Part I.

R E I N F O R C E D C O N C R E T E A R C H .

In part fulfilment of the re-
quirements for the Degree of
Bachelor of Science,

by

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Reinforced Concrete Arch.

Introduction;-

Reinforced concrete has been used for only a few years, but the law governing the combination of concrete and steel, although nettabsolutely fixed, is known with sufficient axactness to permit the design of nearly all classes of stucture with the assurance --employing good materials and first class superintendence--of permanent strength and durability.

The concrete itself plays as an important a part as does the steel, and the variation in the strength and elasticity of this material under different conditions has sometimes been overlooked in the theoretical study of the the combination of concrete and steel. This has led to apparent discrepancies in tests made in different localities, and has retarded the formulation of exact principles and laws of reinforced concrete. The quality of the reinforced concrete depends almost entirely on the materials of which it is composed--cement, steel, stone, sand, and water. It depends to some extent on the surroundings conditions--temperature and moisture. The materials and the conditions will be discussed in the next few pages.

Cement.

Historical Sketch:- The cement industry dates from 1756, when John Smeaton, an English engineer, was trying to build a lighthouse on some gneiss rocks, just off the coast of Cornwall. It was simply necessity that made him look for a mortar that was better than lime mortar. Smeaton in 1756 experimented some with different kinds of limestones and at last found a mortar that would set under water. The lime that was formed by burning the limestone was really what we would call hydraulic lime. It is of this material that the Eddystone lighthouse is built.

Smeaton only used the layers of stone that would slake with water when it had been burned, he never thought about grinding the stone before he used it. In 1596 Joseph Parker took out a patent for "Roman Cement", this cement was made by burning argillo calcareous rock and then grinding the resulting product to a powder. This cement we would now call Rosendale cement. In 1810 Edgar Dolls obtained a patent for the manufacture of an artificial Roman Cement by mixing carbonate of lime and clay in the proper proportions and then burning the mixture. In 1813 Vicat began the manufacture of artificial hydraulic cement in France.

Joseph Aspdin, a bricklayer, gets the credit for inventing Portland Cement, he proposed to mix the dust of the roads with limestone itself combined with clay, and then burn and grind the mixture. He did not likely get what we would call a Portland cement but simply a Roman cement , because he could not carry the burning to the point of incipient vitrifaction, which is a very important point in the manufacture of portland cement.

Aspdin erected a factory and supplied the cement for the Thames Tunnel in 1828. Portland cement for a while had to stay in the background, until John Grant in 1859 decided to use it in the construction of the London drainage Canal. He published a paper and in this paper he gave his reasons for using Portland cement, and this paper he read before the Society of Civil Engineers; since that time it has been coming to the front slowly.

In 1852 the German Portland cement came to the front and it had been the standard up to the last few years, but now the American cement is regarded as the best. The Germans were the first to apply any science to the manufacture of Portland cement, and it was the Germans that first recognized the importance of fine grinding. It is the history, statistics, and prospects of American cement industry that we are most interested in.

The discovery of natural-cement rock, like most other things was simply an accident. When the construction of the Erie Canal was started lime mortar was going to be used; but in the middle of the Canal there was a limestone that would not slake after it had been burned, the quarry from which the stone came was in Madison county.

Canvass White, assistant engineer, who had been to England and examined the cements and mortars that were on public works was sent to examine the stone and see what was the trouble. On account of his previous experience he decided that the obstinate lime was really a high grade of natural cement. This cement was extensively used in the Canal during the years 1818-1819.

We have a contemporary professional estimate of the value of this material, Wright, chief engineer, in a letter dated 1820, summarizes the facts regarding White's cement, stating that it "is found to be a superior water cement, and is used very successfully in the stonework of the Erie Canal, and believed to be equal to any of the kind found in any other country. It is pulverized(as it does not slake) and then used by mixing two parts lime and one part sand. It hardens best under water, and it is believed its properties are partially lost if permitted to dry suddenly, or if not used soon after mixing."

This cement cost about 20 cents per bushel. Canvass White took out a patent for this cement, and for several years a controversy raged as to the tenability of the patent. At last this controversy was settled by the legislature of New York by buying the patent from White for $10,000.

The analysis of this cement was;-

SiO_2	11.766
Al_2O_3	2.733
F_2O_3	1.500
CaO	25.000
MgO	17.833
CO_2	39.333
H_2O	1.500
Total	99.665

Immediately after the Madison County cement had been used in the Erie Canal, a search for other deposits of cement rock was made. Cement rock was found in Onondaga and Cayuga Counties. The greatest of all the natural cement dispoaits--the Rosendale region of eastern New York, is the third among the districts in point of age, it soon became first as a producer, and has ever since maintained a high standard in both quality and quantity of its output.

Since almost any clayey limestone will give a natural cement on burning it can readily be seen that hardly a state will be without limestones sufficiently clayey to be available for natural cement. Since Portland cement has taken such an important position it would be very hard to place a new natural cement on the market in cpmpetition with the other well-established brands of natural cements.

There have been only a few new natural cements established that have started up within the last few years, and these have all been under some peculiar circumstances. The prospects for the natural cement industry do not look very engouraging, and it looks as if it will be only a matter of time until the Portland Cement drives the natural cement off the market. The production of natural cement has been at a standstill ever since 1890, but since 1890 the amount of Portland cement manufactured has increased 66.69 times, while the manufacture of natural cement has decreased 31%.

Engineers brings two charges against natural cement. The faults are: (1) lack of <u>strength</u> as compared with Portland cement, and (2) lack of <u>uniformity</u> in both composition and strength.

These charges are true in a way, but there are some brands of natural cement that are as good as Portland cement. In regard to the first point an advocate of naturalmcements could point out that there are three brands of natural c ements that are now regularly advertised and sold as Portland cements; that they have been tested for use in both state and Federal public works, including canal locks, dams, and breakwaters; and that neither State nor army engineers seem to have even suspected that they are not Portland cements.

The second difficulty could also be removed with out raising the cost of manufacture to a profitless point. One reason why the Natural cement companies do not have a regular product is, because they do not employ a chemist. There is only one natural cement plant that has a chemist, and that plant is:- Pembina Cement Co., of North Dakota.

