CHAPTER XV

DEPOSITING CONCRETE

The actual handling and placing of the concrete after it has been mixed, and the construction of forms for ordinary mass work, are treated in this chapter. Forms for building construction and conduit construction are illustrated in subsequent chapters on these subjects.

Since the introduction of concrete into engineering construction, the opinions of engineers regarding the best methods of placing it have completely changed. For water-tight work or for the strongest construction it is now recognized that the concrete should resemble as nearly as possible one single solid mass of stone with no joints, and it is the usual practice, although not universal, to specify a "quaking," jelly-like consistency, while many authorities go still further and require water enough to be "mushy" or sloppy. Formerly, for all classes of work, concrete was mixed but slightly more moist than damp earth and laid in alternate blocks 6 to 12 inches thick. Then, after hardening, the forms were removed, and the spaces between filled in.

HANDLING AND TRANSPORTING CONCRETE

In handling and transporting concrete, it is essential to prevent the separation of the stones from the mortar. In hand-mixed concrete, especially for thin walls requiring the stuff to be carried in buckets, there is a tendency to allow the stones to separate on the mixing platform so that a lot of them fall together when cleaning up the last shovelfuls.

With the modern slow-setting cement, and in view of the accepted belief that some time may elapse after mixing without injury to the work, there is less difficulty than formerly in handling the concrete, and it can be readily transported to a considerable distance. Moreover, a wet mixture is much easier to handle, because the stones do not so readily separate from the mass.

The usual vehicle for transporting hand-mixed concrete is a wheelbarrow. For machine-mixed concrete, derricks are suitable if the mass is concentrated near the mixer, otherwise cars running on a track, or in some cases wagons, afford a means of conveyance. A combination of car and derrick work is readily effected by using flat cars with derrick buckets or trays upon them. Galvanized iron buckets are sometimes useful when

building by hand a high, thin wall. A bucket elevator is a poor contrivance for elevating concrete. The mortar sticks to the buckets and the ingredients of the concrete separate as it is thrown from them.

Volume and Weight of Loose Concrete. The volume and weight of loose concrete is of importance in designing the implements or vehicles for transporting it and in estimating the quantities which can be handled under different conditions. The weight of well-proportioned concrete after setting, as stated on page 3, generally ranges from 143 to 155 lb. per cubic foot. When green, it will weigh, after ramming, slightly more than this, say from 150 to 160 lb. The weight per cubic foot loose, that is, in the vehicle which transports it from the mixer to place, depends largely upon the consistency. If mixed very wet, it will settle down to very nearly the volume it has after it is placed, perhaps within 5% of it; but if of dry consistency, the volume of the rammed mass is apt to be as much as 25% less than the loose. A fair average weight of loose concrete may be estimated, then, at about 140 lb. per cubic foot, or 1.9 tons per cubic yard, when mixed wet, and 120 lb. per cubic foot, or 1.6 tons per cubic yard, when mixed dry. The weights and volumes vary, of course, with the proportions used in the mixture and the specific gravity of the stone in the aggregate, but for rough estimates these figures are sufficiently accurate. The volumes of loose mixed concrete required for a cubic yard of rammed concrete, based on the above percentages, are 28 cu. ft. of a very wet mixture and 36 cu. ft. of a dry mixture.

The volume of concrete contained in an iron wheelbarrow load of average size is 1.9 cu. ft. place measurement. A large load is about 2.2 cu. ft. place measurement. Special concrete barrows are also made with a capacity up to 6 cu. ft. (see Fig. 96, p. 275). Further data is given in Chapter I.

A single cart on ordinary construction roads will carry about half a batch of concrete of average proportions, which may be assumed as 1 barrel cement to 2½ barrels sand to 5 barrels stone, while with a properly constructed cart which will not overflow or leak, 50% more than this, or about three-quarters of a batch, can be drawn over macadam and paved streets.

