushed stone for use in the surface course of fine-graded bituminous concrete pavements, coarse-graded bituminous concrete pavements, and asphaltic concrete binder consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft, or disintegrated pieces and free from stone coated with dirt or other objectionable matter. The stone should have a percentage of wear of not more than 5 and a toughness of not less than 6. The coarse aggregate for fine-graded bituminous concrete should be of No. 4 to ½-inch size and be well graded between these limits. It should conform to the following requirements:

Passing	*Per cent*
¾-inch sieve	100
½-inch sieve	90-100
No. 4 sieve	0-15
No. 8 sieve	0-5

The coarse aggregate for coarse-graded bituminous concrete or asphaltic concrete binder should be of the No. 4 to 1-inch size and be well graded between these limits. It should conform to the following requirements:

Passing	*Per cent*
1½-inch sieve	100
1-inch sieve	90-100
½-inch sieve	35-60
No. 4 sieve	0-10

DOLOMITE REFRACTORIES

Introduction.—Dolomite is used as a refractory mainly as "dead-burned dolomite." This material results from the burning of dolomite or high-magnesium limestone at such temperatures, usually about 1500°C., as to produce a hard, fully-shrunk product (*44*, p. 4; *75*, pp. 314-315). Dead-burned dolomite made from relatively pure dolomite, if not protected from atmospheric moisture, disintegrates due to slaking or taking up water and carbon dioxide from the atmosphere (*5*). Consequently this type of material must be used within a short time of manufacture or protected by a moisture-proof coating. It is usually burned at the steel plant where it is to be used.

It has been found that a more suitable variety of dead-burned dolomite is produced, the formation of a thoroughly sintered product is facilitated, and the sintering temperature is lowered when iron oxide, silica, and alumina are present in the proper proportions in the raw materials. These compounds may be present naturally in the raw dolomite or, as is more often the case, may be added in any one of a number of forms. Much of the dead-burned dolomite thus prepared is sold under various trade names.

Use.—Dead-burned dolomite is used in large quantities in basic open-hearth furnaces. Prepared refractories composed largely or wholly of dead-burned dolomite and sold under various trade names have been employed, because of their lower cost, as substitutes for magnesite chiefly for making the banks of basic open-hearth furnaces (*19*, p. 31). The greatest use of dead-burned dolomite, however, is for current patching and repair work (*59*, *61*). A considerable tonnage is also used for electric-furnace bottoms (*59*).

Calcined dolomite prepared at the steel plant is used likewise for making banks of the basic open hearth, and for filling holes in the bottom and repairing cuts in the banks of the hearth which develop with use (*19,* pp. 31, 293, 330). It may also be used for making the bottom of the hearth (*19,* pp. 305, 315).

Dead-burned dolomite is also used in basic Bessemer converters, lead-refining reverberatory furnaces, lead cupelling furnaces, crucibles for lead blast furnaces, and in the form of crucibles for melting metals (*44,* p. 3).

For a monolithic furnace lining or bottom, dead-burned dolomite is employed with a suitable binder or a fluxing agent (*44,* p. 4).

For repair work around the open hearth, calcined dolomite is crushed to pass ½ inch (*19,* p. 295).

A very large tonnage of raw dolomite is used for patching, principally around the slag line of the open hearth (*59*).

General chemical specifications.—In general it appears that relatively pure dolomites are used for making dead-burned dolomite, presumably because (a) dolomites containing the requisite impurities in the proper proportions are rare, (b) the calcined product resulting from the dead burning of a relatively pure dolomite has fewer undesirable properties than the product resulting from the burning of impure dolomites in which silica, iron oxide, and alumina are not present in the proper proportions, and (c) a more uniform dead-burned dolomite can be made by sintering a mixture of relatively pure dolomite and a flux, such as flue dust, than from a similar mixture wherein is used impure dolomite which is by nature likely to vary in composition.

The following limits have been suggested for dolomites to be used for refractory purposes: calcium oxide about 33 per cent, magnesia 18 to 20 per cent, carbon dioxide 42 to 46 per cent, silica less than 7 per cent, iron oxide and alumina less than 5 per cent (*75,* p. 314).

Although dolomite containing as much silica as is indicated above was used some 20 years ago, it would probably be difficult now to sell for refractory purposes dolomite containing more than 2½ per cent of silica (*59*).

According to Bowles, dolomite to be dead burned and used in basic bottoms of open-hearth furnaces should contain "less than 1 per cent silica, less than 1.5 per cent combined alumina and ferric oxide, at least 35 per cent magnesium carbonate, and the remainder calcium carbonate" (*7,* p. 13).

The Carnegie Steel Company recommends that calcined dolomite for making the banks of basic open-hearth furnaces and for furnace repairs have approximately the composition shown below (*19,* pp. 32, 332):

Calcined dolomite	*Per cent*
SiO_2	1.66
Al_2O_3	1.24
Fe_2O_3	0.94
CaO	55.01
MgO	38.26

Dead-burned or clinkered dolomite is made from dolomite of high purity by the "incorporation of some 3 to 5 per cent of additional iron oxide with the dolomite" (*59*).

General physical specifications.—The dolomite should be in pieces about 5/8 inch in diameter (*75,* p. 314) or passing a 1/2-inch screen (*19*, p. 295).

Remarks.—As much as one to two tons of dead-burned dolomite may be required to repair a 100-ton basic open-hearth furnace between heats (*78*).

A number of new types of dolomitic refractories have been described (*57*). One of these, which is receiving considerable attention at the present time, is brick composed of stable dolomite refractories. The latter are produced by forming stable and highly refractory calcium silicates from the lime in the dolomite (*59*).

Basic refractories are manufactured in Canada from "magnesitic dolomite" (*25*). Raw material of good grade has the following analysis (*21*):

	Per cent		*Per cent*
SiO_2	2.0—3.5	CaO	9.0—12.0
Al_2O_3	0.2—0.3	MgO	32.0—38.0
Fe_2O_3	0.2—0.4	Loss on ignition (chiefly CO_2)	46.0—48.0

Three principal types of products are made: clinker, an essentially basic brick, and basic plastic refractories (*21*).

In Ohio a synthetic mixture is used in the manufacture of basic refractories which have the same composition as those produced in Canada from natural stone (*25*).

DYE WORKS

Use.—Calcium carbonate is used in the process of halogenation employed in the manufacture of dye intermediates (*71,* p. 435). Lime is used in the manufacture of dyestuffs and intermediates (a) in the manufacture of naphthols by the sulphonation process, (b) in the reduction of nitration products, and (c) in the hydrolysis of chlorine derivatives (*94*).

General chemical specifications.—Possibly a high-calcium limestone is used for the halogenation process. For (a) and (b) above, a high-calcium lime is required, and for (c) "any good quality lime is satisfactory" (*94*). For many chemical purposes in dye works, iron and alkali metals undoubtedly should be low. For the production of dye intermediates, particularly sulfonic acid derivatives, magnesium should also be as low as possible (*69*).

General physical specifications.—Limestone for use as a "base for dyes" should be of such size that it will "all pass through a 20-mesh screen and 97 per cent through 100 mesh" (*66,* p. 91).

EPSOM SALTS (*45*)

Use.—Epsom salts and carbon dioxide are produced from dolomite by a series of processes involving as a primary reaction the treatment of the dolomite with sulphuric acid.