There is no reason whay a poorly ground cement should be placed in the market, as economical fine-grinding machines are obtainable and they would soon repay their first cost. The Portland cement industry was started in this country by Saylor in 1875. He found that the cement they were making at Allentown, Pa., was very good; but that sometimes the harder burned parts would show a strength equal to that of any of the imported Portland cements, but in course of time that it would crumble. He overcame this difficulty by mixing a certain amount of Rock high in lime with his ordinary cement rock he could make a Portland cement, and after many trial lots were burned he turned out a very good Portland cement. Saylor had a great deal of trouble selling his cement after it was made, as he could not sell it much lower than the imported article but he at last worked himself up a good reputation. The most important engineering works upon whose construction Saylors' Portland cement was used are;-

Eads' jetties along the Mississippi River.

Drexel Building in Philiadelphia. Saylor's original plant turned out only 1700 barrels of Portland cement a year, since its inception however, it has grown steadily and now has a great capacity of considerably over this amount a day.

Portland cement plants soon sprang up in other states and now Portland cement is made at a great many places.

Classification;-

From an engineering standpoint, limes and cements may be classified as:-

Portland cement; Natural cement; Puzzolan cement; Hydraulic lime; and Common lime;

Typical analyses of each of these are presented in the table on following page.

Typical Analyses of Cements.

	Portland cement		Natural Cements.				
	Lehigh Valley (Mixed rock)	Western (marl & clay)	American Eastern Rosendale	American Western Louisville	English Roman	French Vassy	French Grapiers
Silica $Si\,O_2$	21.31	21.93	18.38	20.42	25.48	22.60	26.50
Alumina Al_2O_3	6.89	5.98	15.20 (Alumina and Iron Oxid together)	4.76	10.30	8.90	2.50
Iron Oxid Fe_2O_3	2.53	2.35		3.40	7.44	5.30	1.50
Calcium Oxid CaO	62.89	62.92	35.84	46.64	44.54	52.69	63.00
Magnesian Oxid $Mg\,O$	2.64	1.10	14.02	12.00	2.92	1.15	1.00
Sulphuric acid SO_3	1.34	1.54	0.93	2.57	2.61	3.25	0.50
Loss on Ignition	1.39	2.91	3.73	6.75	3.68	6.11	5.00
Other constituents	0.75		11.46	3.74	1.46		

	Puzzolan cement	Hydraulic lime (Le Tiel)	Common lime: Lime	Common lime: Magnesian Lime
Silica $Si\,O_2$	28.95	21.70	1.03	1.12
Alumina Al_2O_3	11.40	3.19	1.27 (Alumina and Iron Oxid together)	0.68
Iron Oxid Fe_2O_3	0.54	0.66		
Calcium Oxid CaO	50.29	60.70	97.02	58.51
Magnesian Oxid $Mg\,O$	2.96	0.85	0.68	39.69
Sulphuric Acid $S\,O_3$	1.37	0.60		
Loss on Ignition	3.39	12.20		
Other constituents	0.30	0.10		

Portland cement is defined by E. C. Echel of the U. S. Geological Survey as follows:-"By the term Portland cement is to be understood the material obtained by finely pulverizing clinker obtained by burning to semi-fusion an intimate artificial mixture of finely ground calcareous and argillaceous materials, this mixture consisting approximately of three parts of lime carbonate to one part of silica, alumina and iron oxid."

It is not nec¢essary to descri be the other cements because only Portland cement is used in first class work.

Proportion of ingredients:-

Le Chatilier stated that the lime and magnesia in Portland cement should not exceed a maximum, $\frac{CaO + MgO}{SiO_2 + Al_2O_3} \leq 3$ nor be less than a minimum, $\frac{CaO+MgO}{SiO_2 - Al_2O_3 - Fe_2O_3} \geq 3$ These formulas represent chemical equivalents and not weights. The best brands of Portland cement approach pretty closely to the above maximum formula, while one corresponding to the minimum formula would be so greatly overclayed as to be practically useless.

Specifiactions for Portland cement:

Adopted May, 1903, by the American Railway Engineering and Maintenance of Way Association.

Portland Cement.

1. Definition.-Portland Cement is a product of the mixture of clay and lime-carbonate in definite proportions, calcinated at a high temperature, and reduced to a fine powder.

2.- Packages.- Cement shall be packed in well-made wooden barrels lined with paper or in strong cotten or paper sacks. Each package shall be plainly marked with the brand and name of the manufacturer, and the net weights shall be exact and uniform.

3. Weight.-One barrel shall contain not less than 376 pounds of cement, and four sacks shall be equivalent in weight to one barrel.

4. Condition.-All cement shall be delivered in sound pack ages, undamaged by moisture or other causes.

5. Storage.- Cement must be stored until used in perfect-

ly dry places in such manner as will insure it from all damage.

6. Rejection.- All cement failing to meet the requirments of the specifications may be rejected, and all rejected cemen whether damaged or rejected for other causes, shallbe removed at once from the company's property.

7. Tests.- All cement subject to the following tests: (1) The selection of the samples for testing, the mumber of packages sampled, and the quantity taken from each package, must be lef to the descretion of the engineer, but each sample should be a fair average of the contents of the package from which it is taken. At least one barrel in every ten should be sampled.

(2) Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

(3) All samples shuuld be passed through a sieve having twenty meshes to the linear inch in order to break up lumps and remove foreign substances. For determining the characteristics of a carload of cement the individual samples may be mixed and the average tested; where time will permit, however, each sample will be tested separately.

8. Fineness.- Not less than 94% of the cement tested shall pass through a No. 100 standard sieve. The standard sieve s shall be circular, about 20 cm.(7.87inches) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan 5 cm. (1.97 ins.) deep and a cover. The wire cloth in the sieve to be woven not twilled from brass wire having a diameter of 0.0045 ins. This cloth to be mounted in the frame without distortion; the mesh should be regular

in spacing and for a No. 100 sieve shall contain not more than 100 nor less than 96 meshes per linear inch. The cement to be tested shall be throughly dried at a temperature of 100° C. (212° Far) before sieveing.

9. Set.- Initial set shall not occur in less than thirty minutes.

(2) Final set shall not occur in less than one hour nor more than ten hours.

(3) The time of setting shall be determined by means of the Vicat needle apparatus as recommended by the Committe e of the American Society of Civil Engineers upon uniform tests of cement in conjunction with the Committ ee of International Association for testing Materials.

(4) Using a paste composed of neat cement and water, of normal consistency, the initial set is said to have commenced when the needle ceases to pass a point 5mm (0.20 in.) above the upper surface of the glass plate in the Vicat apparatus, and is said to have terminated the moment the needle does not sink visibly into the mass.

(5) The paste is of normal consistency when the cylinder of the Vicat apparatus penetrates to a point in the mass 10 mm. (0.39 in) below the top of the ring.