DEPOSITING CONCRETE ON LAND

The methods which may be selected for depositing concrete depend largely upon its consistency. If mixed wet, it can be dropped vertically to any depth or passed through an inclined trough or chute. On the other hand, the stones in a dry mixture, that is, of damp earth consistency, will separate from the mortar on the slightest provocation.

To prevent the ingredients separating when passing down an incline, if the mixture is not plastic enough to prevent the stones running away from the mortar, a pipe with a hopper top and composed of two or more telescoping sections about 15 inches in diameter is often employed. In such a case, the pipe must be often moved or the material shoveled away immediately, to prevent its forming a high cone. Sometimes it is convenient to run the lower end of the pipe into a hopper with a gate at its mouth, sc that the concrete may be drawn out into a vehicle, while the pipe and hopper are kept continually full.*

The illustration in Fig. 97 shows at how flat a slope concrete of very

FIG. 97.—Depositing Concrete through a Trough. (*See p.* 278.)

wet consistency will run through an open trough. The picture is an actual construction photograph of the Jersey City Water Supply Conduit, and shows the concrete flowing directly from the mixer to the crown of the arch. Mr. William B. Fuller, the engineer, states that when the concrete is mixed of exactly the consistency he likes, it will easily run through an iron trough 15 inches wide by 4 inches deep, set on a slope of 8 feet horizontal to 1 foot vertical.

For water-tight work or for maximum strength the concrete should be

**Engineering News*, Dec. 25, 1902, p. 537.

placed so as to form a monolith. To do this on a large structure two or three shifts are employed in twenty-four hours, so that no portion of the mass commences to set until fresh concrete has been laid on top of it. In a large reservoir wall at Little Falls, New Jersey, built *en masse* to sustain 40 feet head of water, the only point where the moisture appeared on the surface was at a layer where the work was stopped for one hour at noon. In most structures it is possible to divide the work into sections, each of which is a monolith. Monolithic construction is necessary for columns, beams and floors.

A tipping car for conveying concrete on a track and dumping it into place is shown in Fig. 98.

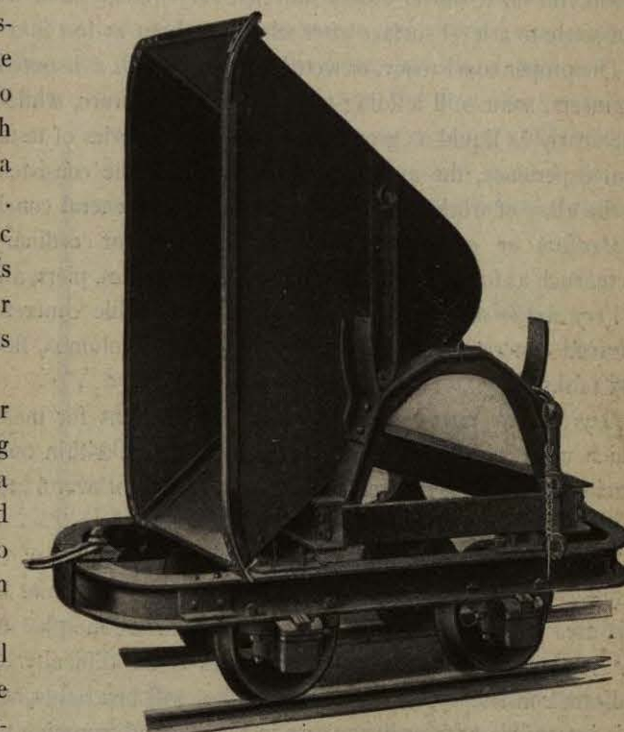

FIG. 98. Dumping Car. (*See p.* 279.)

In a thin wall or a structure requiring especial care, such as a tank, it may be advisable to shovel the concrete from the wheelbarrows. Stones which tend to separate can be thus mixed in with the mortar in the wheelbarrow and a very thin layer formed in the molds, so that even if the concrete is mixed very thin the mortar cannot run off from the stones.

