Triangle Mesh Wire Reinforced Concrete Pavements and Roadways

American Steel & Wire Company

Triangle Mesh Wire Reinforced Concrete

Pavements and Roadways

American Steel & Wire Company

SALES OFFICES

CHICAGO	72 West Adams Street
NEW YORK	30 Church Street
WORCESTER	94 Grove Street
BOSTON	120 Franklin Street
CLEVELAND	Western Reserve Building
PITTSBURGH	Frick Building
BUFFALO	337 Washington Street
DETROIT	Foot of First Street
CINCINNATI	Union Trust Building
ST. LOUIS	3rd National Bank Building
ST. PAUL-MINNEAPOLIS	Pioneer Building, St. Paul
OKLAHOMA CITY	State National Bank Building
DENVER	1st National Bank Building
SALT LAKE CITY	Walker Bank Building

United States Steel Products Company

Export Department,	NEW YORK	30 Church Street
Pacific Coast Department,	SAN FRANCISCO	Rialto Building
	PORTLAND	Sixth and Alder Streets
	SEATTLE	4th Ave. So. and Conn. Street
	LOS ANGELES	Jackson and Central Aves

Triangle Mesh Wire Reinforced Concrete Pavements and Roadways

---

In presenting this booklet on Reinforced Concrete Pavements, it is our object to supply information on this new but rapidly increasing form of construction that will be of assistance to consulting engineers, contractors, municipal authorities and taxpayers alike.

Although much has been said in engineering magazines, reports of committees, etc., about the advantages of concrete pavements over other types, up to the present time very little information has been published covering the use of a reinforcement which is the only sure preventive of cracks and most necessary to insure durability and wear.

We, therefore, in addition to reviewing the requirements of an "ideal pavement" and comparing concrete with other types, have collected data on methods and costs of the construction of existing reinforced concrete pavements and have made such recommendations covering the concrete mixture, thickness, finish, expansion joints, reinforcement, etc., as in our judgment, assisted by the results of actual construction, we believe to be the proper solution of the various problems involved. These recommendations are summarized on pages 81 to 86 in the form of a typical specification which may be used as a guide.

Triangle Mesh Woven Wire Reinforcement has demonstrated its superiority over all other forms of reinforcement for concrete pavements as well as floor, wall and roof slabs and is now adopted by many municipalities as their standard reinforcement for concrete pavements. This material is manufactured from cold drawn steel wire, having an ultimate breaking strength of at least 85,000 pounds per square inch, and consists of either solid or stranded longitudinal members, properly spaced by means of diagonal cross wires so arranged as to form a series of triangles between the longitudinal or tension members; the longitudinal members being invariably spaced four inches apart, the cross wires either two inches or four inches apart, as desired, providing either a 2-inch or 4-inch mesh. The sizes of both longitudinals and cross wires are varied in order to provide the cross sectional areas of steel required to meet the conditions.

The best results are obtained by a close and uniform spacing of all steel members, a requirement properly taken care of by the use of TRIANGLE MESH REINFORCEMENT having the correct spacing of the cross as well as the longitudinal wires. Tables giving the weights of fabric per 100 square feet, number, sizes, spacing and areas of wires and longitudinal strands are given on pages 90 and 91, and the number of square feet contained in the various sizes of rolls is shown on page 92.

History

The subject of the proper improvement and maintenance of roads and streets, is, to a certain extent, of ancient origin. For centuries prior to the birth of Christ, ancients realized the possible advantages of paved thoroughfares connecting districts that could not be reached by water.

Extensive systems of military roads radiating from Rome were constructed for the purpose of acquiring and maintaining new territorial conquests.

The most important of these paved military roads was called "Appian Way," the construction of which was started about 312 B. C. This road, having a length of about 360 miles, consisted of a central portion used for military purposes and two outer portions for horses and carriages. The outer sections were at a lower level than the center and separated from it by stone curbs. The center section was about 3 feet thick and consisted of two courses of flat stones laid in lime mortar, over which was placed a layer of rubble stone. On this was laid gravel mixed with lime forming the bed for the wearing course of stone blocks. The outer sections made use of the two lower courses only with a finished surface of the gravel concrete.

The early French roads made use of several layers of flat stones for a foundation. A layer of smaller stone was then placed and the surface finished with smaller stone. The total thickness was 18 inches at the center and 12 inches at the sides. This form later gave way to a section having a uniform thickness of about 12 inches and having a sufficiently rounded surface to allow of proper drainage. The macadam type of pavement was officially adopted about 1830. The advantage claimed for this type was a more compact and durable mass secured by using angular broken stones instead of the round pebble type previously employed.

The opinion of the early Romans regarding the importance of paved thoroughfares is very well shown by their construction of the old Roman roads in England prior to A.D. 43. In addition to main trunk lines running from north to south and east to west a large number of branch roads were constructed radiating from these main lines. These roads were the only means of communication with the interior for a considerable period after the occupation of Britain by the Romans, but were later allowed to go to ruin and have never been entirely reclaimed.

The history of the United States shows that during the first half century after its establishment, the national government took a very active interest in constructing and maintaining its public roads. They early realized the necessity of and advantages produced by decreasing as far as possible, the difficulties of travel. During the first half century the government appropriated several millions of dollars for the construction and maintenance of public roads. A large amount of private capital was expended for the purpose of constructing and maintaining private thoroughfares known as "turn-pikes" for which a certain charge was made to the users. The "pikes" usually consisted of either gravel, plank or log surfaces. Then came the advent of the railroads and the government turned its attention to their construction, aiding them by land grants and loans to construct thousands of miles of our original railroad systems. All large cities have to a greater or less extent, realized the absolute necessity of properly constructing and maintaining their streets, but it is only the last few years that townships, counties, states and the federal government have taken up the subject of paved roads to a very marked degree.

A bill has recently been proposed in the House of Representatives providing for the construction of an ocean to ocean "National Old Trails Road" which is to include several famous highways of the early days. The bill provides for a 60-foot highway, the cost to be equally divided between state and federal governments. Another bill introduced asks for the creation of a "General Highway Foundation" to be headed by the President; the purpose of the foundation being to co-ordinate the development of highways throughout the country.

The United States Office of Public Roads has issued a report which is believed to cover all roads built in the United States up to 1909. According to this report, there was at that time in the United States, 2,199,645 miles of which 8.66 per cent were improved. Of these improved roads, 2.7 per cent were of stone, 4.7 per cent gravel, and 1.3 per cent bituminous, macadam, asphalt, brick, etc.

During the year 1910, state aid and state construction located 4,278 miles of improvement, this work varying from mere grading to bituminous macadam, brick and concrete pavements, the total cost being approximately $17,000,000. The State of New York* has been recently bonded for $50,000,000 for highway improvement covering 11,000 miles of country and state roads. Data obtained directly from officials of the various states, in the year of 1911 shows that for the forty-nine states and territories, thirteen neither give aid nor exercise any control over any roads; two give services of convicts; one gives convict broken stone; five give engineering services or advice; twenty-eight give more or less direct aid. In addition, are hundreds of miles of roads improved by

*An additional $50,000,000 was appropriated in 1912.

county appropriations; millions of dollars are spent annually by cities; private fortunes are being appropriated and even the railroads now realize the advantages to the farmers and manufacturers, and therefore to themselves, in having roads which are at all seasons of the year easily accessible.

Automobile clubs and associations have become especially active in the nation-wide campaign for State and Federal improved highways. In fact, the first cost and maintenance of our roads and streets has become of such magnitude, that merely as a financial question, pavements deserve most careful attention and study. In this connection we deem it advisable and appropriate to give herewith, a review of the advantages of pavements together with the various points which must be considered in order to arrive at a correct selection of the most advantageous type of pavement.

Advantage

The main purpose of a pavement is the distribution of pressure over a greater area and thereby decreasing the tractive power required. This applies equally to street and country roads, the only difference being the smaller tonnage hauled in the latter case. Decreasing the tractive power decreases the cost of marketing produce or manufactured articles.

Authorities differ in the cost of hauling a ton per mile on paved and unpaved roads. However, in Europe, it is quite generally conceded that the cost is 8 cents per ton per mile on good paved roads, while the average cost in the United States on the average country road is 23 cents per ton per mile.

Several years ago, an estimate was made in Indiana of the work required to haul loads over various types of road surfaces and on that basis, the estimated cost per ton mile to haul goods was as follows:

Asphalt	2.7 cents
Block pavement	5.3 cents
Good macadam	8.0 cents
Gravel road	8.8 cents
Earth, hard and dry	18.0 cents
Macadam with ruts	26.0 cents
Wet sand	32.0 cents
Earth roads, ruts and mud	39.0 cents
Dry sand	64.0 cents

While the above estimate will undoubtedly vary in different localities, it is safe to assume that the percentage of difference for the various types of roads will remain practically constant.

Considering the fact that large areas of the United States will have muddy roads for at least three months during the year, and half of that time these are practically impassable, the economy of the paved road is very apparent.

Some argue that during the seasons of bad roads the farmers are seldom required to haul their produce to the market and, therefore, the improved roads would be used for pleasure purposes only. This idea is opposed by the claim that the farmers are obliged to haul their produce during the season of good roads and thereby often congesting the market. This produces a decrease in the market price and is conducive to wastefulness on the part of the consumer. On the contrary, if the roads are in good condition for the entire year, there will be a better balance between supply and demand, and other conditions being equal, the producers as well as the consumers receive the benefits of the better average prices.

The very rapid advance in the use of autos for heavy trucking as well as pleasure, necessitates in practically all cases, an improvement in road conditions. In this connection, it is well to sound a warning here, and this warning is well justified by recent experience, that what were once considered good roads under team traffic, will require in the very near future, and in fact are now requiring reconstruction because of the severe wear produced by heavy truck as well as light automobile traffic. Many are freely predicting that at no distant date, where roads will permit, long as well as short hauls of farm produce and manufacturers' products will be made with auto-trucks. In fact, there are now many manufacturers, especially in the East, who are hauling their goods many miles to market by this means in competition with good railroad facilities. The main reason being a better and earlier delivery to their customers, and in many cases, an economy to themselves.

Another advantage which applies principally to city streets lies in better sanitary conditions. Dust, mud, and other refuse, very often of an unhealthful nature are less liable to collect on a well-paved street, thereby greatly improving the sanitary conditions.

Requirements of an Ideal Pavement

The pavement classed as "ideal" in one locality may or may not constitute the ideal pavement in another. However, the general requirements will be the same in either case but with a differing valuation or importance attached to the various classifications. In other words, in one community, low first cost, durability, and low maintenance charge, may be the governing factors; in other cases, low tractive resistance and non-slipperiness may be of more importance; while in still other cases the favorableness of good sanitary conditions may far outweigh all other considerations.

The main points to be considered when selecting a pavement for any particular locality are as follows:

(1) Original cost.
(2) Durability.
(3) Maintenance.
(4) Tractive resistance.
(5) Foothold.
(6) Sanitary qualities, including cleanliness and noiselessness.
(7) Favorableness to traffic.

Various authorities have assigned values to these qualities and while these values will vary under different conditions of use, etc., they will give a working basis for comparison.

The following Table No. 1 shows values assigned by a bulletin of the U. S. Forestry Service compiled from opinions from engineers of a number of American Cities, also values assigned by I. O. Baker and G. W. Tillson in their books on Roads and Pavements.

Table No. 1

Relative Values of the Various Qualities of an Ideal Pavement

QUALITY	U. S. Bulletin*	Tillson†	Baker‡
Cheapness—First Cost	14	14	15
Durability	20	21	......
Ease of Maintenance	10	10	20
Ease of Cleaning	14	15	10
Low Tractive Resistance	14	15	10
Non-slipperiness	7	7	5
Favorableness to Travel	4	5	......
Acceptability	4	......	15
Sanitary Quality	13	13	25
TOTAL	100	100	100

*U. S. Forestry Service. Department of Agriculture. Circular 141.
†See G. W. Tillson's "Street Pavement and Paving Material."
‡See I. O. Baker's "Roads and Pavements."

It is interesting to note that the values assigned by the U. S. Bulletin and Mr. Tillson are practically identical; a considerable variation being given, however, by Mr. Baker. It is quite evident that the first two authorities had in mind, a pavement that was to be used for all classes of traffic including heavy drayage, while it would appear that Mr. Baker considered a residence type of pavement. His value for first cost is practically the same as is given by the other two, but the quality of durability has been omitted with the exception of the increased value given to ease of maintenance.

Low tractive resistance and non-slipperiness are assigned a lesser value, while acceptability and sanitary qualities are given a very much higher value as would naturally be expected if residence streets are under consideration.

Original Cost In the majority of cases, first cost has undoubtedly governed the selection of the type of pavement used. In the case of cities, it is the usual custom to charge all or at least the greater portion of the original cost to the abutting property owners, with the maintenance and in many cases, reconstruction being paid by the city; therefore, the pavement of low first cost secures the approval of property owners which naturally also greatly influences the reports of those whose duty it is to recommend the type of pavement to use.

In the case of country highways, low first cost and maintenance are of prime importance, the sanitary conditions and favorableness to travel and in some cases, durability being a minor consideration.

Durability For street pavements, the subject of durability undoubtedly has secured careful consideration. However, there are thousands of city streets in every state in the union whose present condition clearly shows that this requirement has been over-shadowed by the point of low first cost. With the advent of automobile traffic, the question of durability has become to be of prime importance. Paved streets and roads that a few years ago showed comparatively long life under the ordinary wheel traffic are fast going to pieces from the action of automobiles. Pavements laid on poor sub-soil or with insufficient thickness or both, cannot possibly remain in good condition under the excessive loads now being hauled by auto trucks. This same class of traffic and even the lighter pleasure cars will very rapidly disintegrate road surfaces that are not so constructed as to have a very high binding quality. Many authorities state that this disintegration by the lighter and fast-moving automobiles is caused by suction produced by the rapidly moving wheels. While this may be true to a certain extent, it is more likely caused by a pull at the point of contact of the wheel with the pavement, having a direction tangential to the wheel at that point, or in other words, parallel to the average surface of the pavement. This would mean that the rapid change of speed of the auto either increasing or decreasing, exerts a very high pull on the pavement, the disintegration being more rapid after a break is once started.

The heavier types of machines travelling at a high rate of speed, will also produce an excessive hammering upon any points of irregularity of pavement surfaces. On those streets where speed is limited and the traffic is heavy such as those in wholesale and manufacturing districts, the destruction is caused by iron shod wheels under heavy loads and the abrasion, due to horses' feet, assuming the pavement to have sufficient thickness to prevent breaks due to the heavy concentrated loads.

Climatic conditions are in many cases, responsible for the lack of durability. Asphalt pavements during hot weather very often form into waves due to the pushing tendencies of vehicles when passing over the softened surface. Very often these waves will increase in height until the binding course is entirely exposed. Pavements having a hard and non-elastic surface will, under excessive change of temperature, expand or contract to a very marked extent. This will cause a heaving of the pavements due to expansion and the formation of more or less unsightly cracks due to contraction. These cracks also produce a condition of the pavement which allows the same to be more easily attacked by the abrasion of wheels and horses' feet. This difficulty may be more or less eliminated by properly constructed expansion joints.

Maintenance The subject of maintenance is one too often overlooked when considering the prospective type of pavement. For residence streets and country roads carrying light traffic, maintenance charge is made up principally of the item of cleaning which in cases of macadam, or other dust producing surfaces, may prove to be of considerable expense. But even here, the cost of repairs should be taken into consideration as in some classes of pavements, the effect of the excessive changes of temperature together with other weathering influences, are liable to cause more or less rapid deterioration. In the cases of streets and roads carrying heavy traffic, or those used by even light automobiles at comparatively high speed, the annual charge for repairs should be a governing factor in the selection of pavement. Naturally the ideal pavement in so far as maintenance applies, would be one whose yearly charge is practically nothing for at least two-thirds of the average life of the pavement.

Ease of repairs should also be considered, and when these are completed, the surface should be left in as good condition as it was originally.

Tractive Resistance The ideal pavement in so far as tractive resistance applies, is one having a smooth hard surface free from bumps or hollows that would make the hauling of loads difficult. Traffic resistance requires special attention when comparing the economical advantage of a paved over even a well kept dirt surface as will be noticed by referring to values assigned to tractive resistance given on page 6.

Roads that during the dry seasons of the year show a low tractive resistance will often become impassable during the rainy seasons. This condition prevents a uniform movement of all products, over-crowding the markets at times and producing a scarcity at other times.

Foothold The subject of foothold or non-slipperiness should receive consideration on all classes of pavements, whether the same be used for light pleasure vehicles or for heavy hauling. The ideal pavement should not be slippery for autos or horses under all degrees of dampness of the paved surface.

Sanitary Qualities This subject applies principally to city streets and should receive careful consideration, as the healthfulness of the inhabitants is of vital importance. The pavement should be easily cleaned and should not absorb moisture or refuse liquids of any kind. It should not produce dust, which laden with dangerous germs, may become lodged in food, clothing or the home. It should also be noiseless, as the effect of the constant rattle of iron clad wheels or horses' shoes, is very detrimental to the nervous system. It should be pleasing in appearance, thus adding to the benefit of the general public, produced by proper surroundings.

Favorableness to Traffic The pavement should be smooth, thus eliminating any jar to the occupants of vehicles, this being especially applicable for those streets and roads used principally for pleasure.

Freedom from dust may be included under this heading also. Dusty country roads may not be unsanitary, but would certainly be classed as unfavorable to the traveller.

Concrete Compared with other Types of Pavements

The U. S. Department of Labor Bulletin No. 36, Statistics of Cities, September, 1901, shows that for 135 cities in the United States having a population of 30,000 or over, 45 per cent of the paved streets are gravel or macadam. Later statistics show a marked decrease in these types and an increase in the harder, more durable surfaces.

The *Municipal Journal*, dated March 1, 1912, publishes a very complete report of pavements laid in the year of 1911, as compiled from information received from 526 cities in the United States. Of the number of cities reported by the United States census as having a population of more than 30,000, 52 per cent are represented in the report, and practically the same percentage for the smaller cities. This report shows that approximately 30,000,000 square yards of pavement were laid, the percentage of the various types being as follows:

Sheet asphalt	24¼ per cent
Brick	21½ per cent
Plain macadam	14 per cent
Bitulithic	9⅔ per cent
Bitulithic macadam	5¾ per cent
Gravel	5⅔ per cent
Wood block	5½ per cent
Concrete	4¾ per cent
Stone block	3½ per cent

Small amounts of bituminous concrete and asphalt block.

Information received from 334 cities giving the estimates of work to be done during 1912, shows the various types take the following order depending on the amount of each to be laid:

Brick,
Asphalt,
Macadam,
Bitulithic macadam,
Concrete,
Wood block.
Stone block,
Bitulithic,
Gravel,
Bitulithic concrete,
Asphalt block,

Although the estimate of proposed pavements for 1912 is not complete, it is interesting to note the increase in the use of pavements having a hard smooth surface, in comparison with those reported for 1911. Brick and asphalt have changed places; concrete has gone ahead of wood block, and both of the latter have moved ahead of the bitulithic and gravel.

Costs

Note.—For detailed cost of reinforced concrete pavements, see pages 38 to 62.

The first cost of the different types of pavements will vary in different localities, depending upon the condition of the natural foundation, the location of the source of supply of the various materials to be used, labor conditions, specifications, methods of payment, etc. However, there is sufficient cost data available to determine in a general way a comparison of the costs of the various types of pavements.

During the year 1911, Montezano, Wash., laid brick pavements on a 5-inch concrete base at a cost of $3.15 per square yard; asphalt on a 5-inch concrete base at a cost of $2.18 per square yard; while a 6-inch concrete pavement was laid for $1.27 per square yard on alleys, and $1.32 per square yard on streets. Screened river gravel cost $1.50 per cubic yard and labor from $2.00 to $3.00 a day.

Mason City, Iowa, laid during the years 1909-10 approximately 30,000 square yards of concrete pavements having a thickness of 7 inches, at a contract price of $1.26 per square yard. During the year 1909, a brick pavement on concrete base cost $2.80, and wood block on concrete base, $2.20 per square yard.

In Denver, Colo., 6-inch concrete alley pavements have been laid at a cost averaging from $1.08 to $1.27 per square yard. During the same period, the average cost for asphalt pavements was approximately $3.47.

In Richmond, Ind., in 1908 a small amount of concrete pavement having a total thickness of 6½ inches was laid at a contract price of $1.06, while the lowest price for brick pavement was $2.00 per square yard.

During the years 1906-7 there was laid in Panama two miles of concrete pavement at a cost of $2.00 per square yard, as against a price of $4.00 for brick.

Comparative prices of various types of pavements in Summerville, Mass., show the following:

Concrete pavements laid under the Hassam patents	$1.65 per sq. yd.
Granite block, about	2.35 per sq. yd.
Asphalt	3.80 per sq. yd.
Vitrified brick	2.75 per sq. yd.

In Toronto, Canada, a 6½-inch concrete pavement was laid in 1903 at a cost of $1.74; and in 1904, $1.92 (which included a gravel and 2-inch tile drain); while asphalt bitulithic pavements average $2.25; vitrified brick, $2.25 to $2.55; granite block, $3.50.

A concrete pavement laid in accordance with the Blome patent was constructed in Chicago in 1905 for the Western Electric Company at a cost varying from $1.80 to $2.20, which included in some cases a heavy fill. The same type of pavement was laid for Armour & Company at the Union Stock Yards at a cost of $1.75 per square yard. In the year 1909 another pavement of the same type was laid on Emerald Avenue between Seventy-Third and Seventy-Fifth Streets, at the contract price

Table No. 2

Comparative Costs of Various Types of Pavements

LOCATION	YEAR	Average Cost Per Square Yard								REMARKS
		Macadam	Gravel	Concrete	Asphalt	Brick	Granite Block	Bitulithic	Wood Block	
Montesano, Wash.	1911	......	......	$1.27 to 1.32	$2.18	$3.15	......	......	......	Brick and asphalt on 5″ concrete base. Gravel $1.50 per yd.; labor $2 to $3 per day.
Richmond, Ind....	1908	......	......	1.06	......	2.00	......	......	......	Brick price is minimum.
Panama, Cuba....	1906–07	......	......	2.00	......	4.00	......	......	......	
Summerville, Mass.	*	......	......	1.65	3.80	2.75	$2.35	......	......	Concrete pavement—Hassam patents
Toronto, Can......	1903	......	......	1.74	......	......	......	......	......	4″ base, $2\frac{1}{2}$″ wearing surface.
Toronto, Can......	1904	......	......	1.92	......	......	......	......	......	Included gravel and 2″ tile drain.
Toronto, Can......	......	......	......	......	2.25	2.25 to 2.55	3.50	$2.25	......	
Denver, Colo......	......	......	......	1.03 to 1.27	3.47	......	......	......	......	
Chicago, Ill.......	1905	......	......	1.80 to 2.20	......	......	......	......	......	Patented type—Depth of fill varies.
Chicago, Ill.......	1905	......	......	1.75	......	......	......	......	......	Patented type.
Chicago, Ill.......	1909	......	......	1.50	2.03	2.55	3.89	......	$3.44	Patented type—Concrete pavement, 6″ base, 2″ top.
Mason City, Iowa.	1909–10	......	......	1.26	......	2.80	......	......	2.20	
Cincinnati, Ohio...	1907–12	$0.95	......	......	2.30	2.25	3.70	2.65	3.45	Boulder, $1.75; Granitoid, $2.10.
Cedar Rapids, Ia..	1912	......	......	.92	1.67	......	......	......	......	
Wayne Co., Mich..	1910	......	$0.25 to .35	.82 to 1.39	......	......	......	......	......	Low cost of gravel road due to low material cost.
Wayne Co., Mich..	1911	......	.52 to .64	1.15 to 1.74	......	......	......	......	......	Dirt or gravel shoulders charged to cost of concrete; width of shoulders about 4 feet.
Trenton, N. J.....	1911	......	......	1.44	1.90 to 2.00	......	......	......	......	
LeMars, Iowa.....	1904	......	......	1.25	......	2.05	......	......	......	Exclusive of grading.

*Average for four or five years prior to 1911.

of $1.50 per square yard. At this time cement cost approximately $1.20 per barrel; sand $1.60 per cubic yard; stone $1.50; crushed granite for top finish $3.75; and common labor $3.00 per day.

During the year 1909, other types of pavement laid in Chicago cost as follows:

Asphalt, approximately		$2.03 per sq. yd.
Creosote blocks	$3.44 to	3.49 per sq. yd.
Brick		2.55 per sq. yd.
Granite		3.89 per sq. yd.

Table No. 2 gives data in tabulated form, and shows costs for those cities only where data at hand compares concrete with other types of pavements.

Table No. 3 shows bids received at Creston, Iowa, in April, 1912, for various types of pavements. The number of bids received for each type, together with the high, low and average cost per square yard, are shown. Although bids were asked on a small amount of concrete as compared to the other types of pavements, the comparative costs show a decided saving by the use of the concrete. A more extensive list of cost data covering concrete pavements, together with a more detailed description of the same is shown on pages 25 and 37.

Table No. 3

Bids Received at Creston, Iowa, in April, 1912

KIND	Amount Square Yards	Number of Bidders	Cost per Square Yard High	Low	Average	
Bituminous concrete	50,000	10	$1.73	$1.48	$1.585	2″ top on 4″ base
Bitulithic	50,000	3	1.98	1.69	1.838	2″ top on 4″ base
Brick with sand filler	50,000	6	1.94	1.75	1.830	
Brick with pitch filler	50,000	5	2.09	1.92	1.986	22% rattler brick on 2″ sand cushion and 4″ base
Brick block, sand filler	50,000	10	1.94	1.65	1.804	
Brick block, pitch filler	50,000	9	2.09	1.87	1.963	
Concrete	2,600	11	1.33	1.10	1.177	For alleys

Macadam roads constructed at Berea, Ky., having a total thickness of 6 inches after rolling, cost when finished 91½ cents per square yard. The average cost of the stone was 97.7 cents per cubic yard, exclusive of hauling, which averaged half a mile from the car to the road.

A brick road, constructed at Danville, Ill., in 1905, having a 4-inch concrete base, a 4-inch by 12-inch curb on each side, and grouted with cement, cost approximately $1.70 per square yard. A similar road constructed in 1912 at Harrisburg, Ill., cost $1.70 per square yard. The cost in both cases included dirt shoulders on each side.

A study of the foregoing costs will show without question the decided advantage that concrete has over other types of pavements with the exception of plain macadam.

Durability and Maintenance Although the question of durability refers to the average life of a pavement, or in other words, the length of the period after which the pavement must be replaced, regardless of the labor and material that have been required to keep the same in good condition during that time, the subject will here be treated in connection with maintenance. Many of the present text books covering the subject of roads and pavements show maintenance costs as determined before the advent of motor-driven vehicles, but these costs are very much lower than they are shown to be under present conditions of automobile traffic; this being especially true of the macadam type of pavement. For durability, a granite block pavement is undoubtedly superior to any other type, and is the only one more durable than a properly constructed concrete pavement. Brick pavements having the joints filled with asphalt, tar, sand, or any other type of soft filler, will not be as durable as a concrete pavement because these fillers do not prevent a chipping off of the brick. For this reason many authorities, including paving brick manufacturers, are now advocating the use of a cement grout filler, thus giving as near as possible a smooth surface, and reducing the chipping off of the brick.

An estimate of the life of several types of pavements was made by D. W. Mead, and published in Volume 11 of the Journal of Associate Engineering Societies. This estimate is shown in part in Table No. 4.

Table No. 4

Estimate of Life of Various Types of Pavements

KIND	Life, Years		
	Light Traffic	Medium	Heavy
Cedar Block on 6″ concrete base	12	9	......
Cedar Block on 9″ concrete base	......	10	5
Brick on 6″ concrete base	35	20	10
Brick on 9″ concrete base	......	25	15
Sheet Asphalt on 6″ concrete base	15	8	......
Granite on concrete	50	30	15
Macadam—granite top dressing	10	6	......

While it is admitted that such estimates cannot be taken as typical for all localities, they do in a general way show comparative values. On the same basis it is safe to estimate the life of a concrete pavement, properly designed to take care of the particular kind of traffic, to be approximately as follows:

Light traffic	35 years
Medium traffic	25 years
Heavy traffic	15 years

That the use of the cheap macadam form of pavement is not economical for at least trunk lines is clearly shown by the statement of L. W. Page, director of Office of Public Roads, made in a talk before the American Portland Cement Manufacturers at Chicago in which he stated that the macadam roads of New York were costing on an average of $826.00 per mile per year for maintenance. The inadvisability of constructing roads that cost as much in ten years for maintenance as the original cost, is apparent.

A statement accredited to Col. W. D. Sohier, Chairman of the Massachusetts Highway Commission, follows:

"Necessity of using bituminous binder in road construction on account of the automobile wear has increased the first cost of road construction from 20 to 50 per cent. Over $300,000 was spent in 1911 by the Massachusetts Highway Commission in treating with oil or tar the roads used by through automobile traffic. This was necessary not only on account of the dust nuisance along the route, but to prevent the roads being destroyed by the rapidly moving vehicles."

Rhode Island spent in 1910, 21 per cent as much for maintenance as for new construction. For 1911 the appropriation was $200,000, of which $80,000 or 40 per cent was for maintenance.

The report of the Good Roads Committee of Monroe County, N. Y., for 1911, gives some interesting data regarding the life of the macadam type of pavement, having an oiled surface. It is claimed that this county has the largest value of farm products of any county but one in the United States, and therefore has paid special attention to its road construction and maintenance. Up to November 1, 1911, they have constructed 177.7 miles of improved highways, including state and county systems; approximately 50 per cent of which is plain macadam with oiled surface, of either hot or cold application. The first roads built under state and county aid were in 1899, and additional roads have been built every year since except 1910. Of the total mileage of 200.86 built or under construction at the time of the report, all but 33.56 miles have been water bound macadam. All roads have since received surface treatment except 6.8 miles. The average construction cost per mile was $8,371.00; the average cost of maintenance per mile per year, $471.00; and the average age of the state roads has been 6.1 years. The total original cost of the 200.86 miles was $1,374,469.00, and the total maintenance cost has been $457,-683.00, or a total of 33 per cent of the original cost. One road approximately 4.7 miles in length was constructed in 1908 of tarvia bound lime stone at a cost of $10,125.00 per mile. The average maintenance cost per year for the three years of its existence has been $588.00 per mile, or in other words, the maintenance cost for three years has been 17 per cent of its original cost. Compare this with the maintenance charge on the 65 miles of concrete road built in Wayne County, Mich., a part of which is four years old. The total charge has been $300.00, the greater portion being for ditches and shoulders.

A large number of experiments have been made in order to discover some satisfactory method of disposing of the dust nuisance and increasing the wear of macadam pavements. A paper prepared by Spencer Cosby, Col. U. S. Army, in charge of Buildings and Grounds for Washington, D. C., shows the cost in Washington of oiling macadam park roads with an asphaltic oil during 1911 to be from 1.2 to 4.6 cents per square yard per application exclusive of the gravel or stone screenings which required about 1 cubic yard for every 75 to 125 square yards of surface. Various kinds of emulsions were tried but although they were cheaper for first cost, they found the effect of each application only lasted from two to three weeks depending on the amount of rain, etc.

The City of Washington, D. C., has undoubtedly had a more extensive experience with asphalt pavements than any other city in the United States, as a large percentage of its pavements are of that type. During the year 1910, 1,830,000 square yards were relaid and 98,000 square yards during 1911. The average cost of re-surfacing has been 64 cents per square yard, and the maintenance cost per year has been 10.5 cents per square yard if done by contract, or 9.5 cents if by the municipal plant. The average age of the asphalt pavement has been eleven years.

The estimated cost of repairs on asphalt and bitulithic pavement for eleven years in Niagara Falls, N. Y., is 8 cents per square yard per year.

Information given in "Roads and Pavements," by I. O. Baker, and compiled from an article on repairs of asphalt pavements in Buffalo, N. Y., from 1885 to 1897 shows that on business streets the maintenance cost on streets with car tracks increased from 5.1 cents per square yard for pavements one year old, to 23.9 cents for the seventh year; the average per year being 14.8 cents. For streets without car tracks the first year repair charge was 3.2 cents and the seventh year, 18.0 cents; the average being 11.2 cents. On residence streets the average repair charge was 4.8 cents per square yard.

Very often appropriations are made for constructing paved roads or streets without any thought of or arrangements made for replacement or maintenance. New York City has asphalt pavements which should have been replaced several years ago, and the original construction bonds have not yet matured; the obvious conclusion from a study of these conditions being that either a more durable pavement or shorter term bonds or both should have been used.