(6) The amount of water required to make a paste of normal consistency varies with different cements, but will be found to be approximately 20 % of the weight of the cement. It should have a temperature of 70° Fahrenheit.

10. Soundness.- (1) A pat of neat cement 2 1/2 to 3 ins in diameter, 1/2 in. thick at center, tapering to a thin edge, and allowed to take its final set in moist air, must withstand indefi-

nite exposure in water or air at any ordinary temperature without checking distortion or softening.

(2) A pat of neat cement as above, placed in water, which shall be raised slowly to the boiling point and then maintained in that condition for three hours and allowed to cool gradually shallnot show any signs of checking, distortion or softening. The same result should follow exposire to steam not under pressure for three hours. This test may or may not be cause for rejection, at the option of the engineer in charge.

11. Tensile Strength.- (1) The briquette used in testing shall be formed in moulds of the size and form now in customary use and recommended by the American Society of Civil Engineers the stress to applied at a uniform rate of 600 pounds per minute until fractured,

(2) All briquettes of neat cement are to be made from paste of normal consistency in the folowing manner: The molds should be filled with the paste as soon as it is thoroughly mixed and tempered, the material preaased in firmly with the fingers and smoothed off with a trowel with out ramming; the material should be heaped up on the upper sufface of the mold, and in smoothing off the trowel should be drawn over the mold in such a manner as to exert a moderate pressure upon the excess material. The mold should then be turned over and the operation repeated upon the other side.

(3) Briquettes for twenty four hours tests shall be allowed to set twenty-four hours in moist air.

(4) Briquettes for seven and twenty-eight day tests shall be allowed to set one day in moist air and remainder of period in water.

(5) All briquettes are to remain in the water until they are

placed in the testing machine, except in the case of the twenty-four hour tests.

(6) Neat twenty-four-hour tests shall not show less than 125 pounds per square inch. Neat seven day tests shall not showw less than 400 pounds per square inch. Neat twenty-eight day tests shall not show less than 500 pounds per square inch, and should show at least 10% increase above the seven day test.

12. Sand Test.- Owing to insufficient data, the Committee is not prepared to specify a sand test.

13. Specific Gravity.- The specific gravity , determined upon dried cement which has passed through a No. 100 sieve, shall not be less than 3.10 nor more than 3.30. The specific gravity can be conveniently and accurately determined by the use of Le Chatilier's apparatus as recommended by the Committee on Uniform Tests of cements.

14. Chemical.- Chemical analyses should show not more than 5% of magnesia, nor more than 1.75% of sulphuric anhydrid.

15. Uniformity.-If in the tests of any given brand of cement any sudden, irregular or wide variation from its normal action is found, it should be witheld from use until more extended tests shall have demonstrated its reliability.

Steel.

Specifications for steel to be used in first class reinforced concrete:-

1. Process of manufacture. Steel shall be made by the open hearth process.

2. Chemical Properties. Steel shall conform to the following limits in chemical composition;

Phosphorous shall not exceed 0.06
Sulphur shall not exceed 0.06
Manganese shall not exceed 0.80 or be below 0.40.

3. Physical Properties. The steel shall conform to the folbowing physical qualities:

4. Tensile Tests. Tensile strength in pounds per square inch shall be not less than - - - - - - - - - - - - - - - - - - -105,000

Yield point in pounds per square inch shall be not less than52,500

Elongation per cent in eight inches shall be not less than 10

5. For material less than five-sixteenths inch (5/16") and more than three fourths inch (3/4")-in thickness the following modifications shall be made in the requirments for elongation:

(a) For each increase of one eighth(1/8") in thickness above three fourths inch(3/4") a deduction of one percent (1%) shall be made from the specified elongation.

(b) For material from 1/4 inch to, but not including 5/16 inch thick the elongation shall be 8%.

For material from 3/16 inch to, but not including 1/4 inch thick the elongation shall be 7%.

For material from 1/8 inch to, but not including, 3/16inch thick the elongation shall be 6%.

For material less than 1/8 inch thick the elongation shall be 5%.

6. Bending Test. Test specimens for bending shall be bent cold around a diameter equal to their thickness to the following angles with out fracture on the outside of the bent portion.

For specimens 1 inch thick 80°

For specimens 1/2 inch thick 110°

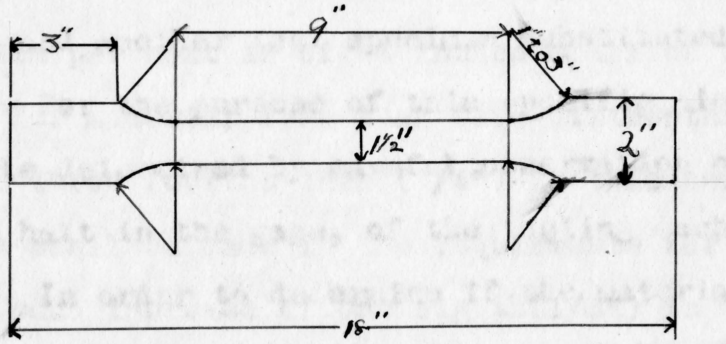
For specimens 3/16 inch thick 140°

For specimens 3/4 inch thick 90°

For specimens 1/4 inch thick 130°

For specimens 1/8 inch thick 160°

7. Test Pieces and Methods of testing.- Where practicable the standard test specimen of eight-inch(8") gaged length shall be used to determine the physical properties specified in paragraph numbers 4 and 5. The standard shape for the test specimen for sheared plates shall be as shown by the following sketch;



For material from which it is impracticable to obtain test specimens like those for sheared plates, the test specimen may be planed or turned parallel throughout its entire length, and in cases where possible two opposite sides of the test specimen shall be rolled surfaces. Small rolled bars of uniform section shall be tested full size as rolled.

8. All test specimens shall be cut from the finished materials as it comes from the rolls, unless such material is to be annealed, in which case the test specimens will be taken after the annealing process. In case several shapes are rolled from one heat, two test specimens will be taken from two different shapes representing their class, for tension, and two for bending. When only one shape is rolled from a heat, two specimens for tension and two for bending will be taken from each ten tons or fraction thereof.

9. Where practicable the bending test specimen shqll be one and one half inches(1 1/2") wide and for material three quarters inch (3/4") and less in thickness, this specimen shall have the natural rolled surface on two opposite sides. For material more

than three quarters inch(3/4") thick, the bending test specimen may be cut to one-half inch(1/2") thick.

10. The bending test may be made by pressure or by blows.

11. In case a test specimen developes flaws or in case it breaks outside of the middle third of its gaged length, it may be discarded and another test specimen substituted therefor.