CONSISTENCY OF CONCRETE

The terms for specifying the consistency, or degree of plasticity, of freshly mixed concrete are variously used by different engineers. In this treatise the term *dry mixture* is applied to concrete of the consistency of damp earth, from which the water rises to the surface only after prolonged ramming, and then simply in a glistening film. A *medium* or *quaking mixture* means a tenacious, jelly-like consistency, which shakes on ramming. A *very wet* or *mushy mixture* is one which will not support the weight of a man and into which an ordinary rammer will sink of its own weight; it will run off a shovel unless shoveled very quickly, and will spread out and settle to a level surface after wheeling about 25 feet in a wheelbarrow.

The proper consistency, or wetness, of concrete is a disputed point among engineers, some still holding to the very dry mixture, while others prefer one nearly as liquid as grout. As a result of a series of tests and of practical experience, the authors advocate varying the consistency according to the class of work, and present the following general conclusions:

Medium or quaking concrete is adapted for ordinary mass concrete, such as foundations, heavy walls, large arches, piers, and abutments.

Very wet or mushy concrete is suitable for rubble concrete and for reinforced concrete, such as thin building walls, columns, floors, conduits, and tanks.

Dry concrete may be employed in dry locations for mass foundations which must withstand severe compressive strain within one month after placing, provided it is carefully spread in layers not over 6 inches thick and is thoroughly rammed.

The experiments of the authors show that while dry concrete, very carefully mixed and rammed, is stronger on short time tests, medium mixtures will attain nearly equal strength in six months' time. One of the arguments against very dry mixtures is the difficulty of obtaining a uniform consistency. Occasional batches will invariably be too dry, and it is impossible with ordinary care in placing and ramming to avoid visible voids or pockets of stone which form weak places and allow the penetration of water.

The 1903 specifications of the American Railway Engineering and Maintenance-of-Way Association are as follows:

> The concrete shall be of such consistency that when dumped in place it will not require tamping; it shall be spaded down and tamped sufficiently to level off and will then quake freely like jelly, and be wet enough on top to require the use of rubber boots by the workmen.

A very wet mixture is more suitable for rubble concrete or concrete rubble because the large stones more readily settle into place and bed themselves. In thin walls very wet concrete can be more easily "joggled"

into position so as to conform to the molds and give a smooth surface. The use of a mixture sufficiently wet to flow under and around metal reinforcement has been found by Prof. Charles L. Norton (see p. 328) to be one of the essentials for the preservation of the metal.

Stone pockets may occur even with very wet concrete because of the mortar running away from the stones. This may appear an imaginary danger to many users of concrete who have never employed a very wet consistency, but the authors have seen concrete mixed with too much water, which after setting and the removal of the forms had the appearance of being mixed too dry. In their opinion, however, the limit of wetness for many classes of work is not reached until there is so much water that with ordinary care in hand-mixing it cannot be made to incorporate with the other materials.

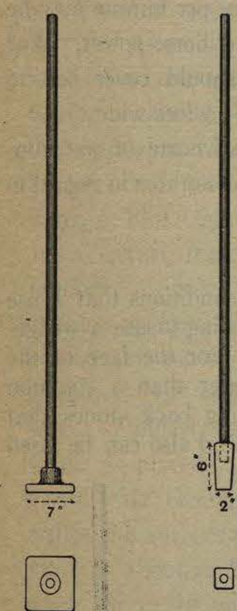

FIG. 99.—Rammers for Dry Concrete. (*See p.* 281.)

RAMMING OR PUDDLING

The method of compacting the concrete or forcing out the air after placing, and the kind of tools to employ for this, depend upon the consistency of the material.