The report of the Bureau of Municipal Research of Cincinnati, Ohio, for 1911, shows average maintenance costs for various classes of pavements for four years to be as follows:

Granite	$0.026 per square yard per year
Asphalt	.073 per square yard per year
Brick	.012 per square yard per year
Macadam	.076 per square yard per year
Bowlders	.033 per square yard per year

The first three pavements were constructed on a 9-inch concrete base. The low maintenance cost of the hard surfaced pavements in comparison with asphalt and macadam is very noticeable. It is rather difficult to understand why the maintenance for granite was higher than for brick or that the maintenance for macadam was but slightly in excess of that for asphalt, but undoubtedly this was due to differences in the class of traffic using the two types.

A history of the durability and maintenance charge for concrete pavements is meager, owing to its comparatively recent use; there are, however, concrete pavements in use today that have had constant wear for from fifteen to twenty years, and with the exception of the wear along expansion joints, more particularly those placed parallel with the curbs, they have shown remarkable durability and are in good condition today.

The earliest concrete pavement of record was laid in Bellefontaine, Ohio, in 1893-4. These pavements were laid around the court house block and have been in constant use by a mixed traffic. With the exception of longitudinal joints the pavement is still in excellent condition.

A concrete alley pavement was laid in the down town district of Richmond, Ind., in 1896, and shows practically no wear at the present time. A small amount of street pavement laid in LeMars, Iowa, in 1904, is now in better condition than an adjacent brick pavement laid about the same time. Concrete alley pavements in Denver are in excellent condition after being subjected to heavy traffic for several years. The Hawthorne Plant of the Western Electric Company has 40,000 square yards of concrete pavement laid in 1905, which has required practically no repairs. A considerable amount of the same type of pavement was laid about the same time for the Sears Roebuck Company at their Harvard Street Plant, Chicago. This pavement is subjected to an exceptionally heavy traffic but is in excellent condition after six years of wear, with the exception of cracks in a number of places along the crown of the street.

In a paper read before the convention of the National Association of Cement Users at Kansas City, in March, 1912, F. P. Wilson, City Engineer of Mason City, Iowa, stated that 6,000 yards of concrete pavement laid in the down town districts of Mason City during 1909 was in as good condition as the day it was finished after standing the severe test of two winters and heavy traffic.

The available records of the durability and maintenance cost of concrete pavements under use for from one to six years, show with but one or two exceptions, unusually good results.

The sixth annual report of the County Road Commissioners of Wayne County, Mich., which gives a description of county roads constructed during the year 1912, states that their decision to adopt the concrete roads as a standard of construction has been amply justified by the results. Their concrete roads which have been used for four years are wearing remarkably well. In fact, their concrete construction has cost practically nothing for maintenance; $300.00 being the total amount spent for repairs on 33 miles of concrete road varying in age from one month to four years; of this amount, the greater portion was used on the ditches and shoulders and the balance or about $100.00 covered the cost of refilling with tar and sand those expansion joints in the older pavements that were not protected by steel plates. Macadam roads which were originally adopted in 1906 are in such condition at present as to require re-surfacing at a considerable expense.

These same conclusions have been reached by practically all cities that have given concrete construction a thorough trial. In fact, the results freely warrant the statement that with the exception of granite blocks, concrete pavements constructed with due regard to traffic conditions will give a more durable pavement with a smaller maintenance cost than any other type. A more complete record of results from the use of concrete pavements, together with a detailed description of each is given later under the headings "Examples of Concrete Pavements, page 25, and "Reinforced Concrete Pavements," page 38.

Low Tractive Resistance Although no tests have been made to determine the tractive resistance of concrete pavements, it is safe to conclude from a study of the causes of resistance that it has no equal. For purposes of comparison we repeat the following information regarding an estimated cost per ton mile to haul goods on various types of road surfaces as estimated in Indiana several years ago:

Asphalt	2.7 cents per ton mile
Block pavement	5.3 cents per ton mile
Good macadam	8.0 cents per ton mile
Gravel road	8.8 cents per ton mile
Earth, hard and dry	18.0 cents per ton mile
Macadam with ruts	26.0 cents per ton mile
Wet sand	32.0 cents per ton mile
Earth roads, ruts and mud	39.0 cents per ton mile
Dry sand	64.0 cents per ton mile

On the basis of the above figures a conservative value for the tractive resistance on concrete pavements would be 2.0 cents per ton mile.

Asphalt pavements in good condition have during cold weather a low tractive resistance. However, during hot days the additional resistance is very noticeable, due to a softening effect of the heat, thus allowing the wagon wheels to sink into the surface. Tests on dry and on wet asphaltic concrete pavements made at Manhattan, Kan., in July, 1912, showed an increase in the required draft during an increase of temperature from 82° F. to 98° F. of 28 per cent on the dry and 17 per cent on the wet surfaces. Creosoted wood block pavements show low resistance, and may be classed with sheet asphalt. A brick pavement with cement filled joints also gives low tractive resistance but has a rougher surface and therefore greater resistance than the concrete pavement.

Non-Slipperiness The subject of non-slipperiness has in the past referred primarily to foothold for horses. However, under present conditions it is also necessary to take into account the skidding tendencies of automobiles. In either case concrete pavements stand at the head of the hard surfaced types.

Asphalt pavements are comparatively free from slipperiness when dry, but are exceedingly slippery when wet. The same may be said of creosoted block pavements, especially those subjected to a surface treatment of a tar or asphalt preparation.

Granite block pavements are also slippery under horses' feet, but unlike the asphalt and wood block, they are more slippery in dry than in wet weather. This was shown by the results of observations in the city of London in 1873, as given in "Roads and Pavements," by I. O. Baker. They found that the number of miles a horse would travel on granite blocks pavement in London before an accident occurred was 78 miles when dry, 168 when damp, and 537 when wet.

Referring to concrete as compared to brick pavements, the following extract from a paper written by A. M. Compton, Commissioner of Public Works of Davenport, Iowa, is a good illustration:

"Seven years ago Davenport paved several rather steep hills with beveled vitrified brick, with a telford macadam strip ten feet wide in the center. These macadam strips washed badly and were recently replaced with a one course concrete pavement from 4 to 6 inches thick, and corrugated with a hit or miss tamper. The grade varied from 9½ to 12 per cent and in one instance the pavement receives heavy traffic. It has been noticed that teamsters generally prefer to drive on the concrete center strip rather than the brick sides."

The City of Panama during 1906 and 1907 laid two miles of concrete pavement on grades up to 8 per cent and found them to be more satisfactory than brick pavements.

In fact, the consensus of opinion of teamsters, automobile owners and even city authorities is that concrete pavements are not unduly slippery under the most trying weather conditions. In one respect concrete pavements as compared with other types are in a class by themselves, that is, the finished surface may be made as rough or as smooth as may be required, although the opinion is becoming quite general that on grades up to 5 per cent and even more, it is not necessary to corrugate the surface.

Sanitary Qualities The early opinion of municipal engineers classes concrete as a noisy pavement. Experience, however, has proven them to be very much freer from noise than at first supposed. Those made with a comparatively smooth surface produced little if any noise from passing wheels except at the expansion joints. Even the striking of horses' shoes does not produce objectionable noise, and they are especially free from that hollow sound produced by horses' feet striking pavements which are constructed with a sand cushion between the base and top.

In other words, concrete pavements are noisier than macadam, asphalt and the various tar surfaced types, but are less noisy than brick or granite pavements. They are not dust producing nor do they absorb oils nor injurious and offensive liquids.

A large number of experiments have been made to discover some method for eliminating the dust nuisance on macadam pavements. This has usually been done by sprinkling them with some mixture of asphaltic oil. On those streets having very little travel this method has proven quite successful in preventing disintegration, but is decidedly unsuccessful when these streets are in any way used by foot traffic. It is also found objectionable for the same reason because of the adherence of the oily mud to the wheels of carriages and automobiles, from which it is often removed by coming in contact with clothing.

Asphaltic oils mixed with water and clay form an emulsion, and experimenters have difficulty in finding a dirt that will prevent this emulsion. Very often a coarse, sharp sand is added but this will eventually grind up to a dust and produce the objectionable oily mud after every rain or sprinkling. This method is also expensive and adds very materially to the maintenance charge.

Concrete pavements can be cleaned with less difficulty and expense than any other type with the exception of sheet asphalt, and can be done either by the sweeping or flushing method. As regards ease of cleaning, the various types of pavements in common use could be listed in the following order:

Concrete,
Asphalt,
Creosote block,
Brick (with cement filler),
Granite,
Bituminous macadam,
Macadam.

The text-book, "Roads and Pavements," by I. O. Baker, states that in past years the city of New York has spent a million dollars a year in substituting sheet asphalt for stone block pavements in the congested tenement districts. This was done chiefly because of the greater ease of cleaning the asphalt pavements. It also states that the cost of sweeping stone block, round wood block and brick pavements will average between 40 and 48 cents per 1,000 square yards for each sweeping, while sheet asphalt will average from 30 to 38 cents. This cost will vary in accordance with frequency of sweeping, kind of business on adjoining property, weather conditions, and amount of traffic.

Favorableness to Traffic The question of comfort to the users is becoming of great importance since the advent of automobiles, especially those for pleasure purposes. This requirement undoubtedly is best taken care of by a smooth concrete surface whose natural durability resists the formation of objectionable hollows and bumps, and reduces the dust nuisance to a minimum.

Summary A summing up of the various qualifications of a concrete pavement in comparison with other types will unquestionably lead to the conclusion that under average conditions a concrete pavement comes the nearest to the ideal. The bulletin of the Department of Agriculture which has been previously referred to and which summarizes the opinions from engineers of a number of American cities, tabulates the qualifications of various types of pavement as shown in Table No. 5. The first column of percentages refers to the ideal pavement, and the various amounts credited to the other types are based on a comparison with the ideal pavement. The last column of the table showing the values for a concrete pavement is here added for comparison and was not given in the bulletin referred to. The average first cost for concrete pavements has been assumed to be $1.25 per square yard, which undoubtedly is a conservative figure. The various values for the other qualifications of concrete pavements are also conservative as have been proven by actual use. It is worthy of note that concrete pavements come nearer to the ideal pavement than any other type and that at a less first as well as maintenance cost.

Table No. 5

Comparative Value of Different Pavements

From Circular No. 141—Forest Service—U. S. Department of Agriculture.

PAVEMENT QUALITIES	Per Cent For Ideal Pavement	Granite	Sandstone	Asphalt (Sheet)	Asphalt (Block)	Brick	Macadam	Creosoted Wood Block	Concrete
Cheapness—First cost	14	4	4	6.5	6.5	7	14	4.5	13
Durability	20	20	17.5	10	14	12.5	6	14	17
Ease of Maintenance	10	9.5	10	7.5	8	8.5	4.5	9.5	9
Ease of Cleaning	14	10	11	14	14	12.5	6	14	14
Low Tractive Resistance	14	8.5	9.5	14	13.5	12.5	8	14	14
Non-slipperiness	7	5.5	7	3.5	4.5	5.5	6.5	4	6
Favorableness to Travel	4	2.5	3.5	4	3.5	3	3	3.5	4
Acceptability	4	2	2.5	3.5	3.5	2.5	2.5	4	4
Sanitary Quality	13	9	8.5	13	12	10.5	4.5	12.5	13
Total	100	71	73.5	76	79.5	74.5	55	80	94
Average Cost per Square Yard (1905)		$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10	$1.25

Note—The values for concrete pavements given in the last column are here added for comparison and were not included in the Government report.

Examples of Plain Concrete Pavements*

The concrete pavement for some unaccountable reason has not been used to anywhere near the extent its many decided advantages has warranted. However, engineers are now awakening to its possibilities and are studying the concrete pavements now in use, comparing the various specifications (and there are many), the cost and results. The following examples will show to a limited extent the history and development of the concrete pavement.

The first pavement of which we have any record was laid at Bellefontaine, Ohio. After observing the remarkable durability of concrete gutters constructed in 1890, the city engineer decided to try concrete pavements on two narrow and two wide streets surrounding the court-house square. The two narrow streets were paved during 1893 and the wide ones in 1894. The specifications were the same in both cases except for the surface finish. The base consisted of 4 inches of concrete mixed in the proportion of one part of Portland cement to four parts of gravel. The top or wearing surface consisted of a 2-inch thickness of a one to one mixture of Portland cement and clean coarse sand. The concrete in both cases was mixed rather dry and tamped into place. The pavement was laid in strips five feet wide and the full length of the street; but these strips afterward were cut every five feet, no expansion joints being used. The surface in the two narrow streets was marked into four-inch square blocks by means of V-shaped grooves, ¼ of an inch wide and ½ of an inch deep; on the wider streets the surface was pitted with a toothed roller. The contract price was $2.25 per square yard, including curb and drains. It is reported that the joints parallel with the curb show considerable wear, but those at right angles to the curb show but little effect of the traffic. The maintenance charge during the nineteen years of its existence has been practically nothing.

The next recorded pavement was laid in a narrow alley in Richmond, Ind., in 1896, at a price of $1.62 per square yard. Several alleys have been paved since then at a lower cost; two alleys paved during 1908 were placed at a cost of $1.06 per square yard. In 1903, a concrete pavement was laid in Sailor Street, and was constructed in a similar manner to the alley pavements. The concrete base consists of 5 inches of a 1:2:5 mixture and the wearing surface 1½ inches of either one part of cement to two parts of coarse sand, or one cement, one sand, and one crushed stone screenings. No markings are used on the surface, the same being troweled and cork floated.

*See "Necessity for Reinforcement," page 64.

A small amount of concrete pavement was laid in LeMars, Iowa, in 1904, and consisted of a 5-inch base of 1:6 gravel mixture and a 1½-inch wearing surface consisting of one part cement and two parts coarse sand. The contract price was $1.25 per square yard. Gravel cost 75 cents per cubic yard and cement $2.00 per barrel. The pavement is today in better condition than an adjoining brick pavement laid the same year at a cost of $2.08 per square yard.

Two miles of single coat work laid in Panama in 1906 and 1907 on grades up to 8 per cent consisted of 5 inches of a 2:2½:5 concrete mixed sufficiently wet to allow mortar to flush to the top when tamped. It was then troweled in the same manner as the wearing course of the two-coat pavement. The pavement was laid in alternate sections of about ten feet each and no expansion joints were used. The cost was approximately $2.00 per square yard.

The City of Bozeman, Mont., laid 27,780 square yards of pavement in 1908. It consisted of a 5½-inch concrete base mixed with one part of cement to six of gravel, and a 1½ inch wearing course made of one part cement, one part of crushed bowlders or pea gravel, and one part of coarse sand. Expansion joints were placed 100 feet apart, perpendicular to the curb, and also along each curb. Separation joints were placed every ten feet. The surface after being troweled and brushed was marked into blocks 4 inches by 10 inches. The contract price, exclusive of excavation and gravel fill, was $1.95 per square yard. At that time cement cost $2.40 a barrel, sand $2.00 per yard, gravel $1.25 per yard, and labor $2.50 per eight hour day. The pavement is reported to be wearing well, except the joints and grooves parallel with the street. The soil is composed of clay and gravel and has allowed the pavement to sink as much as an inch in some places which shows the necessity of good foundation and drainage.

In 1910, approximately 3,000 square yards were laid at a contract price of $2.05, exclusive of grading and foundation. The same specification was used as for the 1908 pavement, except that expansion joints were placed 60 feet apart and the top surface was troweled and brushed but not grooved. The city authorities state that they do not consider their pavements to be as slippery as asphalt and would hesitate marking them even on steep grades.

The City of Tacoma, Wash., laid in 1911, 1.35 miles of pavement varying in width from 24 to 30 feet. The base was constructed 5 inches thick, of a 1:3:6 gravel or sand mixture. The top or wearing course was 2 inches thick, made of a 1:2 mixture. Expansion joints were placed 25 feet apart, at right angles to the street. The contract price was $1.35 per square yard.

In the year 1911, Grand Junction, Colo., laid 17,000 square yards of a two-course pavement having a 5-inch base consisting of one part of cement, three parts sand and six parts of crushed stone. The top course was 2 inches thick, mixed in the proportion of one to two. Expansion joints were placed along the gutters and car tracks and 15 feet apart across the street. The finished top was corrugated with a hand roller. The pavement was laid by day labor and cost $2.20 per square yard. It was reported that 8,000 yards additional will be laid in 1912.

Denver, Colo., uses concrete very extensively for alley pavements, and it is also used by the Denver Tramway for paving between tracks and rails. The usual specification covering alley pavements calls for a 4-inch base of a 1:3:6 mixture and a 2-inch top course mixed 1:2:4. The average cost has been from $1.08 to $1.27 per square yard. A considerable number of these alleys have been subjected to heavy traffic and are reported to be in good condition after several years' use.

The City of Boise, Idaho, has had extensive experience with concrete pavements, practically all of which are of the one-course type. Up to 1912 there has been laid approximately 82,000 square yards, some of which consist of 6 inches of a 1:3:5 crushed rock mixture and the balance 8 inches thick mixed in the proportion of 1:3:7. Expansion joints were constructed along the curbs and across the street every 25 feet. The contract price varied from $1.04 to $1.15 per square yard.

In 1911 Montesano, Wash., laid 2,000 yards of concrete alley pavements and 6,000 yards of street pavements. The base was laid 4 inches thick mixed 1:3:6, using screened river gravel, and the wearing course 2 inches thick consists of a 1:2 mixture. The surface was finished with a trowel and brushed with a street broom. Expansion joints ⅝ of an inch wide were laid along the gutters and every 25 feet across the street, and were filled with oakum or burlap and hot asphalt. This city, having a population of approximately 3,000, has spent $100,000 on their pavements, which are either brick, asphalt or concrete. The city engineer reports that all future pavements will be concrete. Their brick pavement laid on a 5-inch concrete base, cost them $3.15 per square yard. Asphalt on a 5-inch base cost $2.18. Concrete alley pavements 6 inches thick cost $1.27, and 6-inch concrete street pavements cost $1.32 per square yard. The labor cost averaged from $2.00 to $3.00 per day, and screened river gravel $1.50 a yard.

South Omaha, Neb., up to 1912 has constructed approximately 14,500 square yards of the one-course type varying in thickness from 6 to 8 inches. The mixture consisted of one part cement, two and one-half parts sand and five parts crushed lime stone. Expansion joints were placed along the curb and also every 30 feet at right angles to the street. The average contract price has been $1.23 per square yard.

The City of Bemidji, Minn., laid two blocks of concrete pavement in 1910, at a contract price of $1.20 per square yard, and ten blocks in 1911 at $0.90 per square yard. Gravel cost $1.50 per cubic yard, labor $2.25 per day, and cement about $2.20 per barrel in 1910 and $1.80 in 1911. The 1910 pavement consists of a 5-inch base mixed one part of cement to five parts of gravel and a 1:2 sand or screened gravel top 1½ inches thick. The top course was finished with a wooden float, steel troweled, and then brushed with a coarse broom. The 1911 pavement is a one-course type consisting of 5 inches of a 1:3½ gravel concrete, mixed sufficiently sloppy to allow of floating, troweling and brushing, as for the previous pavements. The pavement between curbs was divided into three sections, the two next to each curb being 18 feet wide and the center section 10 feet. The joints between sections were not expansion joints but were painted with paving pitch to make it easier to tear up when it was desired to lay future street car tracks. Expansion joints ¾ of an inch wide along the curb and ½-inch joints every 25 feet across the pavement were filled with paving pitch.

During the year 1911, Liberty, Mo., laid 25,000 square yards of concrete pavement. The base consisted of a 1:2½:5 mixture of river sand and lime stone, and had a thickness of 5 inches. The top course varied from 1 to 2 inches in thickness and consisted of one part of cement to two parts of river sand. The surface was troweled with a steel trowel and brushed with a stiff broom. The expansion joints were ¾ of an inch wide along the curb, and ½ an inch wide at right angles to the curb and spaced 50 feet apart. The edges of these joints were rounded to a ½-inch radius. Contraction joints were also constructed half way between the transverse expansion joints. All expansion joints were filled with a bituminous cement filler. The contract price was $1.18 per square yard including grading.

The City of Independence, Mo., has laid approximately 52,240 square yards of concrete pavement up to the year 1912, at an average contract price of $1.65 per square yard. Crushed stone and sand mixed in the proportion of one to seven were used to construct the base which was 5¼ inches thick. The top course 1¾ inches thick was mixed in the proportion of two to three.

Fort Dodge, Iowa, laid prior to 1912 approximately 37,500 square yards of concrete pavement; 8,602 having been laid in 1911. These pavements consist of a 5-inch base mixed in the proportion of 1:2:5 and a 2-inch top, mixed 1:1:1; granite screenings being used for the top course.

Expansion joints were placed across the street at a distance of from 30 to 50 feet apart. The contract price has averaged from $1.58 to $1.62 per square yard.

Marshalltown, Iowa, laid 7,000 square yards in 1911, the total thickness of which was 7 inches. Gravel was used and mixed in the proportion 1:3:5 for the 5-inch base, and one to two for the 2-inch top. Expansion joints were used along the curb, in the center of the street and every 15 feet transversely. The joints along the curb were ¾ of an inch wide filled with an asphalt filler and the transverse and center joints were ¼ of an inch wide, filled with rubberoid or tar paper. The surface was given a broom finish.

Mason City, Iowa, laid 6,000 square yards of concrete pavements in 1909; 22,000 square yards in 1910, and 45,000 square yards in 1911. The 1909 pavement was laid in the down town district, where it has received a test under severe traffic; the pavement is reported to be in excellent condition after the test of three winters. These pavements were all constructed of a 1:2:5 mixture for the 5-inch base and a 1:2 mixture for the 2-inch wearing course. Expansion joints are 1 inch wide along the curb and ½ an inch wide every 25 feet across the street, all joints being rounded to a ½-inch radius, filled with asphalt filler. Contraction joints were also constructed transversely midway between expansion joints. Parallel to the curb and ten feet out, the wearing surface was cut through to the base. The contract price for the pavements was $1.32 per square yard.

During the year 1912, 50,000 square yards were laid, the specifications being the same as for earlier pavements with the exception of the expansion joints. These were constructed 37½ feet apart at right angles to the curb and were protected with two soft steel plates, one on each side of the joint. These plates are two inches deep and one quarter of an inch thick and anchored into the wearing surface.

Burlington, Iowa, has 5,000 yards of concrete pavement, the greater portion of which was laid in 1911. These pavements have a 6-inch base and a 1-inch top course. The base consists of one part of cement, two parts sand and five parts crushed lime stone. The top course is a 1:2 mixture of cement and sand. Expansion joints were placed along the curb and 30 feet apart across the street. The average contract price was $1.35 per square yard.

Kansas City, Mo., up to March 10, 1912, has laid 46,029 square yards of concrete pavement at an average cost of $1.23 per square yard, and 28,052 square yards of alley pavement at an average of $1.38 per square yard. New contracts have been placed for some 76,000 square yards at a cost varying from $0.96 to $1.04. In 1911 the cost of cement varied from $1.30 to $0.88 per barrel. Sand was $1.00 per cubic yard delivered, and rock $1.35. The first concrete pavement laid was in an alley in 1904 and is reported to be in excellent condition after eight years of wear. The pavements are of the one-course type mixed in the proportion of one part cement, two and one-half parts sand and four and one-half parts crushed stone. For residence streets the total thickness is 6 inches and for heavy traffic streets, 8 inches. The surface is given a broom finish, the degree of roughness depending upon the grades. Reports show that these pavements afford good foothold for horses, are not slippery in wet weather and can be easily laid and repaired by unskilled labor. The expansion joints ½ an inch wide are placed every 50 feet across the street and filled with asphalt, cement or paving pitch.

The largest amount of pavement laid in any city for any one year was laid in Sioux City, Iowa, during 1911, approximately 100,000 square yards being laid in that year. The pavement consisted of one course, 5 inches thick, the concrete being so mixed as to over-fill the voids 5 per cent. If the voids were not determined, the mixture was in the proportion 1:3:4½. After the concrete was placed and tamped, a 1:1 dry mixture was spread over the surface to take up surplus moisture. The pavement was then floated to grade, and broomed. On grades exceeding 7 per cent, the surface is marked into 6-inch by 6-inch blocks; the grooves being ⅜ of an inch deep and ¼ of an inch wide. One-half inch expansion joints were placed along the curbs and every 25 feet across the pavement, these joints being filled with some type of plastic waterproof filler. In addition to a large amount of concrete pavement already placed, the city propose additional construction for 1912 consisting of approximately 120,000 square yards. The contract price for those pavements already laid has varied from $1.17 to $1.25 per square yard.

The City of Eldora, Iowa, laid 15,000 square yards of concrete pavement during 1911 at a contract price of $1.36 per square yard, and an additional 40,000 yards are now under construction. The base consisted of a 1:2½:5 crushed stone concrete, 5 inches thick, and the wearing course a 1:2 mixture 2 inches thick. Expansion joints were placed at the curb line and every 25 feet across the pavement.

The first use of concrete for a wearing surface of pavements in Canada was probably a small amount that was laid in Toronto in 1899. Asphalt pavements that had been laid between car tracks had proven to be unsatisfactory owing to the heavy traffic. The old asphalt surface was removed and on top of the old concrete base was laid a wearing surface of concrete, consisting of one part of cement, one-half part of sand, and two parts of crushed granite. The thickness of this top course was from 2 to 3 inches. This work did not prove to be entirely satisfactory, but a similar construction laid the following year on a residence street has given excellent satisfaction. In 1903 a street subjected to heavy traffic was paved with concrete, the work being done by the city at a cost of $1.74 per square yard. In 1904 a similar pavement was constructed at a cost of $1.92 per square yard, including gravel and 2-inch tile drain. These pavements consist of a 4-inch base; the mixture being one part of cement, three parts sand and seven parts of broken stone. Upon this was laid a 2½-inch wearing surface, consisting of one part of cement, one part sand and three parts crushed granite. Expansion joints ¾ of an inch wide were placed in the center of the pavement. These pavements are reported to be in good condition except for chipping at the expansion joints. The average cost of asphalt pavements laid on a 1:3:7 concrete base 6 inches thick was $2.25 per square yard. Bitulithic pavements laid on a 4-inch base cost $2.25. Vitrified brick on a 6-inch base $2.55, and on a 4-inch base, $2.25. Granite block on a 6-inch base, $3.50 per square yard.

Windsor, Ontario, had laid approximately 20,500 square yards of concrete pavements prior to 1908. These pavements consist of a 4-inch base, mixed in the proportion of one part of cement, three parts sand and seven parts crushed stone. In some cases the wearing surface consisted of a 1:2:4 mixture of gravel concrete 2 inches thick. In others, a 1:2 sand mortar ½ an inch thick was laid on top of 1½ inches of the 1:2:4 gravel concrete. The cost in the first case was 99 cents per square yard and in the other, $1.15. At that time Portland cement was $2.05 per barrel, river sand, $1.15 per cubic yard, screened gravel $1.25 per cubic yard, crushed lime stone, $1.15 per ton, common labor from $1.75 to $2.00 a day. It is reported that these pavements show considerable wear, and have not given entire satisfaction.

Monroe, Mich., prior to 1912 has constructed 15,500 square yards of concrete pavements, consisting of a 4½-inch base, 1:3:5 mixture and a 1½-inch top course of a 1:2 mixture. Expansion joints are placed across the street every 100 feet. The contract price has averaged $1.30 per square yard.

Jackson, Mich., laid a small amount of concrete pavement in 1907 at a contract price of $1.70 per square yard. On a 4-inch gravel foundation was laid a 1:7 gravel concrete base 6 inches thick. The 4-inch wearing course consisted of one part of cement to three parts of crushed granite. This street has been subjected to heavy traffic and has given excellent satisfaction. In 1911, 11,000 square yards were laid at a cost of $1.20 per square yard; the work being done by day labor. These pavements consisted of a 1:2:4 gravel concrete base 4 inches thick and a 2-inch top course consisting of a 1:2 mixture. Over this was spread a thin bituminous wearing surface. Expansion joints were placed 25 feet apart across the street.

Escanaba, Mich., laid 12,000 square yards of concrete pavement during 1911 at a contract price of 87 cents per square yard. The base course was 4 inches thick, consisting of a 1:3:6 stone concrete and the top course 2 inches thick consisting of a 1:2:4 mixture. The surface was troweled and brushed with a street broom. Expansion joints were placed at the gutters and every 25 feet across the street. Several miles of concrete roads were constructed in 1911, having a total thickness of 6½ inches; the bottom course consists of a 1:2:5 mixture and the top course 1:2:4.

Ann Arbor, Mich., has constructed a considerable amount of a new type of concrete pavement or rather a new method of surface treatment. On a 4½-inch gravel concrete base was placed a 1½-inch wearing course, consisting of one part of cement, and two parts of coarse sand. The surface was wood floated and brushed with a street broom. Expansion joints from ¾ of an inch to 1 inch wide were placed along the curb and every 25 feet across the street. Contraction joints were left down the center of the street. After the pavement had hardened, a thin coating of hot bitumen was applied by means of a sprinkler wagon. The bitumen was then brushed with a street broom to obtain a uniform thickness, after which the surface was covered with sand. One-half a gallon of bitumen was used per square yard, and sufficient sand was deposited to make the total thickness from ¼ to ⅜ of an inch, one cubic yard of sand covering approximately 230 square yards. Labor cost in 1910 was from $1.75 to $2.00 per day; cement from $1.07 to $1.32, and sand and gravel, 75 cents per cubic yard. The total cost of the pavement varied from $0.71 to $0.80 per square yard; the work being done by the city. This cost included the bitumen surfacing which averaged five cents per square yard. It is claimed that this type of a surface is less noisy and easier to the eye and to the horses' feet than the plain concrete surface. However, it has the same disadvantage as all of those types of pavements which require a bitumen surface treatment; during hot weather the surface material becomes more or less soft and sticky, adhering to shoes and vehicle wheels and eventually lodging on clothing, carpets and furniture. Resurfacing is required every year, especially along the center of the pavement, at a cost of five or six cents per square yard.

Greenville, Ill., during 1910 laid a mile of county roads, paid for by subscription, which proved to be unsatisfactory. It was laid without any special reference to the foundation, and consisted of a 5-inch, 1:6 concrete base, and a 1½-inch top mixed 1:2. It is claimed that the material used, as well as the workmanship, was of poor quality and was no doubt directly responsible for the unsatisfactory results. Fine sand was used for the finishing coat and dirty water for mixing. A large number of cracks formed crosswise and lengthwise of the pavement and the surface coat spalled off in several places. These were, however, easily repaired with good results. The cost, exclusive of excavation was $0.65 per square yard.

In 1911 additional county roads leading into Greenville were constructed at a cost of $0.92 per square yard, exclusive of excavation. Stone cost $0.50 and sand, $0.80 per cubic yard; cement, $1.22 per barrel, and labor, $1.75 per day. This pavement consisted of a one-course type 8 inches thick, mixed one part cement, two and one-half parts sand and five parts crushed stone. Expansion joints ¾ of an inch wide were constructed every 25 feet across the pavement and were filled with paving pitch. During the same year the city laid 3,500 square yards at a cost of $0.75 per square yard. Sand and gravel cost $0.80 per cubic yard; cement, $1.00 per barrel, and labor, $1.75 per day. These pavements were also of the one-course type, but of a different specification than for the county roads. The pavement, 6 inches thick, consisted of a 1:4 sand and gravel mixture. It was floated, brushed and corrugated with a special roller. Expansion joints ½ an inch thick, filled with paving pitch, were constructed along the curb and every 25 feet across the pavement. The good results obtained with the later pavements induced the city to contract for additional work for 1912.

Burlington, Wis., laid approximately 12,200 square yards during 1911, consisting of a 5-inch stone concrete base and a 1½-inch wearing course, consisting of one part of cement, one of sand, and one of granite screenings. Expansion joints were placed along the gutters and every 30 feet across the street. The contract price was $1.06 per square yard.

DePere, Wis., constructed 18,000 yards of concrete pavement during the year 1909, at a cost of $1.31 per square yard. The base consisted of 6 inches of a 1:2½:5 concrete. The top course consisted of 1½ inches of concrete mixed one part cement, one sand, and one granite screenings. Expansion joints ½ an inch wide were placed every 50 feet across the street and along the curb and gutter. The surface was finished with a steel trowel and brushed with a coarse street broom.

Alley pavements laid in Trenton, N. J., during 1911 have proven to be so satisfactory that it is reported that the city authorities have practically decided to make concrete the standard for alley pavements. Those laid in 1911 cost $1.44 per square yard. The average cost of asphalt pavement during the same period was from $1.90 to $2.00. These concrete pavements were one coat work, consisting of a 1:2½:5 stone concrete 6 inches thick. After placing the concrete was hand tamped until mortar flushed to the top, after which it was brushed with a street broom. Expansion joints, 1 inch wide filled with creosoted soft wood timber were constructed next to the curbs and transversely 50 feet apart.