General chemical specifications.—An average analysis of the rock used is as follows:

	Per cent
$CaCO_3$	54.00
$MgCO_3$	45.00
Fe_2O_3	0.05
Al_2O_3	0.05
SiO_2	0.50
Total	99.60

"The stone is most suitable on account of its freedom from excessive amounts of oxide of iron and aluminum, carbonaceous matter, sulphides, and silica."

General physical specifications.—The dolomite is shipped from the quarry in "one man" lumps but is reduced to 60-mesh at the plant.

EXPLOSIVES (*79*)

Use.—Limestone is used as a neutralizing agent for acids in many types of blasting explosives.

General chemical specifications.—The materials used range from "a rather pure calcium carbonate to marble dust containing as much magnesium as calcium. The impurities in the limestone are of no practical importance in the manufacture of explosives."

Remarks.—"The average dynamite contains less than 1.5 per cent of calcium carbonate but special powders have contained as high as 15 per cent."

FERTILIZERS

Use.—Limestone and dolomite are used as fillers and conditioners of fertilizers. The fillers serve to add weight to and reduce the caking of fertilizers. The conditioners also serve to reduce caking; if a fertilizer contains superphosphate they neutralize any "free" phosphoric acid present; and in the case of the so-called "complete" or "standard" fertilizers, many of which have an acid-forming influence on the soil, they are the basic constituents employed to give a "physiologically basic" product (*3, 62*). Dolomite and high-calcium limestone have both been used satisfactorily but dolomite is generally preferred (*27*).

Limestone is also used "in the manufacture of many nitrogenous fertilizers and fertilizer materials, such as cyanamide, calcium nitrate, ammonium citrophosphate, calcium ammonium nitrate, and ammonium sulphate" (*41,* p. 373).

General chemical specifications.—For filler a reasonably pure limestone or dolomite is required (*27*); for fertilizer manufacture a high-calcium limestone is probably desirable.

General physical specifications.—The sale of dolomite having a fineness of 20 to 80 mesh as a fertilizer filler is reported (*102*).

FILTER STONE

Use.—Crushed limestone or dolomite is used in sewage disposal works to form the beds of the trickling filters over which the liquid portion of the sewage is sprayed. The rock serves as a host for organisms which purify the sewage. The stone is subjected to unusually severe conditions with respect both to mechanical weathering, such as freezing and thawing, and to solution.

General physical specifications.—Filter stone should be carefully screened, clean, and free from dust, fine stone, dirt, and other foreign substances (*93*, p. 10). Various sizes of stone are employed but the usual specification permits a difference of 1 inch between the upper and lower size limits of the stone, as 1 to 2 inches, 1½ to 2½ inches, or 2 to 3 inches. The desired size should be furnished within certain allowable limits; a tolerance of 5 per cent by volume or weight is recommended for both the upper and lower size limits (*93*, p. 10).

An accelerated-soundness test known as the Brard or sodium sulfate soundness test (*53*) is often employed to determine the soundness of filter stone. Freezing and thawing tests are also sometimes used. Methods of preparation of the sulfate solution for the former test and likewise the test procedure have been described by the American Society for Testing Materials, in Tentative Method C89-32T; and the American Society of Civil Engineers also have a recommended procedure (*93*, pp. 28-29). Twenty cycles of the test are usually employed when testing filter stone. According to the committee on filtering materials of the American Society of Civil Engineers, "In general, a durable filtering material should withstand twenty cycles of the sodium sulfate test procedure with little or no loss of material. Any material of which 10 per cent of the number of pieces tested fails, or from which the total debris passing a ½-inch sieve (square openings) amounts to 10 per cent of the total weight of the material tested, should be regarded as unsound and should be used only after careful consideration of all factors and with rigorous restriction of the percentage of the finer material initially included" (*93*, p. 9).

The Iowa Engineering Society specifies (*101*, p. 51) that all particles passing through a 1-inch circular opening shall be considered as the portion which fails to meet the requirements of the sodium sulfate test, and that the per cent by weight of particles retained on a sieve having 1-inch circular openings is specified as the sample's rating. Suitable filter stone should have a rating of 85 per cent or better (*101*, p. 51).

In neither the American Society for Testing Materials test nor the Iowa Engineering Society test is a definite size for the test pieces stated; both specify material "of the same size to be used on the work."

No commonly accepted tests to determine the resistance of filter stone to solution are known. The opinion has been expressed, however, that solution "will not be found a serious matter with rock meeting a high rating on the 20-cycle test" (*101* p. 50).

Undesirable materials.—Substances such as pyrite, clay, shale, ocher, and chert are usually undesirable.

Remarks.—Limestone and dolomite are competitive with granite, quartzite, trap rock, slag, and other materials. The type of materials used depends on its availability, price, and the character of the sewage to be treated.

FLAGGING AND CURBING

Use.—Formerly limestone and dolomite were used extensively for flagstone sidewalks and for curbing. Lately the use of concrete has greatly restricted these fields of utilization but flagstone is employed for walks in parks, courtyards, estate grounds, rock gardens, etc. Curbing is a minor use.

General physical specifications.—Flagstone should occur in natural layers a few inches to about six inches in thickness and the surfaces of the respective layers should be relatively even. The stone should withstand severe weather conditions without cracking or splitting and be sufficiently hard to withstand abrasion, especially if to be used for walks. Few limestones or dolomites are hard enough for curbstones; exceptionally, siliceous limestones are so used (*11*).

Undesirable materials.—Chert, pyrite veinlets, clay, and ocherous materials are undesirable as they are likely to cause cracking, splitting, or pitting of the stone.

FLUX

Limestone and dolomite are used as fluxes in the smelting of various metalliferous ores. They combine with impurities in the ore to form a slag which can be separated from the metals.

BLAST-FURNACE FLUX

Use.—Both limestone and dolomite are used for flux in the production of pig iron in blast furnaces.

General chemical specifications.—In either limestone or dolomite the total calcium and magnesium carbonates usually exceeds 90 per cent and often 95 per cent, and the combined silica and alumina are less than 5 per cent and often less than 3 per cent. According to Goudge (*40*, p. 45), alumina should not exceed 2 per cent, sulphur and phosphorus should not exceed 0.1 per cent each. Other authors specify a 0.5 per cent maximum for sulphur (*14*). Flux for the manufacture of iron by the acid Bessemer process should contain less than 0.01 per cent phosphorus (*7*, p. 6).

General physical specifications.—The stone used is clean, coarse, and usually ½ inch to 4 inches in diameter. Some operators use coarser stone (*8*, p. 16). Goudge (*42*) specifies as desirable "a noncrumbly stone between 1½ and 4 inches in size."

Remarks.—If the slag from the smelting operation is to be used for making cement, the magnesia content of the slag should be less than 3 per cent (*65*). A flux low in magnesium carbonate would therefore have to be employed.

The best slag for road metal is said to contain 7 to 10 per cent magnesia (*7*, p. 9).

In describing fluxes the term "available carbonates" is applied to "the percentage of calcium and magnesium carbonates available for fluxing the ore after a sufficient percentage has been deducted to neutralize the impurities in the stone itself" (*7*, p. 4).

BASIC OPEN-HEARTH FLUX

Use.—Limestone is used as a flux in the basic open-hearth process of making steel.

General chemical specifications.—Limestone containing less than 1.5 per cent alumina, 1 per cent silica, and 10 per cent magnesium carbonate (5 per cent magnesia) is used (*7*, p. 12). Goudge says, "Silica should not exceed 3 per cent" (*42*). Phosphorus and sulphur should be low (*40*, p. 45).