In concrete mixed with a small amount of water the thickness of layers is usually specified at 6 to 10 inches, the former being the most common, but with a very wet or mushy concrete 12 to 15 inches may be placed at once, the chief object being to expel bubbles of air by puddling or joggling. In using very wet concrete there is danger of too much ramming, which results in wedging the stones together and forcing the finer material, the sand and cement, to the surface.

The style of rammers ordinarily used for dry mixed or medium concrete are similar to the forms shown in Fig. 99. The style on the left of the figure is the ordinary type, and on the right is a style convenient for use close to the forms.

The rammer shown in Fig. 100, page 282, which weighs about 8 pounds, is the design of Mr. William B. Fuller for very wet or mushy concrete. The handle may be lengthened, as shown, by screwing a pipe coupling on to the wood.

A "post-hole" tamping bar with iron shoe, shown in Fig. 101, has been successfully used by the authors for mushy concrete. A piece of 2 by

3-inch studding cut to the required length and smoothed off so as to be readily grasped by the hands is also a serviceable tool.

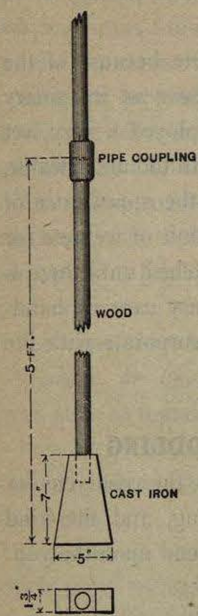

FIG. 100.—Rammer for Mushy Concrete. (*See p.* 281.)

A pneumatic rammer built on the principle of a pneumatic riveting machine, as illustrated in Fig. 102, has been used upon dry mixed concrete with fair success.

Mr. Rafter and Mr. Daniel F. Fulton have designed a rammer based on the principle of the steam drill which is arranged upon a traveling carriage resting upon cross girders which run on tracks. A speed of from 400 to 600 strokes per minute may be maintained with from 4 to 5 horse-power. For ramming street pavements, it should cover 600 to 800 linear feet of a street 30 to 40 feet wide.

Mr. Clarence R. Neher, an advocate of wet concrete, replies to an inquiry of the authors in regard to rammers, as follows:

I am governed so much by conditions that I use no standard tool, the principle being to use a wedge-shaped rammer of some kind. For the face of the work nothing appears much better than a common spade. This is useful in pushing back stones that have separated from the mass, and also can be used to select the softer and finer portions of the mass and place at the face, while working the spade up and down along the face until it is thoroughly filled. Care must be taken not to pry with the spade, as it will spring the form outward unless excessively strong.

In narrow forms where a man cannot stand in the concrete, a piece of 2-inch by 3-inch scantling, — with the upper portion rounded to make a convenient grip and the tamping end wedge-shaped, — of a length determined by the depth of the form, is convenient and cheap.

In heavy mass work I prefer this same form of rammer to the ordinary type, and thoroughly incorporate the different deposits together, avoiding as much as possible a smooth, flat finish, so frequently insisted on. I consider the use of the term "layers" as describing just what you do not want. I deposit as much concrete in a form as the rammer will penetrate and enter into the deposit below. The


FIG. 101.—Rammer for Mushy Concrete. (*See. p.* 281.)

amount will thus be governed by the size of the form and method of filling.

In elevator foundations we have filled columns 3 feet by 11 feet by 22 feet high in five hours, dumping 14 cubic feet at a time, and not trimming, but shoving the rammer through the mass. The work is absolutely free from voids.

Labor of Ramming. The number of men required for leveling and ramming concrete depends upon the thickness of the wall and the consistency of the mass.

In the table of concrete data in Chapter I, page 9, we have specified 11 cubic yards as the work of an average man in ten hours, including both leveling the material as it is dumped from barrows and the actual ramming. This figure is based upon actual records of a large number of jobs where the concrete was laid of the medium consistency most commonly employed in ordinary mass work. Similarly, a large day's work is placed at 16 cubic yards. Mr. George W. Rafter writes the authors that 4 cubic yards is about an average day's work for an Italian laborer on dry mixed concrete. Mr. Neher estimates for ordinary conditions 10 to 15 cubic yards of wet concrete per man per day with an average of about 12 cubic yards per ten-hour day. Mr. Fuller, who employs a still wetter mixture, considers 25 to 50 cubic yards a day's work for a man joggling.