Wayne County, Mich., in which the city of Detroit is located, has for several years been constructing county roads under state aid. With possibly one or two exceptions, Wayne County is the leader in the construction of permanent county roads. Their work contemplates the improvement of the main highways leading into the city of Detroit, and extending from the county line to the city limits. Also the main highways radiating from the smaller towns in the county, together with secondary highways connecting the main roads.

Some sixty years ago, Wayne County granted long term franchises to companies whose purpose was the construction of toll roads leading into Detroit. These roads in general consisted of heavy oak planks laid directly on the natural soil and the ends of the planks were covered with dirt. These plank roads later gave way to the use of a gravel construction. Very little was done during the later years covered by these franchises to keep the roads repaired and naturally they became practically impassable during the winter and early spring months. In 1893 the state passed a law providing for direct county supervision of the construction and maintenance of the various roads in each county. The law also provided that it should be operative only in those counties which would adopt the system by direct vote. It was not until 1906 that Wayne County approved of the system, and a tax of ¼ of a mill was authorized by the Board of Supervisors, and the following year one-third of a mill. After this the county was bonded for $2,000,000 to be used during a period of five years for the construction of permanent highways and the same are now under construction. Their first pavements were constructed of either water-bound macadam or gravel. These have since proven to be entirely inadequate for the purpose, as the excessive wear by automobiles has so destroyed the roads as to make it necessary to practically re-surface them at a considerable expense. In 1909 two miles of experimental concrete road were constructed and have given such excellent satisfaction that concrete has been adopted as a standard for their future work. In the fifth annual report of the

Wayne County Road Commissioners it is stated that the decision to adopt the concrete road as a standard has been amply justified by the results, the cost of maintenance having been practically nothing.

A number of different specifications have been used in constructing the 33 miles of concrete road laid in Wayne County up to and including 1911, as is shown by Tables No. 6 and No. 7.* The costs shown in these tables are figured on the basis of the actual concrete surface only, but include the cost of constructing shoulders on each side; these shoulders usually consist of stone or gravel and have a width from three to four feet on each side of the concrete.

Table No. 6

Concrete Roads Constructed in Wayne County, Mich., in 1910

See Fourth Annual Report of Board of County Road Commissioners of Wayne County, Mich.

ROAD	Length in Miles	Width in Feet	Thickness and Description: Bottom Course	Thickness and Description: Top Course	Cost Per Sq. Yd.	REMARKS
Wayne Road, So.	0.502	10	6″–1:2:4	None	$1.39	
Woodward Ave..	1.210	18	4″–1:2½–5	2½″–1:2:3	1.20	
Mt. Elliott Road.	0.909	12	4″–1:2½–:5	2″–1:2:3	1.29	For light traffic.
Michigan Ave....	2.412	18	7½″–1:2:4	None	1.27	Labor troubles; heavy fill.
Grand River.....	1.616	16	4″–1:2½–:5	2½″–1:2:3	1.16	
Van Dyke.......	1.000	15	4″–1:2½–:5	2″–1:2:3	1.27	
River...........	0.740	15	6″–1:2:3	None	.82	
Mack...........	0.309	15	6″–1:2:4	None	1.34	
Eureka..........	1.000	12	6″–1:2:4	....	....	Not completed Sept. 30, 1910.
Gratiot..........	1.700	12	....	....	....	Not completed Sept. 30, 1910.
Fort............	0.500	....	....	....	....	Not completed Sept. 30, 1910.

Note.—All expansion joints filled with four-ply tar paper. All top courses used washed sand and crushed cobble stone.

In some cases the work has been done by contract, but the greater portion has been constructed by day labor. The costs include office, hospital, engineering and supervision expenses, together with a 15 per cent depreciation for machinery, but do not include costs for drainage.

The pavements constructed during 1911 and those to be constructed in the future, consist of the single course type; the concrete consisting of a richer mixture than formerly, namely 1:1½:3; depth increased to 7 inches and expansion joints protected with a soft steel plate ¼ of an inch thick and 3 inches wide, having shear members bent back and cast into the concrete. The spaces between these plates are filled with tarred or asphalted felt or with a paving pitch or asphalt filler.

*Approximately thirty additional miles were constructed during 1912—See Sixth Annual Report.

Table No. 7

Concrete Roads Constructed in Wayne County, Mich., in 1911

See Fifth Annual Report of Board of County Road Commissioners of Wayne County, Mich.

ROAD	Length in Miles	Width in Feet	Thickness and Description		Cost Per Square Yard	REMARKS
			Bottom Course	Top Course		
Fort Road......	.500	12	6″–1:2 :4	None	$1.38	(*a*)
Eureka..........	1.000	12	6″–1:2 :4	None	1.28	
Gratiot..........	3.236	16	7″–1:1½:3	None	1.35	(*b*)
Grand River.....	2.510	16	7″–1:1½:3	None	1.74	See note below.
Wayne Road, So.	.500	15	1:1½:3	None	1.15	
Van Dyke.......	1.052	15	7″–1:1½:3	None	1.61	
Michigan Ave....	7.523	16 to 20	7″–1:1½:3	None	1.43	
Mt. Elliott......	.455	15	7″–1:1½:3	None	1.58	
Mack...........	.263	15	7″–1:1½:3	None	....	Not completed.
River...........	3.500	15	7″–1:1½:3	None	....	Not completed.

(*a*) Surface rutted in spots. Afterwards covered with thin bitumen surfacing.
(*b*) One mile has steel protected expansion joints 25 feet apart. Long haul for material.

Note.—The high cost for Grand River Road due to the necessity of tearing out old plank and logs long haul, scarcity of water supply, poor sub-grade and heavy fills.

A large amount of concrete pavement has been laid in Chicago, the greater portion of which, with the exception of those laid in alleys, has been constructed in accordance with the specifications covered by the Blome patents for granitoid pavements. These specifications are approximately as follows:

A 1:3:6 concrete base 6 inches thick and a 1½-inch top course mixed in the proportion of two parts of cement, one and one-half parts torpedo sand, and one and one-half parts crushed granite. The surface is corrugated into blocks approximately 4 inches by 10 inches, the grooves being about ½ an inch in depth and ¼ of an inch wide.

In 1905, 40,000 square yards were laid at the Hawthorne Plant of the Western Electric Company, at a price varying from $1.80 to $2.00 per square yard depending upon the amount of fill.

During the same year, a considerable amount was laid for Armour & Company at their plant at the Union Stock Yards. The cost of the pavement was approximately $1.75 per square yard.

A large amount was laid during the same year at the Sears Roebuck & Company Plant, Chicago. In this pavement expansion joints were placed at the curbs and every 24 feet across the pavement. A similar pavement was laid about 1909 on Emerald Avenue from Seventy-third to Seventy-fifth Street, Chicago, at a cost of $1.50 per square yard. At that time cement cost $1.30 per barrel, sand $1.60 per cubic yard, stone $1.50, crushed granite $3.75, and common labor $3.00 per day. These various Chicago pavements have shown remarkable durability under heavy traffic, and undoubtedly would give even better satisfaction if a reinforcing steel had been used to prevent cracks and the corrugations omitted, as it is at these points that the pavements show the greatest wear.

In addition to the concrete pavements which have been here briefly described, the following cities also have constructed this type in various quantities and under various specifications:

Alpena, Mich.	Clarinda, Iowa.
Lynn, Mass.	Knoxville, Iowa.
Muncie, Ind.	Omaha, Neb.
New Orleans, La.	Birmingham, Ala.
Niagara Falls, N. Y.	Little Rock, Ark.
Portland, Ore.	New Haven, Conn.
Superior, Wis.	Waukegan, Ill.
Worcester, Mass.	Dubuque, Iowa.
Mattoon, Ill.	Cadillac, Mich.
Haverhill, Mass.	Lexington, Mo.
Greenville, S. C.	Asheville, N. C.
Grand Forks, N. D.	Norristown, Pa.
Fond du Lac, Wis.	Charleston, S. C.
Philadelphia, Pa.	Jackson, Tenn.
Troy, N. Y.	Knoxville, Tenn.
St. Joseph, Mo.	Green Bay, Wis.
Gary, Ind.	Summerville, Mass.
Osage, Iowa.	Sheboygan, Wis.
Cedar Rapids, Iowa.	

These and many more, including hundreds of cities having concrete alley pavements, show actual results obtained by the use of this practically ideal pavement; however, owing to the great variation in the specification used, it is but natural to suppose that the resulting construction has shown a considerable variation in regard to durability, etc.

Experiments have been made with the idea of eliminating the various troubles, one of the more recent and successful methods being the use of a steel reinforcement, examples of which follow.

Reinforced Concrete Pavements

The concrete pavements described on the foregoing pages have not made use of any reinforcing steel. We have listed them here, however, to show that the concrete type is being very extensively used in all parts of the United States as well as Canada, and that by the use of a wire mesh reinforcement a durable and economical pavement can be secured.

The following examples are a few of the more prominent pavements that have made use of reinforcing steel for elimination of temperature cracks, etc. A full description of the wire mesh reinforcement used in each case showing the size of wires, spacing, sectional areas per foot of width, and weights per 100 square feet is given on page 90.

One of the first pavements constructed using a reinforcement was that laid at Plymouth, Wis., during the summer of 1910. Approximately 11,000 square yards were laid at that time at a cost of $1.235 per square yard including the grading. This pavement consisted of what is known as a two-course type, the base being made 5 inches thick and the top or wearing course, 1½ inches thick, making a total of 6½ inches. The specifications called for a concrete mixture in the proportion of 1:3½:6 for the base, the crushed stone to be free from dust and of varying sizes, all of which shall pass through a 2-inch ring and be held on a ½-inch ring, the sand to be of such a size as will pass a ¼-inch square mesh. The top or wearing course consisted of one part of cement to one and one-half parts of crushed granite, the granite to be properly graded from dust to ½ inch in size. After placing the bottom course, Triangle Mesh Reinforcement Style No. 7 was laid, the longitudinal wires being placed crosswise of the street, after which the wearing course was placed before the base had taken any appreciable set.

The accompanying cut shows the wire fabric in place ready for the wearing coat. The top course was troweled to a smooth finish and while still soft, granite screenings varying in size from ¼ to ¾ of an inch were scattered over the entire surface, the idea being to produce a surface that would be practically smooth and at the same time one that would not be unnecessarily slippery. Expansion joints were placed every forty feet across the pavement and also along the gutters. On streets having street car tracks, joints were also placed on each side of the track at the end of the ties. These joints were made by using 1 inch by 8 inch cypress boards for forms, these boards being allowed to remain in the work and form the filler for the joints. Engineers have reported

Reinforced Concrete Pavement, Plymouth, Wis.

100,000 Square Feet Triangle Mesh Reinforcement Used. Designing Engineer: W. G. Kirchoffer, Madison, Wis.

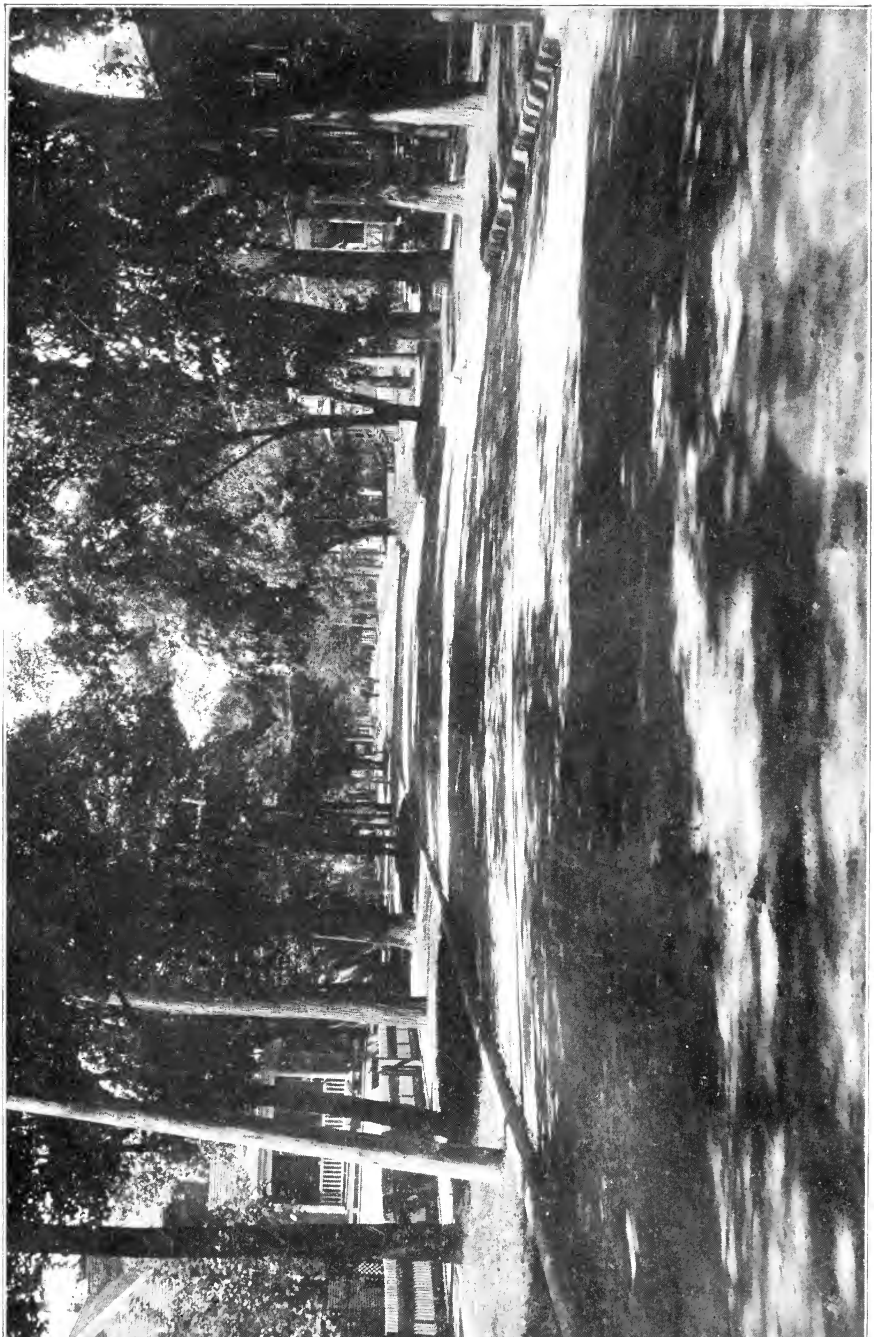
this pavement to be in excellent condition after two and one-half years' wear. It was designed by Mr. W. G. Kirchoffer, Consulting Engineer of Madison, Wis., who also supervised the work.

The City of Platteville, Wis., in 1911 constructed approximately 9,000 square yards of pavement similar to the one above described at Plymouth, Wis.

During the year 1911, Sheboygan, Wis., had approximately 15,000 square yards of reinforced concrete pavement laid and during 1912, approximately 45,000 square yards. The base consisted of 5 inches of concrete mixed in the proportion of one part of Portland cement, three parts of sand and five parts of crushed limestone and was laid 5 inches thick at the center of the street and 3 inches at the curbs. The wearing surface was 1¾ inches thick and consisted of 40 per cent of Portland cement, 50 per cent of granite screenings and 10 per cent of torpedo sand. The granite screenings were graded to 20 per cent having a size of 1-16 to ¼ of an inch and 30 per cent ¼ to ¾ of an inch. Triangle Mesh Reinforcement Style No. 7 was laid between the wearing surface and the base, the longitudinal wires being placed crosswise of the street. The wearing course was floated by means of a wood float after which the surface was broomed transversely to give a slightly roughened surface. The pavement was sprinkled for seven days and no teams were allowed upon the same for ten days. One-inch expansion joints filled with asphalt were constructed along the curbs and every 40 feet across the street. These pavements were designed by City Engineer C. V. Bowley, the contract price being $1.20 per square yard.

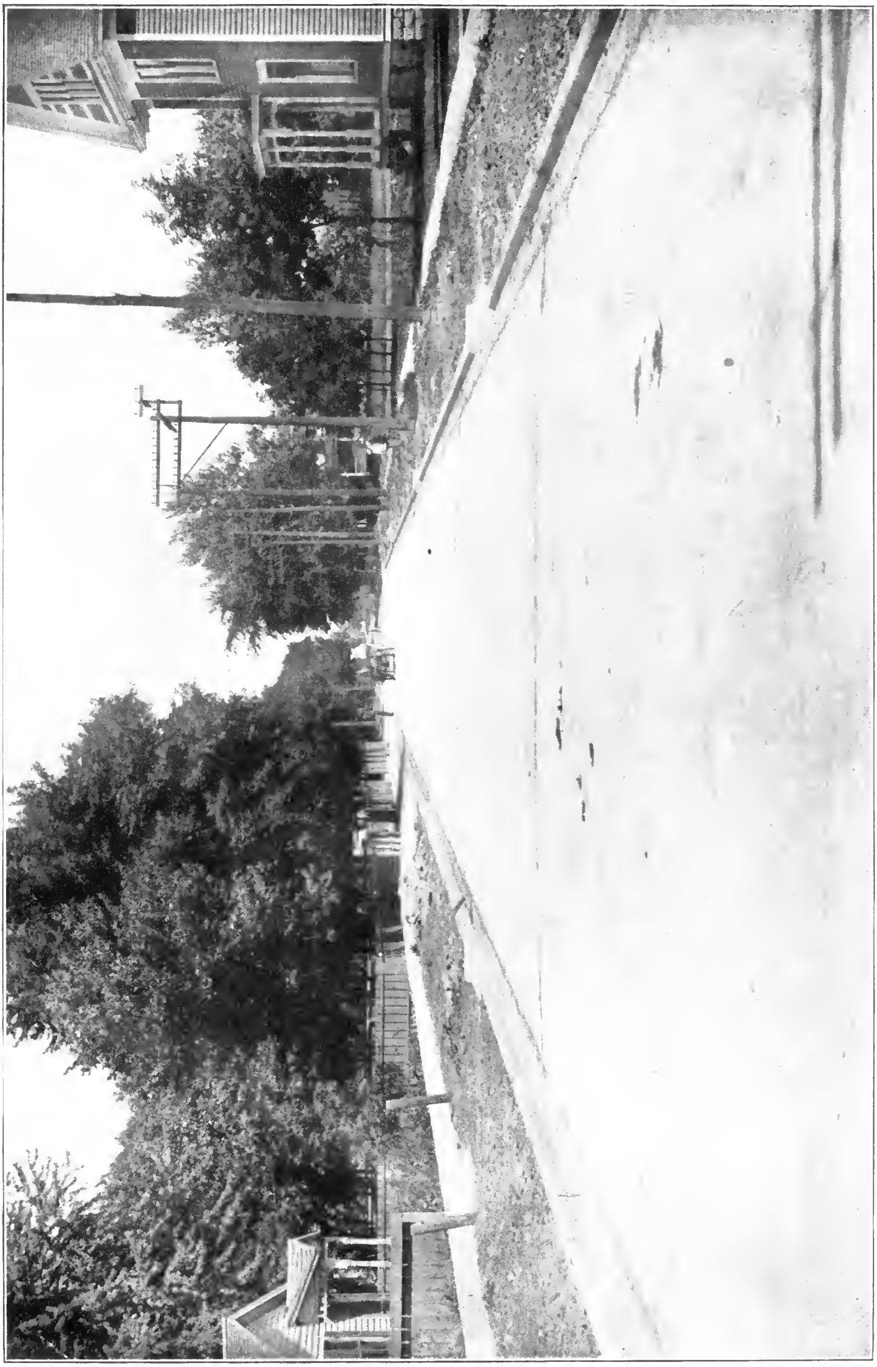
The City of Fond du Lac, Wis., has made extensive use of concrete pavements, both plain and reinforced, having constructed during 1908 approximately 17,300 square yards of plain pavement at an average price of $1.325 per square yard, and in 1909, approximately 69,200 square yards at an average price of $1.235 per square yard. Since 1910 their concrete pavements have all been reinforced, using Triangle Mesh Reinforcement Style No. 7 for a width of 18 feet down the center between curbs, the principal reason for using the reinforcement being to eliminate the longitudinal cracks that formed in the plain pavements along the center line of the street. For the year 1910 the average price for 44,300 square yards was $1.177 and for 1911 the average price of 11,000 square yards was $1.25. An additional 8,000 square yards were laid during the year 1912. All pavements carry a five year guarantee, so that for the first five years at least there will be no maintenance charges.

The usual type of combination curb and gutter is first constructed, after which the center portion of the street is excavated and rolled to the proper elevation. Upon this foundation is laid a 5-inch base course consisting of one part of Portland cement, two and one-half parts of sand and five parts



Reinforced Concrete Pavement, Fond du Lac, Wis.

284,150 Square Feet Triangle Mesh Reinforcement Used. City Engineer: S. McCullough. Contractors: J. Rasmussen & Sons Co. Geo. H. Stanchfield.



Reinforced Concrete Pavement, Fond du Lac, Wis.

284,150 Square Feet Triangle Mesh Reinforcement Used. City Engineer: J. S. McCullough. Contractors: J. Rasmussen & Sons Co. Geo. H. Stanchfield.

of clean crushed limestone, 4 inches being laid first upon which is placed the wire fabric reinforcement, the longitudinal wires running crosswise of the street, and immediately thereafter is placed the additional 1 inch of concrete. The wearing surface is immediately applied and consists of 1½ inches of a mixture of one part of cement, one part of clean sharp sand and one part of crushed granite, this granite consisting of sizes ranging from dust to ¼ of an inch. The surface is then troweled and before hardening it is roughened by brushing the same crosswise with an ordinary street broom. Expansion joints are placed along each gutter and every 50 feet across the street and have a width of ¾ of an inch. The forms for the expansion joints are allowed to remain in place until the concrete is hardened, after which they are removed and the joint is filled with an asphalt preparation. The surface is kept wet for one week and then the street is thrown open for traffic.

The pavements have been designed and the construction supervised by J. S. McCullough, City Engineer for Fond du Lac. The contractor for the 1910 and 1912 pavements was George H. Stanchfield, Fond du Lac, and for the 1911 pavements, J. Rasmussen & Sons Company, Oshkosh, Wis.

In regard to the difficulty of opening trenches through concrete pavements, it is interesting to note the statement made by the City Engineer J. S. McCullough before the Association of American Portland Cement Manufacturers in Chicago in May, 1911. The City of Fond du Lac found it necessary to cut trenches 18 to 20 inches wide for a length of about 4,300 feet. This was done by drilling holes about twelve inches apart along both sides of the trench and the slab was then broken out by the use of wedges. The holes were drilled with a small steam drill and Mr. McCullough is authority for the statement that 400 feet could be drilled in a day and that it required two additional men to break out the slab. After the trench was back filled and properly tamped, the pavement was replaced with new material finished identically the same as the original pavement. This repair work cost approximately $1.83 per square yard as against $2.27 for similar work through a brick pavement.

During the year 1912, Superior, Wis., laid 9,602 square yards of reinforced concrete pavement designed by the City Engineer E. B. Banks. The base consisted of 6 inches of concrete mixed in the proportion of one part of Portland cement, two and one-half parts of sand and five parts of crushed stone. The top or wearing course is 1½ inches thick and consists of one part Portland cement, one part of sand and one part of crushed trap rock varying in size from ¼ to ¾ of an inch. The reinforcement used was Triangle Mesh Wire Fabric Style 29 placed with the longitudinal wires crosswise of the street and extending from curb to curb. The first 4 inches of the base were placed upon the rolled foundation and upon this was laid the reinforcement, after which the additional two inches of the base were laid. Immediately upon this completed base was placed the wearing course which was troweled and roughened by brushing with a street broom. One-half inch expansion joints were placed along the curbs and across the street every 24 feet. The finished pavement cost $1.29 per square yard exclusive of the excavation, the material and labor costs being as follows:

Cement	$1.35 per barrel.
Sand	.75 per cubic yard
Crushed stone	1.65 per cubic yard
Common labor	2.50 per day

The City of St. Johns, Mich., laid during 1912 approximately 15,000 square yards of reinforced concrete pavement consisting of a base 5 inches thick mixed in the proportion of one part of Portland cement to seven parts of gravel including sand. The top or wearing course is 2 inches thick mixed in the proportion of one part of Portland cement to three parts of clean sharp sand. Triangle Mesh Reinforcement Style No. 29 was used as a reinforcement, the same being placed between the base and wearing courses. Expansion joints were constructed along the curbs and across the street every 30 feet, all joints being protected with the Baker Armor Plate which consists of a flat piece of steel about 3-16 of an inch thick and 2½ inches wide, bent to conform to the shape of the finished pavement. Two plates are used in each joint and are separated from ¼ to ⅜ of an inch. They are held in place by means of shear members which occur about 12 inches apart and are bent back at right angles to the plate and extend into the concrete. This pavement was designed and supervised by E. G. Hulse, City Engineer, the contractor being James A. McKay, of Clare, Mich.

A very successful reinforced concrete pavement has been laid in Hamtramck, Mich., (a suburb of Detroit) the same having been designed and constructed by the R. D. Baker Company, Detroit, Mich. During the year 1912, 15,000 square yards were laid, having a base 5 inches thick consisting of a concrete mixture of one part Portland cement, three parts of sand and six parts of crushed stone. The wearing course is 2 inches thick, mixed in a proportion of one part Portland cement, one part of sand and two parts of crushed granite having a size not to exceed ½ an inch. The reinforcement used was Triangle Mesh Style No. 28, placed between the base and top course and was laid with the longitudinal wires at right angles to the center line of the street. Expansion joints were placed along the curbs and every 30 feet across the street, and were protected by means of the Baker Armor Plates, a description of which is given on page 67. The cost of the finished pavement was $1.35 per square yard exclusive of excavation, the material and labor costs being as follows:

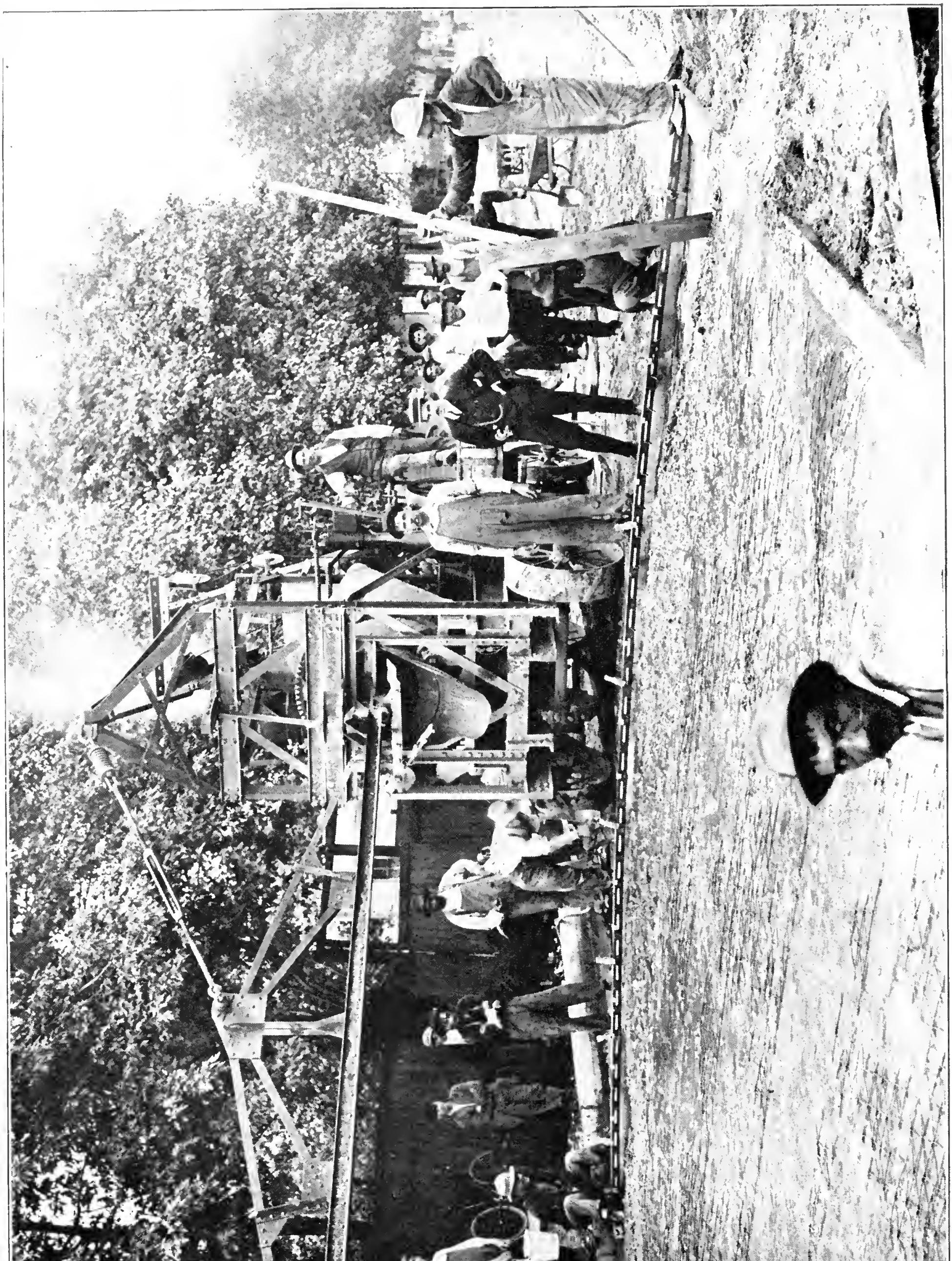
Cement............................$1.02 per barrel
Sand.............................. .75 per cubic yard
Crushed stone...................... 1.15 per cubic yard
Crushed granite.................... 3.15 per cubic yard
All above being f. o. b. cars, Hamtramck.
Common labor cost $2.60 per day.

The City of Port Huron, Mich., laid about 9,000 square yards of reinforced concrete pavement in the year 1912. This pavement had a total thickness of 7 inches, consisting of a 5½-inch base and a 1½-inch wearing course. The concrete for the base was mixed one part Portland cement to five parts of river run gravel. The wearing course consisted of one part cement, one and one-half parts sand, and one and one-half parts of ¾-inch crushed field stone. Triangle Mesh Reinforcement Style No. 4 was placed between the top and bottom courses. Expansion joints were placed every 16 feet across the street and where car tracks occurred, joints were placed one foot from the track on each side for the full length of the street. All joints were protected by the Baker Armor Plate. The price of the finished pavement was $1.22 per square yard exclusive of excavation. The material and labor costs were as follows:

Cement............$1.02 per barrel
Sand............... 1.15 per cubic yard f. o. b. the work
Gravel............. $1.15 per cubic yard f. o. b. the work
Common labor was $2.25 to $3.00 per day.

The designing engineer was E. R. Whitmore, Port Huron, Mich., the contractors being J. H. Baker & Son, Port Huron, Mich.

The City of Rockville, Ind., constructed during 1912, 4,400 square yards of reinforced concrete pavement. This pavement was of a different type than the ones listed on previous pages, it being a one-course instead of a two-course type. Although the use of a reinforcement necessitated placing the pavement in two layers, both layers consisted of the same concrete mixture, this being one part of Portland cement, two parts of sand and two and one-half parts of gravel. The total thickness of the pavement was 5 inches and the reinforcement was Triangle Mesh Reinforcement Style No. 7, placed approximately in the center of the slab. The curb is 6 inches high and 5 inches thick, built directly upon the pavement and anchored to the same by means of steel loops placed every 5 feet. Expansion joints occur every thirty-three feet across the



Reinforced Concrete Pavement, Hamtramck, Mich.

106,000 Square Feet Triangle Mesh Reinforcement, Style No. 28, Used. Contractor: R. D. Baker Co., Detroit, Mich.

Reinforced Concrete Pavement, Hamtramck, Mich.

106,000 Square Feet Triangle Mesh Reinforcement, Style No. 28 Used. Contractor: R. D. Baker Co., Detroit, Mich.

Reinforced Concrete Pavement, Hamtramck, Mich.
106,000 Square Feet Triangle Mesh Reinforcement, Style No. 28 Used. Contractor: R. D. Baker Co., Detroit, Mich.

pavement and are protected by means of the Baker Armor Plate, the joints being filled with tar. The finished pavement cost $1.10 per square yard including excavation and the material and labor costs were as follows:

Cement	$1.25 per barrel
Sand	1.25 per cubic yard
Gravel	1.25 per cubic yard
Common labor	.20 per hour

Very little excavation was required beyond surfacing to grade. The foundation consisted of a yellow clay which required the depositing of a small amount of gravel in some places. The crown of the street was 4 inches for a width of pavement of 26 feet. The designing engineer was H. L. Davies of Judson, Ind., and the contractors were Ireland Brothers, Bloomingdale, Ind.