12. For the purpose of this specification, the yield point shall be determined by careful observation of the drop of the beam, or the halt in the gage, of the testing machine.

13. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of clean drillings taken from a small test ingot.

14. Variation in Weight. A variation in cross section or weight of more than 2 1/2 per cent from that specified will be sufficient cause for rejection.

15. Finish. Finished material must be free from injurious seams, flaws, cracks, and have a workmanlike finish.

16. Annealing. All bars which, owing to their shape or size, are liable to be under strain after cooling, must be reheated to a temperature not less than 1250° Fahrenheit nor more than 1375°F and this heating and subsequent cooling must be done in an approved manner.

Stone.

The size of the largest particle of stone and gravel which may be used in a concrete is often limited by parctical considerations of mixing and placing. For most work it is specified that the stone shall pass through a 2 inch or, more often, through a 2 1/2 inch ring. For ordinary mass concrete of wet consis tency the limit may be placed as high as 3 inches. In some cases however, the stone must be small enough to pack readily around reinforcing metal, while in walls whose surface is to be picked or washed a better appearance will result with stones under one inch in diameter, although the strength of the concrete appears generally to increase with the size of the largest particles of stone in the mixture.

John kyle nearly doubled the strength of 1:2:6 concrete made with 1 1/2 inch stone by substituting 4 parts of 3 1/2 inch stone for a like portion of the 1 1/2 inch.

The ultimate strength of concrete is often limited by the texture or strength of the coarse aggregate. This is evidently the case with cinder concrete .Experiments by G. W. Rafter gave the strength of concrete made with hard broken sandstone and various proportiens of mortar from 1.5 to 2.4 times the strength of similar mixtures of shale and mortar, and this discovery led to the rejection of the latter as a material for concrete. If concrete is mixed is such proportions or by such methods that the ultimate strength is reached before the stones shear, the strength of the particles of stone is a much smaller factor in the result.

Sand.

The coarser the sand the stronger the mortar.

Fig. 1. Absolute volumes of sand per unit volume of sand not shaken.

Fig. 2. Absolute volumes of sand per unit volume of sand shaken to refusal.

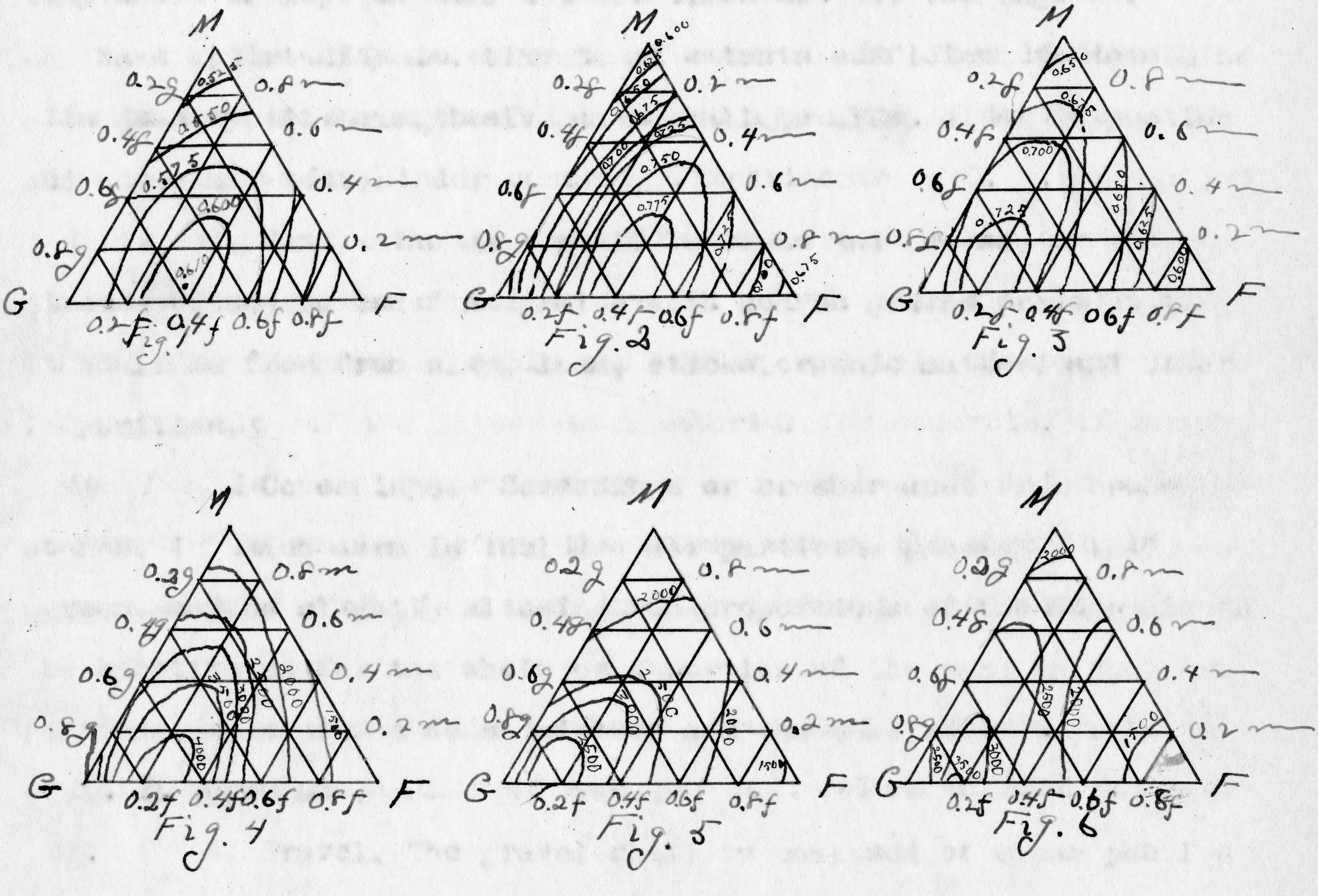
Fig. 3. Absolute volumes of solid materials (c s) per unit volume of fresh mortar in proportions 1:3 (by weight).

Fig. 4. Compressive strength in pounds per square inch of 1:3(by weight) Mortars with different mixtures of sand, after 9 months of

air and three months in sea water.

Fig. 5. Compressive strength in pounds per square of in mortars with various mixtures of sand, after one year in fresh water. Proportions 100 lb. Portland cement to 3.2 cu.ft. mixed sand.