General physical specifications.—Specifications call for coarse clean stone in pieces 2 to 12 inches in diameter (*7*, p. 12); a usual size is between 4 and 8 inches (*42*).

Remarks.—High-calcium stone is used rather than dolomite because calcium oxide possesses a greater affinity for phosphorous than does magnesia. Phosphorous is the most important material the flux is required to remove (*7*, p. 12).

NONFERROUS-METAL FLUX

Use.—Limestone is used as a flux in smelting copper, nickel, lead, zinc, gold, silver, antimony, and other metals (*8*, pp. 19-22; *40*, p. 45).

General chemical specifications.—In general, fluxes should be high in carbonate; commonly a high-calcium limestone is employed.

Remarks.—High-calcium lime is used as a chemical reagent in flotation and cyanide refining processes (*40*, p. 45).

GLASS

Use.—Limestone or dolomite is used as part of the mixture employed for making glass.

General chemical specifications.—Either high-calcium limestone, or dolomite, of uniform composition is used. Iron oxide is very undesirable. The U. S. Bureau of Standards divides limestone and dolomite for glass making into three classes, class 1 being the highest grade, and gives the following specifications for limestone and dolomite to be used in making the various classes of glass (*98*).

Table 4.—Composition of Nonvolatile Portion of Limestone, Quicklime or Hydrated Lime

	Class 1		Class 2		Class 3	
	Max.	Min.	Max.	Min.	Max.	Min.
Calcium and magnesium oxides	....	96	....	91	....	83
Ferric oxide	0.2	....	0.4	....	0.8	....
Sulphuric and phosphoric anhydrides	1.0	....	1.0	....	1.0	....
Silica	4.0	....	9.0	....	17.0	....
Alumina	3.0	....	5.0	....	5.0	....

The amount of ferric oxide allowable in limestone or dolomite for class 1 glass, as shown in the above table, is probably higher than would be acceptable to many manufacturers of high-grade glass. Most of them specify a ferric oxide content of less than 0.10 per cent (*88*).

General physical specifications.—The stone should be crushed to pass a 16-mesh sieve having a 1.19 mm. opening (*98*). The preferred grading is as follows (*35*):

	Per cent
On 16 mesh	None
On 30 mesh	15–80*
On 60 mesh	15–50
On 120 mesh	0–15
Through 120 mesh	0–20

* Presumably the per cent "on 30 mesh" refers to the material passing 16 mesh and retained on 30 mesh. The figures for 60 mesh and 120 mesh are probably to be interpreted similarly.

Remarks.—Limestone or dolomite may constitute as much as 30 per cent of some glass batches (*40*, p. 47).

It is essential that a deposit of stone to serve as a source of limestone or dolomite for glass, be of uniform character laterally and vertically in order that a product of constant chemical composition may be produced.

GROUND LIMESTONE OR DOLOMITE

Use.—Ground limestone or dolomite, not necessarily white in color, is used for dusting coal mines to prevent explosions; as rubber filler; as asphalt filler; and as a filler in a number of other products, listed under whiting substitute (p. 43), whose color does not require the use of a white material.

General physical specifications.—Stone free from grit and relatively easy to crush is preferred. Limestone or dolomite for dusing mines is usually pulverized so that about 50 per cent passes a 200-mesh sieve and all of it a 20-mesh sieve. A light colored powder is desired. Usually a relatively pure limestone free from grit is employed (*70*). Limestone or dolomite for asphalt filler in sheet asphalt or bituminous concrete pavements is required to pass a No. 30 sieve, not less than 95 per cent should pass a No. 80 sieve, and not less than 65 per cent should pass a No. 200 sieve (*92*, pp. 21-22). A more finely ground filler is used with asphalt for other purposes. Rubber filler must be so finely ground that at least 98 per cent will pass a 300-mesh sieve (*54*, p. 128).

LIME

Introduction.—Lime is made by burning limestone or dolomite at a temperature which drives off the carbon dioxide. The technology of lime manufacture is complex, and the production of satisfactory lime depends on the chemical properties of the raw stone, its physical characteristics, and on the manner in which it is burned (*104*).

Limes may be divided into two general groups, non-hydraulic limes and hydraulic limes. The latter possess the ability to set under water whereas the former have this property only slightly or not at all. Of the varieties of non-hydraulic lime* (Table 5), the high-calcium and high-magnesium limes are of greatest importance in the United States. Although hydraulic limes are common products in Europe only a limited amount of hydraulic lime is made in this country (*83*).

A classification of limes compiled from several sources is given in Table 5. In this classification the use of 5 per cent as the minimum amount of silica and alumina in hydraulic lime, and the specification that non-hydraulic limes contain over 95 per cent calcium oxide plus magnesium oxide, is based on the statement by Bowles and Banks, in their discussion of non-hydraulic limes, that "commercial limes usually do not contain more than 5 per cent total silica, ferric oxide, and alumina" (*15*, p. 2). Also the American Society for Testing Materials specifies that quicklime for structural purposes should contain more than 95 per cent calcium oxide plus magnesium oxide (*107*). It is important to note, however, that the hydraulic properties of lime are, in large part, dependent on the way in which it is burned (*24*, p. 14), and therefore a chemical analysis may not accurately indicate the extent to which the lime possesses hydraulic properties.

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* In European and some American literature on lime, the terms "fat" or "rich" limes are used to describe limes of high purity and the terms "lean" or "poor" lime for more impure limes which are not hydraulic or only slightly so.

TABLE 5.—CLASSIFICATION OF LIMES [a]

Non-hydraulic limes more than 95% $CaO + MgO$	High-calcium lime more than 90% CaO less than 5% MgO Low-magnesium lime 5–25% MgO High-magnesium lime [b] 25–42% MgO
Hydraulic limes [c] more than 60% $CaO + MgO$ more than 5% $SiO_2 + Al_2O_3$	Feebly hydraulic lime 5–15% $SiO_2 + Al_2O_3$ Moderately hydraulic lime 15–25% $SiO_2 + Al_2O_3$ Eminently hydraulic lime 25–35% $SiO_2 + Al_2O_3$

a The classification of non-hydraulic limes is from Bowles and Banks (*15*, p. 2) and that of hydraulic limes from Cowper (*24*, p. 16). This classification is on a nonvolatile basis. Bowles and Banks state that commercial limes fresh from the kiln "should contain no water and less than 0.5 per cent carbon dioxide."

b Bowles and Banks used 45 per cent as the maximum amount of magnesium oxide in high-magnesium lime. As 42 per cent magnesium oxide is the maximum amount theoretically obtainable from pure dolomite this figure is used.

c Hydraulic limes are made from siliceous or argillaceous limestones (*30*, p. 176) which usually contain less than 10 per cent magnesium carbonate (*52*, p. 17).

The specification of the American Society for Testing Materials covering quicklimes for structural purposes, according to their chemical composition when calculated to a nonvolatile basis, is as follows (*107*):

	Calcium lime *(Per cent)*	Magnesium lime *(Per cent)*
Calcium oxide, minimum	75	
Magnesium oxide, minimum		20
Calcium and magnesium oxides, minimum	95	95
Silica, alumina, and oxides of iron, maximum	5	5
Carbon dioxide, maximum		
(a) if sample is taken at the kiln	3	3
(b) if sample is taken at any other place	10	10

Use.—Lime possesses a great number and wide variety of uses which are enumerated in detail in a chart prepared by the National Lime Association (*66*, p. 110). It is employed in such building materials as mortar, plaster, slag cement, sand-lime brick, stucco, and cold-water paints; it is used in making silica brick; as an aid to crop production and in some stock feeds; it enters into many processes of drug and chemical manufacture; it is widely used in the purification of water and in the treatment of sewage; and it is involved in many commercial processes such as tanning of leather, sugar refining, pulp and paper making, and in the manufacture of bleaching powder and caustic soda.