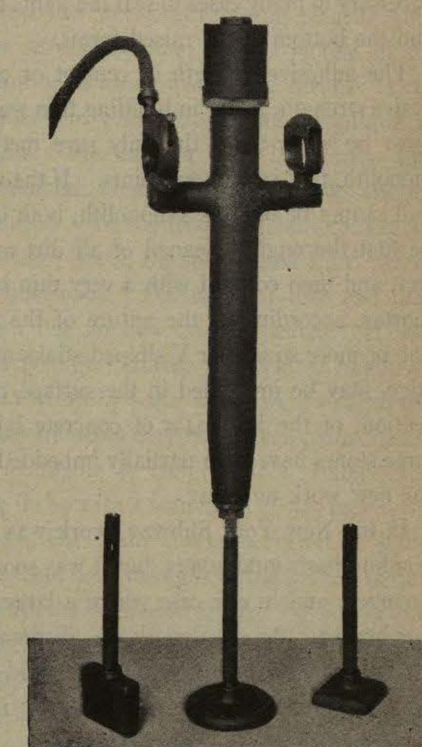
FIG. 102.—Pneumatic Concrete Rammer. (*See p.* 282.)

On the author's basis of 11 cubic yards per day, the average cost of leveling and ramming mass concrete with labor at $1.50 per day, allowing for superintendence and contractor's profit, is about 18 cents per cubic yard. For a 4 or 6-inch wall the cost may be two or three times this figure.

BONDING OLD AND NEW CONCRETE

In a foundation or other structure where the strain is chiefly compressive, the surface of the concrete laid on the previous day should be cleaned and wet, but no other precaution is necessary. Joints in walls or in other locations liable to tensile stress are coated with mortar, which should be richer in cement than the mortar in the concrete, proportions 1:2 being commonly used.

Some engineers spread the cement dry upon the wetted surface of the old concrete, while others make it into a mortar; the latter method is necessary in many cases to seal the joints between the top of the old concrete and the bottom of the raised forms.

The adhesive strength of cement or concrete is much less than its cohesive strength, hence in building thin walls for a tank or other work which must be water-tight, the only sure method is to lay the structure as a monolith, that is, without joints. If the wall is to withstand water pressure and cannot be built as a monolith, both horizontal and vertical joints must be first thoroughly cleaned of all dirt and "laitance" or powdery scum, wet, and then covered with a very thin layer of either neat cement or 1:1 mortar, according to the nature of the work. As an added precaution, one or more square or V-shaped sticks of timber, say 4 or 6 inches on an edge, may be imbedded in the surface, or placed vertically at the end of a section, of the last mass of concrete laid each day. In some instances large stones have been partially imbedded in the mass at night for doweling the new work next day.

In the New York Subway, work was commenced with no provision for bonding horizontal layers, but it was soon found that more or less seepage occurred, and in one case where a large arch was torn down the division line between two days' work was distinctly seen. Accordingly, at the end of each day's concreting a tongue-and-grooved joint was formed by a piece of timber 4 inches square partly imbedded in the top layer. This was removed before resuming work.

Roughening the surface after ramming or before placing the new layer will aid in bonding the old and new concrete.

Acid* is sometimes used for cleaning and roughening the surface of the set concrete. The acid must be thoroughly washed off before placing the new concrete or mortar.

In reinforced concrete, joints should be made so as to least affect the strength. In columns, joints should be made at lower surface of girder or at bottom of haunch, if any. In a floor system, or in reinforced walls resisting pressure, it is best to make the joints perpendicular to the surfaces at or near the center of the span.