Fig. 6. Compressive strength in pounds per square inch of mortars with various mixtures of sand, after one year in air. Proportions 100 lb. Portland cement to 3.2 cu.ft. mixed sand.



Water.

The water should be free from acids or alkalies. It should also be free from salt.

Specifications for concrete;-

1. Cement.- The cement shall be first-class Portland cement of reputable brand which shall conform in all respects to the cement specifications herewith annexed. The cement shall be stored in a building which will protect it from the weather. The floor upon which the cement is placed shall be at least six inches above the ground. It shall be stored so as to permit easy access for inspection and indentification of each shipment. A sufficient quantity shall be kept on hand a t all times so that the Engineer may have opportunity and time to make tests sufficient to determine its quality. At least twelve days shall be allowed for inspection and necessary tests.

2. Sand.- The samd shall be clean and coarse, or a mixture of coarse and fine grains with coarse grains predominating. It shall be free from clay, loam, sticks,organic matter, and other im purities.

3. Screenings.- Screenings or crusher dust from broken stones,-in which term is included all particles passing a 1/4" screen,-may,by slightly altering the proportions of the ingredients be substituted for the whole or a portion of the sand in such proportions as to give a dense mixture and the same relative volumes of total aggregate.

4. Gravel.-The gravel shall be composed of clean pebbles free from sticks and other foreign matter and containing no clay or other materials adhering to the pebbles in such quantity that it cannot be removed by lightly brushing with the hand or dipping in water. It shall be screened to remove the sand, which shall afterwards be remeixed with it in the required proportions.

5. Broken Stone.- The broken and crushed stone s hall

consist of hard and durable rock, such as trap, limestone, granite or conglomerate. The dust shall be removed by a 1/4 inch screen, to be afterwards remixed, if desired, with and used as a part of the sand, except that of the product of the crusher is delivered to the mixer so regularly that the amount of dust, as determined by frequently screening samples, is uniform, the screening may be omitted and the average pergentage of dust allowed for in measuring the sand.

6. Water. The water shallbe free from allacids or strong alkalies.

9. Hand Mixing. If the concrete is mixed by hand , the cement and aggregate shall be mixed and the water added on a tight platform large enough to provide space for the partially simultaneous mixing of two batches not more than one cubic yard each. The sand and cement shall be mixed dry, being spread in thin layers , until of a uniform color. This mixture may be spread upon the layer of stone or the stone shoveled upon it before adding the water, or it may be made into a lortar before spreading with the stn stone. In the former method the materials shall be turned at least three times,--in addition to the mixing of the sand and cement already mentioned, the waterbeing added on the first turning,- and in addition to the shoveling from the platform to the place or to the vehicle for transportation. In the latter method, that is, if the sand and cement are first made into a mortar, the mass of mortar and stone shall be turned twice. Whatever method is employed, the number of turnings shall be sufficient to produce a resulting loose concrete of uniform color and appearance, with the stones thoroughly incoporated into the mortar and the consistency uniform throughout.

10. Machine Mixing.- If the concrete is mixed in a ma-

chine mixer a machine shall be selected into which materials, including water, can be precisely and regularly proportioned, and w which will produce a concrete of uniform consistency and color with the stones and water thoroughly mixed and incorporated with the mortar.

11. Consistency.- (a) A medium or quaking mixture of a tenacious, jelly-like consistency, which quakes on ramming, shall be used for ordinary mass concrete work, such as foundations, he heavy walls, large arches, piers, and abutments.

(b) Very wet or mushy concrete, so soft that it must be handled quickly or it will rum off the shovel, shall be used for rubble concrete, and for reinforced concrete, such as thin building walls, columns, doors, conduits, and takns.

(c) Dry concrete, of the consistency of damp earth, may be employed in dry locations for mass foundations, which must withstand severe compressive strain within one month after p lacing, provided it is spread in 6-inch layers and rammed until water flushes to the surface. Dry mixed concrete shall never be em ployed with steel reinforcement.

12. Placing. Concrete shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients, or, incases where such separation inadvertently occurs, the concrete shall be remixed before placing. Each layer in which concrete is placed shall be of such thickness that it can be incorporated with the one previously laid. Concrete shall be used so soon after mixing that it can be rammed or puddled into place as a plastic homogenous mass. Any which has set before placing shal be rejected. When placing fresh concrete upon an old concrete surface, the latter shall be cleaned of all dirt and scum or laitance,

and thoroughly wet. Noticeable voids or pockets discovered after the forms are remobed shall be immediately filled with mortar mixed in the same proportions as the mortar in the concrete. (For horizontal joints in thin walls or in walls to sustain water pressure or in other important locations, a joint of mortar in proportions designated by the Engineer may be required, and no allowance over and above the normal unit price shall be made to the contractor for the material or labor used.)

13a Ordinary Surface.- Surfaces shall have no special treatment further than care in placing the concrete to avoid noticeable voids or stone pockets. Forms shall be wet(except in freezing weather) before placing the concrete against them.

13b Exposed faces. Faces exposed to view shall be made smooth by thrusting a spade or chisel through the concrete slose to the form to force back the large stones and prevent stone "pockets", The forms shall be greased with crude oil before placing the concrete against them. On removal of the forms, surfaces shall be----------------

13c. Mortar Surface. Moldings, cornices, and other ornaments requiring mortar surfaces, shall be formed by spreading plastic mortar upon the interior of finely constructed molds, just as concrete is being laid. No exterior plastering shall be permitted.

14, Freezing Weather. No concrete except that laid in large masses, or heavy walls having faces whose appearance is of no importance, shall be exposed to frost until hard and dry. Materials employed in mass concrete in freezing weather shall contain no frost. Surface shall be protected from frost. Portions of surface concrete which shall have been frozen shall be removed before laying frsh concrete upon them.

15. Forms. The lumber for the forms and the design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For exposed surfaces the surface next to the concrete shall be dressed. Forms shall be sufficiently tight to prevent loss of cement or mortar. They shall be thoroug ly braced or tied together so that the pressure of the concrete, or the movement of men, machinery or materials, shall not throw them out of place. Forms shall be left in place until, in the judgment of the engineer, the concrete has attained sufficient strength to resist accidental thrusts and permanent strains which may come upon it. Forms shall be thoroughly cleaned before being used again.

16. General Requirments. Imperfect work or materials, or work or materials which may become damaged from any cause before its acceptance, shall be properly replaced to the satisfaction of the Engineer.

Foremen employed by the contractor shall be skilled in concrete mixing, and they shallreceive and obey orders from the Engineer.