In general, high-calcium lime is used in most of those processes involving the production of chemicals and also in the construction and many manufacturing industries. High-magnesium lime is used chiefly in the building industry and in certain chemical and commercial manufacturing processes, such as the manufacture of magnesia and in making certain grades of paper (*31*), notably sulphite pulp by the milk-of-lime process. Low-magnesium and hydraulic limes are used mainly in construction.

General chemical specifications.—Most of the limestones burned for lime in the United States contain more than 97 per cent carbonates (*10,* p. 388). The approximate composition of limestone and dolomite for making different types of limes is shown in table 6. The data in this table have been calculated from table 5. The figures given should be considered approximate as it has been assumed of necessity that all materials excepting calcium carbonate and magnesium carbonate would remain in unchanged amounts during the process of lime burning. This is not exactly true. Nor can allowance be made for certain other minor variables. Despite these shortcomings it is felt that the table will indicate in a general way the type of lime which might be produced from a limestone or dolomite of known chemical composition.

TABLE 6.—APPROXIMATE COMPOSITION OF LIMESTONES AND DOLOMITES FOR MAKING DIFFERENT TYPES OF LIMES

Non-hydraulic limes	High-calcium lime	More than 91% $CaCO_3$ Less than 6% $MgCO_3$ Less than 3% other constituents
	Low-magnesium lime	68–95% $CaCO_3$ 5–29% $MgCO_3$ Less than 3% other constituents
	High-magnesium lime	54–72% $CaCO_3$ 28–46% $MgCO_3$ Less than 3% other constituents
Hydraulic limes [a]	Feebly hydraulic lime	91–97% carbonates 3– 9% other constituents [b]
	Moderately hydraulic lime	84–91% carbonates 9–16% other constituents [b]
	Eminently hydraulic lime	77–84% carbonates 16–23% other constituents [b]

a The carbonates are calculated as calcium carbonate, inasmuch as magnesium carbonate is a minor constituent of rocks used for hydraulic lime (30, p. 176).
b Principally silica and alumina.

General physical specifications.—The stone is commonly in 6- to 10-inch pieces if burned in vertical kilns; but if burned in rotary kilns, clean dry stone generally in pieces from ½ to 1½ inches is used (*15,* p. 32).

Remarks.—"Hydrated lime is a fine dry powder, consisting essentially of calcium hydrate and magnesium oxide" (*32,* p. 10). It is prepared by "adding to quicklime just sufficient water to insure complete slaking" (*32,* p. 10).

Vienna lime is a high-magnesium lime used for buffing numerous materials and for giving an "under surface" blue to nickel after plating (*29*). The chemical composition of a dolomite used for making Vienna lime is roughly 55 per cent calcium carbonate, 43 per cent magnesium carbonate, with traces of silica, iron, and alumina (*29*). While the chemical composition of the dolomite from which the lime is made is important, other factors such as texture, porosity, crystallinity, and mode of burning also appear to be significant (*44,* p. 9; 77).

Grappier cements "are made by grinding finely the lumps of unburned and overburned material which remain when a hydraulic lime is slaked. The lumps consist partly of lime silicate and partly of unburned limestone." Lafarge cement is a grappier cement made in France (*30,* p. 189).

Scott's cement, selenitic cement, or selenitic lime "consists essentially of lime (CaO) plus a small percentage of sulphur trioxide (SO_3). The lime used as a basis for this cement is always a more or less hydraulic variety, while the sulphur trioxide may be added to it in the form of either plaster of Paris or sulphuric acid" (*30,* p. 196).

Slag cement is made by finely grinding an intimate mechanical mixture of hydrated lime and granulated slag of suitable chemical composition (*30,* p. 584).

LITHOGRAPHER'S STONE

Very pure uniform fine-grained limestone or dolomitic limestone of exceptionally even texture and free from grit or other granular impurities, at one time was used extensively in the lithographic process of printing. Other materials have now supplanted lithographic stone and it is employed only in small amounts for certain types of high-grade work (*52,* p. 278; *54,* pp. 323-324).

Little, if any, lithographer's stone is now produced in the United States.

MAGNESIUM

The magnesium produced in the United States in 1936 was manufacured from natural brines (*33*). However, in 1929 a plant in Utah is reported to have started extracting magnesium from dolomite; the present status of the plant is not known. The process used was in part secret but involved treatment of dolomite with a hot solution which dissolved magnesium carbonate leaving the calcium carbonate. The leach liquor was clarified and the magnesium recovered electrolytically (*1*).

Magnesium is also reported to be extracted from dolomite in Europe (*41,* p. 374).

MINERAL FEEDS FOR STOCK

Use.—Mineral mixtures containing limestone are fed to stock to provide a diet containing the proper proportion of minerals. Limestone is used to furnish calcium carbonate which is utilized in the building of bone and in other body processes.

General chemical specifications.—A high-calcium limestone containing over 95 per cent calcium carbonate is commonly recommended (*63*). The limestone should be essentially free from fluorine compounds. "The feeding of rations containing approximately 0.03 per cent or more fluorine derived from rock phosphate or sodium flouride impaired growth" and had an undesirable effect on teeth and bone structure of swine (*51*). Likewise small amounts of fluorine have also been found to be detrimental to the health and general condition of dairy animals (*80*).

General physical specifications.—The stone is used in pulverized forms, usually through 200 mesh or finer.

MONUMENTAL STONE

Use.—Limestone or dolomite is used for markers, headstones, monuments, etc.

General physical specifications.—"Usually stone that takes a good polish is requisite; in fact, the very highest types of flawless, uniform stone are used for monumental purposes. However, monuments with tooled, hammered, or even rough-hewn surfaces are not unusual, and less flawless stone may be thus employed" (*10,* p. 25).

MOSAICS

The sale of limestone for mosaics is reported (*23*). The stone is probably used in the form of blocks or chips of special color or texture.

NATURAL CEMENT

Use.—Limestone or dolomite is used for making natural cement for construction purposes.

General chemical specifications.—Natural cement is made from rock containing 13 to 35 per cent clayey material of which silica is 10 to 22 per cent, and alumina and iron oxide 4 to 16 per cent. The remainder of the stone may be either calcium carbonate or calcium and magnesium carbonates in any proportions (*30,* p. 206).

General physical specifications.—The stone is used in pieces of approximately equal size (*30,* p. 218) and probably mostly in relatively large pieces.

Remarks.—Natural cement grades into hydraulic lime but differs from it in not possessing the property of slaking in water (*52* p. 240).

NEUTRALIZATION

Use.—Limestone is used for neutralizing factory effluents, pickling acids, acid mine water, etc. (*52* p. 263). For the last purpose finely pulverized limestone is used (*41* p. 373).

General chemical specifications.—The value of the limestone for neutralizing purposes will vary directly as the calcium carbonate equivalent (see Chemical Specifications under Agricultural Limestone, p. 9).

PAPER

Limestone and dolomite are used in the manufacture of paper by the sulphite, soda, and sulphate processes.