During the year 1912, Vinton, Iowa, laid 11,000 square yards of a two-course reinforced concrete pavement of a total thickness of 7 inches. The 5-inch base course consisted of a mixture of one part Portland cement, three parts of sand and five parts of crushed stone. The 2-inch wearing course was mixed one part of cement to two parts of clean sharp sand. The reinforcement used was Triangle Mesh Reinforcement Style No. 26, placed between the top and bottom courses over the center 16 feet of the pavement and was laid with the longitudinal wires at right angles to the center line of the street. Expansion joints were constructed along curbs and across the street every 40 feet, these joints being protected with steel plates ¼ of an inch thick and 2 inches wide, the same being anchored into the concrete by means of anchor bolts. The cost of the finished pavement exclusive of excavation was $1.07 per square yard, the costs of material and labor being as follows:

Cement	$1.00 per barrel
Sand	.50 per cubic yard for hauling
Crushed stone	1.30 per cubic yard
Common labor	2.25 per nine-hour day

The designing engineer was P. P. Smith, Cedar Rapids, Iowa, the contractor being F. K. Hahn, of Cedar Rapids.

Connersville, Ind., contracted for the construction of 65,000 yards of reinforced concrete pavement during the year 1912 at a cost of $1.02 per square yard, including excavation. The base is 5 inches thick at the curbs and 7 inches at the center and the top or wearing course is 1½ inches thick over the entire pavement. The concrete for the base is mixed one part of Portland cement, two parts of sand and four parts of crushed stone or gravel. The mixture for the wearing course is one part of cement to one and one-half parts of clean sharp sand. The pavement is reinforced with Triangle Mesh Style No. 7, placed between the top and base courses. Extension joints protected by means of Baker Armor Plate and filled with an asphalt filler are placed along the curbs and across the street every 30 feet. The material and labor costs were as follows:

Cement............................	$1.02 per barrel
Sand..............................	.50 per cubic yard
Gravel............................	.45 per cubic yard

All f. o. b. Connersville, Ind.
Common labor, $2.00 per day.

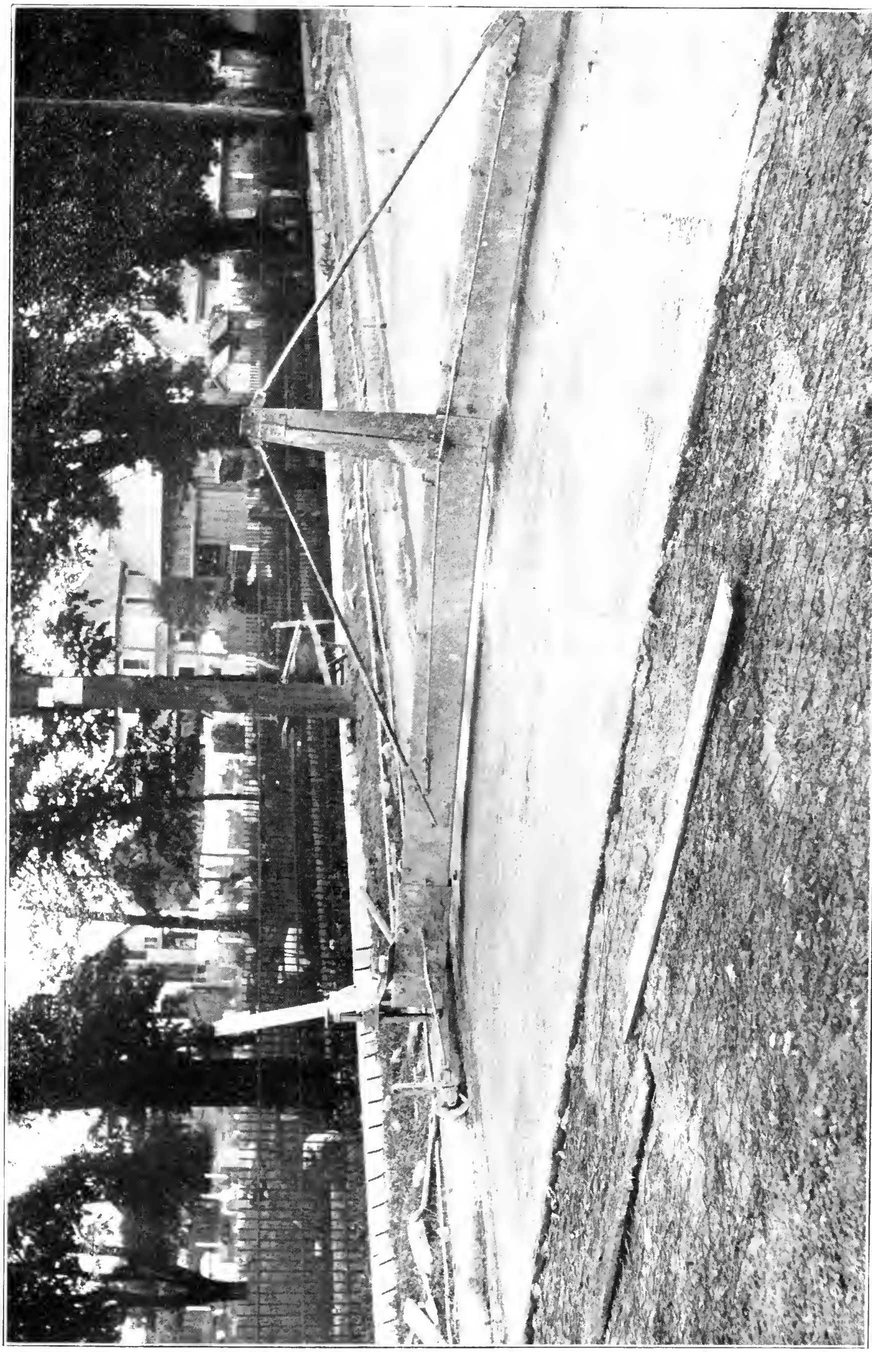
The designing engineer was W. F. Ridpath, City Engineer of Connersville, and the contractors were Greenwood, Connor, Boots & Gant of Connersville, Ind.

It may be interesting to note the comparative bids for other types of pavements that were entered at the time the contract was let for this Connersville work. The bids for brick pavements varied from $1.62 to $1.98 per square yard and for asphalt from $1.65 to $1.95 per square yard. Bids were asked for the following four types of concrete pavements:—

One-course with Baker Armor Plate protected joints,—the bids entered vary from $0.93 to $1.15 per square yard; two-course work with Armor Plate joint protection,—bids varied from $0.99 to $1.44 per square yard; two-course with Armor Plate joint protection and Wire Mesh Reinforcement,—from $1.02 to $1.51 per square yard; two-course work without Armor Plate joint protection, but using Wire Mesh Reinforcement,—$0.96 to $1.50 per square yard.

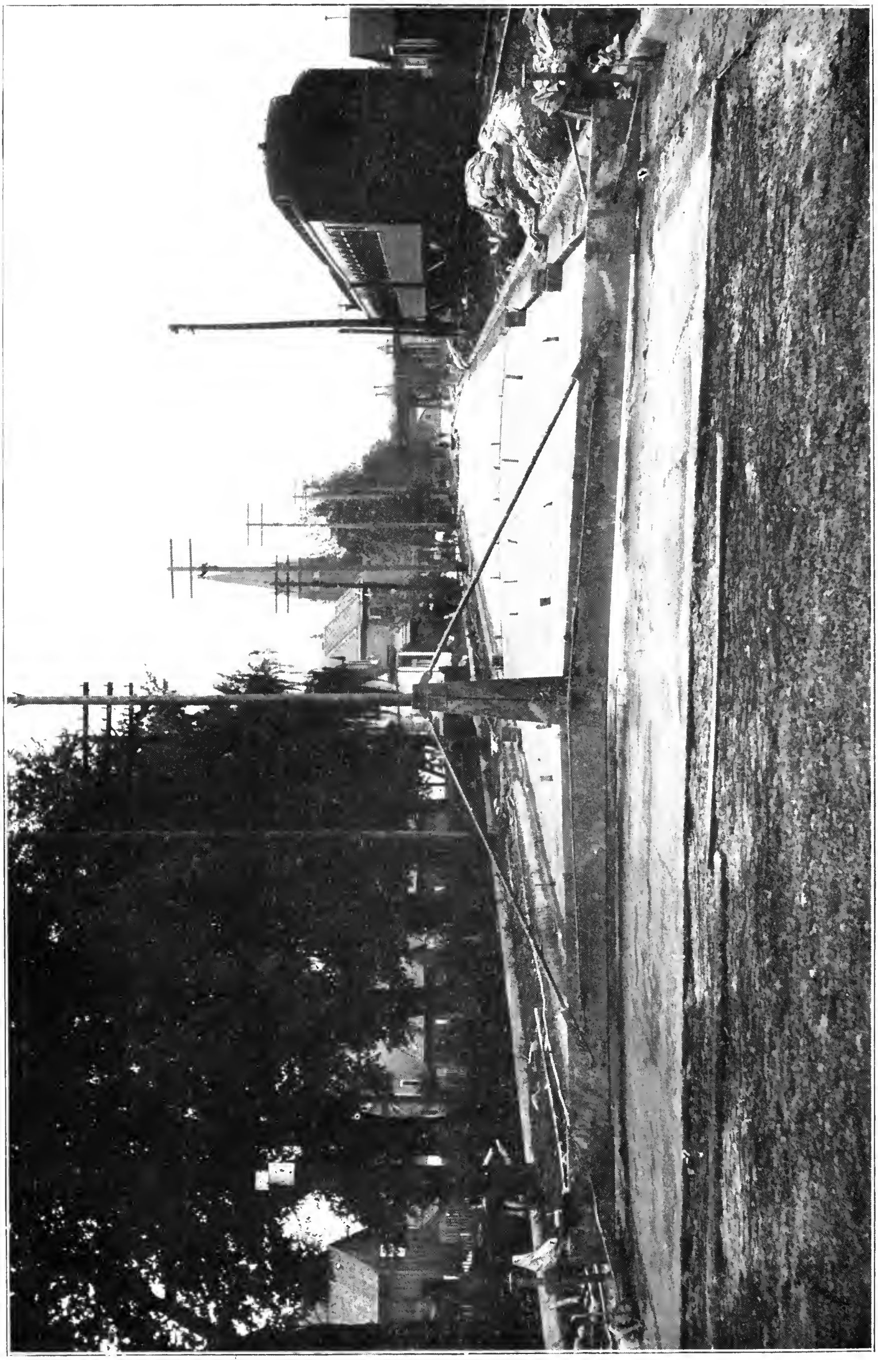
It will be noted that it was decided to use the highest class of construction using the two-course reinforced concrete type and all joints protected with steel plates.

Stanley, Wis., laid during 1912, 9,000 square yards of reinforced concrete pavement having a total thickness of 6½ inches. The 5-inch base consisted of one part Portland cement to five parts gravel and the 1½-inch wearing course consisted of one part of cement to two parts sand and granite screenings. The reinforcement used was Triangle Mesh Style No. 7 placed between the top and bottom courses. Expansion joints were placed along the curbs and across the street every 30 feet. No steel protection was used on the joints but the edges were rounded to a small radius to prevent the chipping off under wheel traffic. This pavement was laid at a cost of $1.52 per square yard including excavation. The designing engineer was L. G. Arnold, Chippewa, Wis., and the contractor was Fred Eul, Menasha, Wis.



Reinforced Concrete Pavement, Connersville, Ind.

585,000 Square Feet Triangle Mesh Reinforcement Used. City Engineer: W. F. Ridpath. Contractors: Greenwood, Connor, Boots & Gant.



Reinforced Concrete Pavement, Connersville, Ind.

585,000 Square Feet Triangle Mesh Reinforcement Used. City Engineer: W. F. Ridpath. Contractors: Greenwood, Connor, Boots & Gant.

Reinforced Concrete Pavement, Connersville, Ind.

585,000 Square Feet Triangle Mesh Reinforcement Used. City Engineer: W. F. Ridpath. Contractors: Greenwood, Connor, Boots & Gant.

The City of Mitchell, South Dakota, laid several blocks of reinforced concrete pavement during 1912, in accordance with plans and specifications furnished by S. H. Smith, City Engineer, the contractors being the Watertown Cement Products Company of Watertown, S. D. The base course was laid 5½ inches thick and consisted of a concrete mixed in the proportion of one part of cement, three parts of sand and five parts of crushed stone. The sand was to be well graded and to contain no pieces larger than would pass a No. 4 mesh screen. The crushed stone was graded in sizes ranging from ¼ of an inch to 2 inches. On top of the base was placed Triangle Mesh Wire Reinforcement Style No. 7 for a width of 20 feet in the center of the pavement on Main Street and 15 feet on intersecting streets. This required 114,000 square feet of reinforcement. The main longitudinal wires were placed crosswise of the pavement and the entire mesh was tamped into the freshly laid concrete. Over this was placed the wearing course 1½ inches thick consisting of one part of cement to one and one-half parts of a mixture of equal parts of sand and stone screenings. In order to give the finished pavement a dark color there was to be added one-fourth of a pound of

Reinforced Concrete Roadway, De Kalb, Ill.
Triangle Mesh Reinforcement, Style No. 26A used.
State Engineer: A. N. Johnson.
Shows method of handling materials.

lamp black to each sack of cement. The wearing course was properly floated to grade and troweled, and after becoming sufficiently hardened it was roughened with a street broom. Expansion joints ¾ of an inch wide were placed along all curbs and joints ⅜ of an inch wide were placed across the street every twenty-five feet, and around all catch basins or man-hole covers. The edges of all expansion joints were rounded to ½-inch radius. After the pavement had taken sufficient set, the joints were to be filled with a suitable elastic waterproof compound.

The Township of DeKalb, Ill., constructed a short piece of reinforced concrete roadway pavement in 1912, the work being done under the supervision of A. N. Johnson, State Engineer. The pavement consists of one-course work, laid 6½ inches thick, the concrete mixture being 1:2 and 3. Expansion joints were constructed across the pavement every 50 feet and protected by the Baker Steel Armor Plate. Triangle Mesh Reinforcement Style No. 26A was placed approximately in the center of the slab with the longitudinal wires at right angles to the center of the roadway. The accompanying photograph shows the reinforcement during the process of placing.

Reinforced Concrete Roadway, De Kalb, Ill.
Triangle Mesh Reinforcement, Style No. 26A used.
State Engineer: A. N. Johnson.

In addition to the above examples, 18,000 square feet of Triangle Mesh Reinforcement Style No. 27 were used for reinforcing concrete pavements at Owosso, Mich., and 52,000 square feet of Style No. 7 at Iron River, Mich.

The City of Davenport, Iowa, laid during 1911, several blocks of reinforced concrete pavement in which the reinforcement was placed near the bottom surface of the slab for structural reasons. The soil over which this pavement was to be laid consisted of refuse from saw mills such as sawdust, chips, bark, etc., and was almost constantly saturated with river water. The street itself and the railroad track paralleling the same settled from eighteen to twenty-four inches every year. As the usual type of pavements could not possibly be expected to prove satisfactory with such a type of sub-soil (the pavement also being subjected to heavy and high speed traffic) it was decided to construct a concrete pavement reinforced with a sufficient amount of steel to produce a monolithic slab that would spread over a greater area, any excessive loads coming upon the same under the traffic conditions. The pavement was laid 7 inches thick of a 1:3:5 concrete mixture and reinforced with 0.5 per cent of Triangle Mesh Reinforcement placed near the lower surface of the pavement. The total cost for the work was $0.93 per square yard which, considering the unusual conditions, is an exceptionally low price. It is stated that, during the time, and immediately after the pavement was laid, there was a very heavy rain fall for several weeks leaving the soil in a very soft condition. Although the curbing settled very badly, there were no signs of failure in the pavement. It is also stated that even expansion and contraction cracks had not developed, although subjected to a variation of 130 degrees in temperature during the first year.

The City of Oakland, Cal., solved the problem of how to construct pavements on filled ground by selecting and constructing a reinforced concrete pavement on the street parallel to the United States Bulkhead and Estuary. The specification called for Triangle Mesh Reinforcement Style No. 28 as manufactured by the American Steel & Wire Company, 25,025 square feet being used. The following extract from the magazine* published by real estate interests, together with the accompanying photographs will clearly show the bad conditions of the foundation over which this reinforced concrete pavement was placed.

"One of the most difficult engineering problems that has presented itself to the Board of Public Works has been the construction of a street giving access between the piers and the various business concerns adjacent to the "made-ground."

An unstable clay foundation, which has not yet dried out, afforded

*The Syndicate's Magazine, Oakland, California, February, 1913.

Reinforced Concrete Pavement, Oakland, Cal.

Triangle Mesh Reinforcement, Style No. 28 used. Pavement laid on filled ground. City Engineer: Perry F. Brown. Contractors: Ransome-Crummey Co.

Reinforced Concrete Pavement, Oakland, Cal.
Triangle Mesh Reinforcement, Style No. 28 Used. Pavement laid on filled ground.
City Engineer: Perry F. Brown. Contractors: Ransome-Crummey Co.

but little more than a spongy mass as a road basis. When it is considered that these streets must be suitable for hauling heavy machinery, possibly ten tons to the load, the character of the problem is evident.

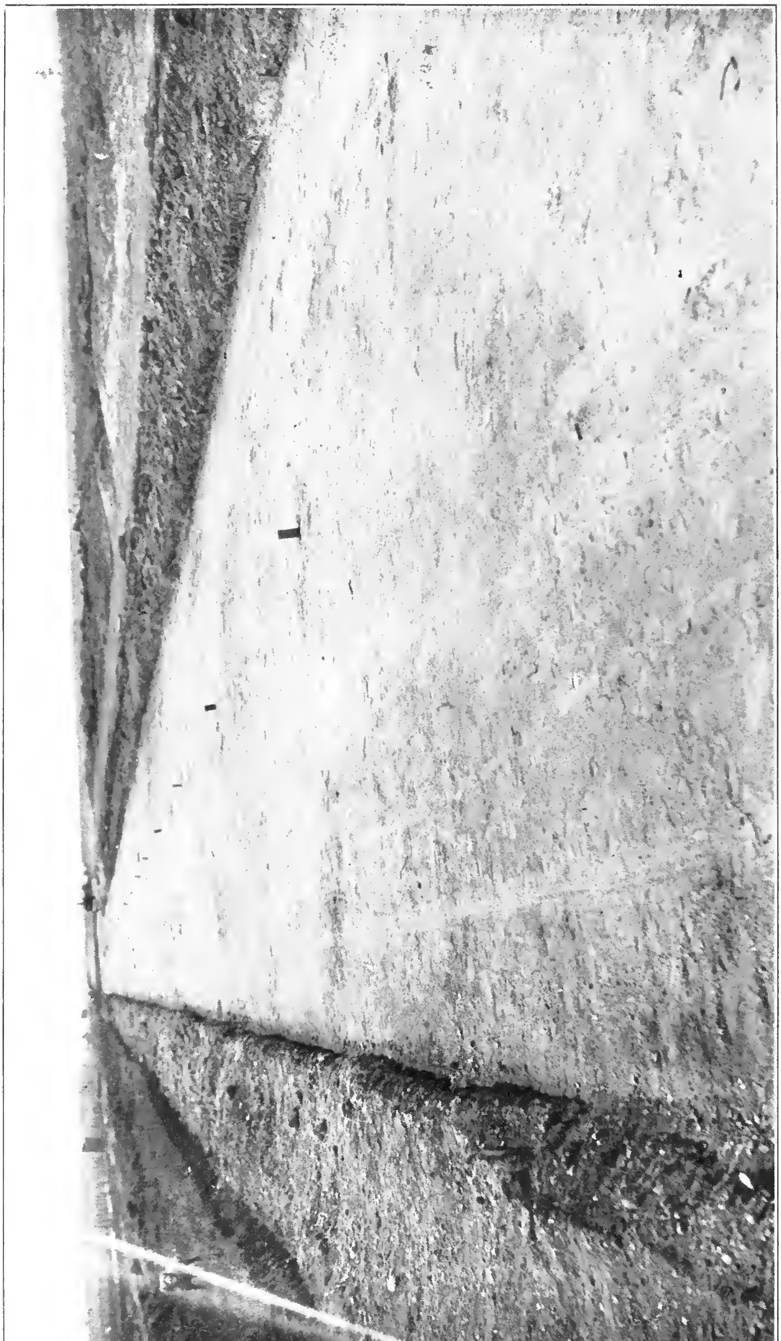
The necessity for permanent construction rejected the idea of a corduroy road of wood and the soft character of the foundation made macadam totally unsuitable for the heavy traffic.

It was finally decided to lay a six-inch concrete slab reinforced near the bottom with a steel wire mesh. Upon especially soft spots a second thickness of the wire fabric was laid at right angles to the other.

This "Triangle Mesh" reinforced roadway is giving good service and bids fair to solve one of the greatest problems of road building."

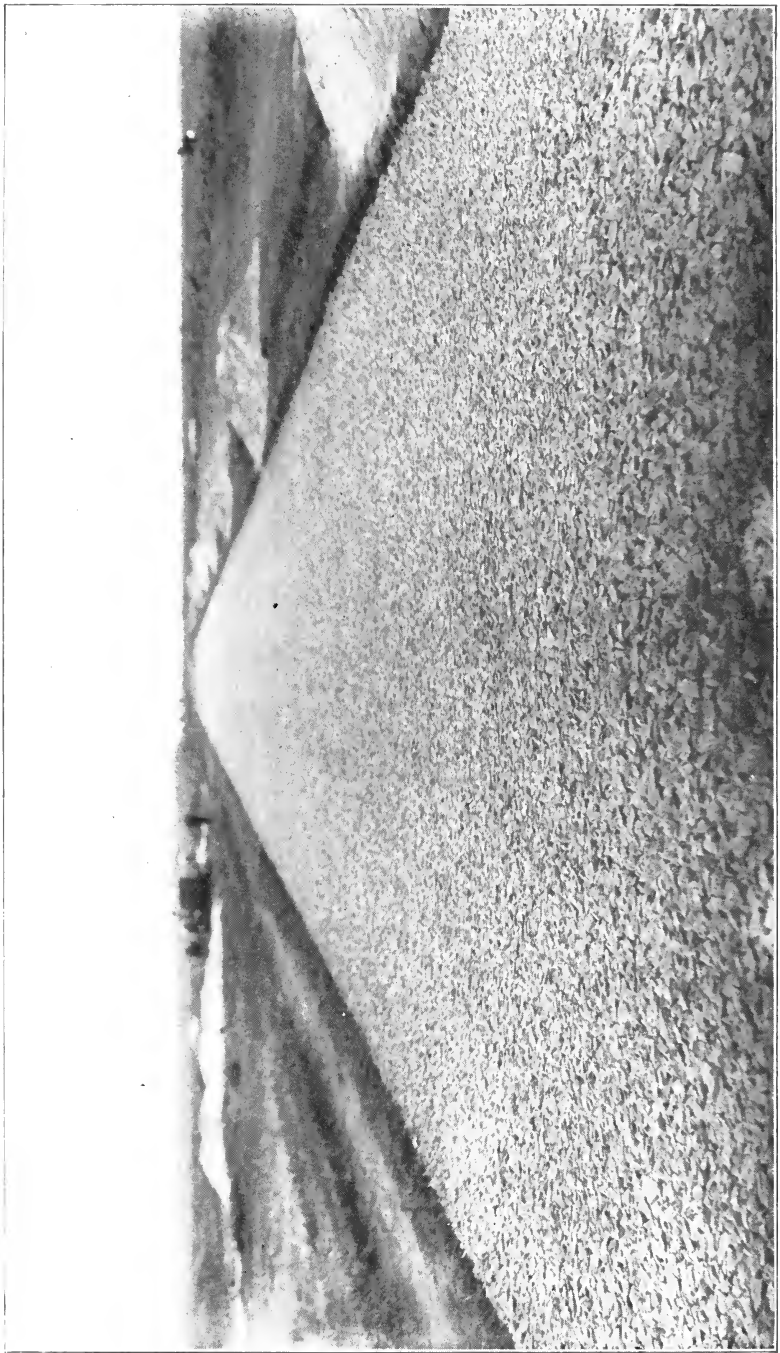
The design, supervision and construction were taken care of by the following: Perry F. Brown, City Engineer; Harry Anderson, Commissioner of Public Works; T. E. Risley, Assistant City Engineer, in charge of Harbor Improvements; Ransome-Crummey Company, Contractors.

The Long Island Motor Parkway constructed during the year of 1908 is another type of a reinforced pavement. The work was done by the Hassam Paving Company, and constructed in accordance with their patents. After preparing the road bed, about 2 inches of crushed stone was laid and on top of this was placed Triangle Mesh Reinforcement Style No. 8, the longitudinal wires being placed parallel with the direction of the pavement. Then additional crushed stone was placed of a sufficient depth to make the total finished slab 4 inches thick after rolling with a ten ton roller. A sand and gravel grout was then poured over the entire area until all the voids of the stone were filled and a sufficient amount remained on the surface to produce a smooth finish. Ten miles of this roadway 28 feet wide were laid without any expansion joints. The reinforcement was used to give added strength to the pavement and prevent depressions forming due to settlement of the foundations under the heavy automobile loads. Although the road has given very good satisfaction, the amount of reinforcement used was insufficient to prevent cracks forming across the pavement at regular intervals. The reinforcement used consisted of No. 12½ gage wires spaced 4 inches apart longitudinally and No. 14 gage diagonal cross wires spaced to form a four-inch mesh. This is an exceptionally light material and should not be expected to prevent temperature cracks in pavements having no expansion joints.



Long Island Motor Parkway. Reinforced Hassam Pavement.
Shows Parkway excavated to proper depth. Triangle Mesh Reinforcement Used.

Long Island Motor Parkway. Reinforced Hassam Pavement.
Shows Stretching of Triangular Mesh Reinforcement over first layer of broken stone and being covered by second layer of stone.



Long Island Motor Parkway. Reinforced Hassam Pavement.

Reinforced fabric and stone all in place and thoroughly rolled, ready for cement grout. Triangle Mesh Reinforcement Used.

Summary

The excellent results obtained by the use of Triangle Mesh Wire Reinforcement in the foregoing examples of reinforced concrete pavements proves conclusively that many of the difficulties encountered in the use of plain concrete pavements have been eliminated. At a small additional cost, a permanent and in every way satisfactory pavement has been obtained, the extra cost for reinforcement varying from 5 to 15 cents per square yard depending on the weight of reinforcement used. It has been shown that a high quality of pavement using only the best grades of material can be laid at an average price of $1.10 to $1.25 per square yard. Excluding the cost of maintenance which is lower for concrete than for any other type, and assuming the life of the various types of permanent pavements to be the same, a saving in the first cost can be obtained by the use of reinforced concrete that could be used to pay for at least 50 per cent of the total replacement cost when such replacement is found to be necessary. This saving at 4 per cent compound interest for twenty years would amount to the original cost of the pavement, or in other words comparing a reinforced concrete pavement with the cheapest and best of other types, the original cost of the latter will construct a high class reinforced concrete pavement and replace the same at the end of twenty years. The above assertions can be easily verified and should prove of interest to prospective builders.

One decided advantage gained by the use of a reinforced concrete pavement that has not been previously touched upon here is the enormous saving to vehicles of all kinds, whether buggy, wagon, automobile or auto truck produced by the elimination of all jar and accompanying vibration because of the smooth pavement surface. One company manufacturing automobiles advertises the fact that they test their cars for efficiency by running them over the country roads. This statement is not very complimentary to the roads, but it gives us an insight into the destructive effect of rough roads on automobiles.

Although this effect is slight for those types of pavements having surfaces that are not absolutely smooth as compared with the average unpaved country roads, it unquestionably shortens the life of all rolling stock. What this destructiveness amounts to for the country in dollars and cents is difficult to determine within even approximate limits, but it undoubtedly will reach into millions now that automobiles and auto trucks with their many and intricate parts requiring careful adjustment have come into such general use.

Necessity for Reinforcement

It is becoming more and more generally recognized that steel reinforcement is required in the proper construction of concrete pavements, the chief reasons for its use being unsatisfactory foundation or sub-soil and expansion and contraction stresses.

The formation of cracks due to the soft and yielding sub-soil can only be prevented by the use of a proper amount of steel reinforcement. In this case the reinforcement is used to add structural strength to the concrete slabs. Although ordinarily it is advisable to improve the condition of the foundation by drainage or by removal of the soft portions of the soil and replacing the same with material that may be properly rolled into a substantial and satisfactory foundation, or by both methods combined, many times this is impossible or at least prohibited as was the case with the reinforced concrete pavement laid at Davenport, Iowa, a description of which is given on page 56.

Under average conditions, the question of expansion and contraction presents the greater number of difficulties. It is now very well known that concrete will expand and contract under changes of temperature and also that the cement during the setting period, will contract to a marked degree. This means that the pavement moves over the sub-soil, this movement in itself causing the setting up of tension or compression stresses depending upon whether it is a case of contraction or expansion of the material. Although the concrete in itself has a certain amount of tensile value it has been found advisable to eliminate this value in concrete computations. For this reason, steel reinforcement is placed in the pavement to take up or at least assist the concrete in taking care of these temperature stresses. In the construction of the two-course pavements, the top or wearing course has a very much richer mixture than the base and since richer mixtures will expand and contract under temperature changes and will contract during setting a greater amount than a leaner mixture, there will be formed a plane of weakness between the two courses which often results in the splitting off of the top course from the base. This difficulty is very readily eliminated by the use of a light reinforcement that is slightly tamped into the base prior to the placing of the top course, and thereby increasing the adhesion between the two mixtures. Additional stresses occur because of the fact that especially during the hot weather, the top or exposed portion of the pavement has a temperature considerably in excess of the under surface. Steel reinforcement also tends to equalize the stresses due to this variation in temperature.

Expansion Joints

Since it is known that pavements will increase and decrease in length under average conditions, it is undoubtedly advisable to make use of expansion joints across the pavement at certain definite intervals and these joints should be of sufficient width to allow for the maximum expansion. Since concrete during the time of setting will contract an amount equal to that due to a change in temperature of approximately 100 degrees, it has been argued by some engineers that contraction joints are of more importance than expansion joints. By contraction joints is meant a cutting through of the entire pavement or in other words, simply a line of separation of adjacent sections. This may be produced by either using a very thin sheeet of steel or by the construction of alternate sections of the pavement. It is, however, in our opinion unnecessary and in fact, not advisable to make use of contraction joints for the reason that assuming that the pavement is constructed during the warmer portions of the year and that the contraction cracks will open up due to the setting of the concrete or to a decrease in temperature or both, these cracks under traffic will become filled with dust and grit to such an extent as to prevent the pavement from expanding when the temperature again rises. We believe therefore, that expansion joints properly filled with an elastic material should be used to the exclusion of contraction joints.

An examination of plain concrete pavements shows that in the majority of cases a more or less regular crack forms down the center of the street. If the temperature of the pavement rises, providing the pavement is prevented from expanding sidewise due to rigid curbs, etc., it may be that these longitudinal cracks will be formed by a heaving action. Since the form of the pavement is a segment of a circle, the compression stresses produced by the resistance of the curbs to the expansion of the pavement, will produce a condition similar to an eccentric load and since the thickness of the concrete is small in comparison to the width of the pavement, the compression due to this side restraint will cause a raising of the crown and accompanying cracks. In some cases these cracks are undoubtedly formed by the raising of the outside edges produced by the freezing of the foundation at that point. If water draining from the pavement is allowed to seep into the foundation and if the same does not have adequate drainage, the soil will become sufficiently saturated to allow either a depression of the outside edges during warm weather or a raising during freezing weather. Either of these conditions will undoubtedly result in longitudinal cracks forming in the center of the pavement. Some engineers have endeavored to decrease this difficulty by constructing expansion or contraction joints in the center of the street.

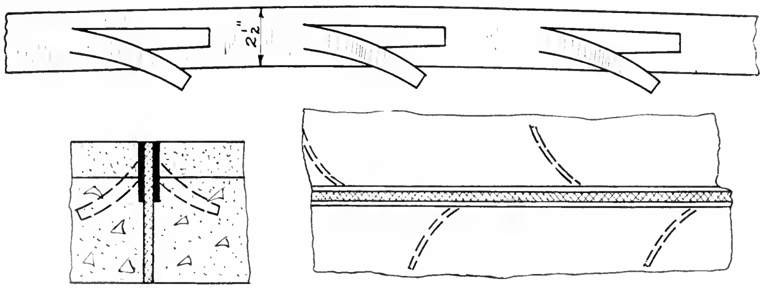
However, as this will add materially to the cost of the pavement and in addition will increase the destruction due to the action of wagon wheels, it is undoubtedly more advisable to eliminate all longitudinal joints and reinforce the pavement to prevent the cracks.