No claims for extra work shall be allowed unless made in writing previous to its performance and signed by both parties or their authorized representatives.

In case of disagreement as to the meaning of the terms of the contracts or as to the manner of its execution, one arbiter shall be appointed by each party within one week after notification in writing by eitherparty, and in case these cannot agree, a third arbitrator shall be selected by these two, and the decision of the majority of the arbitrators shall be final and binding on both parties.

Proportioning cement.

From the following table it can be seen that the probable proportions for an arch should be 1:2 1/2:5.

Structure	Nominal Proportions	Portland cement bbl. 380lb	Loose sand cu.ft.	Loose stone cu.ft.	Authority
New Brooklyn Bridge Piers		1	8.5	19.5	Asst. Engineer
Boston El. Ry. Column Foundations	1:2 1/2:5	1	9.5	19.1	G. A. Kimball
N.Y.C.&H.R.R.R.					
Footings	1:4:7 1/2:	1	13.9	26.2	W. J. Wilgus
Abutments	1:3:6	1	12.2	23.7	
Facing old masonry	1:2:4	1	7.0	14.0	
Coping & Bridge seats	1:1:2	1	3.5	7.1	
C.M.&S.P.Ry.					
Piers and abutments	1:2:5	1	7.8	21.4	W. A. Rogers
Culverts&Foundations	1:3:7 1/2	1	10.5	28.5	
Or. R. R. & Nav. Co.					
Abutments,piers&culv.	1:3:5	1	11.0	18.3	W. H. Kennedy
Foundations&light bldg	1:3 1/2:6	1	12.8	22.0	
	1:4:7	1	14.7	25.7	
C.&E.I.R.R.	1:2:5	1	9.3	26.7	A. S. Markly
Northern Pacific R.R.					
Foundations	1:3:5	1	11.2	20.2	E. H. McHenry
Abutments & Piers	1:3:5	1	11.2	20.2	
C.,B.& Q.R.R.	1:3:6	1	12.5	22.5	Fred Eilers
Mexican Central Ry.	1:3:6	1	13.5	27.0	Lewis Kingman
N. Y. Subway					
Roofs and sidewalks not over 18" thick	1:2:4	1	7.2	14.4	N.Y.R.T.Com.
Sidewalls or tunnel arches	1:2 1/2:5	1	9.0	18.0	
Wet Foundations not over 24" thick	1:2:4	1	7.2	14.4	
Wet Foundations exceeding 24" thick	1:2 1/2:5	1	9.0	18.0	
Boston Subway	1:2 1/2:4	1	8.3	13.2	H. A. Carson
Harvard University Stadium	1:3:6				

Structure	Nominal Proportions	Portland cement bbl. 380lb	Loose sand cu.ft.	Loose stone cu.ft.	Authority
Maine fortifications					
Leveling for foundations	1:5:10	1	18.2	36.5	S. W. Roessler
Walls & masses not exposed to fire	1:4:8	1	14.6	29.2	
Walls & masses exposed to fire	1:3:6	1	11.o	22.0	
Masses for greater imperviousness	1:3:5	1	11.0	18.3	
Little Falls					
Mass Concrete	1:3:7	1	11.4	26.6	W. B. Fuller
Tanks, Buildings etc.	1:2:4	1	7.6	15.2	
Duluth Ship Canl		1	11.8	23.8	C. Coleman
Boonton, N. J. Dam	1:2 3/4:6 1/4	1	10.5	23.8	W. B. Fuller
Genesee Dam	33% mortar	1	11.4	36.8	Geo. B. Rafter
Buffalo Breakwater		1	5.o	30.00	Emile Low
Pennsylvania Tunnel	1:2 1/2:5	1	9.6	19.3	Specifications
East Boston Tunnel	1:2 1/2:4	1	7.7	12.4	H. A. Carson.

The following article from the Engineering Digest by De Vesian gives the up-todate conception of the"building material of the future".

Reinforced Concrete: its applications to Engineering constructions.

Definition of reinforced concrete; Reinforced concrete is a combination of concrete and steel in which the steel takes the tension stresses and the concrete the compression. It may rightly be termed a new material, conforming to laws of its own.

For instance, if a beam of concrete alone will extend 1/10 inch, a similar beam reinforced properly with steek will extend 1 in. or ten times as much, without showing signs of cracking and ditress. The more the steel can be subdivided throughout the tension area of the concrete the better; or, in other words, small round bars are preferable to rolled sections of considerable area. By the suitable employment of such bars the designer is enabled to secure monolithic construction in which all parts are connected absolutely without joints, and the reinforcement extends throughout the concrete, imparting the necessary resistance to tensile and other stresses to individual members, and by passing from one member to another the bars perform a most valuable duty by helping to distribute the forces over diffrenet parts of the structure.

Durability of Reinforced Concrete.

The durability of concrete need hardly be entered upon after the experience we have had fr om olden times. Many old works give us instances of the preserving effects that good concrete has on iron.

Sewer pipes with steel reinforcements have recently been replaced on the Continent after 40 years of use, and the steel was found to be in good condition. As an instance, coming under the author's personal notice of the preservation of steel when imbeded in good concrete, the case of some piles at Southampton may be usefully mentioned. As these piles were originally made too long, the tops were sawed off and thrown upon the seashore, where they have remained for more than eight years, being covered and uncovered four times a day by the double tides prevailing in Southampton water. Some of these stumps have been examined by various eminent engineers, as well as by the author, and in every case the steel was found to be perfect 1/4 inch only below the surface, while the bars which had been protruding where they were cut off were, of course, completely rotted away. Another very common exam-le of the preservation of steel and iron by Portland cement is furnished by old ships, whose bottoms have been coated inside with cement when built. In such cases the plates have always been found in a state of perfect preservation under this coating when replaced in after years on account of corrosion from without.

Concrete Mixing.

The proper mixing of the concrete is of the greatest importance, and as good concrete may be improved 100% in strength by thorough mixing, it is preferable to employ a mixing machine than to attempt to do this work by hand. The machine is certain to do it all alike, whereas no workman, however much locked after, can perform the operation so effectively. The concrete mixture should be just plastic, and must always be well rammed.

Fire Resistance.

Brick and coke concrete should not be used as aggreagtes in reinforced concrete. These materials make a concrete which is far too weak to withstand compressive and tensile stresses, and they make a porous concrete, which exposes the metal to risk of corrosion.