SULPHITE PULP—TOWER SYSTEM

Use.—Limestone or dolomite is used in the sulphite process of pulp manfacture by the Tower System.

General chemical specifications.—Limestones, magnesium limestones, and dolomites containing as much as 8 per cent total alumina, silica, and iron oxide have been used but the less the stone contains of these impurities the better. It is especially desirable that iron oxide be low (*40,* p. 46). In general, rock containing more than 95 per cent calcium carbonate, less than 2½ per cent magnesium carbonate and less than 2½ per cent other impurities is preferred. Mica or graphite flakes, carbonaceous material, and pyrite are very undesirable (*22*).

The United States Bureau of Standards recommends the following specifications for limestone to be used in American paper mills in the manufacture of sulphite pulp (*99*).

Table 7.—Specifications for Limestone and Dolomite for Pulp Manufacture

	High-calcium Stone (Per cent)		High-magnesium Stone (Per cent)	
	Max.	Min.	Max.	Min.
Calcium oxide	....	53.0	....	29.8
Magnesium oxide	1.5	....	....	17.9
Oxides of silicon, iron, and aluminum	1.5	....	1.5	....
Organic matter	0.5	....	0.5	....

The chemical composition of the stone should be uniform, especially the ratio between calcium and magnesium. The impurities present in the stone must be evenly distributed throughout the mass and must not be concentrated in visible strata or nodules which would clog the grates.

General physical specifications.—The stone should be medium to fine grained. Very fine-grained or coarse-grained rocks are avoided; 8 to 14-inch lumps are most desirable (*40*, p. 46). Each piece of limestone should be retained on a 3-inch ring and be small enough to be lifted by one man. The stone should have a density of 150 to 180 pounds per cubic foot (*99*).

Remarks.—The stone is used in the raw state in the Tower system. High-calcium limestone is used in most plants, but dolomite and magnesian limestone are used in making certain grades of pulp (*43*).

SULPHITE PULP—MILK-OF-LIME SYSTEM

Use.—High magnesium lime is used in making sulphite pulp by the milk-of-lime system.

General chemical specifications.—The lime should be made from a pure dolomite essentially free from iron, silica, and dark specks (see Table 7 preceding).

SODA PULP AND SULPHATE PULP

Use.—Lime is used in the soda and sulphate processes of pulp manufacture.

General chemical specifications.—A high-calcium lime containing less than 2 per cent magnesia is desired. Lime having as much as 7 per cent iron oxides, silica, and alumina has been used (*40*, p. 46), but in general the purer the lime the better (*43*).

PHENOL

Use.—Limestone is calcined to give lime and carbon dioxide, both of which are used in the benzene sulfonate method of making synthetic phenol (*71*, p. 563).

General chemical specifications.—A high-calcium limestone as low as possible in magnesia, iron oxide, and alkali metals is required (*69*).

PIPE MANUFACTURE

The sale, or use by the producer, of limestone for pipe manufacture is reported (*23*). No specific data were noted regarding this use but it is believed the use parallels that of lime as a "lubricant and acid neutralizer in the process of steel wire drawing. For this use the lime must be absolutely free from grit" (*40*, p. 45). Either a magnesium or calcium lime may be used (*44*, p. 10).

PLASTIC MAGNESIA

Use.—Plastic magnesia "is a form of caustic magnesia that is adaptable to forming magnesium oxychloride cement when mixed with magnesium chloride solution of the proper consistence" (*68*, p. 2). This cement is also known as "Sorel" or magnesia cement. "Plastic magnesia has been variously known as 'calcined magnesite,' 'caustic burned magnesite,' and 'light burned magnesite'" (*68*, p. 2).

Oxychloride cements are used for flooring, wallboard, and stucco. Caustic calcined magnesite is employed as a chemical accelerator in rubber, as a base for magnesium salts, and for heat insulating materials (*86*).

Remarks.—A considerable amount of promising research has been done (*6, 68*) on means of producing from dolomite a material suitable for making oxychloride or magnesian cements. So far as is known, however, no plastic magnesia is being made from the usual types of dolomite found in the United States. Magnesite is the common raw material. Caustic calcined magnesitic dolomite is produced in Canada from magnesitic dolomite (*91*).

PORTLAND CEMENT

Use.—Limestone is used as a constituent of the raw mix for Portland cement manufacture.

General chemical specifications.—Limestone is used for making Portland cement with or without the addition of shale or clay. Relatively pure limestones require the addition of one part of shale or clay to three or four parts of limestone; impure limestones require less shale or clay and some varieties of limestone known as "cement rock" require the addition of little or no shale or clay. In some places iron blast-furnace slag in which calcium oxide exceeds 30 per cent is used with limestone in making Portland cement (*30*, pp. 320, 322).

The raw mix for making Portland cement should contain "about 75 per cent calcium carbonate and about 20 per cent silica, alumina, and ferric oxide together, the remaining 5 per cent or so containing any magnesia, sulphur, and alkalies that may be present" (*30*, p. 271). Finished cement should not contain over 4 per cent ferric oxide or over 5 per cent magnesia. Most limestones used for Portland cement contain less than 2 per cent magnesium carbonate. Limestones should not contain pyrite in excess of 2 or 3 per cent or over 1 or 1½ per cent total sulphur (*30*, p. 279).

Shale or clay when used in the cement mix should contain roughly 2½ to 4 times as much silica as alumina; ferric oxide should not exceed alumina, and the best proportion is one to three; silica should not be less than 55 per cent and preferably 60 to 70 per cent; alumina and ferric oxide together should not exceed ½ the amount of silica, and the best relation is secured when alumina and ferric oxide equal about one-third the percentage of silica; magnesia should be less than 3 or 4 per cent; sodium oxide and potassium oxide should not exceed 6 per cent, as an excess may cause an unsound or quick-setting cement; nodules of gypsum, pyrite, or calcium carbonate are undesirable if present in quantity (*30*, p. 325; *64*, pp. 60-61).

General physical specifications.—As limestone and shale or clay for making cement must be pulverized to about 100-mesh size before burning, it is desirable that the stone crush and pulverize readily. The limestone should be free from sand or flint; the shale or clay should also be as free as possible from gravel and sand. A content of more than 5 per cent sand (SiO_2) retained on a 100-mesh sieve usually makes a shale or clay unsuited for cement (*64*, p. 61).

Remarks.—In addition to the standard type of Portland cement, the raw materials for which have been briefly described above, a considerable variety of cements, in which limestone is an important constituent, have recently been developed, designed to meet special conditions or needs. Some of these are Portland cements, others are not. The list of such cements includes rapid-hardening Portland cement; quick-setting Portland cement, also known as high-early-strength or high-initial-strength Portland cement; low-heat Portland cement; white Portland cement; Portland-pozzuolan cement, also called blended cement; corrosion-resistant cement; sulphate-resistant cement; high-silica cement; aluminous, high-alumina, or bauxite cement; and high iron oxide or iron-ore cement (*2; 58; 71*, p. 152; *73; 97*).

These various cements are produced by one or more of the following procedures: modification of the composition of standard Portland cement by varying the amounts of its constituent compounds; more thorough mixing of raw materials; finer grinding of raw materials or of the cement clinker; and incorporation during or after grinding of alkali chlorides, natural or artificial pozzuolanas, or possibly other substances.

The limestone used in white Portland cement should be very low in iron compounds.

