the volume changes decrease as the proportion of cement decreases, until a certain lower limit is reached where the change in volume is purely a capillary phenomenon.

If this line of reasoning is correct those concrete structures should be most stable when exposed to the weather in which there is just sufficient cement to give strength but not enough to cause excessive volume changes. Practical experience apparently confirmes this view.

Stucco.—There are many instances where stucco has remained perfect even when exposed to the weather for half a century. There are probably more instances, especially in recent years, where stucco has failed miserably in five years. The excellence of old stucco is sometimes laid to the natural rock cement with which most of it was made. It is not safe to deny this on the evidence of a single experiment, yet attention may be drawn again to the one natural rock cement which has been tested in our laboratory, whose volume changes were in every way much greater than those of Portland cement.

Is it not more probable that the old stucco has survived because of its lower proportion of cement? When it was simply a question of providing a rough brick or stone wall, entirely durable in itself, with a smooth surface, and when in addition hydraulic cement was expensive, it was natural to use a mortar containing just enough cement to adhere to the wall. With the introduction of metal lath as the support for stucco, and the necessity of protecting the metal from corrosion, coincident with the drop in price of Portland cement came the use of richer stuccos.

The step was apparently an unfortunate one, for a volume change of 1 in. in 100 ft. as shown by the stucco 156 E as it changes from the wet to the dry state cannot but cause cracks. They may be only hair cracks, for with a crack every 12 ins. each crack need only be 0.01 in. wide to take up the whole change in volume. The elastic metal lath will probably yield without mechanical injury, but the protection against corrosion which the stucco is supposed to afford disappears with the first hair crack, and unless the lath has been better protected, by galvanizing or painting, than most sorts are by the manufacturers, its days are numbered. It would have been better to have used a leaner stucco and kept it free from cracks.

A stucco rich in cement may also split off in time from brick where a lean stucco would have remained good. The change in volume of brick when wet and dry is, according to Schumann, less than 0.02 per cent. If the change in the stucco is 0.08 per cent. there is opportunity for a stress corresponding to a volume change of 0.06 per cent. which might be 1,500 lbs. per sq. in. The fact that the stucco has not split off in one or two years does not mean that it may not split off in five or ten years.

Interior Floors.—The question of reinforced concrete is discussed in a later paragraph. Here only the changes in the concrete itself will be considered. The usual practice will be assumed in which there is a base of rather lean concrete covered with a wearing coat of mortar sometimes as rich as 1:1.

The first case assumed will be that of a cellar floor where the base is tamped down and the top coat at once put on, giving the best conditions for bonding. The whole mass gradually dries out and shrinks, but the top coat, because of its high content of cement, shrinks more. The top coat will tend to separate from the base, but since a cellar is always relatively damp there will probably be little trouble.

The situation is not so favorable when a top coat is to be laid on an upper floor of a concrete building. The main portion of the floor has been poured for possible three months and has already completed most of its shrinkage. Its surface is also probably dirty so that the freshly poured mortar will not readily unite with it. Both of these circumstances are unfavorable. The fact that the main portion of the floor has already dried out and shrunk causes an even greater differential shrinkage of the top coat. The advice is usually given to wet the floor thoroughly before pouring the top coat. It would be better to keep it wet for 24 hours beforehand in order to give it an opportunity to expand to somewhere near its initial volume.

It is not surprising if, under these crcumstances, the top splits off the base, shrinkage cracks appear, and the individual slabs curl up somewhat at the edges in the effort to relieve the shrinkage strains. In case electric conduits, etc., are bedded in the top coat their course will be indicated by shrinkage cracks following the lines of weakness which they cause. Since these floors remain continually dry, conditions will become constant after a few months, and there will be little further change.

Sidewalks and Pavements.—The chief factor which influences the behavior of sidewalks and pavements is the weather. The influence of temperature is well known and will not be dwelt upon. A sidewalk usually consists of a base of rather lean concrete covered with a wearing coat of cement mortar which may be as rich as 1:1, and is not usually poorer than 1:2. The walk is cut into blocks and is sometimes provided with expansion joints.

As the walk dries out the top coat shrinks more than the bottom, as shown in the experimental study of compound bars. The effect can often be seen in sidewalks where the contraction has dished the entire slab so that shallow puddles of water stand in them after a rain. When the walk is wet by the rain the top expands more than the base. The alternate bending stresses thus developed all too often show themselves after a few years when the top coat splits off the base.

The necessity of expansion joints is now well recognized, although they are put in principally to take care of expansion due to changes of temperature. The experiments presented in this paper on both neat and sand briquettes indicate that the expansion of cements kept wet ceases at the end of a year, and that the total expansion does not amount to over 0.1 per cent. This would require a ¼-in. expansion joint every 20 ft. In addition there must be the joints to care for the expansion due to summer heat, which for a rise of 100° Fahr. is 0.05 per cent., about half of what may be expected from moisture. To take care of the volume changes from both these causes a ¼-in. expansion joint every 10 ft. should be adequate, although it does not include much margin of safety. In hot weather after a long rain these joints would be almost closed. In dry or colder weather they would be open.

According to the experimental figures any evils due to expansion should make themselves evident during the first two years, but practice does not always bear out this assumption. Reference was made at the commencement of this article to the cement walk laid around the campus of the University of Michigan twenty years ago, which is still showing expansion and giving mute evidence of the pressure generated by occasionally thrusting up two adjacent slabs in an inverted "V". This is not a phenomenon due to summer heat for it occurs usually in the spring. What is the cause which is still making this walk expand after twenty years?

An explanation may be suggested, although it is not possible to prove it completely. It is well known that the glass of thermometers expands when heated and contracts when cooled, but not to its original length except after a long lapse of time. Thermometers which are used frequently at