Numerous experimental tests and actual conflagrations have demonstrated the security of reinforced concrete against the effects of fire.
of

A fire and water test was made on July 9, 1904, on a reinforced concrete chamber 5ft. 8ins.long by 6ft. wide by 4ft. 4ins. high, two of the walls being 4 ins. thick, the other two 6ins. thick, and covered by a flat roof 4 ins. thick. From the middle of the slab projected a reinforced concrete beam 4 ins. wide by 6 ins. deep, unsupported at either end. The top of the chamber was loaded with bricks and stones to 336 lbs. per sq. ft. over the whole area. Next to one of the 4 ins. walls an enclosure with 4 1/2 brick walls was built with a window and a doorway, and covered with a plain concrete roof. The object of this enclosure was to ascertain what increase of temperature would take place in a room divided by a thin reinforced concrete wall from another room in which a violent fire was raging.

At 11 a. m. on the day of the test a fire of wood and tar barrels was lighted under the chamber, and kept buring for two and one half hours, smoke and gases of combustion escaping through two square openings left near the roof. After this fire had been burning for some time the temperature reached 1,500° Fahr., but in the adjoining room the temperature rose only 8° Fahr.

After two and a half hours jets of water were played upon the outside and on the inside of the chamber. The concrete was then cut into with cold chisels and found to be as hard as it was before the test. The stability of the structure was not impaired in the least.

In the great Baltimore fire in America a reinforced concrete building with brick outer walls stood alone after the conflagration had ceased, and tests made on the floors gave even better results than when handed over originally to the client. The brick walls had fallen to a great extent, but the reinforced concrete was intact and uninjured.

Several similar instances giving equally good results have occured on the continent.

Method of Calculation.

Up to a certain point the calculations necessary for the design of reinforced concrete are the same as those employed in the case of all other structural materials. When the forces have been determined for all the members of any particular structure, the cross-sectional area of the concrete may be made sufficient to resist the compression stresses with or without the help of steel as a reinforcement, and a proper proportion added of steel in tension areas. The shearing forces are provided for by placing auxiliary reinforcement in such a manner as to relieve the concrete from forces tending to rupture it in vertical, horizontal or diagonal directions, and to form a link between the compression and tension portions of the construction.

It is very easy to settle the cross-sectional area of concrete for resisting compression in any member, but when we come to add steel, whether for resisting compression or tension, difficulties and complications at once arise from the fact that the modulis of elasticity of concrete is variable. The modulus of elasticity is fairly constant for the type of steel used in reinforced concrete, but the the modulus of elasticity of the concrete may vary from, say 500,000lbs. per sq.in. to 4,000,000 lbs. per sq.in., according to the quality of the cement, sand and aggregate, the proportions of the mixture, the manner in which it is treated by the workmen, the amount of water used, and the age of the material.

The trouble is further increased by the fact which has been proved by the tests of many experimenters such as Prof. Bach and M. Considere on the Continent and Profs. Hatt and Talbot in America, that that modulus of elasticity of concrete varies with the stress to which it is subjected, so altogether we have no less than six different causes which may affect the modulus of elasticity of concrete. To use words of an American author, Mr. A. W. Buel , concerning the numerous theories in existence," while some of these theories are deduced from a few experiements, others are entirely theoretical, and none are fully demonstrated to be absolutely true."

The allowable stresses taken by the author and his colleahues are as follows:

Steel in compression, 14,000 lbs. per sq.in. 17,000 lbs. per sq.in.

Concrete in tension, nil.

Concrete in compression, 340 lbs. to 400 lbs. per sq.in.

Concrete in shear, nil.

Adhesion of concrete to steel, nil.

These stresses are far more conservative than those recommended by most authorities, but bearing in mind the various causes which may operate in actual construction to reduce the theoretical resistance of reinforced concrete, the author does not consider any increase would be desirable.

Relative economy of Reinforced concrete.

A few figures will show that the combination of steel with concrete must be economical if properly done. The cost of a cubic foot of steel weighting, say, 490 lbs., at $42.50 per ton, is approximately $9.25, and the cost of a cubic foot of concrete at, say, $5 per cubic yard, is $0.175. So volume for volume steel costs fifty times as much as concrete. The safe load of steel in compression may be , say, 15,000 lbs. per sq.in., and the safe load on concrete in compression say, 500 lbs. per sq.in. This means that for equal area steel will carry thirty times as much as concrete. The safe load on steel in tension being taken at 15, 000 lbs. per sq.in., and the safe tension on concrete being taken at, say, 50 lbs. per sq.in., the result is that for equal areas steel will carry 300 times as much as concrete.

Thus we find that concrete in compression costs only30/50 or 315 as much as steel, while concrete in tension would cost 300/50, or six times as much as steel.

In reinforced concrete beams something must be put down for the concrete in tension whose resistance is not considered, but a great deal of expensive labor is required for preparing steelwork for use, and this costs more than the cheap labor which suffices for dealing with the concrete and plain steel bars of which reinforced concrete in composed.

Itwill be understood that the figures givem are intended merely to illustrate in a rather rough and ready way the economic advantage of reinforced concrete over structural steel. The actual saving to be effected in any givem case, depends very much upon the market prices of materials and the locality in which the work is to be executed. An example is the case of a highway erected last year over the river Suir at Waterford, at a cost pf $40,000, compared with over $100,000, the estimated cost of a steel structure, as stated by the engineer. This is perhaps an exceptionally favorable case, but it shows the possibilities of the new system of construction.

There is very little difference between the sost of timber and reinforced concrete structures such as wharves, quays and jetties, but the superior durability and strength of reinforced concrete, and the fact that it is immune fromnthe attacks of destructive seaworms, renders that matterial far cheaper in the long run, especially when used for marine work. In London and other cities, where the saving in annual unkeep, charges for painting, etc., are most important factors in favor of the use of reinforced concrete in such works as bridges, piers, etc., local regulations demand that walls made of it shall be as thick as ordinary brickwwalls; consequently there is no chance of effecting a saving by its use.

Fortunately more reasonable counsels prevail in many parts of the country, and railway companies, who are exempt from ordinary building laws, have able to employ reinforced concrete with much advantage and economy in the erection of stations, warehouses and other buildings. Governmentbdepartments being also free from such restrictions, have been able to make a considerable saving by the adoption of reinforced concrete, as testified by the answers to recent questions in Parliament, when it was stated that the cost of reinforced concrete structures recently erected was approximately 20% cheaper than brick construction,

Systems of Reinforced Concrete.

There are in Great Britain several systems of reinforced concrete, the best known being the Coignet armored concrete, the Conside're spiralled and armored concrete, the expanded metal system of steel and concrete, the indented steel bar system of reinforced concrete, the trussed concrete steel and the Wells.