Width of Expansion Joints The necessary width for expansion joints varies principally with the distance between joints. The average concrete has a coefficient of expansion of about .000005 per degree of temperature. Therefore, for an average variation of 100 degrees in temperature, the theoretical width of joints for various spacings would be as follows:

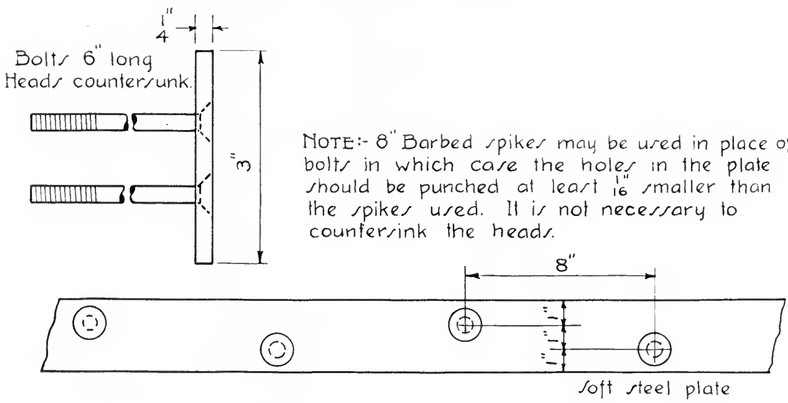
30-foot joint spacing	$\frac{3}{16}$" width
40-foot joint spacing	¼" width
50-foot joint spacing	⅓" width
100-foot joint spacing	⅝" width
130-foot joint spacing	¾" width

The present practice for joints spaced from twenty-five to forty feet apart has been to use a width of expansion joint of ½ an inch, and although we believe future experience will show this width of joint to be sufficient for joint spacing up to at least 150 feet, it is advisable for the present to use ¾-inch joints for a spacing of more than 50 feet.

Expansion Joint Protection The earlier concrete pavements were all constructed without using any special means to protect the joints with the exception of rounding the edges to a radius of about one-half an inch. For pavements carrying light traffic this method may prove satisfactory; however, for those pavements carrying the ordinary mixed traffic it has been found to be more economical to protect the edges of the joints by the use of steel angle irons or plates. By this means it is possible to not only decrease the wear of the joints, but also to eliminate the jar of the vehicles as the wheel passes over the joint. These angles or plates are anchored into the concrete by means of bolts or by shearing out strips of the metal at regular intervals and blending the same back into the concrete. This prevents the steel from separating from the edges of the concrete and gives excellent protection to the joints. The plates or angles should be bent to conform to the surface of the pavement.



Baker Armor Plate.



Suggestion for Joint Protection.

Armor Plates for Expansion Joint Protection.

Expansion Joint Filler After the concrete has properly set, the joints should be filled with an elastic waterproof compound that will not become hard and brittle in cold weather, or sufficiently soft to run out of the joints during hot weather. There have been various types of fillers used, and although in some localities one particular type has proven to be satisfactory, reports show that apparently the same type is not considered satisfactory in other localities. Information collected by the American Society of Municipal Improvements and published in the *Municipal Journal* of September 8, 1912, gives the opinion of a number of city engineers on the question of expansion joint fillers. Little Rock, Ark.; Waukegan, Ill.; Eldora, Iowa; Cadillac, Mich.; and Grand Forks, N. D., report an asphaltic preparation as being entirely satisfactory. Dubuque, Iowa; New Orleans, La.; Ashville, N. C.; Philadelphia, Pa.; Charleston, S. C.; and Green Bay, Wis., report the bituminous filler as satisfactory, but New Haven, Conn.; Richmond, Ind.; Lexington, Mo.; and Toronto, Ont., report the bituminous filler as not entirely satisfactory. This variation of opinion may be due to the difference in the specifications; however, the reports do not give sufficient information to determine this point. Charleston, S. C., reports a soft wood filler as being satisfactory and very easy to set, while Cadillac, Mich., reports this type of a filler as being unsatisfactory. Memphis, Tenn., states their tar filled joints failed but that creosoted yellow pine with the grain placed vertically was satisfactory. The board of County Commissioners of Wayne County, Mich., report the use of two layers of ⅛-inch asphaltic felt as being satisfactory. One advantage of using the felt is in being able to place the filler before laying the concrete. It would appear from the varying results that it would be advisable to require a guarantee covering the filler used in the construction of the expansion joints.

Preparing Steel Plate Expansion Joint Protection.
Asphalted Felt Used Between Plates

Location and Spacing of Expansion Joints Expansion joints should be placed at the intersection of the curbs and pavements or at the outside edge of the gutter when the combination curb and gutter is used. Joints should also be placed at all street intersections, at the intersection of alleys and streets and at the beginning and ending of curves; also around manhole covers, etc. Joints should also be placed across the street at right angles to the center line, the spacing between joints varying with conditions. The usual practice has been to space the joints from 25 to 40 feet apart. However, since it is admitted that the expansion joints are the weakest parts of the concrete pavement, it is advisable to decrease the number of joints as far as possible. This can be done by increasing the weight of the reinforcement used. The average cost of expansion joints including steel protection plates is about six cents per square yard for a joint spacing of 30 feet. By increasing the spacing to an average of 100-foot centers, the cost for expansion joints will be decreased two thirds or approximately four cents per square yard. This saving can be economically used towards supplying a heavier reinforcement and as a result, the pavement will have a higher wearing value as well as a more pleasing appearance.

Foundation or Sub-Base

All engineers agree to the importance of properly draining the foundations of roadways and pavements and the proper compacting of the sub-grade regardless of the type of pavement to be constructed. In general, pavements should not be expected to entirely resist the distorsion due to heavy loads, or in other words, to bridge over the soft places in the sub-soil and for that reason the foundation should be properly drained especially for soils composed of clay or loam. If moisture is allowed to remain in this class of material, it must be expected that trouble will occur due to an insufficient foundation of the pavement. Difficulties from this source are more liable to occur in country roads than in street pavements, but it is always advisable to keep this point in mind and if necessary construct pipe drains leading into sewers or other outlets. Although the proper compacting of the soil by rolling is considered essential, it is believed by many that this is of lesser importance than proper drainage. Under ordinary conditions, the ten-ton roller will produce the best results, but in many cases, a lighter one is advisable as it has been found that with some classes of soil a heavy roller has a tendency to produce a soft or quaking formation from what was apparently a hard soil. Many times it will be found advisable to remove at least a portion of the sub-soil and deposit in its place a material that may be compacted to a desirable foundation; cinders, crushed stone, gravel and sand will usually produce the best results for this purpose.

One and Two-Course Pavements

All reinforced concrete pavements are constructed of either a one or two-course type. The one-course type consists of the same concrete mixture for the entire depth. It received its name from the fact that originally the entire pavement was laid in one course. However, when a reinforcement is used, it is necessary to make the construction of two courses although the mixture for both is the same. This is required in order to place the reinforcement in the proper position in the slab. The two-course type consists of a base of a comparatively lean mixture, and a thin wearing course of a rich mixture, the idea being for the base to act as a solid foundation and the top course to resist abrasion from traffic.

Some engineers advocate the one-course type and claim it to be cheaper than the two-course work. This statement may or may not be true, depending largely upon local conditions as it is necessary to use a richer mixture for the entire thickness of the slab than is required for the base of a two-course type. For this reason, although the wearing course of a two-course type consists of a rich mixture, it may be more economical in some localities than the one-course. We believe that eliminating the question of cost, the two-course pavement is superior as the material that is used in the top or wearing course will be superior to the surface material of the one-course pavement. Although it is usual to construct the one-course work so that a sufficient amount of fine material will be flushed to the surface, to allow the same to be troweled to a smooth and uniform finish, it will be impossible to secure as uniform and satisfactory a wearing material as is secured by the use of a separate layer consisting of a mixture that is carefully graded to give the best wear possible.

Concrete Mixtures The success or failure of a concrete pavement depends very largely upon the selection and proper mixing of the ingredients, and too much care cannot be given to this point. The coarse aggregate should consist of a good hard durable crushed stone or screened gravel and since it is advisable to decrease the voids in the stone to a minimum, the more carefully the stone is graded, the greater the strength of the finished work. This is also true of the fine aggregate which may be made up of crushed stone screenings, granite preferred, from which all dust has been removed, or from good coarse sharp sand. In all cases the fine and coarse aggregate should be clean and free from all vegetable or other injurious particles.

By referring to the examples of pavements now in use as listed on previous pages, it will be noticed that a number of different concrete mixtures have been specified. In some cases the base of the two-course pavements has been of a 1:2:4 mixture, while in other cases a mixture of 1:3½:6 has been used. Although it is impossible to say definitely without knowing more about the quality of the aggregate used, it can in general be said that for a two-course type, a mixture for the base of 1 part of cement, 2½ parts of clean sharp sand to 5 parts of crushed stone should give satisfactory results. However, the engineer in charge of the design should determine in each case the proper mixture to use, depending upon the material that will be furnished. His selection should be based not only upon the quality of the material, but also upon the voids which it contains. The cement should over-fill the voids in the fine aggregate by at least 10 per cent and the cement and fine aggregate should overfill the voids in the coarse aggregate by at least 10 per cent. A sufficient amount of water should be added so that a light tamping would be required to flush the water to the surface. The wearing course should be mixed in about the proportion of 1 part of Portland cement to 2 parts of fine aggregate. This aggregate may consist of clean coarse sharp sand or limestone screenings from which the dust has been removed, but the best results will be obtained by using crushed granite for at least 50 per cent of the fine aggregate.

For the one-course type, the same care should be used in the selection and grading of the materials and it can in general be said that the most satisfactory mixture will be 1 part of Portland cement, 1½ parts of fine aggregate and 3 parts of the coarse aggregate. Sufficient water should be added so that the fine material will flush to the surface when tamped. In other words, the larger stones should be forced below the surface a sufficient amount to permit of a proper floating and finishing.

Thickness The proper thickness for a pavement depends largely upon the amount and kind of traffic it will be required to carry. Although the condition of the foundation and the amount and position of the reinforcement used may require a different thickness, it will in general be advisable to make a total thickness of 6 inches on residence streets and 7 inches on business streets carrying heavy loads. For the two course type of pavement, the wearing course should be at least 1½ inches thick.

The above figures are now considered good practice, but it should be possible to decrease these quantities by using a sufficient amount of reinforcement.

Finish The earlier concrete pavements constructed had the surface corrugated into small rectangular blocks which were formed by cutting grooves about ¼ or ⅜ of an inch in depth and spaced from 4 to 8 inches apart, the idea being that this was necessary in order to give the proper foothold for the horses' hoofs. It is now, however, almost universally conceded that these markings or grooves are not necessary for at least the ordinary street grades. There are at present examples of concrete pavements in use having a grade up to 10 per cent that have no surface markings and are proving entirely satisfactory. It undoubtedly is advisable to eliminate these grooves as far as possible because they tend to make the pavement noisier, owing to the hammering effect of ironclad wheels and in addition they decrease the wearing qualities of the pavement very materially. The grooves at right angles to the pavement cause a hammering effect of the wheels which tends to wear away the surface and those running longitudinally are scraped and otherwise worn away by the wheel action. The pavement constructed at Plymouth, Wis. (a description of which is shown on page 38), makes use of a thin layer of granite screenings that are spread on the concrete before the same has had an opportunity to set. This gives a slightly roughened surface that decreases the slipperiness.

The best practice seems to be to float the finished coat with a wood float, care being taken to bring the pavement to the proper elevation, and after the cement has partially hardened, a stiff broom is drawn across the surface crosswise of the street. This causes a slight roughness of the finished pavement and has proven to be very satisfactory for horses as well as automobiles.

Reinforcement If reinforcing steel is placed in the pavement for the purpose of adding to its structural strength, that is, to increase the efficiency of a weak sub-soil, it is placed as near to the bottom of the concrete slab as possible and still secure the necessary protection to the steel. The amount of reinforcement required for this purpose depends entirely upon the conditions. In some cases a light reinforcement which is furnished by Triangle Mesh Reinforcement Style No. 28 would be sufficient, and in other cases a very much heavier material may be necessary. The amount of reinforcement for this purpose should in each case be determined by the engineer in charge of the design.

The amount of reinforcement required to prevent the splitting off of the wearing coat on a two-course pavement or to eliminate cracks due to expansion and contraction stresses can be more easily selected without a definite study of all the conditions. By referring to the examples of reinforced concrete pavements as listed on pages 38 to 63, it will be seen that the reinforcement used for this purpose varied from Triangle Mesh Style No. 7, having a cross sectional area of steel per foot of width of .041 square inches up to and including Style No. 26, having a cross sectional area of .11 square inches per foot of width.

A full description showing the size of wires, spacing, weight and cross sectional area of steel is shown in the tables on pages 90 and 91.

Although apparently the light mesh has given good satisfaction, it is our opinion that for the slight additional expense it is decidedly advisable to use a heavier material. For narrow streets and roadways, say up to 20 feet, and where the transverse expansion joints are spaced not to exceed 30 feet, we would advise the use of Style No. 29, which gives approximately the same sectional area of steel in both directions. For wider streets or where transverse joints are spaced not to exceed 50 feet, we would suggest the use of Style No. 28, which has a total cross sectional area of steel of .066 square inches in one direction and .038 square inches in the other. The usual practice has been to place the longitudinal wires crosswise of the street with the reinforcement placed between the base and wearing courses of two-course pavements and 2 inches below the surface of one-course pavements. Photographic reproductions showing the Wire Mesh Reinforcement in place ready for the finishing coat are shown in connection with the examples of the various reinforced concrete pavements listed on pages 38 to 63.

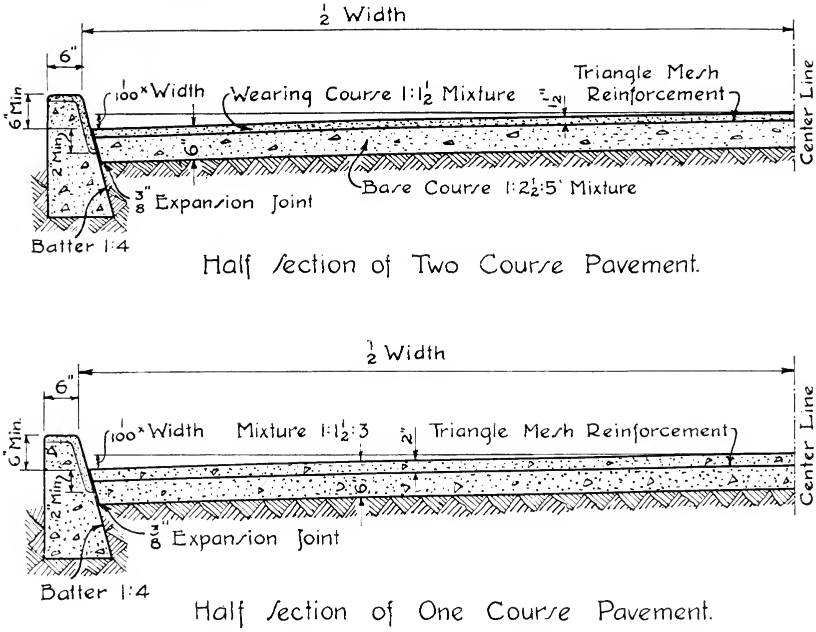
In accordance with the discussion on the subject of proper spacing of expansion joints given on page 68 we believe it advisable to eliminate as many of the expansion joints as possible and in general, place one at each end of a city block and two additional ones between. This will mean a spacing of approximately 80 to 100 feet. The reinforcement in this case should be heavier and the longitudinal wires should extend parallel with the curb. This can very easily be done by unrolling the rolls upon the base and just ahead of the finished work. This idea is shown very clearly in the photograph shown on page 61 representing the construction of the Long Island Motor Parkway; although in this case, the reinforcement is being used in connection with crushed stone, the same idea can be carried out for concrete construction. For this spacing of expansion joints of a maximum of 100 feet, we would suggest the use of Triangle Mesh Style No. 26 having a sectional area of steel of .11 square inches per foot of width with a cross wire section of .038 square inches. In all cases the reinforcement should be lapped at the sides of the sheets at least one inch and where necessary to make end laps, these should be at least twelve inches. The reinforcement should in no case extend across expansion joints.

For reinforcing concrete pavements, a woven wire reinforcement is the best that can be used. In order to furnish an economical construction using loose bars it would be necessary to space the same at a distance that would not give a satisfactory distribution of the steel. Small bars spaced from 18 to 24 inches apart could not possibly give satisfactory results in comparison with a woven wire reinforcement having an equal and close spacing of the members.

By referring to the tables shown on pages 90 and 91, which give a full specification of the various styles of Triangle Mesh Wire Fabric manufactured, it will be seen that the same can be furnished in 150, 200 and 300-foot lengths of rolls and in widths of 18, 22, 26, 30, 34, 38, 42, 46, 50, 54 and 58 inches. This reinforcement is manufactured from cold drawn wire properly tested to give uniform results and has a minimum ultimate breaking strength of 85,000 pounds per square inch. Although all styles, widths and lengths of rolls are not carried in stock, it is always possible to secure satisfactory shipments.

Crown It is not necessary to use as great a crown on concrete pavements as is the practice for macadam or bitulithic types. The primary object of constructing a crown on a pavement is to secure a suitable drainage of surface water and because of the rapidity of flow of water over concrete surfaces and because of the positive and uniform slopes produced by the working of a plastic material, a comparatively slight crown is all that is necessary for a concrete pavement. The crown or rise in the pavement in the center should be at least one one-hundredth of the width of the pavement, the usual form of the crown being the segment of a circle. In some cases, however, it is made with straight slopes having a very slight fall from the center for the central half of the width with an increased fall for the outside quarters. This had been done in order to decrease the tendency for horses and vehicles to slip sidewise in the direction of the curb. However, for a rise of one one-hundredth of the width of the pavement, this consideration will not be necessary and undoubtedly a circular form will give a more pleasing appearance.

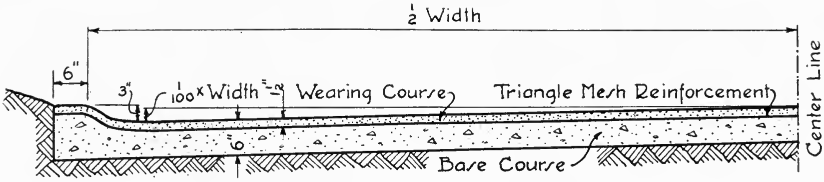
Curbs In some cities the practice has been to construct the usual type of combination curb and gutter leaving an expansion joint between the outer edge of the gutter and the pavement. As this type not only increases the cost, but also introduces one more element of weakness due to the possible wear at the joint, it will be more satisfactory to construct the vertical curbs and produce the pavement to include the gutter. This would also require an expansion joint, but it would not be necessary to protect the same with steel plates as owing to its position, very little, if any wear should occur from wheel action. The edges in this case should be rounded to a half inch radius and the joints filled with an elastic material as mentioned in this subject under the heading of "Expansion Joint Filler." For driveways in parks or pavements in residence districts, especially where it is not necessary to



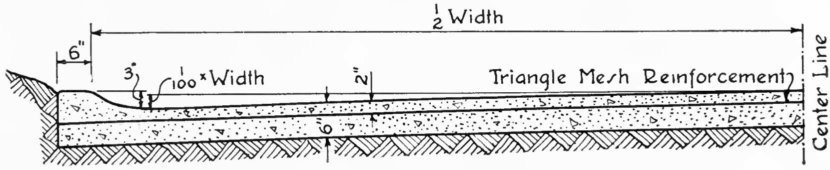
Proposed Reinforced Concrete Pavements for Streets.

take care of very extensive rainfalls, the curbs could be eliminated and the pavement curved upwards at the outer edges as is shown in figure No. 76. In this case the reinforcement should extend to the outer edge of the gutter. One advantage of the use of a vertical curb lies in the fact that the curb may be constructed first and may be then used as a guide for securing the proper pavement elevations. It is also the general practice to use a bridge spanning the pavement and resting upon the curbs, and used by the workmen in floating and finishing the pavement surface. If the curbs are not constructed prior to the pavement, it is necessary to use heavy planks for the outside forms and the same should be securely staked to the proper grade so that they may be used as a guide for the pavement elevations and also for carrying the bridge above referred to.

Protection of Finished Pavement In order to give the finished pavement the proper protection from the weather, it should be kept covered for several days with canvas, a layer of sand, or other suitable material. Since the presence of water is necessary to secure the proper setting of the cement, the finished work should be kept moist for several days, the length of time depending principally



Half Section of Two Course Pavement.



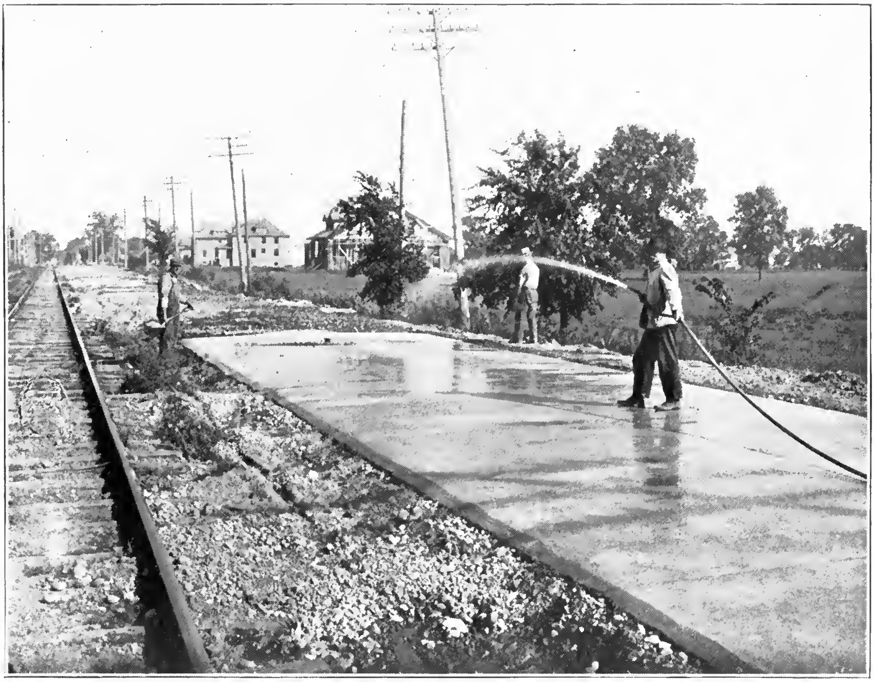
Half Section of One Course Pavement.

Proposed Reinforced Concrete Pavements for Driveways, Parks, Etc.

upon the weather conditions, but in general the sprinkling should be carried on for at least four days. Traffic should be excluded until the pavement has secured sufficient strength to prevent injury. The length of time should be subject to the directions of the engineer.

Maintenance Should cracks form in the pavement the same should be cleaned and great care used to remove all sand and other particles that may have become lodged and the cracks then filled with the same material as is used for regular expansion joints. If for any reason weak spots occur in the wearing surface such as may be caused by freezing during construction, or improper mixing of the ingredients, these spots should be cut away to at least the full depth of the wearing course and replaced with new material mixed in the same proportion as the original. Before replacing, the old concrete should be very thoroughly cleaned so as to remove all loose particles. If possible, the reinforcement should be sufficiently exposed to allow the new material to surround at least one-half of the wires so that the adhesion of the new to the old material will be increased. One course pavements can be best repaired by cutting away for the full depth of the concrete.

Where it is necessary to cut through the pavement to lay piping, etc., the pavement should be cut away on as near straight lines as possible, a

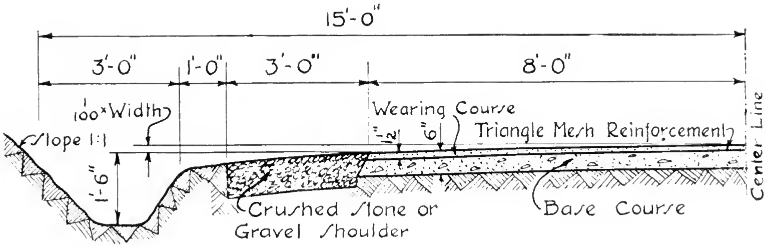


Concrete Pavement Protected with Dirt and Sprinkled Continuously for Several Days.

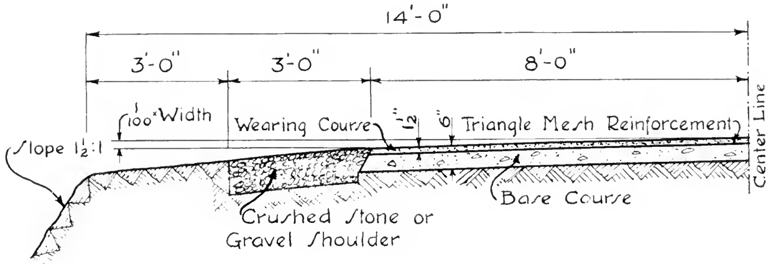
suitable method being that described in the case of the reinforced concrete pavement at Fond du Lac, Wis. (a description of which is given on page 40). Experience has shown that concrete pavements can be repaired where it has been found necessary to cut through the same and the results are very much more satisfactory than with any other type of pavement. Since the material used is in a plastic state, there is nothing to prevent the securing of an absolutely smooth surface after repairs have been made.

Alley Pavements Alley pavements should be constructed in the same manner as street pavements except that the finished surface should be depressed instead of crowned in order to allow for suitable drainage. The slope towards the center line should be at least one one-hundredth of the width of the pavement. If the outer edges are not protected by a building, a fence or other permanent construction that will prevent wagon wheels from striking the edges, they should be protected by a steel plate or angle as recommended for expansion joint construction.

Country Roads The usual custom for improving country roads where it has been desirable to secure permanent construction has been to make use of a water bound macadam type of pavement. While in the past this proved fairly satisfactory, it is now conceded that for trunk line roads and especially those that will be used to any extent by automobile traffic, a more permanent construction is required. Although a reinforced concrete roadway would add somewhat to the original cost of a macadam type, there will be a very material saving



Half Section of Pavement in Cut.
Two Course Type.



Half Section of Pavement in Fill.
Two Course Type.

Proposed Reinforced Concrete Pavements for Country Roads.

in maintenance charges and since the concrete pavement will have a longer life than the macadam, it undoubtedly is advisable to construct these roadways of reinforced concrete. The problems to be met will be similar to those for street pavements except that greater difficulties may be encountered in delivery of materials, securing of proper water supply, etc. The remarks that have been previously made regarding proper foundation for street pavements will apply for country roads except that in many cases there will be better opportunities of securing natural drainage in the case of country roads. If this natural drainage is not possible, artificial drainage will be necessary, the common method being to lay ordinary drain tile along one or both sides of the roadway and connect it up with a suitable outlet. Side ditches should be supplied having a sufficient capacity to take care of all surface water. The proper preparation of the road bed, thicknesses of pavement, concrete mixture, method of finishing, expansion joints, etc., have been discussed under the more general subject of reinforced concrete pavements and the same information will apply for country roads. All trunk line roads should have a width of concrete pavement from 16 to 18 feet and other or less important roads, from 10 to 16 feet.

Durable shoulders should be constructed on both sides of the roadway, the same having sufficient width to make the total width about 25 feet including the concrete. These shoulders should have a total thickness equal to at least the thickness of the concrete pavement and should be made of crushed stone or gravel placed in layers of about three or four inches in depth and properly rolled to secure a compact mass. In order to allow surface water to drain off as fast as possible, the shoulders should be constructed with a slope of about one inch per foot. They should not be placed before the concrete roadway has attained sufficient strength to withstand injuries due to the heavy roller used for the shoulder construction. This would require from two to four weeks' time after the concrete has been placed.

The forms for the outer edges of the concrete should consist of 2-inch planks securely staked so that they may be used as guides for securing the proper elevation of the various classes of work. In order to secure best results, these planks should be protected along their upper edge with small steel angle-irons which will prevent any wear or other injuries when the templets used for striking off the finished surface are moved along these outer forms. As soon as the concrete has sufficient strength to hold its shape but before the concrete has completely set, these side forms should be removed and the edge of the concrete rounded off so as to make a more satisfactory connection between the concrete roadway and the shoulders.

Striking Off Concrete Pavements

Finishing the Surface of Concrete Pavements.

Specifications for Reinforced Concrete Pavements

The local conditions should in every case be taken into consideration when preparing plans and specifications for reinforced concrete pavements; however, in order to assist engineers in securing the proper construction, the following is given as a guide:

Grading

The street shall be graded from curb to curb to a depth sufficient to allow of the construction of the pavement to the specified thickness including the sub-base, should such be required. Should a greater amount of soil be removed than is necessary, a sufficient amount of material hereinafter specified for a sub-base shall be placed and rolled to secure a compact sub-grade.

Sub-Grade

The sub-grade shall be at all places parallel to the surface of the finished pavement and at a depth below this surface equivalent to the specified thickness of pavement and sub-base if the latter be required.

The sub-grade shall be brought to a firm unyielding surface by rolling with a steam roller, weighing not less than ten tons, and all portions of the sub-grade not accessible to the roller shall be sufficiently tamped with a hand tamper to be satisfactory to the engineer. All soft or yielding places shall be removed and the space re-filled with gravel, broken stone, or other suitable material hereinafter specified for use as a sub-base. The same shall be deposited in layers not exceeding six (6) inches in thickness and each layer thoroughly tamped or rolled. When a fill exceeding one (1) foot in thickness is required, it shall be made in a manner satisfactory to the engineer.

Sub-Base

If the nature of the soil should be such as to require a sub-base, the same shall consist of cinders, crushed stone, gravel or other suitable material ranging in size up to and not exceeding four (4) inches and shall be thoroughly rolled and tamped to a finished sub-grade as before specified. The thickness of the sub-base shall be such that after rolling, the surface will be at a distance below the surface of the finished pavement equal to the total thickness of the concrete pavement.

Drainage

When required, a suitable drainage system shall be installed and connected with sewers or other drainage as indicated by the engineer.

Materials

Cement:—The cement shall meet the requirements of the standard specifications for Portland Cement of the American Society for Testing Materials.

Fine Aggregate:—Fine aggregate shall consist of sand, crushed stone or gravel screenings graded uniformly from fine to coarse and passing when dry, a screen of one-quarter (¼) inch mesh; not more than three (3) per cent shall pass a sieve having one hundred (100) meshes per lineal inch. It shall be clean, coarse and durable material free from dust, loam, vegetable or other injurious material. In no case shall fine aggregate containing frost or lumps of frozen material be used.

Coarse Aggregate:—The coarse aggregate shall consist of screened gravel or crushed stone graded in size from one-quarter (¼) of an inch to one and one-half (1½) inches. It shall be clean, hard, durable and free from loam, vegetable or other injurious material and shall contain no soft, flat or elongated particles. In no case shall coarse aggregate containing frost or lumps of frozen material be used.

Natural Mixed Aggregates:—The natural mixed aggregates shall not be used until the same have been screened and remixed to agree with the proportions specified.

Water

Water shall be clean, free from oil, acid, alkali, or vegetable matter.

Mixing and Placing

All material except cement shall be measured in suitable bottomless boxes or by other means that will produce definite measurements. The cement shall be measured by the sack. One sack of ninety-four (94) pounds net shall be considered a cubic foot. The concrete shall preferably be mixed by machine, a batch mixer being used of a type that will insure a uniform mixture of the desired consistence. Whenever possible, the concrete shall be deposited directly from the mixer to the proper position without re-handling. When it is necessary to mix by hand, the same shall be done on a water-tight platform. The cement and fine aggregate shall be mixed dry until a uniform color is secured. The required amount of coarse aggregate and water shall then be added and the mixing continued until the entire mass is homogeneous. Under no circumstances shall re-tempered material be allowed.

Forms

All forms shall be of steel or wood and shall be free from warp and shall have sufficient strength to resist springing out of shape. Forms shall be well staked or otherwise held to the established lines and grades and the upper edges shall conform to the established grade of the finished pavement. All forms shall be cleaned free of old cement or other injurious covering. All wooden forms shall be thoroughly wetted or oiled and all metal forms shall be oiled before using.

Two Course Pavements

The finished concrete pavement shall have a total thickness as shown on the plans but in no case shall the same be less than six (6) inches.

Base:—The concrete for the base shall be so mixed as to produce the most dense possible mixture. The cement shall be of a sufficient amount to over-fill the voids in the fine aggregate by at least ten (10) per cent and the mortar shall over-fill the voids in the course aggregate by at least ten (10) per cent. When the voids are not determined the concrete shall be mixed at least in the proportion of one (1) part Portland cement to two and one-half (2½) parts fine aggregate and five (5) parts of coarse aggregate. Sufficient water should be used during the mixing to produce a concrete of a consistency which will require light tamping to flush mortar to the surface. The base shall have a total thickness of at least four and one-half (4½) inches for residence streets and five and one-half (5½) inches for business streets. Before depositing the concrete, the foundation shall be sprinkled with a sufficient amount of water to prevent a rapid drying out of the concrete mass. The concrete should be deposited continuously between expansion joints. Under no circumstances shall more than thirty (30) minutes elapse between the mixing and the depositing of any one batch and under no circumstances shall concrete be used that has taken a partial set.