POULTRY GRIT

Use.—Limestone is fed to poultry to furnish calcium carbonate for the formation of egg shells and bones.

General chemical specifications.—A limestone high in calcium carbonate and low in magnesium carbonate is desired. A limestone containing fluorine in excess of 0.1 per cent (*20*) is undesirable as the fluorine has harmful effects on poultry.

General physical specifications.—Limestone for this purpose usually will pass a 4- or 6-mesh sieve and be retained on a 10-mesh sieve.

Remarks.—Experiments have shown that poultry utilizes crushed limestone and crushed oyster shell with about equal effectiveness (*18*).

PURIFICATION OF COPPER

The sale, or use by the producer, of limestone for the purification of copper is reported (*82*). It is probably used as a flux (see p. 23) or as lime in the refining process, particularly as a "slag-forming material in the electrothermic refining of copper" (*43*).

PURIFICATION OF SULPHURIC ACID

The sale of limestone for use in the purification of sulphuric acid is reported (*82*). No specifications have been found covering this use.

RAILROAD BALLAST

Use.—Limestone or dolomite is used as ballast for railroad tracks.

General physical specifications.—Specifications of various railroads differ. In general, ballast should be crushed to pass a 3-inch screen, should be sufficiently hard to produce a minimum of dust when in service, and well graded so as to give a compact road bed with a well-distributed load-supporting ability and free drainage. The American Railway Engineers Association recommend the following size grading employing round-hole screens: 95 per cent through a 2¾-inch opening, 40 to 50 per cent through a 1¼-inch opening and not more than 5 per cent through a ¾-inch opening. A few roads use stone having a maximum size of 3 inches and a minimum of ½, ¾, or 1 inch (*84*). Ballast should resist weathering well and accelerated-soundness tests or freezing and thawing tests are used for determining this property. Clay, pyrite, and chert are usually undesirable in limestone for ballast if minimum breakage is desired.

The following data taken from the specifications for limestone ballast of the Missouri Pacific Lines (*95*) is believed to indicate the nature of the requirements which ballast used by Class I railroads must meet:

Weight–not less than 168 pounds per cubic foot *

Toughness–more than 10. Test procedure, American Society for Testing Materials Specifications, Serial Designation D-3-18.

Soundness–must pass 5 cycles of the sodium sulphate soundness test without exhibiting checking, cracking, or disintegration. *

Wear–5 per cent or less. Test procedure, American Society for Testing Materials Specifications, Serial Designation D-2-26.

Cementing quality–A maximum cementing value is specified. *

Selection of samples–each stratum of a quarry shall be tested separately.

Averaging–for obtaining the values of physical tests, the average of the results on 5 specimens shall be taken.

Size–stone fragments shall range with fair uniformity between the size which will in any position pass through a 2½-inch ring and the size which will not pass through a ¾-inch ring; 95 per cent should pass a 2¾-inch round-hole screen, and 95 per cent be retained on ¾-inch round-hole screen.*

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* Method of testing specified by the company.

Remarks.—The specifications assembled and modified from time to time by the American Railway Engineers Association indicate the properties of ideal ballast. Actually, however, a wide variety of ballast materials are employed according to the importance of the railroad, the character of traffic it carries, the availability of high-grade ballast, and the financial condition of the railroad. Cinders, chat from lead mines, glacial gravel, chert gravel, crushed igneous rock, slag, limestone, and dolomite are employed depending upon the above factors.

RIPRAP

Use.—Riprap is uncut stone of variable size used for filling around the base of piers, dams, trestles, abutments, and the like. It is also placed promiscuously or laid as a revetment along the banks of water courses and is employed to sink willow mats to control the courses of streams.

General phyical specifications.—Specifications generally are made by the engineer or architect in charge of any specific project. In general, however, the stone should be weather resistant and be free from cracks, laminae, or other structures which will cause it to split or spall.

Undesirable materials.—Pyrite veinlets, clay partings, and chert are undesirable in riprap, as these substances commonly result in the disintegration of stone exposed to the weather. However, in some cases rocks containing one or more of these substances are used because the stone is readily available at low cost.

ROAD STONE

Crushed limestone and dolomite are used in the construction of many types of "rock roads" both as a base course and as a surfacing material. The use of crushed stone as an aggregate in concrete roads is discussed under "Concrete Aggregate" (p. 16).

TRAFFIC-BOUND ROADS

Use.—Crushed limestone and dolomite are used in the construction of roads in which the surfacing material is compacted by traffic.

General physical specifications.—In Illinois (*105*, pp. 322-323) it is specified that crushed stone for the surface course of traffic-bound roads shall have a percentage of wear of not more than 8 per cent. The stone must be uniformly mixed and well graded from the maximum to the minimum size, but it can be of any of three gradations as follows:

Passing	*Per cent* Stone 1	Stone 2	Stone 3
1-inch sieve	95–100		
¾-inch sieve	60–85	95–100	
½-inch sieve	45–75	45–85	95–100
⅜-inch sieve			70–90
No 4 sieve	25–40	25–40	10–20
No. 16 sieve	0–12	0–12	

STABILIZED ROADS

Use.—Stabilized soil roads "may be defined in a general way as road surfaces composed of fine-grained soils, either with or without mineral aggregates, in which sufficient strength has been provided, by any one of several methods, so that they can carry traffic at all seasons of the year without structural failure" (*50*). Mineral aggregates are used in stabilized roads of the graded type in which a mixture of coarse aggregate, fine aggregate, silt, and clay is employed in proportions designed to yield a mat having the minimum of voids (*36*).

General physical specifications.—The specifications of the Illinois Division of Highways (*105*, pp. 152-153) covering the mixture of crushed stone and binder soil for stabilized surfaces are as follows:

The surface course mixture shall consist of a uniformly graded mixture of aggregate and binder soil, supplied individually or in combination, meeting the following composition limits by weight:

Passing	*Per cent*
1-inch sieve	100
¾-inch sieve	80–100
½-inch sieve	65–100
No. 4 sieve	40–60
No. 10 sieve	30–50
No. 40 sieve	18–30
No. 100 sieve	12–20
No. 200 sieve	8–15

The material passing the No. 40 sieve shall have a plasticity index between 6 and 14, but the liquid limit of this fraction shall not exceed 35 per cent. The fraction passing the No. 200 sieve shall not be more than two-thirds of the fraction passing the No. 40 sieve.

It is stated (*37*) that "it is quite likely that the above mentioned specification will be used only for stabilized gravel surface courses in the future and that the following will be added to take care of the use of crushed stone:

If crushed stone is used, the following gradation will be permitted as an alternate:

Passing	*Per cent*
1-inch sieve	100
½-inch sieve	50–90
No. 4 sieve	30–55
No. 10 sieve	25–45
No. 40 sieve	10–30
No. 200 sieve	5–15

The test for plasticity index will not be required if crushed stone meeting the above gradation is used.

In Illinois approximately 8 to 12 per cent binder soil is employed in the construction of stabilized surfaces (*37*).

Remarks.—Deliquescent and water-retentative chemicals such as calcium chloride and sodium chloride have been introduced as supplements in the construction and maintenance of stabilized roads of the graded type (*50*).

Asphaltic emulsions, other bituminous materials, and Portland cement have been introduced as water-insoluble binders for fine-grained or poorly graded soils. Though aggregates may not be essential in roads thus stabilized their use "is advantageous from the standpoint of economy" (*50*).