The expanded metal system imported some years ago from the United States has not been develpped as a complete method ofconcrete construction, although the special form of metalenetwork made by the company has been largely used for reinforcing concrete floors, partitions, walls, tanks, conduits, and various structural details. The five systems in question and the Hennebique system all possess distinctive features, but are alike in the respect that steel bars of different forms are used with the object of reinforcing concrete against tensile, compressive and shearing forces.

Bridges.

Reinforced concrete girder bridges need not be discussed at length, because their essential parts are main and secondary beams, slabs, piers and walls designed on the principles already described. Still, although, the design of the separate members may appear to be a very simple thing, it is not by any means an easy task to satisfactorily design a c omplete bridge.

Reinforced concrete arch bridges represent a special class of design, but when the lines of resultant pressures and the stresses in the arch ribs have been determined in the usual way, the bars and stirrups reinforcing the concrete against tension, compression and shear are arranged in the same general way that has already been described.

Piles.

One of the most interesting uses of reinforced concrete is for the construction of reinforced concrete piles. The fact that a baulk of concrete 60 ft. to 70 ft. long with some steel rods in it can be carried about like a piece of wood and driven through the hardest strata is wonderful.

A 14 14 in. reinforced concrete pile will in practice comfortably carry 65 to 75 tons with a large factor of safty. Theuse of these piles, therefore , becomes highly economical, as their number is necessarily far fewer than if timber were used, although foot for foot pitch pine may be the cheaper material, unless the length required is very great. They are quite unaffected by sea water, are proof against theattack of sea worms, and can be driven through harder ground than any timber piles. That concrete is capable of standing great vibrations is proved by reinforced concrete piles, which have to stand about as severe a test in this direction as it is possible to conceive.

The author has known of piles receiving upwards of 10,000 blows from a 2-ton monkey with damage. The weight of the monkey used with reinforced concrete piles should not be less than two tons and should increase with the weight of the pile. As reinforced concrete piles are much heavier than timber, the blows of a light monkey would be ineffective for driving, and would tend to smash the head.

Piles of this kind have been extensively used in the foundations of bridges, wharves, quays, piers, jetties, reservoirs and buildings of all kinds.

Practical Construction.

Every reinforced concrete construction derives its value not only from the proper distribution and quality of its component parts, but also from the care which is exercised during its execution.

A good deal depends upon the design, construction and erection of the molds, centering and shuttering. Contractors who take up reinforced concrete work for the first must certainly be prepared to face a considerable outlay in timber for molds and accessories, but by careful attention to details they will be able to arrange matters so that the timeber may be used over and over again.

All molds, centering and shuttering must be of well seasoned timber, not liable to shrink or twist when exposed to the weather; They must have close joints so as to prevent leaking, and be of sufficient strength for supporting the weight of materials and the impact of depositing and ramming the concrete without appreciable deflection.

Column molds should be made with one side open so that concrete can be deposited and rammed in layers not more than 2 ins. thick and the open side gradually closed up as the layers are finished by nailing board across. In molding columns the vertical bars are first secured in position with the steel links threaded over them, tied up at a suitable height to leave a clear space for ramming. As the successive layers are deposited the links are lowered set by set, and so on until the columns are finished. This insures all the concrete being of uniform consistency, whereas in columns with vertical or other lateral reinforcement which has to be fixed in place before the concrete is deposited, the molds have to be formed with all sides fixed, and the concrete poured in from the top and poked into place as well as possible with long rods. Besides the risk that pieces of wood, shavings and other foreign materials may be accidentally dropped into the molds without being noticed, there is always the possibility of voids, and the consistency of the concrete varies, the tendency being for stones to settle to the bottom and sand and cement to come to the top. The The result may be that the actual strength of columns so molded may be far less than the strength contemplated by the designer. When closed molds of this kind are used an inspection hole at the foot should be provided so that the foreman may see that no foreign material is present before concretion is started.

Beam models should be made so that the sides can be taken off before the bottoms are removed, so permitting air to get at the concrete and assist the hardening process.

Molds and centering of all kinds must be adequately braced and supported to guard against movement in any directions.

Extreme caution must be observed in removing the molds and centering. The supports must not be removed until it has been decided by some qualified and duly authorized person that the concrete has sufficiently set. Neglect of these precautions has been the cause of several serious mishaps on the Continent and in America, and the author fe ars that similar accidents will take place in this country if too much confidence is reposed in contractors lacking experience in reinforced concrete work, especially if not responsible to the designer.

Another important thing is that no load of any kind should be placed on green beams, deckings, or floors, but in exceptional cases where imperative to do so the construction must be strongly propped up so as to throw the whole weight on the temporary supports, so that no fraction of it shall be borne by the reinforced concrete.

All bars used for reinforcement must be free from oil and paint, but if rusty the adhesion of the concrete will be better than if the bars were perfectly clean and bright. The reason is that the oxid of iron combines chemically with the concrete, forming a protective covering of ferrite of calcium.

No welds must be made in any of the bars, and most bending should be done cold by the gradual application of force.

All the bars and stirrups must be laid and secured in the correct positions shown by the working drawings. Particular attention must be given to see that the stirrups are in actual contact with the main bars.

When the reinforcement has been laid out and fixed it should be carefully inspected by a responsible person to make sure that the intentions of the designer have been complied with in every respect. Too much care cannot be brought to bear on this point.

Concrete must be deposited as soon as possible after mixing. It is desirable that all concrete made shall be used up before suspending work, even for a short time. The balance of any batch not so used should be thrown away. After it has once commenced to set, the concrete must be protected from shocks and vibration, which interfere with proper setting. These are points to which very particular attention should be paid by someone in authority.

When the construction of beams, deckings or floors has to be interrupted before completion, the edges must be thoroughly roughened with a cutting tool and thoroughly cleansed from all foreign matter before work is resumed on it. Cement grout must then be poured on the surface of the edge before the concreting operations are resumed, and special care should be taken to ram fresh concrete as hard as possible on tb the old work. The proper place for stopping concreting should always be decided by the reident engineer or some competent person.

Fresh concrete work should be freely watered for several days and if this cannot be done it should be kept in a moist state. This precaution is imperative when the work is exposed to heat.

The foregoing notes embody some of the chief points requiring careful and constant attention on the part of resident engineers, contractors and foremen, and they are sufficient to show that the rough-and-ready- way in which mass concrete is treated for ordinary structural work cannot be followed with impunity in reinforced construction.

Respectfully Submitted

John W. Bierer