Wearing Course:—The wearing course shall be properly mixed in the proportion by volume of one (1) part of Portland cement to not more than two (2) parts of fine aggregate. At least fifty (50) per cent of the fine aggregate for the wearing course shall consist of granite screenings or other hard durable material satisfactory to the engineer. The mortar shall be of a consistency that will not require tamping and can be easily spread into the proper position. The thickness of the wearing course shall in all cases be at least one and one-half (1½) inches. The mortar shall be placed immediately after mixing and in no case shall more than fifty (50) minutes elapse between the time of the mixing of the concrete for the base and the placing of the wearing course. The wearing course shall be struck off preferably by means of a templet to the proper street grade. It shall then be finished with a wood float and before complete hardening has taken place, the surface shall be roughened by brushing with a stiff broom. Under no circumstances shall workmen be allowed upon the top course. All necessary finishing work should be done from planks or bridges. If artificial coloring is used, it shall be mixed dry with the cement and aggregate until the entire mass is of a uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

Reinforcement

The reinforcement shall consist of a woven wire fabric manufactured by the American Steel & Wire Company and known as TRIANGLE MESH REINFORCEMENT Style No. 26. (Note:—If transverse expansion joints have a maximum spacing of fifty (50) feet use Style No. 28. For a maximum spacing of thirty (30) feet between longitudinal or transverse joints use Style No. 29.) The mesh should be laid directly upon the base immediately after the same has been finished to the proper grade and it should be lightly tamped so that at least fifty (50) per cent of the wires are imbedded therein. The longitudinal wires should be so placed as to be parallel to the center line of the pavement. (Note:—If expansion joints are spaced not to exceed fifty (50) feet, longitudinal wires may be placed at right angles to the center line of the street.) All laps at the sides of the sheets should be at least one (1) inch and all laps at the ends of the sheets should be at least twelve (12) inches. The reinforcement shall cover the entire pavement area between expansion joints, but in no case shall reinforcement be continuous across expansion joints. Reinforcement required because of unsatisfactory foundation shall be of an amount as shown on the plans and the same shall be placed in the base course at a distance of at least one (1) inch above the bottom surface. A reinforcement having a rust coat sufficient to form scales shall not be used.

Expansion Joints

All expansion joints shall extend through the entire depth of the pavement and all edges except those adjacent to vertical curbs, shall be protected by means of a steel angle or plate of a minimum thickness of three-sixteenths (3-16) of an inch properly anchored into the concrete to insure absolute rigidity under traffic. All joints that are not protected by steel angles or plates shall have edges rounded to a one-half (½)-inch radius. The joints shall be filled with a suitable elastic waterproof compound that will not become hard and brittle in cold weather or sufficiently soft during hot weather to run out of the joints. Before placing the filler, the joints shall be cleaned to insure freedom from concrete chips or other injurious material. Expansion joints shall be constructed across the street at right angles to the center line, four (4) joints being placed in each block, one to be located at each end of the block and two at intermediate points or as otherwise called for on the plans, but in no case shall the distance between joints exceed one hundred (100) feet. Expansion joints shall also be placed between the pavement and all curbs or between the pavement and the gutter of the combination curb and gutter; also around all man-holes and catch basins and all intersections of alley and street pavements. Where car tracks occur, joints shall be placed parallel to the tracks at a distance outside of each rail sufficient to clear the ends of the ties. All transverse joints shall have a width of three-quarters (3/4) of an inch. (Note:—For a maximum spacing between joints of fifty (50) feet, a width of one-half (1/2) an inch will be sufficient.) All other joints shall have a width of three -eighths (3/8) of an inch.

Crown

The finished pavement shall have a crown or rise at the center of one-one hundredth (1-100) of the width of the pavement.

Protection

After completion, the pavement shall be properly protected to prevent injury by the elements. After hardening, the pavement shall be kept moist and shall have a covering of sand or other suitable material for at least seven (7) days. It shall not be opened to traffic until such a time as is satisfactory to the engineer in charge.

Shoulders

Where the concrete pavement is not abutted by a curb or where other means are not used to exclude traffic outside of the pavement, the outer edges of the concrete shall be rounded and shoulders shall be prepared consisting of gravel or crushed stone of a thickness at least equal to the full depth of the pavement and having a width of at least three (3) feet. These shoulders shall be thoroughly rolled and otherwise compacted and shall have a slope on the finished surface equal to at least one (1) inch per foot of width. These shoulders shall not be placed until the concrete pavement has attained sufficient strength to prevent any injury, but in no case prior to two (2) weeks after completion of the concrete pavement.

One Course Pavement

The specifications governing two-course pavements shall apply to one-course pavements with the following exceptions:

Concrete Mixture:—The concrete shall be mixed in the proportion of one (1) part of Portland cement to one and one-half (1 1/2) parts of fine aggregate as specified for the wearing course of a two-course pavement and three (3) parts of coarse aggregate graded in size from one-quarter (¼) of an inch to one (1) inch.

Placing:—The concrete shall be placed and leveled off to a depth of two (2) inches below the finished surface. The reinforcement shall then be placed after which the additional two (2) inches of concrete is deposited.

Finishing:—The coarse particles in the top two (2) inches shall be forced to a sufficient depth below the surface to allow finishing as specified under "Two-Course Pavements."

Reinforcement:—The reinforcement shall consist of American Steel & Wire Company's Triangle Mesh Reinforcement of a style number as specified for Two-Course Pavements and shall be placed two (2) inches below the finished top surface of the pavement.

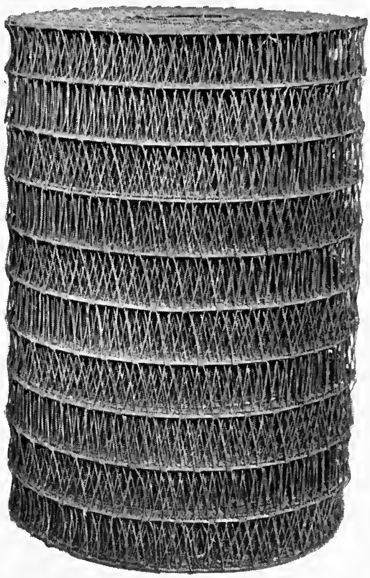
Alley Pavements

The specifications governing street pavements shall apply on all alley pavements with the following exceptions:—

Unless otherwise called for on plans, the finished surface of all alley pavements shall be depressed in the center and the slopes from outer edges to the center line shall be at least one-one hundredth (1-100) of an inch per foot width of pavement. All outer edges of alley pavements not protected by curbs, buildings or other permanent construction shall be protected by a steel angle or plate as specified for expansion joint protection.

Triangle Mesh Steel Wire Reinforcement

Triangle Mesh Steel Woven Wire Reinforcement is made with both single and stranded longitudinal, or tension members. That with the single wire longitudinal is made with one wire varying in size from a No. 12 gage up to and including a ¼-inch diameter, and that with the stranded longitudinal is composed of two or three wires varying from No. 12 gage up to and including No. 4 wires stranded or twisted together with a long lay. These longitudinals either solid or stranded are invariably spaced 4-inch centers, the sizes being varied in order to obtain the desired cross sectional area of steel per foot of width.



2-inch Mesh — Single Longitudinals

The transverse or diagonal cross wires are so woven between the longitudinals that perfect triangles are formed by their arrangement, thereby not only lending additional carrying strength to the longitudinal or tension members, but positively spacing them and providing a most perfect distribution of the steel. These diagonal cross or transverse wires are woven either 2 or 4 inches apart, as is desired. It is the most perfect reinforcement for concentrated loads, distributing the stress imposed by the load throughout the slab. A hinge joint is provided on each longitudinal, which enables this reinforcement to be folded longitudinally in any desired shape, making it adaptable to all kinds of concrete construction. Its design provides a most perfect mechanical bond between the steel and the concrete, and from the fact that it is not galvanized (unless specially ordered) the maximum adhesive bond is developed.

While we recommend the use of a fabric made with a steel having an ultimate strength of 85,000 pounds per square inch, we can furnish it in any strength of steel desired.

Triangle Mesh Reinforcement, we believe, is the most efficient material on the market for the purposes:

It provides a more even distribution of the steel, reinforcing in every direction.

Tension or carrying members accurately spaced.

A most perfect mechanical bond.

When a specific size of fabric or area of steel is specified it is impossible to leave out any portion of the reinforcement.

Minimum cost of installation.

Easily handled and stored on the work.

Low cost of inspection.

An absolutely continuous action from one end of the structure to the other.

Higher elastic limits with the same quality of steel due to cold drawing.

Every ounce of steel is tested, as it cannot be cold drawn without showing defects, if any.

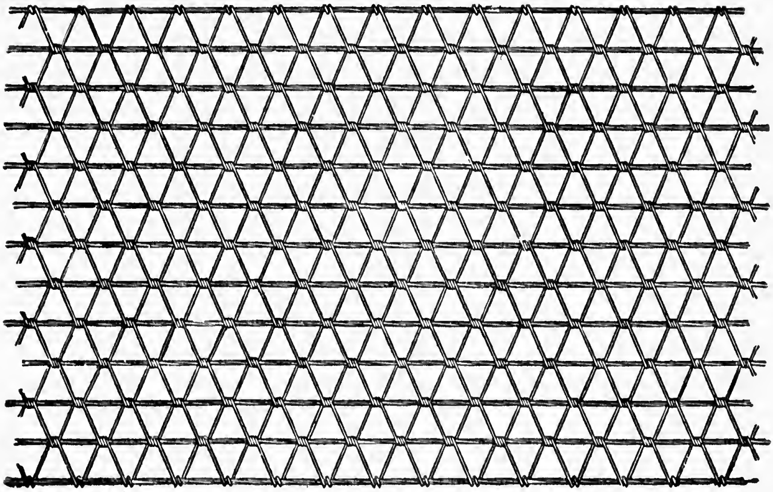
Distributes the stresses due to a concentrated load over a greater area.

Triangle Mesh Reinforcement is the only design of woven wire fabric in which the cross or diagonal wires assist the longitudinal or tension members in carrying the load.

It is a well-known fact that steel thoroughly imbedded in a proper mixture of concrete does not rust, and in the case of a smooth round rod used as reinforcement it is more desirable to have a thin surface coat of rust than if it were perfectly bright and smooth, provided the rust has not penetrated sufficiently far to pit the steel and produce a scale. This slight coating of rust provides a rougher surface and therefore a better bond.

The following article reprinted from *Scientific American* issue of Oct. 16, 1909, Vol. CI, No. 16, is an excellent explanation of the action of cement on rusted steel:

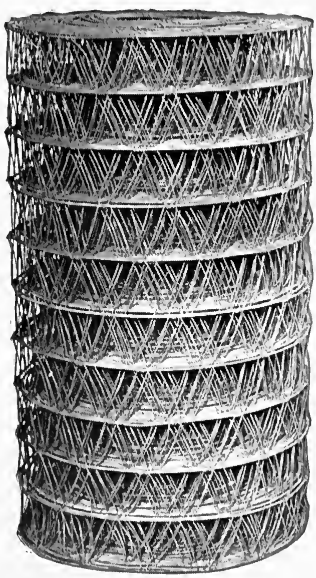
The cause of the disappearance of rust from iron bars, etc., used in the erection of reinforced concrete structures, has been traced by Rohland, in Stahl and Eisen, to the presence of acid carbonates and sulphates in the cement, these salts dissolving the iron oxide and leaving the metal bright. The cement in setting absorbs carbonic acid from the air, thus forming the necessary acid carbonates; and experience has shown that the de-rusting process is affected while the concrete is setting and commencing to harden. This discovery affords an additional guarantee for the safety of reinforced concrete structures, inasmuch as the metal is protected from rusting by the alkaline reaction of the cement during the mixing process, and any rust on the bars is removed by the action of the acid carbonates at an early stage by the erection of the structures.



Patents Applied for

4-inch Triangle Mesh Concrete Reinforcement.

Showing Stranded Longitudinals.



4-inch Mesh — Single Longitudinals

Triangle Mesh Wire Reinforcement. Made in 150, 200 and 300 foot lengths, and in 18, 22, 26, 30, 34, 38, 42, 50, 54 and 58 inch widths.

Longitudinals Spaced 4-Inch Centers
Cross Wires Spaced 4-Inch Centers

Number and Gage of Wires, Areas Per Foot Width and Weights Per 100 Square Feet

Styles Marked * Usually Carried in Stock

Style Number	Number of Wires, Each Long.	Gage of Wire, Each Long.	Gage of Cross Wires	Sectional Area, Long. Square Inches	Sectional Area, Cross Wires Square Inches	Cross Sectional Area per Foot Width	Approximate Weight per 100 Square Feet
* 4	1	6	14	.087	.025	.102	43
* 5	1	8	14	.062	.025	.077	34
* 6	1	10	14	.043	.025	.058	27
* 7	1	12	14	.026	.025	.041	21
*23	1	¼″	12½	.147	.038	.170	72
24	1	4	12½	.119	.038	.142	62
25	1	5	12½	.101	.038	.124	55
*26	1	6	12½	.087	.038	.110	50
*27	1	8	12½	.062	.038	.085	41
*28	1	10	12½	.043	.038	.066	34
*29	1	12	12½	.026	.038	.049	28
*31	2	4	12½	.238	.038	.261	106
*32	2	5	12½	.202	.038	.225	92
33	2	6	12½	.174	.038	.196	82
34	2	8	12½	.124	.038	.146	63
35	2	10	12½	.086	.038	.109	50
36	2	12	12½	.052	.038	.075	37
*38	3	4	12½	.358	.038	.380	151
39	3	5	12½	.303	.038	.325	130
*40	3	6	12½	.260	.038	.283	114
41	3	8	12½	.185	.038	.208	87
*42	3	10	12½	.129	.038	.151	66
43	3	12	12½	078	.038	.101	47

Special Sizes on Application

Length of Rolls: 150-foot, 200-foot and 300-foot.

Widths: Approximately 18-inch, 22-inch, 26-inch, 30-inch, 34-inch, 38-inch, 42-inch, 46-inch, 50-inch, 54-inch and 58-inch.

Elastic limit of regular stock from 50,000 to 60,000 lbs. per square inch, sectional area, 85,000 lbs. or over, ultimate strength.

Higher elastic limits and breaking strengths may be furnished when required.

Note—Material may be furnished either plain or galvanized. Unless otherwise specified, shipments will be made of material not galvanized.

Stock material usually carried in 150-foot rolls, and 42-inch, 50-inch and 58-inch widths.

Longitudinals Spaced 4-Inch Centers
Cross Wires Spaced 2-Inch Centers

Number and Gage of Wires, Areas Per Foot Width and Weights Per 100 Square Feet

Styles Marked * Usually Carried in Stock

Style Number	Number of Wires, Each Long.	Gage of Wire, Each Long.	Gage of Cross Wires	Sectional Area, Long. Square Inches	Sectional Area, Cross Wires Square Inches	Cross Sectional Area per Foot Width	Approximate Weight per 100 Square Feet
4–A	1	6	14	.087	.050	.102	53
5–A	1	8	14	.062	.050	.077	44
6–A	1	10	14	.043	.050	.058	37
*7–A	1	12	14	.026	.050	.041	31
23–A	1	¼″	12½	.147	.076	.170	86
24–A	1	4	12½	.119	.076	.142	76
25–A	1	5	12½	.101	.076	.124	70
26–A	1	6	12½	.087	.076	.110	64
27–A	1	8	12½	.062	.076	.085	55
28–A	1	10	12½	.043	.076	.066	48
29–A	1	12	12½	.026	.076	.049	42
31–A	2	4	12½	.238	.076	.261	120
32–A	2	5	12½	.202	.076	.225	107
33–A	2	6	12½	.174	.076	.196	97
34–A	2	8	12½	.124	.076	.146	78
35–A	2	10	12½	.086	.076	.109	64
36–A	2	12	12½	.052	.076	.075	52
38–A	3	4	12½	.358	.076	.380	165
39–A	3	5	12½	.303	.076	.325	145
40–A	3	6	12½	.260	.076	.283	129
41–A	3	8	12½	.185	.076	.208	101
42–A	3	10	12½	.129	.076	.151	81
43–A	3	12	12½	.078	.076	.101	62

Special Sizes on Application

Length of Rolls: 150-foot, 200-foot and 300-foot.

Widths: Approximately 18-inch, 22-inch, 26-inch, 30-inch, 34-inch, 38-inch, 42-inch, 46-inch, 50-inch, 54-inch and 58-inch.

Elastic limit of regular stock from 50,000 to 60,000 lbs. per square inch, sectional area, 85,000 lbs. or over, ultimate strength.

Higher elastic limits and breaking strengths may be furnished when required.

Note—Material may be furnished either plain or galvanized. Unless otherwise specified, shipments will be made of material not galvanized.

Stock material usually carried in 150-foot rolls, and 42-inch, 50-inch and 58-inch widths.

Table Giving Areas in Square Feet per Roll of Triangle Mesh Reinforcement

Width of Roll Inches	Square Feet of Reinforcement in Roll		
	150-foot Roll	200-foot Roll	300-foot Roll
18	225	300	450
22	275	367	550
26	325	433	650
30	375	500	750
34	425	567	850
38	475	633	950
42	525	700	1050
46	575	767	1150
50	625	833	1250
54	675	900	1350
58	725	967	1450

As indicated in the above table, Triangle Mesh Reinforcement is made up in the following widths: 18, 22, 26, 30, 34, 38, 42, 46, 50, 54 and 58 inches, and in standard lengths of rolls of 150, 200 and 300 feet.

For the lighter styles, rolls of any of the above lengths may be used. Material of medium weights is recommended to be used in 150 or 200-foot lengths, while with the heaviest styles it is more conveniently handled in rolls containing 150-foot lengths.

American Steel and Wire Co.'s Steel and Iron Wire Gage and Different Sizes of Wire

Diameter Inches	Steel Wire Gage	Diameter Inches	Area, Square Inches	Pounds per Foot	Pounds per Mile	Feet per Pound	Feet per 2,000 Lbs.
$\frac{1}{2}$		.500	.19635	.6625	3498.00	1.50	3018
	$\frac{7}{0}$	.490	.18857	.6363	3359.66	1.51	3023
$\frac{15}{32}$		.468	.17202	.5804	3064.51	1.72	3445
	$\frac{6}{0}$	.460	.16619	.5608	2961.02	1.78	3566
$\frac{7}{16}$		.437	.14998	.5061	2672.21	1.97	3952
	$\frac{5}{0}$	.430	.14532	.4901	2587.72	2.04	4081
$\frac{13}{32}$		.406	.12946	.4368	2306.30	2.28	4578
	$\frac{4}{0}$	.393	.12130	.4094	2161.63	2.44	4885
$\frac{3}{8}$		.375	.11044	.3726	1967.33	2.68	5367
	$\frac{3}{0}$	.362	.10292	.3473	1833.74	2.87	5758
$\frac{11}{32}$		.343	.09240	.3117	1645.78	3.20	6412
	$\frac{2}{0}$	.331	.08604	.2904	1533.31	3.44	6887
$\frac{5}{16}$		.312	.07645	.2579	1361.71	3.87	7755
	0	.307	.07402	.2497	1318.41	4.00	8011
	1	.283	.06290	.2123	1120.94	4.71	9420
$\frac{9}{32}$		.281	.06210	.2092	1104.57	4.78	9560
	2	.263	.05432	.1834	968.35	5.45	10905
$\frac{1}{4}$		.250	.04908	.1656	874.36	6.03	12077
	3	.244	.04675	.1578	733.18	6.33	12674
	4	.225	.03976	.1342	708.57	7.45	14903
$\frac{7}{32}$		.218	.03732	.1259	664.75	7.94	15885
	5	.207	.03365	.1135	559.28	8.81	17621
	6	.192	.02895	.0977	515.85	10.23	20471
$\frac{3}{16}$		.187	.02746	.0926	488.92	10.79	21598
	7	.177	.02460	.0830	438.24	12.04	24096
	8	.162	.02061	.0696	367.48	14.36	28735
$\frac{5}{32}$		.156	.01911	.0644	340.03	15.52	31056
	9	.148	.01720	.0580	306.24	17.24	34482
	10	.135	.01431	.0483	255.02	20.70	41408
$\frac{1}{8}$		.125	.01227	.0414	218.59	24.15	48309
	11	.120	.01130	.0382	201.69	26.17	52356
	12	.105	.00865	.0292	154.17	34.24	68493
$\frac{3}{32}$		.093	.00679	.0229	120.91	43.66	87336
	13	.092	.00664	.0224	118.27	44.64	89286
	14	.080	.00502	.0169	89.23	59.17	118343
	15	.072	.00407	.0137	72.33	72.99	145985
	16	.063	.00311	.0105	55.44	95.23	190476

Comparative Sizes of Wire Gage in Decimals of an Inch

No. of Wire Gage	Steel Wire Gage	American Standard (B. & S.)	Birmingham or Stubs	British Imperial Standard*	Old English or London	French
0000000	.4900	. .	. .	.500		
000000	.4615	.58000	. .	.464		
00000	.4305	.51650	.500	.432		
0000	.3938	.46000	.454	.400	.4540	
000	.3625	.40964	.425	.372	.4250	
00	.3310	.36480	.380	.348	.3800	
0	.3065	.32486	.340	.324	.3400	
1	.2830	.28930	.300	.300	.3000	.0325
2	.2625	.25763	.284	.276	.2840	.040
3	.2437	.22942	.259	.252	.2590	.050
4	.2253	.20431	.238	.232	.2380	.0625
5	.2070	.18194	.220	.212	.2200	.068
6	.1920	.16202	.203	.192	.2030	.083
7	.1770	.14428	.180	.176	.1800	.097
8	.1620	.12849	.165	.160	.1650	.110
9	.1483	.11443	.148	.144	.1480	.120
10	.1350	.10189	.134	.128	.1340	.135
11	.1205	.09074	.120	.116	.1200	.149
12	.1055	.08081	.109	.104	.1090	.162
13	.0915	.07196	.095	.092	.0950	.172
14	.0800	.06408	.083	.080	.0830	.185
15	.0720	.05706	.072	.072	.0720	.197
16	.0625	.05082	.065	.064	.0650	.212
17	.0540	.04525	.058	.056	.0580	.225
18	.0475	.04030	.049	.048	.0490	.238
19	.0410	.03589	.042	.040	.0400	.250
20	.0348	.03196	.035	.036	.0350	.263
21	.0317	.02846	.032	.032	.0315	.279
22	.0286	.02535	.028	.028	.0295	.290
23	.0258	.02257	.025	.024	.0270	.303
24	.0230	.02010	.022	.022	.0250	.316
25	.0204	.01790	.020	.020	.0230	.331
26	.0181	.01594	.018	.018	.0205	.342
27	.0173	.01420	.016	.0164	.01875	.356
28	.0162	.01264	.014	.0148	.01650	.371
29	.0150	.01126	.013	.0136	.01550	.383
30	.0140	.01003	.012	.0124	.01375	.394
31	.0132	.00893	.010	.0116	.01225	.408
32	.0128	.00795	.009	.0108	.01125	.419
33	.0118	.00708	.008	.0100	.01025	.431
34	.0104	.00630	.007	.0092	.00950	.448
35	.0095	.00561	.005	.0084	.00900	.458
36	.0090	.00500	.004	.0076	.00750	.472
37	.0085	.00445	. .	.0068	.00650	.485
38	.0080	.00396	. .	.0060	.00575	.499
39	.0075	.00353	. .	.0052	.00500	.509
40	.0070	.00314	. .	.0048	.00450	.524

* Also called New British or English Legal Standard

Weights and Areas of Square and Round Bars and Circumferences of Round Bars

One Cubic Foot of Steel Weighing 489.6 Pounds

Thickness or Diameter in Inches	Weight of Square Bar 1 Foot Long	Weight of Round Bar 1 Foot Long	Area of Square Bar in Square Inches	Area of Round Bar in Square Inches	Circumference of Round Bar in Inches
0					
1/16	.013	.010	.0039	.0031	.1963
1/8	.053	.042	.0156	.0123	.3927
3/16	.119	.094	.0352	.0276	.5890
1/4	.212	.167	.0625	.0491	.7854
5/16	.333	.261	.0977	.0767	.9817
3/8	.478	.375	.1406	.1104	1.1781
7/16	.651	.511	.1914	.1503	1.3744
1/2	.850	.667	.2500	.1963	1.5708
9/16	1.076	.845	.3164	.2485	1.7671
5/8	1.328	1.043	.3906	.3068	1.9635
11/16	1.608	1.262	.4727	.3712	2.1598
3/4	1.913	1.502	.5625	.4418	2.3562
13/16	2.245	1.763	.6602	.5185	2.5525
7/8	2.603	2.044	.7656	.6013	2.7489
15/16	2.989	2.347	.8789	.6903	2.9452
1	3.400	2.670	1.0000	.7854	3.1416
1/16	3.838	3.014	1.1289	.8866	3.3379
1/8	4.303	3.379	1.2656	.9940	3.5343
3/16	4.795	3.766	1.4102	1.1075	3.7306
1/4	5.312	4.173	1.5625	1.2272	3.9270
5/16	5.857	4.600	1.7227	1.3530	4.1233
3/8	6.428	5.049	1.8906	1.4849	4.3197
7/16	7.026	5.518	2.0664	1.6230	4.5160
1/2	7.650	6.008	2.2500	1.7671	4.7124
9/16	8.301	6.520	2.4414	1.9175	4.9087
5/8	8.978	7.051	2.6406	2 0739	5.1051
11/16	9.682	7.604	2.8477	2.2365	5.3014
3/4	10.41	8.178	3.0625	2.4053	5.4978
3/16	11.17	8.773	3.2852	2.5802	5.6941
7/8	11.95	9.388	3.5156	2.7612	5.8905
15/16	12.76	10.02	3.7539	2.9483	6.0868

Quantities of Materials for One Cubic Yard of Rammed Concrete Based on a Barrel of 4 Cubic Feet

(See important foot-notes, also page 225)

(Reprinted by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," page 232)

Proportions by Parts			Proportions by Volumes			Volume of Mortar in Terms of Percentage of Volume of Stone	Percentages of Voids in Broken Stone or Gravel														
							50%*			45%†			40%‡			30%§			20%§		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
			bbl.	cu. ft.	cu. ft.		bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu yd.	bbl.	cu. yd.	cu. yd	bbl.	cu. yd.	cu yd.	bbl.	cu. yd.	cu. yd.
1	...	1	1	...	4	89	4.99	...	0.74	4.80	...	0.71	4.62	...	0.69	4.23	...	0.63	3.91	...	0.58
1	...	2	1	...	8	49	3.57	...	1.06	3.37	...	1.00	3.20	...	0.95	2.84	...	0.84	2.56	...	0.76
1	...	3	1	...	12	35	...	...	...	2.60	...	1.16	2.45	...	1.09	2.13	...	0.95	1.90	...	0.84
1	...	4	1	...	16	28	...	...	...	...	...	...	...	...	...	1.71	...	1.01	1.51	...	0.89
1	...	5	1	...	20	24	...	...	...	...	...	...	...	...	...	1.43	...	1.06	1.26	...	0.93
1	...	6	1	...	24	22	...	...	...	...	...	...	...	...	...	1.22	...	1.08	1.07	...	0.95
1	...	7	1	...	28	20	...	...	...	...	...	...	...	...	...	...	...	...	0.94	...	0.98
1	...	8	1	...	32	18	...	...	...	...	...	...	...	...	...	...	...	...	0.83	...	0.98
1	...	9	1	...	36	17	...	...	...	...	...	...	...	...	...	...	...	...	0.75	...	1.00
1	...	10	1	...	40	16	...	...	...	...	...	...	...	...	...	...	...	...	0.68	...	1.01
1	...	11	1	...	44	15	...	...	...	...	...	...	...	...	...	...	...	...	0.62	...	1.01
1	...	12	1	...	48	15	...	...	...	...	...	...	...	...	...	...	...	...	0.57	...	1.01
1	1	1½	1	4	6	96	3.08	0.46	0.68	2.97	0.44	0.66	2.87	0.42	0.64	2.69	0.40	0.60	2.53	0.38	0.56
1	1	2	1	4	8	73	2.74	0.41	0.81	2.63	0.39	0.78	2.52	0.37	0.75	2.33	0.34	0.69	2.17	0.32	0.64
1	1	2½	1	4	10	59	2.47	0.37	0.91	2.35	0.35	0.87	2.25	0.33	0.83	2.06	0.31	0.76	1.90	0.28	0.71
1	1	3	1	4	12	50	2.25	0.33	1.00	2.13	0.32	0.95	2.03	0.30	0.90	1.85	0.27	0.82	1.70	0.25	0.76
1	1½	2	1	6	8	92	2.39	0.53	0.71	2.30	0.51	0.68	2.22	0.49	0.66	2.07	0.46	0.61	1.94	0.43	0.58
1	1½	2½	1	6	10	74	2.18	0.48	0.81	2.09	0.46	0.77	2.01	0.45	0.74	1.86	0.41	0.69	1.73	0.38	0.64
1	1½	3	1	6	12	62	2.01	0.45	0.89	1.91	0.42	0.85	1.83	0.41	0.81	1.68	0.37	0.75	1.56	0.35	0.69
1	1½	3½	1	6	14	54	1.86	0.41	0.96	1.77	0.39	0.92	1.68	0.37	0.87	1.54	0.34	0.80	1.42	0.32	0.74
1	1½	4	1	6	16	48	1.73	0.38	1.03	1.64	0.36	0.97	1.56	0.35	0.92	1.42	0.32	0.84	1.30	0.29	0.77
1	1½	4½	1	6	18	43	1.62	0.36	1.08	1.53	0.34	1.02	1.45	0.32	0.97	1.31	0.29	0.87	1.20	0.27	0.80
1	1½	5	1	6	20	39	1.52	0.34	1.13	1.43	0.32	1.06	1.35	0.30	1.00	1.22	0.27	0.90	1.11	0.25	0.82
1	2	3	1	8	12	74	1.81	0.54	0.80	1.74	0.52	0.77	1.67	0.50	0.74	1.54	0.46	0.68	1.44	0.43	0.64
1	2	3½	1	8	14	64	1.69	0.50	0.88	1.61	0.48	0.83	1.54	0.46	0.80	1.42	0.42	0.74	1.31	0.39	0.68
1	2	4	1	8	16	56	1.58	0.47	0.94	1.51	0.45	0.89	1.44	0.43	0.85	1.32	0.39	0.78	1.21	0.36	0.72
1	2	4½	1	8	18	51	1.49	0.44	0.99	1.41	0.42	0.94	1.34	0.40	0.89	1.23	0.36	0.82	1.13	0.34	0.75
1	2	5	1	8	20	46	1.40	0.42	1.04	1.33	0.39	0.98	1.26	0.37	0.93	1.15	0.34	0.85	1.05	0.31	0.78
1	2	5½	1	8	22	42	1.33	0.39	1.08	1.26	0.37	1.03	1.19	0.35	0.97	1.08	0.32	0.88	0.98	0.29	0.80
1	2	6	1	8	24	39	1.26	0.37	1.12	1.19	0.35	1.06	1.13	0.34	1.00	1.02	0.30	0.91	0.93	0.28	0.83
1	2½	3	1	10	12	86	1.65	0.61	0.73	1.59	0.59	0.71	1.53	0.57	0.68	1.42	0.52	0.63	1.33	0.49	0.59
1	2½	3½	1	10	14	75	1.55	0.57	0.80	1.48	0.55	0.77	1.42	0.52	0.74	1.32	0.49	0.68	1.23	0.46	0.64
1	2½	4	1	10	16	66	1.46	0.54	0.87	1.39	0.51	0.82	1.33	0.49	0.79	1.23	0.46	0.73	1.14	0.42	0.68
1	2½	4½	1	10	18	59	1.38	0.51	0.92	1.31	0.48	0.87	1.25	0.46	0.83	1.15	0.43	0.77	1.06	0.39	0.71
1	2½	5	1	10	20	54	1.31	0.48	0.97	1.24	0.46	0.92	1.18	0.44	0.87	1.08	0.40	0.80	0.99	0.37	0.73
1	2½	5½	1	10	22	49	1.24	0.46	1.01	1.18	0.44	0.96	1.12	0.41	0.91	1.02	0.38	0.83	0.93	0.34	0.76
1	2½	6	1	10	24	45	1.18	0.44	1.05	1.12	0.41	1.00	1.06	0.39	0.94	0.96	0.36	0.85	0.88	0.33	0.78
1	2½	6½	1	10	26	42	1.13	0.42	1.09	1.07	0.40	1.03	1.01	0.37	0.97	0.92	0.34	0.89	0.84	0.31	0.81
1	2½	7	1	10	28	39	1.08	0.40	1.12	1.02	0.38	1.06	0.96	0.36	1.00	0.87	0.32	0.90	0.79	0.29	0.82
1	3	4	1	12	16	75	1.35	0.60	0.80	1.30	0.58	0.77	1.25	0.56	0.74	1.15	0.51	0.68	1.08	0.48	0.64
1	3	4½	1	12	18	67	1.28	0.57	0.85	1.23	0.55	0.82	1.18	0.52	0.79	1.08	0.48	0.72	1.01	0.45	0.67
1	3	5	1	12	20	60	1.22	0.54	0.90	1.16	0.52	0.86	1.11	0.49	0.82	1.02	0.45	0.76	0.94	0.42	0.70
1	3	5½	1	12	22	55	1.16	0.52	0.95	1.11	0.49	0.90	1.06	0.47	0.86	0.97	0.42	0.79	0.89	0.40	0.72
1	3	6	1	12	24	50	1.11	0.49	0.99	1.06	0.47	0.94	1.01	0.45	0.90	0.92	0.41	0.82	0.84	0.37	0.75
1	3	6½	1	12	26	48	1.06	0.47	1.02	1.01	0.45	0.97	0.96	0.43	0.92	0.87	0.39	0.84	0.80	0.36	0.77
1	3	7	1	12	28	44	1.02	0.45	1.06	0.97	0.43	1.01	0.92	0.41	0.95	0.83	0.37	0.86	0.76	0.34	0.79
1	3	7½	1	12	30	42	0.98	0.44	1.09	0.93	0.41	1.03	0.88	0.39	0.98	0.79	0.35	0.88	0.73	0.32	0.81
1	3	8	1	12	32	39	0.94	0.42	1.11	0.89	0.40	1.05	0.84	0.37	1.00	0.76	0.34	0.90	0.69	0.31	0.82
1	4	5	1	16	20	75	1.08	0.64	0.80	1.03	0.61	0.76	0.99	0.59	0.73	0.92	0.55	0.68	0.86	0.51	0.64
1	4	6	1	16	24	63	0.99	0.59	0.88	0.95	0.56	0.84	0.91	0.54	0.81	0.83	0.49	0.74	0.77	0.46	0.68
1	4	7	1	16	28	55	0.92	0.54	0.95	0.88	0.52	0.91	0.83	0.49	0.86	0.76	0.45	0.79	0.70	0.42	0.73
1	4	8	1	16	32	48	0.86	0.51	1.02	0.81	0.48	0.96	0.77	0.46	0.91	0.70	0.42	0.83	0.64	0.38	0.76
1	4	9	1	16	36	43	0.80	0.47	1.07	0.76	0.45	1.01	0.72	0.43	0.96	0.65	0.39	0.87	0.60	0.36	0.80
1	4	10	1	16	40	40	0.75	0.44	1.11	0.71	0.42	1.05	0.67	0.40	0.99	0.61	0.36	0.90	0.55	0.33	0.81
1	5	10	1	20	40	47	0.70	0.52	1.04	0.66	0.49	0.98	0.63	0.47	0.93	0.57	0.42	0.84	0.52	0.38	0.77
1	6	12	1	24	48	46	0.59	0.52	1.05	0.56	0.50	1.00	0.53	0.47	0.94	0.48	0.43	0.85	0.44	0.39	0.78

NOTE—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by the 10 per cent in either direction.