BITUMINOUS MACADAM ROADS

Use.—Crushed stone is used as an aggregate in bituminous macadam roads. In the construction of the surface course, stone of three gradations is commonly used—a coarse aggregate is rolled, impregnated with hot bituminous binder, an aggregate of intermediate size is applied and rolled, and after a second application of the binder a fine aggregate of stone chips is rolled into the surface.

General physical specifications.—The specifications of the Illinois Division of Highways (*105*, pp. 321-322) require that the stone consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, and free from particles coated with dirt or other objectionable matter. The stone must have a per cent of wear of not more than 6, and a toughness of not less than 6. It shall pass the sodium sulphate accelerated-soundness test, except that aggregates failing in the accelerated-soundness test may be used if they pass a satisfactory freezing and thawing test. It is required that the aggregates be well graded and conform to the following limits:

Passing	*Per cent*
(1) Coarse aggregate:	
2½-inch sieve	95–100
2-inch sieve	25–75
1¼-inch sieve	0–15
(2) Intermediate aggregate:	
1¼-inch sieve	95–100
1-inch sieve	25–75
¾-inch sieve	0–15
No. 4 sieve	0–3
(3) Chips:	
¾-inch sieve	95–100
½-inch sieve	25–75
No. 4 sieve	0–15

WATERBOUND MACADAM ROADS

Use.—Crushed stone is used in the construction of macadam roads of the waterbound type. In building these roads a coarse aggregate of crushed stone is rolled, covered with a fine aggregate of stone screenings, rolled again, the surface saturated with water and rolling continued until a smooth hard surface is produced.

General physical specifications.—Specifications vary but in general stone resistant to abrasion and fracture and one which bonds well is desired for waterbound macadam roads. In Illinois (*105*, p. 320) it is specified that the stone have a percentage of wear of not more than 7. The stone should be well graded, 100 per cent should pass a 3-inch sieve, and not more than 10 per cent should pass a 1½-inch sieve. The stone screenings should be well graded with 100 per cent passing a ¾-inch sieve, 30 to 70 per cent passing a No. 10 sieve, and not over 15 per cent passing a No. 100 sieve. Flat, elongated, soft, or disintegrated pieces are undesirable in macadam road stone.

ROCK WOOL (*55, 56*)

Use.—Impure limestones or dolomites are used for making rock wool. In the common method of manufacture the rock is melted in a cupola and, upon issuing in the molten state, is atomized by a jet of steam into numerous fine threads which accumulate as a mass resembling sheep's wool. Rock wool is used for heat and sound insulation.

General chemical specifications.—Limestones or dolomites for making rock wool, often called "woolrocks," should contain roughly between 20 and 30 per cent carbon dioxide, which is equivalent to approximately 45 to 65 per cent calcium carbonate, or calcium carbonate and magnesium carbonate. The balance of the woolrock should be principally silica, or silica and alumina. Magnesium carbonate is not necessary in woolrocks although some operators prefer it. The same applies to alumina. Iron sulphide is undesirable (*34*).

General physical specifications.—The size of the rock used depends in a large measure on several variables involved in the operation of the cupola. In general, it is desirable that the stone be broken into as small pieces as can be used without restricting the blast through the cupola to a point of inefficiency; from 2 to 5 inches is probably the most common size.

Remarks.—Rock wool can be made from mixtures of limestone or dolomite with shale, sandstone, or other siliceous or aluminous rocks. The mixture should meet the chemical and physical specifications given above.

A woolrock in which the noncalcareous constituents occur in small particles well distributed through the rock mass, rather than in large masses, is preferable because such an intimate mixture facilitates melting.

Rock wool is one member of a general class of materials known as mineral wool. The other members are slag wool and glass silk or wool.

SALT REFINING

In one method of purifying salt (sodium chloride) brines, lime is used together with other chemicals to precipitate calcium and magnesium salts. Another method involves electrolyzing a brine and blowing carbon dioxide through it. Carbonates are thus formed which are removed by filtration (*72*, p. 195). Either the lime or the carbon dioxide so employed may be made from limestone. Probably high-calcium limestone is used for making the lime.

SOAP

Use.—The sale of limestone for "the purification of soap" is reported (*82*). It is probably converted to lime.

Lime is used as a precipitating agent in the purification of soap and may be employed as a neutralizing agent (*43*). Lime is also used in the process for making glycerine from animal and vegetable fats. This process also yields lime soaps which may be used in making lubricants or greases or may be treated with sulphuric acid and the fatty acids recovered for use in the manufacture of soap (*32*, p. 23).

General chemical specifications.—The lime whose use is described above should be a high-grade high-calcium lime. "It should contain less than 2 per cent magnesia and less than 1 per cent insoluble material and the available lime content of quicklime or the available calcium hydroxide content of hydrated lime should be at least 90 per cent" (*15*, p. 19). On the basis of the first two items, limestone from which such lime could be made would have approximately the following composition: more than 98 per cent calcium carbonate, less than 1.2 per cent magnesium carbonate, and less than 0.6 per cent insoluble material.

STONE CHIPS FOR STUCCO, TERRAZZO, ROOFING, CONCRETE FACING, AND ARTIFICIAL STONE

Use.—Limestone and dolomite chips are used for stucco; as the aggregate in terrazzo; as roofing "gravel"; for facing concrete or concrete blocks to give them a special finish; and as facing for or aggregate in artificial stone.

General physical specifications.—The stone chips probably should be clean and free from dust, pyrite, soft particles, and shale. Common sizes are believed to be between ¼ and ½ inch. Coarser chips may be used in terrazzo and artificial stone and finer chips for facing purposes. The chips, especially those to be used for roofing, should have good weather resistance. An attractive color is essential for all uses except possibly for roofing "gravel."

Remarks.—Limestone and dolomite are competitive with other materials for purposes listed.

STONE SAND

Use.—"'Stone sand' is the term now used to designate the fine, granular material (usually less than ¼ inch in diameter) prepared by crushing rock, screening it to the proper gradation, and removing excess dust by washing or other means. Stone sand is well suited for any purpose for which natural sand is used and is an ideal material for concrete products manufacture" (*39*, p. 1). Limestone and dolomite are used for stone sand.

General physical specifications.—A number of specifications for stone sand have been published (*28*; *38*; *39*, p. 35). The National Crushed Stone Association (*39*, pp. 36-37) recently has suggested specifications for stone sand which are in part reproduced below:

General Characteristics:

The stone sand shall consist of clean, hard, durable particles of rock produced from a deposit of satisfactory quality. It shall be especially prepared by crushing and screening operations and by the removal of excess dust. This specification shall not be construed as including unprepared stone screenings.

Quality of Rock:

When tested in the standard Deval Abrasion Test, the rock shall have a percentage of wear of not more than 6.0 per cent.

Note: It is not intended to exclude rock of softer quality provided concrete tests and service records show such rock to be satisfactory.

Deleterious Substances:

The amounts of deleterious substances shall not exceed the following permissible limits:

Deleterious Substance	Recommended Permissible Limits *Per cent by weight*	Maximum Permissible Limits *Per cent by weight*
Material finer than No. 200 sieve		
(a) Concrete subject to abrasion	3	4
(b) All other structures..	4	5
Shale, mica, coated grains, soft or flaky particles..........	3	5
Total of all deleterious substances	3	5

Gradation:

Stone sand shall be well graded from coarse to fine and when tested by means of laboratory sieves shall conform to the following requirements:

Sieve	Total Passing *Per cent by weight*
⅜ in.	100
4 mesh	95–100
8 mesh	85–100
16 mesh	50–75
50 mesh	5–25
100 mesh	3–10

Soundness:

The fine aggregate when subjected to five alternations of the sodium sulfate soundness test shall conform to the following requirements:

	Recommended Permissible Limit *Per cent*	Maximum Permissible Limit *Per cent*
Average weighted loss, not more than	12	15

Besides these specifications the Association suggests that stone sand should pass tests for uniformity, organic impurities, and mortar strength.