* See U. S. Letters Patent No. 800942.

CONTRACTION JOINTS

Temperature changes are apt to produce contraction in concrete in air because in temperate climates most concrete is laid during the warm season. Moreover, it is generally recognized that while setting and hardening in air, concretes and mortars contract for a period.

It is probable that this contraction may be due, in part at least, to the cooling of the cement, which when setting attains a high temperature.* This is further evidenced by the fact that cracks in a thin building wall, 4 or 6 inches thick, open up within a few weeks after being placed, while heavier walls may not crack for several months. The concrete in the interior of a mass like a large dam cools very slowly, and records at the Boonton, N. J., dam indicate that the contraction cracks continue to increase in width for several years. The interior of a large mass like this is but slightly affected by atmospheric changes, and the cracks are but slightly wider in winter than in summer. In the Boonton Dam† no cracks were discovered during the first winter, but in the second and third winter seasons numerous vertical cracks developed. During the fourth and fifth winters all these cracks re-opened, but no new ones appeared. It was noticed that the cracks which were largest during one winter might be smaller the next, and be exceeded in width by some which were smaller the previous season. Approximate measurements gave: seventeen main cracks, 2.5 inches; sixteen smaller cracks averaging $\frac{1}{32}$ inch, 0.5 inch; thirty-three half cracks, averaging $\frac{1}{32}$ inch, 0.5 inch; with a sum total of 3.5 inches for a length of 2150 feet of masonry. The main cracks occurred at quite regular intervals of about 100 feet except near the ends of the dam. It was apparent that proportionally more cracks developed in that portion of the dam in which the masonry was laid during the warmer months.

Special measurements made upon a retaining wall along the Boston and Albany Railroad tracks at Newton Highlands, showed that for a length of wall of 673 feet the total contraction for a given period amounted to $1\frac{7}{16}$ inches. The range of temperature of the wall during this time was about 30°, which corresponds closely to the theoretical range necessary to produce the contractions, for assuming the coefficient of expansion to be 0.0000055, as given on a succeeding page, the range should be $32\frac{1}{2}$°.

Measurements were made by one of the authors of widths of opening of contraction joints in a long warehouse in Cincinnati, and found to agree almost exactly with that which would be expected by the range in temperature.

In an ordinary wall, if no cracks occur after nine months' setting there is apt to be no further danger, although after joints once form they will vary in width with the variations in temperatures.

*See page 130.
† Transactions American Society Civil Engineers, Vol. LXIII, 1909.

Contraction in concrete walls is provided for by forming joints at intervals to divide the wall into separate sections, and confine the cracks to straight lines, or else by reinforcing with sufficient steel to withstand shrinkage. The use of steel reinforcement is treated under Retaining Walls in Chapter XXVI.

Joints in vertical walls may be made simply by placing a temporary dam between the molds to remain until the concrete has set, when it is removed and the next section is filled in. To be sure of clear-cut cracks, however, it is necessary to insert non-adhesive material, as indicated below. In a reinforced wall rods may be run through holes in the dam if it is desired to tie the two sections together. If the old work has thoroughly set and the rods project only a few inches into the new, the adhesion between the old and new work will be so slight that a joint which will open as the concrete shrinks will be formed at the desired point. For bonding the two sections, a V-shaped groove may be molded into the part first laid, or alternate courses may be lapped or toothed out.

As a rule only contraction joints need to be provided, since expansion merely compresses the concrete. Sometimes, however, as in a long wall with recesses or in a reservoir floor with a channel in the middle, the expansion may cause a break at the angle. In such cases, water-tight joints may be made by leaving slits about $\frac{1}{2}$-inch wide and filling them with a plastic material, one of the best for this purpose being pure asphalt of medium hardness. Lime dust is sometimes mixed with the asphalt. Another way of forming a joint is to insert two or more thicknesses of roofing paper.

