the deflections in the beams of these tests illustrate very well the progressive sag.

That slabs and beams in buildings in service do show sags increasing from year to year has been verified in a large number of instances. That some are more noticeable than others may be accounted for, neglecting the factors of inaccuracies in design and construction which may frequently be present, by the differences in thickness, the differences in strengths of the concrete and the relative loadings. The effect of the thickness or depth largely accounts for the fact that slabs sag considerably more than beams; for which the same unit deformation at the top and little or no change at the bottom the angular movement between sections originally parallel, and hence the deflection, is less the greater the depth.

In regard to the effect of strength of concrete and relative loading it may be stated that from some tests not quoted here the time yield seems to be a function of the ratio of the unit stress to the untimate strength of the concrete. Thus, with a unit stress of 650 pounds per square inch the time yield would be much greater in a concrete of ultimate strength of 1,800 pounds than in one with an ultimate strength of 2,500 or more. If such differences in concrete as represented by these ultimate strengths exists in different structures, then varying degrees of sag may be expected from this cause. That such differences do occur in structures built under the same specifications seems to be probable. They result from the use of different aggregates, consistencies and methods of curing, as well as from the seasonal differences at the time of construction, both as to temperature and humidity. In regard to the relative loading, some buildings practically never receive their full load while others may be loaded almost continuously, and frequently with an excess over that for which the floor was designed. This would produce a difference in the ratio of actual stress to ultimate strength that might account for a considerable difference in yield even in buildings of about the same grade of concrete. The notoriously high compressive stresses around the column heads of some of the earlier flat slab designs may account for a large part of the sag noted in many examples of this type of construction.

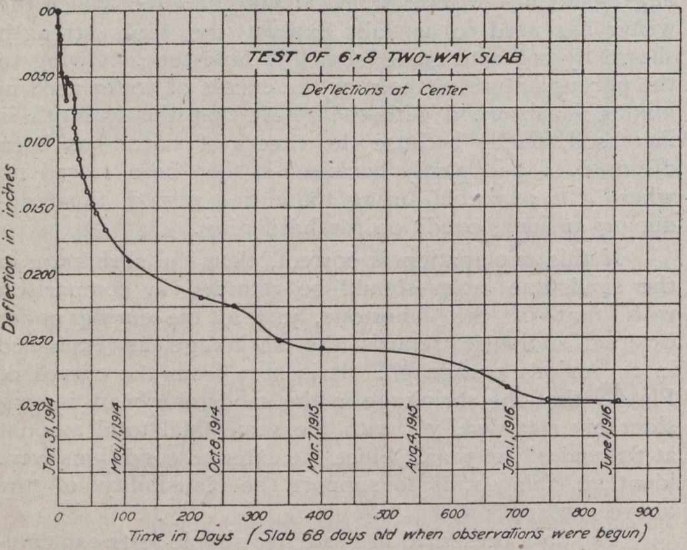

Plate 6.

In addition to offering an explanation of the continued sag in reinforced concrete floors, a study of the data from these two simple tests raises the two important questions concerning the probable initial stresses in the steel of beams, slabs and columns due to shrinkage, and the probable final stress in reinforced columns due to both shrinkage and time yield. Theoretical calculations based on the data of the first two tests presented are of little value in predicting these stresses because of various factors which it is impossible to estimate, such as: the modulus of elasticity of the concrete and its variation through the early hardening period, the rate at which a perfect bond between the steel and concrete is developed, and the ability of the concrete to accommodate itself to the strained condition during the early hardening period. For these reasons these questions will be left to the discussion of the tests which follow in which special effort was made to obtain data bearing on the points raised.

Test of 6-ft. x 8-ft. Two-Way Slab.—Some of the results of the test of this slab extending over a period of one year were published in the Engineering News for March 11, 1915, and in Bulletin No. 3, Engineering Series, University of Minnesota, "Shrinkage of Time Effects in Reinforced Concrete." The results are brought up to date and given here for they bring out very clearly the features of continued sag and initial stresses in the reinforcement.

This slab was cast in November, 1913, from a 1:2:4 mixture using a crushed limestone of pea size for the coarse aggregate. Eight-inch by sixteen-inch cylinders cured with the slab 72 days showed a compressive strength of 1,825 pounds per square inch and a modulus of elasticity of two and one-half millions. Transverse specimens at the same age gave a modulus of rupture of 380 pounds per square inch. The slab is three inches thick and is supported on four sides with spans of 6 and 8 feet. The reinforcement the short way consists of twelve 5/16 inch round rods placed 2⅝ inches below the top with spacing varying from six inches at the centre to ten inches at the edge. The longitudinal rods were 5/16 inch rounds, six in number, placed immediately above those in the transverse belt, with the spacing varying from nine inches to twelve inches. The rods of both belts were hooked at the ends.

In this slab measurements were not begun until just before the first load was applied at the age of ten weeks. The shrinkage, however, is probably nearly all included in the results given, for the slab had been kept covered with wet sand and the forms in place until a few days before loading. A load of 50 pounds per square foot was first applied; this was increased to 100 three days later, which, except for one removal and reapplication soon after, has been continuously in place to the present time. Calculated on the basis of the recommendations of the Joint Committee the load of 100 pounds per square foot gives stresses of 650 pounds per square inch in the concrete and 16,000 in the steel. These assumptions are undoubtedly very conservative, which accounts for the fact that the concrete is still holding in tension after two and one-half years.

The data it is desired to show from this test is given in Plates 5 and 6. In plate 5 are shown the results of measurements of shrinkage and of stresses in the steel of both belts, as well as the maximum concrete deformations. It will be observed that except at the first application of the load and for a very short time thereafter the steel stresses are all compressions. The transverse belt, it will be noted, shows considerable less compression than the longitudinal. This is to be expected, for in addition to the greater tendency toward tension in the short way steel from bending, the effect of its higher percentage and greater distance from the unrestrained surface in resisting shrinkage would be considerable. The greatest compressions in the transverse belt are 4,500 pounds per square inch after 80 days under load, about the same