* Use 50 per cent columns for broken stone screened to uniform size. † Use 45 per cent columns for average conditions and for broken stone with dust screened out. ‡ Use 40 per cent columns for gravel or mixed stone and gravel. § Use these columns for scientifically graded mixtures.

Quantities of Materials for One Cubic Yard of Rammed Concrete Based on a Barrel of 3.8 Cubic Feet

(See important foot-notes, also page 225)

(Reprinted by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," page 231)

Proportions by Parts: Cement	Proportions by Parts: Sand	Proportions by Parts: Stone	Proportions by Volumes: Packed Cement (bbl.)	Proportions by Volumes: Loose Sand (cu. ft.)	Proportions by Volumes: Loose Stone (cu. ft.)	Volume of Mortar in Terms of Percentage of Volume of Stone	50%* Cement (bbl.)	50%* Sand (cu. yd)	50%* Stone (cu yd.)	45%† Cement (bbl.)	45%† Sand (cu. yd.)	45%† Stone (cu. yd.)	40%‡ Cement (bbl.)	40%‡ Sand (cu. yd)	40%‡ Stone (cu. yd.)	30%§ Cement (bbl.)	30%§ Sand (cu. yd.)	30%§ Stone (cu. yd.)	20%§ Cement (bbl.)	20%§ Sand (cu. yd.)	20%§ Stone (cu. yd.)
1	...	1	1	...	3.8	94	5.09	...	0.72	4.90	...	0.69	4.73	...	0.67	4.33	...	0.61	4.02	...	0.57
1	...	2	1	...	7.6	51	3.67	...	1.03	3.48	...	0.98	3.30	...	0.93	2.93	...	0.82	2.65	...	0.75
1	...	3	1	...	11.4	36	...	...	...	2.69	...	1.14	2.54	...	1.07	2.22	...	0.94	1.98	...	0.84
1	...	4	1	...	15.2	29	...	...	...	...	...	...	...	...	...	1.78	...	1.00	1.58	...	0.89
1	...	5	1	...	19.0	25	...	...	...	...	...	...	...	...	...	1.49	...	1.05	1.31	...	0.92
1	...	6	1	...	22.8	22	...	...	...	...	...	...	...	...	...	1.28	...	1.08	1.12	...	0.95
1	...	7	1	...	26.6	20	...	...	...	...	...	...	...	...	...	...	...	...	0.98	...	0.97
1	...	8	1	...	30.4	19	...	...	...	...	...	...	...	...	...	...	...	...	0.87	...	0.98
1	...	9	1	...	34.2	18	...	...	...	...	...	...	...	...	...	...	...	...	0.78	...	0.99
1	...	10	1	...	38.0	17	...	...	...	...	...	...	...	...	...	...	...	...	0.71	...	1.00
1	...	11	1	...	41.8	16	...	...	...	...	...	...	...	...	...	...	...	...	0.65	...	1.01
1	...	12	1	...	45.5	15	...	...	...	...	...	...	...	...	...	...	...	...	0.60	...	1.01
1	1	1½	1	3.8	5.7	99	3.19	0.45	0.67	3.08	0.43	0.65	2.97	0.42	0.63	2.78	0.39	0.59	2.62	0.37	0.55
1	1	2	1	3.8	7.6	75	2.85	0.40	0.80	2.73	0.38	0.77	2.62	0.37	0.74	2.43	0.34	0.68	2.26	0.32	0.64
1	1	2½	1	3.8	9.5	61	2.57	0.36	0.90	2.45	0.34	0.86	2.34	0.33	0.82	2.15	0.30	0.76	1.99	0.28	0.70
1	1	3	1	3.8	11.4	51	2.34	0.33	0.99	2.22	0.31	0.94	2.12	0.30	0.90	1.93	0.27	0.82	1.77	0.25	0.75
1	1½	2	1	5.7	7.6	93	2.49	0.53	0.70	2.40	0.51	0.68	2.31	0.49	0.65	2.16	0.46	0.61	2.03	0.43	0.57
1	1½	2½	1	5.7	9.5	76	2.27	0.48	0.80	2.18	0.46	0.77	2.09	0.44	0.74	1.94	0.41	0.68	1.80	0.38	0.63
1	1½	3	1	5.7	11.4	64	2.09	0.44	0.88	2.00	0.42	0.84	1.91	0.40	0.81	1.76	0.37	0.74	1.63	0.34	0.69
1	1½	3½	1	5.7	13.3	55	1.94	0.41	0.96	1.84	0.39	0.91	1.76	0.37	0.87	1.61	0.34	0.79	1.48	0.31	0.73
1	1½	4	1	5.7	15.2	49	1.80	0.38	1.01	1.71	0.36	0.96	1.63	0.34	0.92	1.48	0.31	0.83	1.36	0.29	0.77
1	1½	4½	1	5.7	17.1	44	1.69	0.36	1.07	1.60	0.34	1.01	1.51	0.32	0.96	1.37	0.29	0.87	1.25	0.26	0.79
1	1½	5	1	5.7	19.0	40	1.59	0.34	1.12	1.50	0.32	1.06	1.42	0.30	1.00	1.28	0.27	0.90	1.17	0.25	0.82
1	2	3	1	7.6	11.4	75	1.89	0.53	0.80	1.81	0.51	0.76	1.74	0.49	0.74	1.61	0.45	0.68	1.50	0.42	0.63
1	2	3½	1	7.6	13.3	65	1.76	0.49	0.87	1.68	0.47	0.83	1.61	0.45	0.79	1.48	0.42	0.73	1.38	0.39	0.68
1	2	4	1	7.6	15.2	57	1.65	0.46	0.93	1.57	0.44	0.88	1.50	0.42	0.84	1.38	0.39	0.78	1.27	0.36	0.72
1	2	4½	1	7.6	17.1	51	1.55	0.44	0.98	1.48	0.42	0.94	1.41	0.40	0.89	1.28	0.36	0.81	1.18	0.33	0.75
1	2	5	1	7.6	19.0	47	1.47	0.41	1.03	1.39	0.39	0.98	1.32	0.37	0.93	1.20	0.34	0.84	1.10	0.31	0.77
1	2	5½	1	7.6	20.9	43	1.39	0.39	1.08	1.31	0.37	1.01	1.25	0.35	0.97	1.13	0.32	0.87	1.03	0.29	0.80
1	2	6	1	7.6	22.8	40	1.32	0.37	1.11	1.25	0.35	1.06	1.18	0.33	1.00	1.06	0.30	0.89	0.97	0.27	0.82
1	2½	3	1	9.5	11.4	87	1.72	0.61	0.73	1.66	0.58	0.70	1.60	0.56	0.68	1.49	0.52	0.63	1.40	0.49	0.59
1	2½	3½	1	9.5	13.3	75	1.62	0.57	0.80	1.55	0.55	0.76	1.49	0.52	0.73	1.38	0.49	0.68	1.29	0.45	0.64
1	2½	4	1	9.5	15.2	66	1.52	0.54	0.86	1.46	0.51	0.82	1.40	0.49	0.79	1.29	0.45	0.73	1.19	0.42	0.67
1	2½	4½	1	9.5	17.1	60	1.44	0.51	0.91	1.37	0.48	0.87	1.31	0.46	0.83	1.20	0.42	0.76	1.11	0.39	0.70
1	2½	5	1	9.5	19.0	54	1.37	0.48	0.96	1.30	0.46	0.92	1.24	0.44	0.87	1.13	0.40	0.80	1.04	0.37	0.73
1	2½	5½	1	9.5	20.9	49	1.30	0.46	1.01	1.23	0.43	0.95	1.17	0.41	0.91	1.07	0.38	0.83	0.98	0.34	0.76
1	2½	6	1	9.5	22.8	46	1.24	0.44	1.05	1.17	0.41	0.99	1.11	0.39	0.94	1.01	0.36	0.85	0.92	0.32	0.78
1	2½	6½	1	9.5	24.7	42	1.18	0.42	1.08	1.12	0.39	1.02	1.06	0.37	0.97	0.96	0.34	0.88	0.88	0.31	0.80
1	2½	7	1	9.5	26.6	40	1.13	0.40	1.11	1.07	0.38	1.05	1.01	0.36	0.99	0.91	0.32	0.90	0.83	0.29	0.82
1	3	4	1	11.4	15.2	76	1.42	0.60	0.80	1.36	0.57	0.77	1.30	0.55	0.73	1.21	0.51	0.68	1.12	0.47	0.63
1	3	4½	1	11.4	17.1	68	1.34	0.57	0.85	1.28	0.54	0.81	1.23	0.52	0.78	1.13	0.48	0.72	1.05	0.44	0.66
1	3	5	1	11.4	19.0	61	1.28	0.54	0.90	1.22	0.52	0.86	1.17	0.49	0.82	1.07	0.45	0.75	0.99	0.42	0.70
1	3	5½	1	11.4	20.9	56	1.22	0.52	0.94	1.16	0.49	0.90	1.11	0.47	0.86	1.01	0.43	0.78	0.93	0.39	0.72
1	3	6	1	11.4	22.8	52	1.16	0.49	0.98	1.11	0.47	0.94	1.05	0.44	0.89	0.96	0.41	0.81	0.88	0.37	0.74
1	3	6½	1	11.4	24.7	48	1.12	0.47	1.02	1.06	0.45	0.97	1.01	0.43	0.92	0.92	0.39	0.84	0.84	0.35	0.77
1	3	7	1	11.4	26.6	45	1.07	0.45	1.05	1.01	0.43	0.99	0.96	0.40	0.95	0.87	0.37	0.86	0.80	0.34	0.79
1	3	7½	1	11.4	28.5	42	1.03	0.44	1.09	0.97	0.41	1.02	0.92	0.39	0.97	0.83	0.35	0.88	0.76	0.32	0.80
1	3	8	1	11.4	30.4	40	0.99	0.42	1.11	0.93	0.39	1.05	0.88	0.37	0.99	0.80	0.34	0.90	0.73	0.31	0.82
1	4	5	1	15.2	19.0	76	1.13	0.61	0.80	1.08	0.61	0.76	1.04	0.59	0.73	0.96	0.54	0.68	0.90	0.51	0.63
1	4	6	1	15.2	22.8	64	1.04	0.59	0.88	0.99	0.56	0.84	0.95	0.54	0.80	0.87	0.49	0.73	0.81	0.46	0.68
1	4	7	1	15.2	26.6	55	0.96	0.54	0.95	0.92	0.52	0.91	0.88	0.50	0.87	0.80	0.45	0.79	0.74	0.42	0.73
1	4	8	1	15.2	30.4	49	0.90	0.51	1.01	0.85	0.48	0.96	0.81	0.46	0.91	0.74	0.42	0.83	0.68	0.38	0.77
1	4	9	1	15.2	34.2	44	0.84	0.47	1.06	0.80	0.45	1.01	0.76	0.43	0.96	0.68	0.38	0.86	0.63	0.35	0.80
1	4	10	1	15.2	38.0	40	0.79	0.44	1.11	0.75	0.42	1.06	0.71	0.40	1.00	0.64	0.36	0.90	0.58	0.33	0.82
1	5	10	1	19.0	38.0	47	0.73	0.52	1.03	0.69	0.49	0.97	0.66	0.46	0.93	0.60	0.42	0.81	0.55	0.39	0.77
1	6	12	1	22.8	45.5	46	0.62	0.52	1.04	0.58	0.49	0.98	0.56	0.47	0.94	0.50	0.42	0.84	0.46	0.39	0.78

(Percentages of Voids in Broken Stone or Gravel: 50%*, 45%†, 40%‡, 30%§, 20%§)

NOTE—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities 10 per cent in either direction.

*Use 50 per cent columns for broken stone screened to uniform size. †Use 45 per cent columns for average conditions and for broken stone with dust screened out. ‡Use 40 per cent columns for gravel or mixed stone and vel. §Use these columns for scientifically graded mixtures.

Quantities of Materials for One Cubic Yard of Rammed Concrete Based on a Barrel of 3.5 Cubic Feet

(See important foot-notes, also page 225)

(Reprinted by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," page 230)

Proportions by Parts			Proportions by Volumes			Volume of Mortar in Terms of Percentage of Volume of Stone	Percentages of Voids in Broken Stone or Gravel														
							50%*			45%†			40%‡			30%§			20%§		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
			bbl.	cu. ft.	cu. ft.		bbl.	cu. yd.	cu. yd.	bbl.	cu. yd	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu yd	cu. yd.
1	...	1	1	...	3.5	101	5.25	...	0.68	5.07	...	0.66	4.89	...	0.63	4.51	...	0.58	4.19	...	0.54
1	...	2	1	...	7.0	54	3.84	...	1.00	3.64	...	0.94	3.47	...	0.90	3.09	...	0.80	2.80	...	0.73
1	...	3	1	...	10.5	39	...	...	...	2.85	...	1.11	2.69	...	1.05	2.35	...	0.91	2.10	...	0.82
1	...	4	1	...	14.0	31	...	...	...	...	...	...	...	...	...	1.90	...	0.99	1.69	...	0.88
1	...	5	1	...	17.5	27	...	...	...	...	...	...	...	...	...	1.59	...	1.03	1.41	...	0.91
1	...	6	1	...	21.0	24	...	...	...	...	...	...	...	...	...	1.37	...	1.07	1.21	...	0.94
1	...	7	1	...	24.5	21	...	...	...	...	...	...	...	...	...	...	...	...	1.06	...	0.96
1	...	8	1	...	28.0	20	...	...	...	...	...	...	...	...	...	...	...	...	0.94	...	0.98
1	...	9	1	...	31.5	18	...	...	...	...	...	...	...	...	...	...	...	...	0.84	...	0.98
1	...	10	1	...	35.0	17	...	...	...	...	...	...	...	...	...	...	...	...	0.77	...	1.00
1	...	11	1	...	38.5	16	...	...	...	...	...	...	...	...	...	...	...	...	0.70	...	1.00
1	...	12	1	...	42.0	16	...	...	...	...	...	...	...	...	...	...	...	...	0.65	...	1.01
1	1	1½	1	3.5	5.2	104	3.37	0.44	0.65	3.26	0.42	0.63	3.15	0.41	0.61	2.95	0.38	0.57	2.78	0.36	0.54
1	1	2	1	3.5	7.0	78	3.02	0.39	0.78	2.89	0.38	0.75	2.78	0.36	0.72	2.58	0.33	0.67	2.41	0.31	0.62
1	1	2½	1	3.5	8.7	64	2.73	0.35	0.88	2.60	0.34	0.84	2.49	0.32	0.80	2.29	0.30	0.74	2.12	0.28	0.68
1	1	3	1	3.5	10.5	54	2.49	0.32	0.97	2.37	0.31	0.92	2.25	0.29	0.88	2.06	0.27	0.80	1.90	0.25	0.74
1	1½	2	1	5 2	7.0	95	2.64	0.51	0.68	2.55	0.49	0.66	2.46	0.47	0.64	2.30	0.44	0.60	2.16	0.42	0.56
1	1½	2½	1	5.2	8.7	78	2.42	0.47	0.78	2.32	0.45	0.75	2.23	0.43	0.72	2.07	0.40	0.67	1.93	0.37	0.62
1	1½	3	1	5.2	10.5	65	2.23	0.43	0.87	2.13	0.41	0.83	2.04	0.39	0.79	1.88	0.36	0.73	1.74	0.34	0.68
1	1½	3½	1	5.2	12.2	56	2.07	0.40	0.94	1.97	0.38	0.89	1.88	0.36	0.85	1.72	0.33	0.78	1.59	0.31	0.72
1	1½	4	1	5.2	14.0	50	1.93	0.37	1.00	1.83	0.35	0.95	1.74	0.34	0.90	1.59	0.31	0.82	1.46	0.28	0.76
1	1½	4½	1	5.2	15.7	45	1.81	0.35	1.05	1.71	0.33	0.99	1.62	0.31	0.94	1.47	0.28	0.86	1.35	0.26	0.78
1	1½	5	1	5.2	17.5	41	1.70	0.33	1.10	1.60	0.31	1.04	1.52	0.29	0.99	1.37	0.26	0.89	1.25	0.24	0.81
1	2	3	1	7.0	10.5	77	2.02	0.52	0.79	1.94	0.50	0.75	1.86	0.48	0.72	1.73	0.45	0.67	1.61	0.42	0.63
1	2	3½	1	7.0	12.2	67	1.89	0.49	0.85	1.80	0.47	0.81	1.73	0.45	0.78	1.59	0.41	0.72	1.48	0.38	0.67
1	2	4	1	7.0	14.0	59	1.77	0.46	0.92	1.69	0.44	0.88	1.61	0.42	0.83	1.48	0.38	0.77	1.37	0.35	0.71
1	2	4½	1	7.0	15.7	53	1.67	0.43	0.97	1.58	0.41	0.92	1.51	0.39	0.88	1.38	0.36	0.80	1.27	0.33	0.74
1	2	5	1	7.0	17.5	48	1.57	0.41	1.02	1.49	0.39	0.97	1.42	0.37	0.92	1.29	0.33	0.84	1.18	0.31	0.76
1	2	5½	1	7.0	19.2	44	1.49	0.39	1.06	1.41	0.36	1.00	1.34	0.35	0.95	1.21	0.31	0.86	1.11	0.29	0.79
1	2	6	1	7.0	21.0	41	1.42	0.37	1.10	1.34	0.35	1.04	1.27	0.33	0.99	1.14	0.30	0.89	1.04	0.27	0.81
1	2½	3	1	8.7	10.5	90	1.84	0.59	0.72	1.78	0.57	0.69	1.71	0.55	0.66	1.60	0.52	0.62	1.50	0.48	0.58
1	2½	3½	1	8.7	12.2	78	1.73	0.56	0.78	1.66	0.53	0.75	1.60	0.52	0.72	1.48	0.48	0.67	1.38	0.44	0.62
1	2½	4	1	8.7	14.0	68	1.63	0.52	0.85	1.56	0.50	0.81	1.50	0.48	0.78	1.38	0.44	0.72	1.28	0.41	0.66
1	2½	4½	1	8.7	15.7	61	1.55	0.50	0.90	1.47	0.47	0.86	1.41	0.45	0.82	1.29	0.42	0.75	1.20	0.39	0.70
1	2½	5	1	8.7	17.5	55	1.47	0.47	0.95	1.39	0.45	0.90	1.33	0.43	0.86	1.22	0.39	0.79	1.12	0.36	0.73
1	2½	5½	1	8.7	19.2	51	1.39	0.45	0.99	1.32	0.42	0.94	1.26	0.41	0.90	1.15	0.37	0.82	1.06	0.34	0.75
1	2½	6	1	8.7	21.0	47	1.33	0.43	1.03	1.26	0.41	0.98	1.20	0.39	0.93	1.09	0.35	0.85	1.00	0.32	0.78
1	2½	6½	1	8.7	22.7	44	1.27	0.41	1.07	1.20	0.39	1.01	1.14	0.37	0.96	1.03	0.33	0.87	0.94	0.30	0.79
1	2½	7	1	8.7	24.5	41	1.22	0.39	1.11	1.15	0.37	1.04	1.09	0.35	0.99	0.98	0.32	0.89	0.90	0.29	0.82
1	3	4	1	10.5	14.0	77	1.52	0.59	0.79	1.46	0.57	0.76	1.40	0.54	0.73	1.30	0.50	0.67	1.21	0.47	0.63
1	3	4½	1	10.5	15.7	69	1.44	0 56	0.84	1.38	0.54	0.80	1.32	0.51	0.77	1.22	0.47	0.71	1.13	0.44	0.66
1	3	5	1	10.5	17.5	62	1.37	0.53	0.89	1.31	0.51	0.85	1.25	0.48	0.81	1.15	0.45	0.75	1.07	0.42	0.69
1	3	5½	1	10.5	19 2	57	1.31	0 51	0.93	1.25	0.48	0.89	1.19	0.46	0.85	1.09	0.42	0.78	1.01	0.39	0.72
1	3	6	1	10.5	21.0	53	1.25	0.48	0.97	1.19	0.46	0.93	1.13	0.44	0.88	1.03	0.40	0.80	0.95	0.37	0.74
1	3	6½	1	10.5	22.7	49	1.20	0.47	1.01	1.14	0.44	0.96	1.08	0.42	0.91	0.98	0.38	0.82	0.90	0.35	0.76
1	3	7	1	10.5	24.5	46	1.15	0.45	1.04	1.09	0.42	0.99	1.03	0.40	0.93	0.94	0.36	0.85	0.86	0.33	0.78
1	3	7½	1	10.5	26.2	43	1.11	0.43	1.08	1.05	0.41	1.02	0.99	0.38	0.96	0.90	0.35	0.87	0.82	0.32	0.80
1	3	8	1	10.5	28.0	40	1.06	0.41	1.10	1.01	0.39	1.05	0.95	0.37	0.99	0.86	0.33	0.89	0.78	0.30	0.81
1	4	5	1	14.0	17.5	77	1.22	0.63	0.79	1.17	0.61	0 76	1.12	0.58	0.73	1.04	0.54	0.67	0.97	0.50	0.63
1	4	6	1	14.0	21.0	65	1.12	0.58	0.87	1.07	0.55	0.83	1.02	0 53	0.79	0.94	0.49	0.73	0.87	0.45	0.68
1	4	7	1	14.0	24 5	56	1.04	0.54	0.94	0.99	0.51	0.90	0.94	0.49	0.85	0.86	0.44	0.78	0.80	0.41	0.73
1	4	8	1	14.0	28.0	50	0.97	0.50	1.01	0.92	0.48	0.95	0.87	0.45	0.90	0.80	0.41	0.83	0.73	0.38	0.76
1	4	9	1	14.0	31.5	45	0.91	0.47	1.06	0.86	0.44	1.00	0.81	0.42	0.94	0.74	0.38	0.86	0.68	0.35	0.79
1	4	10	1	14.0	35.0	41	0.85	0.44	1.10	0.81	0.42	1.05	0.76	0.39	0.98	0.69	0.36	0.89	0.63	0.33	0.82
1	5	10	1	17 5	35.0	48	0.79	0 51	1.02	0.75	0.49	0.97	0.71	0.46	0.92	0.65	0.42	0.84	0.59	0.38	0.76
1	6	12	1	21.0	42.0	46	0.67	0.52	1.04	0.63	0.49	0.98	0.60	0.47	0.93	0.54	0.42	0 84	0 50	0.39	0.78

NOTE—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10 per cent in either direction.

*Use 50 per cent columns for broken stone screened to uniform size. †Use 45 per cent columns for average conditions and for broken stone with dust screened out. ‡Use 40 per cent columns for gravel or mixed stone and gravel. §Use these columns for scientifically graded mixtures.

Volume of Plastic Mortar made from Different Proportions of Cement and Sand

Quantities of Materials Per Cubic Yard

(See page 227)

(Reprinted by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," page 229)

Relative Proportions by Volume*		Volume of Compacted Plastic Mortar						Materials for 1 Cubic Yard Compact Plastic Mortar Based on Barrel of					
		From 1 Cu. Ft. Cement			From 1 Barrel Cement								
		Based on Portland Cement Weighing			Based on Barrel of			3.5 Cubic Feet		**3.8 Cubic Feet †**		4 Cubic Feet	
Cement	Sand	108 Pounds per Cubic Foot	**100 Pounds per Cubic Foot †**	95 Pounds per Cubic Foot	3.5 Cubic Feet	**3.8 Cubic Feet †**	4 Cubic Feet	Packed Cement	Loose Sand	**Packed Cement**	**Loose Sand**	Packed Cement	Loose Sand
		cu. ft.	**cu. ft.**	cu. ft.	cu. ft.	**cu. ft.**	cu. ft.	bbl.	cu. yd.	**bbl.**	**cu. yd.**	bbl.	cu. yd.
1	0	0.93	0.86	0.80	3 2	3.2	3.2	8 31	....	8.31	....	8.31	
1	½	1 12	1.06	1.02	3 9	4.0	4 1	6.92	0.46	6 73	0.47	6.61	0.49
1	1	1.48	1 42	1.38	5 2	5.4	5 5	5 22	0.68	5.01	0.71	4.88	0.72
1	1½	1.84	1.78	1.74	6.4	6.7	7.0	4 20	0.81	4.00	0.84	3.87	0.86
1	2	2.20	2.14	2.11	7.7	8 1	8.4	3.51	0 91	3.32	0 93	3 21	0.95
1	2½	2 56	2.50	2.47	9.0	9.5	9.9	3.01	0 98	2.84	1.00	2 74	1.01
1	3	2 92	2.86	2.83	10 2	10.9	11.3	2 64	1 03	2 48	1.05	2.39	1.06
1	3½	3.28	3.23	3.19	11.5	12.2	12.8	2.35	1.06	2.20	1.08	2.12	1.10
1	4	3 64	3.59	3.55	12.8	13.6	14.2	2.12	1.10	1 98	1.11	1 90	1.13
1	4½	4.01	3.95	3 91	14.0	15 0	15 6	1.92	1.12	1.80	1.14	1.72	1.15
1	5	4.37	4.31	4 28	15.3	16.4	17.1	1.77	1.15	1.65	1 16	1.58	1.17
1	5½	4.73	4.67	4 64	16.6	17.7	18.5	1.63	1.16	1.52	1.18	1.46	1.19
1	6	5.09	5.03	5 00	17.8	19.1	20.0	1 52	1.18	1 41	1.19	1.35	1.20
1	6½	5.45	5.39	5.36	19.1	20.5	21.4	1 41	1.19	1.32	1.21	1 26	1.21
1	7	5 81	5.76	5.72	20.3	21.9	22.9	1.33	1.21	1 23	1.21	1.18	1.22
1	7½	6 18	[illegible]	6.08	21.6	23.2	24.3	1.25	1.21	1 16	1.22	1.11	1.23
1	8	6 54	6 48	6 41	22.9	24 6	25 8	1.18	1.22	1 10	1 24	1.05	1.24

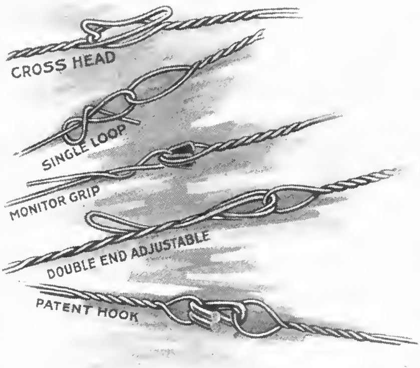
NOTE – Variations in the fineness of the sand and the cement, and in consistency of the mortar may affect the values by 10 per cent in either direction.

*Cement as packed by manufacturer, sand loose.

† **Use these columns ordinarily.**

Contents

Contents—Continued



American Bale Ties

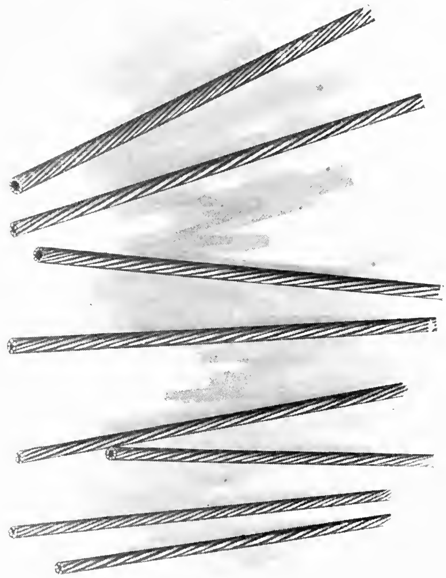
Made by

American Steel & Wire Company

For baling or bundling Hay, Straw, Flax, Tow, Excelsior, Broom Corn, Wool, Cotton, Cotton Seed Hulls, Rags, Lintels, Shavings, Sawdust, Leather, Headings, Staves, Etc.

For use in any kind of Press

Hollow Cable Clothes Lines



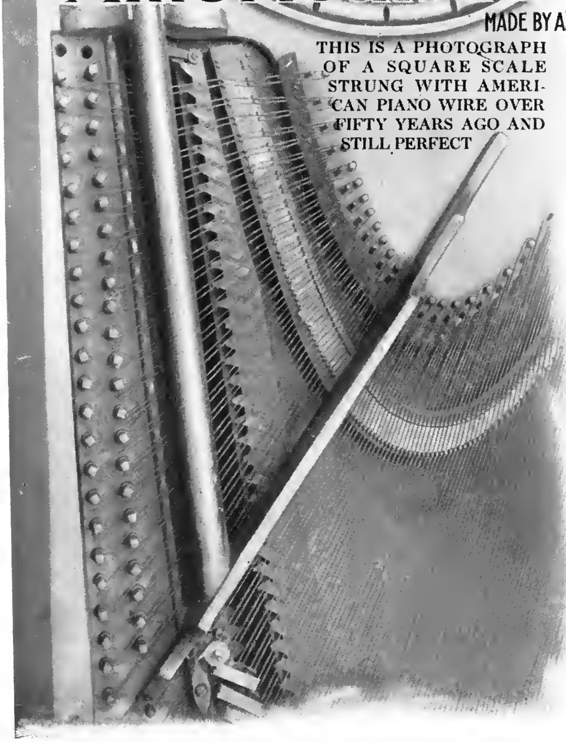
In addition to regular lengths scheduled below, we furnish these lines in 2,500 and 5,000 ft. lengths, on reels.

	Estimated Average Weight in Pounds per Dozen					Estimated Average Number of Dozen to Barrel				
Size	100 ft.	90 ft.	75 ft.	60 ft.	50 ft.	100 ft.	90 ft.	75 ft.	60 ft.	50 ft.
No. 1	18	16	14	11	9	12	12	15	21	24
No. 2	22	20	17	13	11	8	8	12	14	16
No. 3	30	27	23	18	15	6	6	8	11	12
No. 4	42	38	32	25	21	5	5	8	9	10
No. 17	56	50	42	34	28	5	5	6	7	8
No. 18	46	41	35	27	24	6	6	7	7	10
No. 19	35	31½	25	21	17	8	8	10	12	15
No. 20	25	22½	20	15	13	10	10	12	14	18
*No. 8	84	76	63	50	42	4½	5	6	7	8
*No. 9	70	63	52	42	35	5½	6	7	8	9
*No. 10	58	52	43	35	29	6⅙	7	8	9	10

*Nos. 8, 9 and 10 are solid lines (one wire).