Bowles states (*12*) that stone sand prepared in sizes ranging from ⅛ to 3/16 inch rather than ⅜ inch promotes better workability of concrete.

Remarks.—Methods of preparing stone sand have been discussed by several writers (*28; 39,* p. 1; *76*).

STUDIO SNOW

The sale of limestone for studio snow, probably for use in motion picture studios, is reported (*23*). Pulverized limestone or limestone granules are probably used for this purpose.

SUGAR

Use.—Limestone is used in refining beet sugar by the carbonation process. The limestone is burned to lime at the refinery and both the lime and carbon dioxide gas are used (*40,* p. 47).

General chemical specifications.—Goudge specifies "a particularly pure limestone having less than 1 per cent silica and less than 1 per cent magnesia." Iron oxide is undesirable (*40,* p. 47). Turner gives 97 per cent calcium carbonate as the minimum acceptable (*85*). Calcium sulphate, silica, and magnesia are said to be particularly objectionable (*26, 85*).

General physical specifications.—Goudge specifies 2- to 6-inch pieces (*40,* p. 47); Turner 6- to 8-inch pieces (*85*).

Remarks.—Ground lime is used in the Steffen process to precipitate sugar from impure molasses, and milk of lime is employed "in clarifying and purifying juice extracted from either beets or cane to be used in the manufacture of sugar" (*15,* p. 18). Manufacturers of cane sugar buy their lime (*15,* p. 18). A limestone of purity similar to that utilized in the manufacture of beet sugar by the carbonation process is employed to make the lime used in sugar refining by the defecation process (*40,* p. 47). The U. S. Bureau of Standards specifies (*100*) that limestone for the Steffen process should contain a minimum of 90 per cent sugar-soluble lime and not more than 3 per cent magnesium oxide, when the results of chemical analysis are calculated to a nonvolatile basis. On the same basis, limestone for other sugar-refining processes should contain a minimum of 85 per cent sugar soluble lime and not more than 3 per cent magnesium oxide.

TECHNICAL CARBONATE

Use.—Dolomite is used for making technical carbonate which is employed for general heat insulation, especially pipe and boiler coverings, in pharmaceutical products, and in certain paints and varnishes (*44,* p. 5.)

General chemical specifications.—A dolomite high in magnesium carbonate and high in total carbonates is used. Dolomite containing 40 to 45 per cent magnesium carbonate is used in Pennsylvania. Silica should preferably be less than 1 per cent (*66,* p. 99).

General physical specifications.—Coarse stone, 8 to 12 inches in diameter, is specified (*66,* p. 99).

Remarks.—The Pattinson process or some modification thereof is used in England and the eastern part of the United States for separating the calcium and magnesium carbonates of dolomite (*44*, p. 5). The process as described by the Magnesia Association of America (*54*, p. 205; *66*, p. 100) involves in brief: burning of the dolomite; slaking with water; saturation with carbon dioxide, thus precipitating calcium carbonate and leaving the magnesium in solution as the bicarbonate; the calcium carbonate is filtered off; and the magnesium bicarbonate liquor boiled, thereby causing the precipitation of basic hydrated magnesium carbonate ($4MgCO_3.Mg(OH)_2. 5H_2O$). This material is known as "technical carbonate," "basic magnesium carbonate," "light magnesium carbonate," "block magnesia," "magnesia alba," or "magnesia alba levis." Technical carbonate mixed with asbestos fibres and molded into various shapes is known as "85 per cent magnesia" and is widely used as an insulating material (*52*, p. 239).

Another process for separating magnesia from magnesian (magnesium) limestone or dolomite, which is said to have been used in a German plant, is known as the Scheibler process and consists of treating burned magnesian (magnesium) limestone or dolomite with water and adding molasses which produces a saccharate of lime. This is soluble and is removed from the magnesium hydroxide by filtration (*30*, p. 158).

Several other processes have been proposed for separating the carbonates of dolomite (*30*, p. 159; *52*, pp. 206-207; *96*).

WHITING SUBSTITUTE*

Introduction.—The four principal commercial types of finely divided calcium carbonate are whiting, whiting substitute, precipitated chalk, and by-product precipitated chalk. Whiting is made by the mechanical reduction of lump chalk; whiting substitute by the fine-grinding of limestone, marble, or calcite; precipitated chalk from chalk or high-calcium limestone by a carefully controlled process involving calcination of the raw material, hydration of the resulting lime, screening or other treatment to remove undissolved or insoluble particles, and recarbonation to yield calcium carbonate; and by-product precipitated chalk as a by-product in certain chemical operations, principally the soda-ash lime process of caustic soda manufacture (*106*). Dolomite is also used for making whiting substitute but to a less extent than pure limestone, calcite, or marble (*54*, p. 201).

Uses.—Whiting and whiting substitute have numerous uses. The latter "may be employed in most of the applications for which whiting is used, but for some uses substitutes have not been satisfactory" (*9*, p. 7). Below are listed uses for whiting or whiting substitute (*9*, pp. 7-8; *54*, p. 130).

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* See also "Ground Limestone or Dolomite" (p. 25).

Used as a constituent of:

- Calcimine and cold water paints
- Paints (inert extender)
- Putty
- Ceramic glazes, enamels, and bodies
- Cigarette papers
- White ink
- Dressing for white shoes
- Picture frame moldings
- Dolls
- Wire insulation
- Dyes
- Tooth paste
- Fireworks

Used as a filler in:

- Rubber
- Oilcloth
- Window shades
- Linoleum
- Asphalt (may be off color whiting)
- Magazines and book papers (precipitated calcium carbonate) (*41*, p. 374.)

Used for:

- Compounding rubber goods (footwear, heels, hard rubber objects, white rubber stock, molded rubber goods, sponge rubber, hose, belts, mats, and electric cable insulation) (*41*, p. 374.)
- Facing molds and cores in brass casting
- A coating on glazed paper
- Neutralizing in fermentation processes
- Making buff brick from red-burning clay (*41*, p. 373)
- Dusting unburned brick to prevent sticking in the kiln (*89*)

Used in:

- Metal polish
- Manufacture of citric acid (*52*, p. 269)

Used in the following industries:

- Structural iron
- Shipbuilding
- Locomotive works
- File manufacture
- Explosives
- Medicines
- Leather
- Printing and engraving
- Shoe manufacturing
- Roofing cement
- Chemical manufacture

General specifications.—No attempt is made here to give detailed specifications for the uses of whiting and whiting substitute for the reasons that specifications vary and, until recently at least, no entirely satisfactory chemical, physical, or microscopic tests have been devised for the valuation of whiting and whiting substitute for all their various uses (*54*, p. 128). In most cases the suitability of whiting substitute for a given use is best determined by submitting it to the prospective consumer for those tests which he has found diagnostic for the material he requires.

Remarks.—A detailed report discussing the occurrence, properties, and preparation of limestone and chalk for whiting has been issued by the United States Bureau of Mines (*90*).

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