In building the concrete filter tanks at Little Falls, N. J., which are 15 by 24 feet in horizontal area and rest upon concrete girders, the walls of adjoining tanks were laid on different days, and thus kept separate from each other. Contraction is provided for in each tank by sloping the ledges on which its walls rest, so that, in case of contraction, they will slide without cracking.

At the same plant* occasional expansion wells or vertical openings were built the entire height of the 40-foot retaining wall, to confine cracks to these places, and later, in cold weather, when the cracks were furthest open, these wells were filled with concrete.

From practical experience it appears that heavy walls require fewer contraction joints than light ones. In concrete retaining wall construction in Chicago† joints formed every 50 or 60 feet opened up quite noticeably in cold weather. Where the walls were of small cross-section a hair crack appeared half-way between the joints, tending to show that in thin walls joints should be provided about every 30 feet.

* Transactions American Society of Civil Engineers, Vol. L, p. 406.

† "The Coefficient of Expansion of Concrete," Journal Western Society of Engineers, Vol. VI, p. 549; republished in *Engineering News*, Nov. 21, 1901, p. 380.

By properly distributed reinforcement, cracks may be made so small as to be unnoticeable. (See Chapter XXI.)

The Harvard Stadium, 575 feet in net length or 1390 feet measured around the U, which is illustrated in our frontispiece, is an example of the possibility of providing sufficient steel to withstand the contraction due to hardening and temperature changes.

Prof. William D. Pence, by very careful experiments at Purdue University, in 1899 to 1901,* determined the coefficient of expansion of concrete in air from changes of temperature to be 0.0000055 per each degree Fahrenheit. He experimented with Portland cement concrete mixed in proportions 1 : 2 : 4 broken stone and 1 : 2 : 4 gravel. The apparatus was designed to give extremely accurate results, and the variation in the coefficient of expansion in the different tests was from 0.0000052 to 0.0000057 per degree Fahrenheit. Two brands of Portland cement were employed, and in the broken stone concrete, two different stones. The average result for the gravel concrete was 0.0000054 per degree Fahrenheit, and for the broken stone concrete 0.0000055 per degree Fahrenheit. Prof. Pence concludes that "the coefficient of expansion of concrete is about 0.0000055 per degree Fahrenheit. (This value is conveniently remembered as five zeros fifty-five.)" The coefficient of expansion of the limestone used in a part of the tests was the same as that of the concrete made from it. Experiments† under the direction of Prof. Hallock at Columbia University gave 0.00000561 as coefficient for 1 : 2 mortar and 0.00000655 for 1 : 3 : 5 concrete. Prof. Burr calls attention to the similarity of this to the coefficient of linear thermal expansion of steel, which is about 0.0000066 per degree Fahrenheit. This fact is of great practical value to the engineer in the construction of reinforced concrete because it shows that the concrete and steel will be similarly affected by temperature changes.

A coefficient of 0.0000055 corresponds to a contraction of $\frac{1}{3}$ inch in 100 feet for 50° Fahrenheit fall in temperature.

The effect of hardening upon the volume, although less definitely determined, has been experimented upon by Prof. Bauschinger,§ of Munich, and Prof. George F. Swain,‖ of the Massachusetts Institute of Technology. As a result, the Committee on Cements of the American Society of Civil Engineers in 1887 reached the following conclusions:¶

First. Cement mortars hardening in air diminish in linear dimensions at least to the end of twelve weeks, and in most cases progressively.

* "The Coefficient of Expansion of Concrete," Journal Western Society of Engineers, Vol. VI, p. 549; republished in *Engineering News*, Nov. 21, 1901, p. 380.

† Burr's "Materials of Engineering," 1903, p. 378.

§ Transactions American Society of Civil Engineers, Vol. XV, p. 722.

‖ Transactions American Society of Civil Engineers, Vol. XVII, p. 213.

¶ Transactions American Society of Civil Engineers, Vol. XVII, p. 214.