American Piano Wire

MADE BY AMERICAN STEEL & WIRE COMPANY



We began the manufacture of Piano Wire under the supervision of Jonas Chickering in 1850 and were awarded the Grand Prize over the whole world at the Paris Exposition in 1900.

WE have developed by our own original research and experiment through the past 60 years, the manufacture of our "Perfected" and "Crown" brands of music wire, which represent the most advanced ideas in the blending of metals for perfect acoustic results.

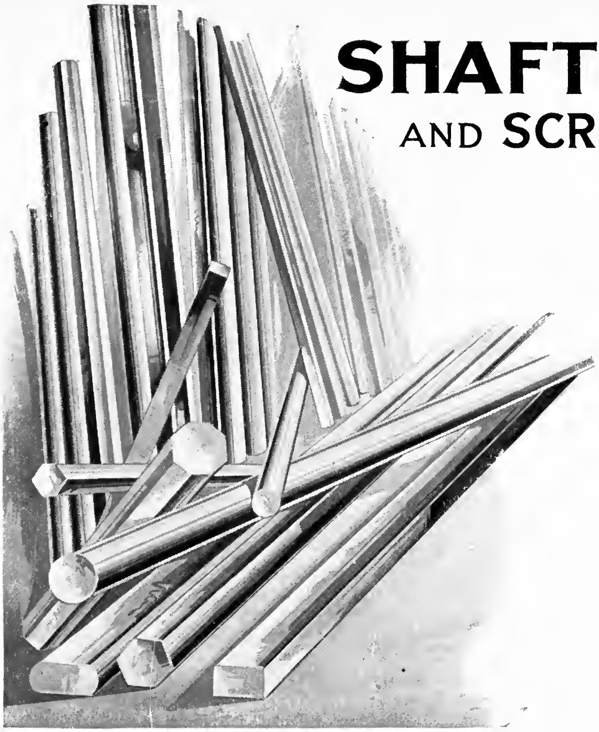
Music Spring Wire for all Manufacturing Purposes

Comparison of STEEL WIRE GAGE with the new MUSIC WIRE GAGE, adopted as standard for piano wire upon recommendation of the United States Bureau of Standards.

The Music Wire Gage is the same as heretofore employed under the name "American Steel & Wire Co's Music Wire Gage."

Number of Gage	Steel Wire Gage	Music Wire Gage	Number of Gage	Steel Wire Gage	Music Wire Gage	Number of Gage	Steel Wire Gage	Music Wire Gage	Number of Gage	Steel Wire Wire	Music Wire Gage
6/0	.4615	.004	8	.162	.020	21	.03175	.047	34	.0104	.100
5/0	.430	.005	9	.1483	.022	22	.0286	.049	35	.0095	.106
4/0	.3938	.006	10	.135	.024	23	.0258	.051	36	.009	.112
3/0	.3625	.007	11	.1205	.026	24	.023	.055	37	.0085	.118
2/0	.331	.008	12	.1055	.029	25	.0204	.059	38	.008	.124
1/0	.3065	.009	13	.0915	.031	26	.0181	.063	39	.0075	.130
1	.283	.010	14	.080	.033	27	.0173	.067	40	.007	.138
2	.2625	.011	15	.072	.035	28	.0162	.071	41	.0066	.146
3	.2437	.012	16	.0625	.037	29	.015	.075	42	.0062	.154
4	.225	.013	17	.054	.039	30	.014	.080	43	.006	.162
5	.207	.014	18	.0475	.041	31	.0132	.085	44	0058	.170
6	.192	.016	19	.041	.043	32	.0128	.090	45	.0055	.180
7	.177	.018	20	.0348	.045	33	.0118	.095			

Write for American Piano Wire News, illustrating and describing use of our piano wire in the great pianofortes for 60 years. Also, the nature of sound in the production of music. Free on request.



SHAFTING
AND SCREW STOCK

Rounds
Squares
Hexagons
Octagons
Flats

Cold Drawn Steel, Free Cutting Screw Steel, Pump Rods, Roller Bearing Rods for all purposes.

Shafting Catalogue furnished upon

Sulphate of Iron
In Water Purification
The Quincy Process

FOR THE PURIFICATION OF CITY WATER SUPPLY, DESTRUCTION OF FARM WEEDS, DISINFECTANT, DYEING, PURIFICATION OF GAS AND FOR PLATE GLASS POLISHING

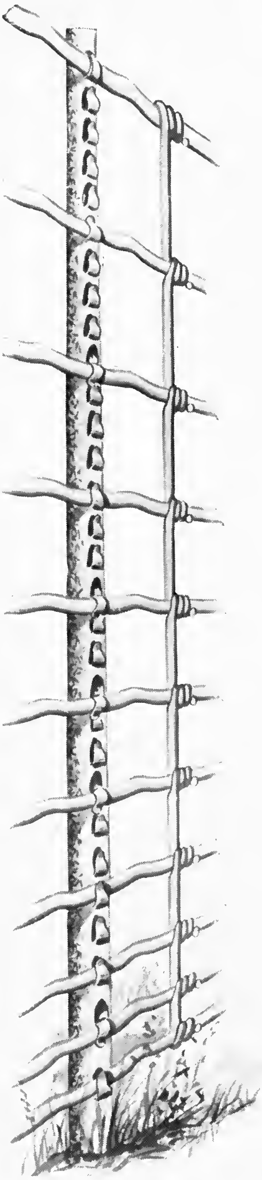
THIS chemical was first largely introduced by us in the purification of the water of the city of Quincy, Ill., in July, 1902, through W. B. Bull's Quincy process. Two years later this process was adopted by the city of St. Louis as well as by many other cities. In 1908 the same system was installed in Cincinnati and New Orleans. This process is absolute in its operation, affording a safe, pure water, free from injurious bacteria, wholesome and of crystal clearness.

We employ Sulphate of Iron extensively in the destruction of wild mustard and other choking farm weeds. Its great success in connection with modern spraying machines is now thoroughly demonstrated.

Sulphate of Iron is a by-product of the manufacture of wire. As its name indicates, it is nothing more nor less than iron in solution, drawn by our patented process of manufacture into crystals resembling rock candy or granulated sugar. It is non-poisonous, being in various ways assimilated with foods and medicines for live-stock and possessing all the remedial properties of iron, of which it is the essence.

"Farm Weeds and Farm Sanitation," a publication descriptive of the use of Sulphate of Iron in destroying weeds, and affecting sanitary conditions, furnished free upon request.

American Steel Fence Post



Made by American Steel and Wire Company

QUALITY—Made of suitable high-class steel, heavily coated with zinc inside and outside.

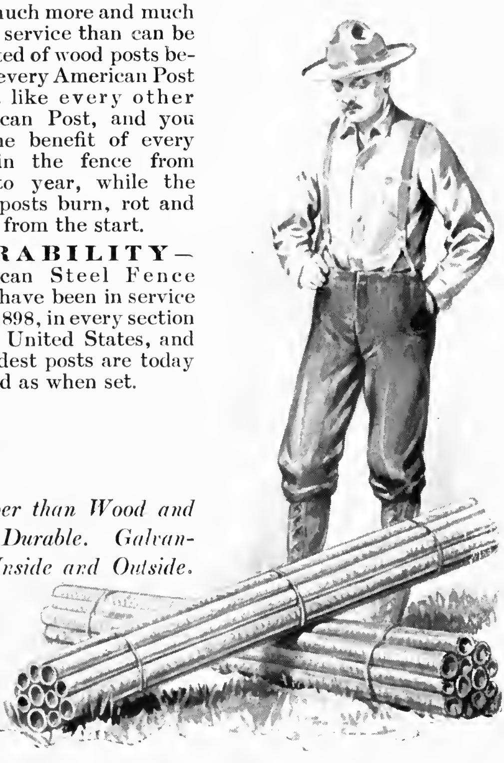
STRENGTH—Line posts strong enough to hold up any wire fence and furnish all necessary resistance. End and corner posts so strong that they will maintain any wire fence made.

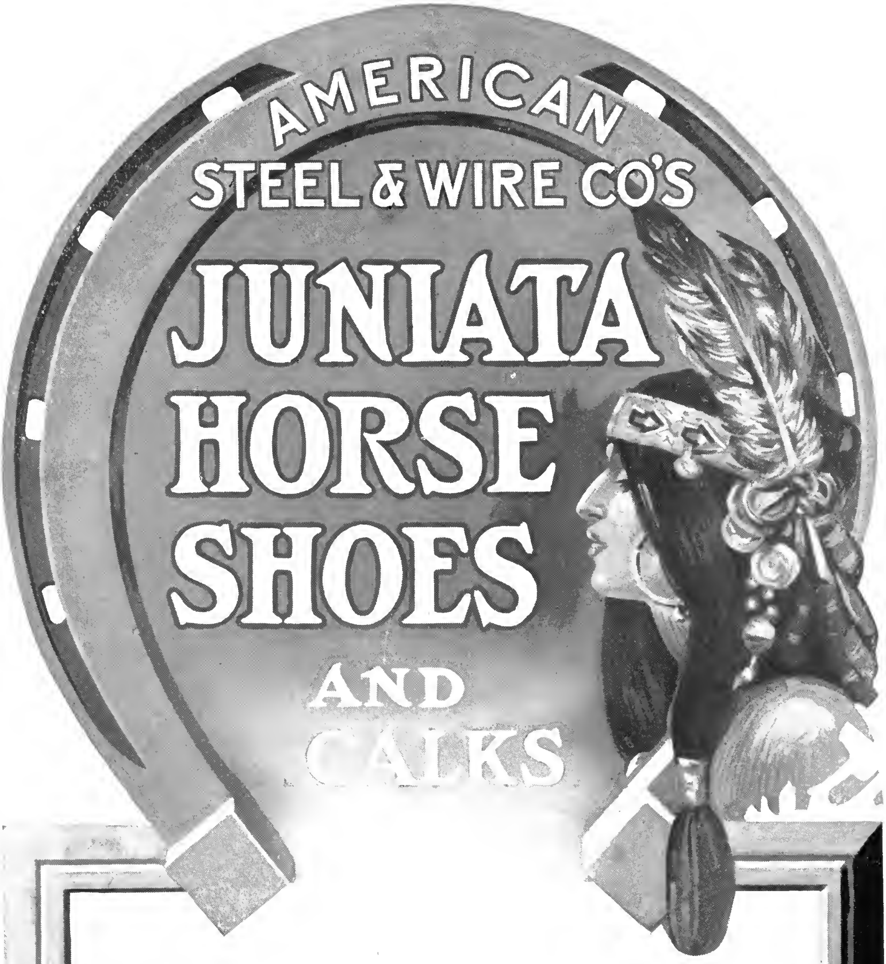
ADAPTABILITY—Adapted to all conditions and will prove absolutely satisfactory wherever a good wire fence is desired, no matter how heavy the wire or how hard the usage after the fence is erected.

SERVICE—The American Steel Fence Post will give much more and much better service than can be expected of wood posts because every American Post is just like every other American Post, and you get the benefit of every post in the fence from year to year, while the wood posts burn, rot and decay from the start.

DURABILITY—American Steel Fence Posts have been in service since 1898, in every section of the United States, and the oldest posts are today as good as when set.

Cheaper than Wood and More Durable. Galvanized Inside and Outside.



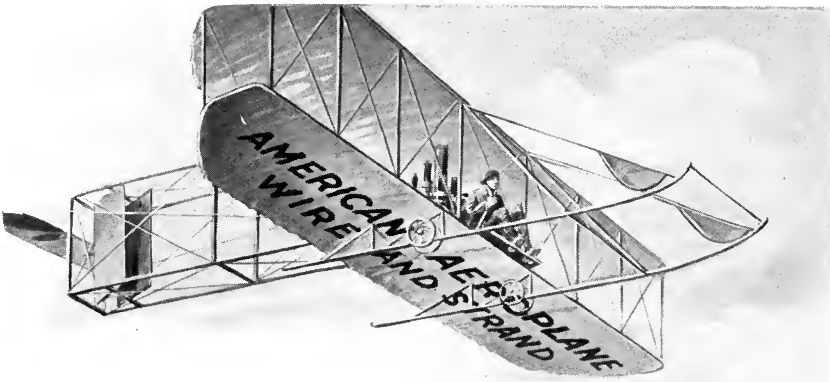


Packed in kegs with red heads.

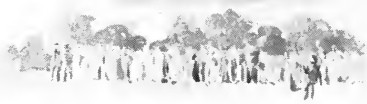
Made in all sizes and patterns from the best steel or iron.

The experience of nearly half a century of progressive manufacture is embodied in the Juniata shoe. The product is a shoe thoroughly adapted to all requirements in shape, finish and quality of metal.

Juniata toe and heel calks are made in blunt, medium and sharp patterns, in all sizes and dimensions.

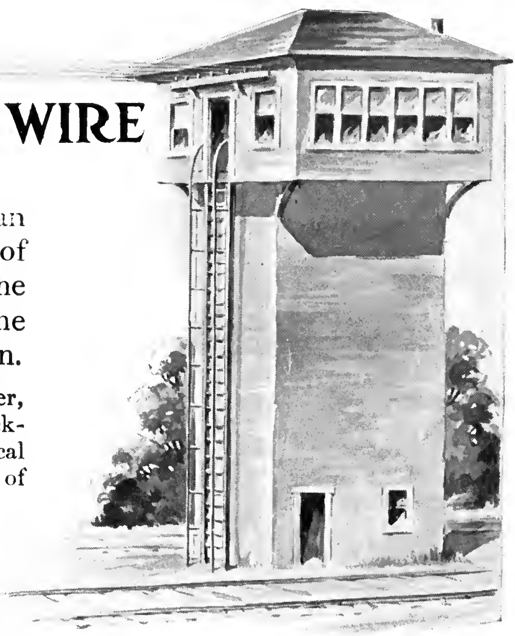


AFTER continued experiments in the aviation field we now produce aeroplane wire, strand and cables, adapted for all requirements upon aeroplanes.



Send for special publication illustrating the many forms of attachments to planes, and other useful aviation data.

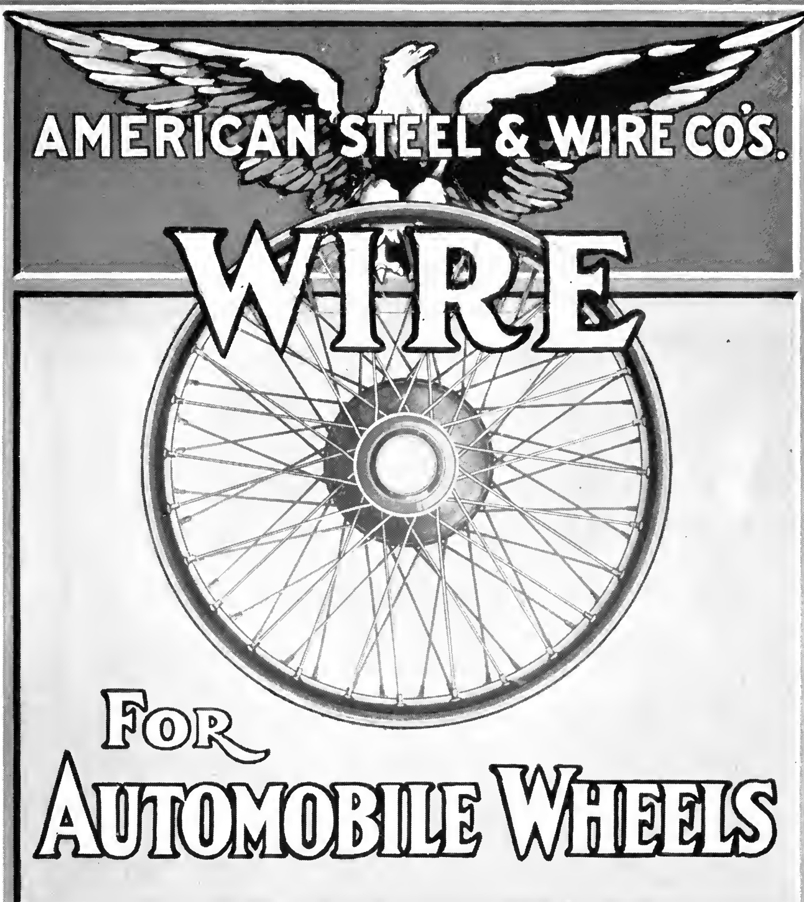
30% SIGNAL WIRE



We are manufacturing an extremely high quality of Signal Wire, meeting the exacting requirements of the Railway Signal Association.

Thirty per cent Para rubber, cylindrical, true to gage and thickness of wall, and subject to critical examination at every stage of manufacture.

Samples on request



WIRE WHEELS mean nearly 70% more tire mileage over wooden wheels because the bare rims and wire spokes radiate the heat; and further, they softly float over obstructions while wooden wheels rigidly bounce. Wire wheels are much stronger by actual test, and are also considerably lighter, especially at the rim and this materially economizes engine power. Eighty per cent of recent Grand Prix racing cars were equipped with wire wheels; and this is about the percentage of wire wheels used on all pleasure cars in Europe. They are destined to become universal as their beauty, economy and engineering advantages make them the only correct wheel for automobile use. You should insist upon having them on your car.

Write for our *American Wire Wheel News*, fully describing all makes and methods of manufacture, and how you can adapt them to your car.

FRANK BAACKES, V. P. and G. S. A.
72 West Adams Street **Chicago**

American Rail Bonds

Made by

American Steel & Wire Company

We manufacture four different styles of Rail Bonds.

Crown Rail Bonds—having single stud terminals either solid for compression, or tubular for pin expansion, the conductors between the terminals being either solid wires, or strands composed of a number of small round wires.

United States Rail Bonds—having single stud terminals either solid for compression, or tubular for pin expansion, the conductor being composed of flat strips or ribbons.

Twin-Terminal Rail Bonds—having two or more studs on each terminal, the conductors between the terminals being strands composed either of a number of small round wires, or of flat ribbons.

Soldered Rail Bonds—having flat terminals, the connection with the rails being made with solder, the conductors between the terminals being strands composed either of a number of small round wires, or strands composed of flat ribbons.

We also manufacture a very complete outfit of high-grade Tools for installing bonds; and have ample facilities for making Rail Bonds or Tools, of special design for special conditions.

We solicit inquiries for prices and for information on any rail-bonding problems, asking particularly that the conditions may be fully described to us.

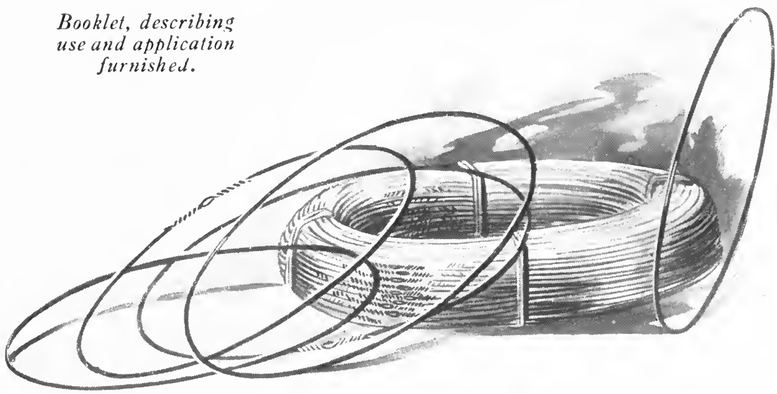
Rail Bond Catalogue furnished upon request.

American Wire Hoops

Our wire hoops make strong packages, are uniform in quality and cost less than wood hoops. They are manufactured to size, ready to apply.

Samples furnished free of charge.

Booklet, describing use and application furnished.



American Steel & Wire Co.'s

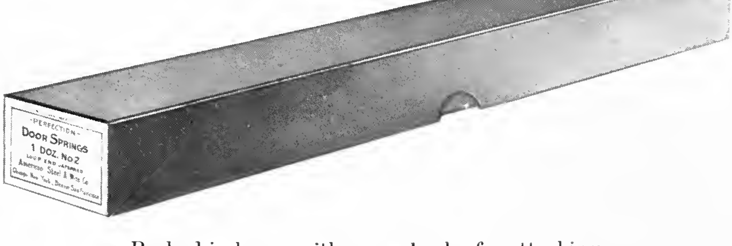
Perfection Door Springs

The best steel is used in the manufacture of these springs, ensuring permanent resiliency and freedom from breakage. The spring is well adapted for screen doors or other doors. It is easily applied with simply two screw hooks, one in the door and one in the frame. Made in sizes No. 1 to No. 7 with double wire loop ends. No. 1 for light screen doors, up to No. 4 for ordinary doors, No. 5 for heavy doors, and Nos. 6 and 7 for gates, etc.

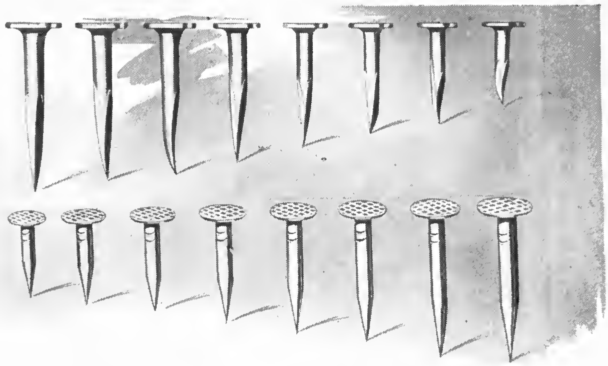
Japan or nickel finish.

Packed in paper boxes as illustrated below, one dozen in a box.

NOTE—Springs to be properly adjusted, should be fastened at the top of the door.



Packed in boxes with screw hooks for attaching.



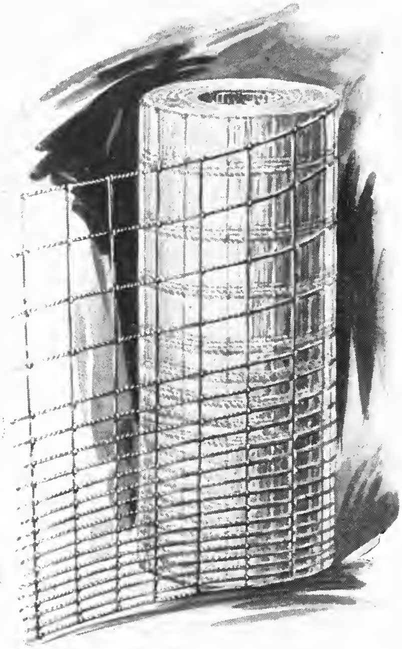
AMERICAN WIRE TACKS AND PEERLESS TACKS

combine all the essential features of good tacks, and are sold under our guarantee of full weight and full count.

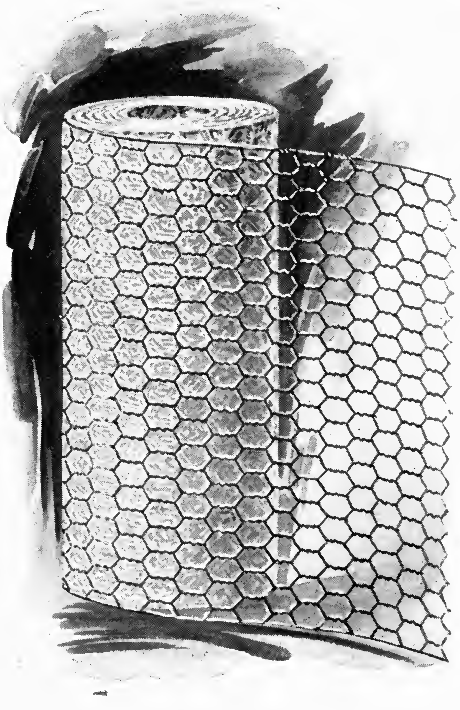
Furnished in either carpet, upholsterer, bill-poster or railroad styles; in finished, polished or blued, tinned, coppered or galvanized; packed in bulk, kegs or boxes, count papers, colored cartons and toy barrels.

Illustrated catalogue and prices furnished on request.

Union Lock Poultry Fence



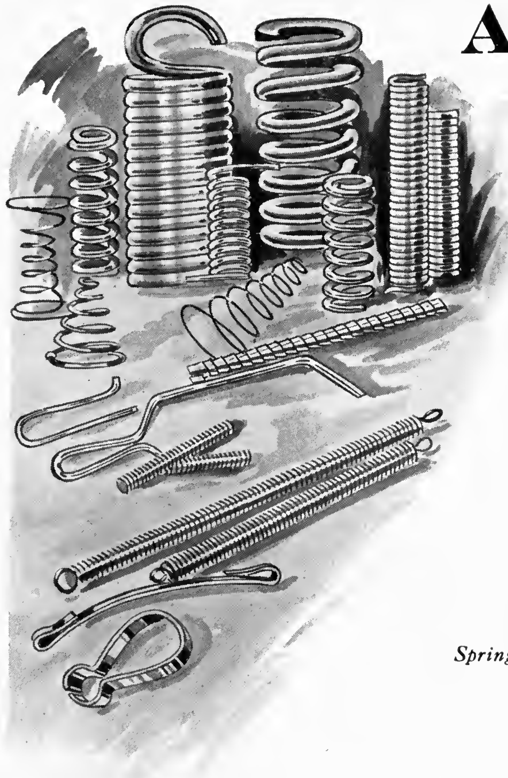
MADE in all heights and widths for poultry fencing use. This poultry fence occupies the middle field between the lighter nettings and the heavier stock fences. It has very small meshes at the bottom whereby the smallest animals or chicks are retained or excluded. Can be safely used next to pasture. Thoroughly galvanized and lasts for years. An absolutely reliable light fencing fabric, firmly establishing the claims originally made years ago when first put upon the market.



American Hexagon Poultry Netting

American Hexagon Poultry Fence

GALVANIZED either before or after weaving, as ordered. A thoroughly made netting, in all standard meshes and widths, adapted for all poultry netting uses. Spreads out smooth and even like a carpet. All wires drawn with equal tension. Rolls compact.



American Springs

Made By

American Steel & Wire Company

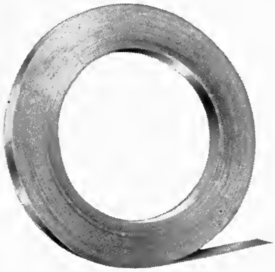
Springs Catalogue furnished upon application.

We are thoroughly equipped to handle specifications for all kinds of springs, made to suit the most exacting requirements of elasticity, temper, strength and durability. We make all shapes and tempers, adapted to every use; and with large capacity can promptly deliver.

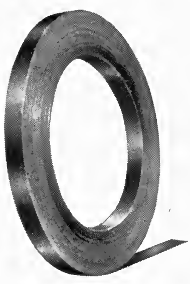
We can assist you in adapting standard forms, or figure new designs in flat or round steel. Our experience is at your disposal in any way that we may be of service. We solicit the favor of your inquiries.

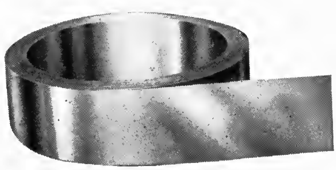
American Flat Wire

Flat Cold Rolled Steel

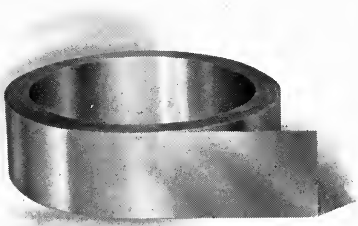


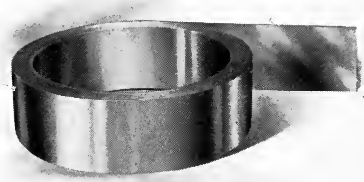
MADE in all widths up to 9 inches, for shaping into all forms of manufacture in automatic machines, or otherwise, such as butts, hinges, tubes, roller skates, keys, typewriter parts, sewing and adding machine and automobile parts, cream separator discs, buttons, stove and show case trimmings, gun parts, wire chair rims, go-cart parts and any difficult or plain forming where flat steel of great ductility, strength, finish and uniformity is required.





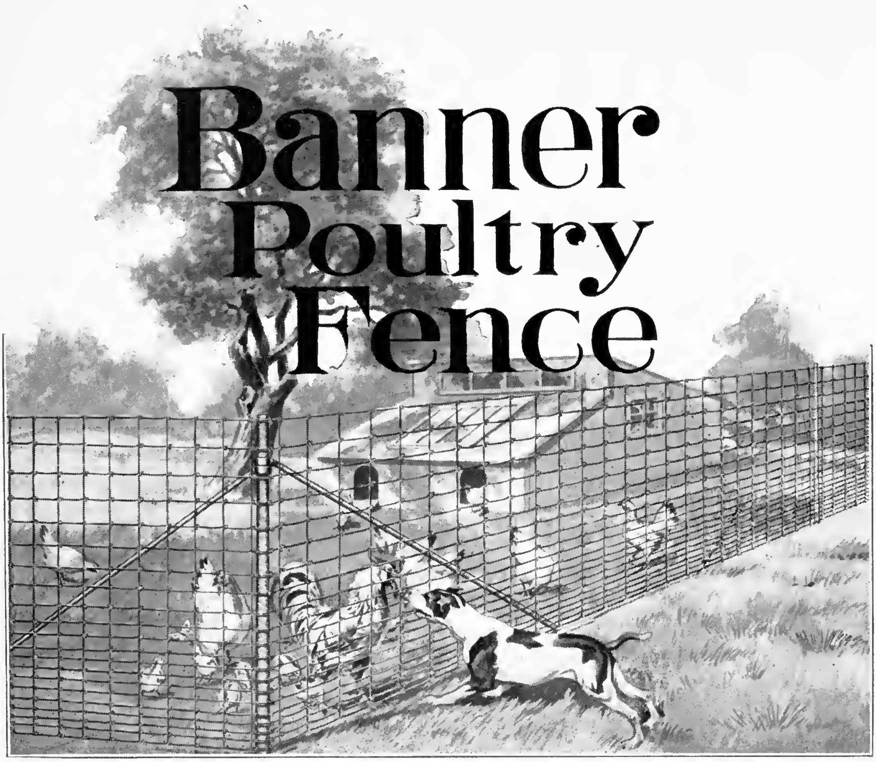
"Flat Wire Bulletin" describing many uses of flat wire, sent free upon request.





AMERICAN STEEL & WIRE COMPANY'S SQUARE, OVAL AND ODD SHAPED WIRE FOR ALL PURPOSES

Wire can be drawn in round, flat, square, oval and other odd shapes for various uses. Frequently savings can be affected by using a drawn shape where formerly much machine work has been done in shaping plain bars. Inquiries for odd shapes of every description are solicited.



WE offer exceptional value in this good fence. Substantially made, close mesh, strong, durable, handsome. Well advertised, popular. We will back the DEALER as well as the PURCHASER.

Write for our literature and our proposition

Made by

American Steel & Wire Company

Patent applied for.

Soft, flexible steel cable of great strength, with chain and hook at each end.

American Auto Towing Cable

THIS cable consists of crucible cast steel rope of fine wires, 30 feet long, as flexible and adaptable as a manila rope.

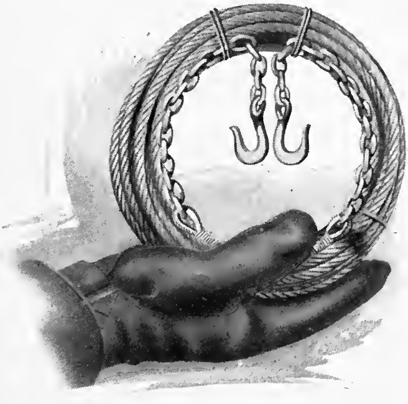
Its strength is 5 tons.

The cable is attached by means of chain and hook at each end. This is the handiest, best understood, quickest and most adaptable form of attachment.

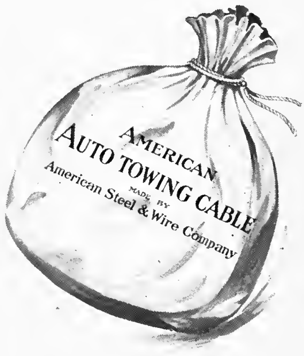
The great flexibility of this cable permits it to be easily and compactly coiled, thus taking up very little room. And its smooth finish makes it clean handling, mud and waterproof.

It readily may be wrapped around a tire in emergency where traction is desired or where it may be necessary to bind up a damaged tire to get home.

A necessity in every automobile tool box and a handy safety-appliance in many possible emergencies.



Readily coiled into small space.



Packed in a neat sack like a Weed chain.

List Price, $3.75