The compression specimens were 6 ins. in diameter and 12 ins. high, made on plate glass so that a plane surface was secured on one end, the other being bedded in plaster of Paris when tested.

The tension specimens were similar in shape to the standard cement briquettes, having a sectional area at the centre of 25 sq. ins. The specimen was 5 ins. deep and at the narrowest part was 5 ins. wide, while the length was 12 ins. With a specimen of this type the concrete may be placed in the mold in the same way in which it is placed on the road. The line of stress is also the same in both cases.

The abrasion specimens consisted of a large concrete ring 20 ins. in inside diameter, 28 ins. in outside diameter, and 8 ins. deep. The 4-in. thickness of concrete was reinforced with two steel rods to prevent cracking from unequal stresses in the rattler. The specimen was molded between two concentric metal forms held in place by metal spacers. This specimen can be handled by one man without the assistance of any apparatus, the average weight being about 200 lbs.

Testing the Specimens.—In testing the compression and tension specimens a 100,000-lb. Olsen testing machine was used, the load in both cases being applied at a speed of 0.05 in. per minute. One end of each compression specimen was bedded in plaster. In testing, the spherical bearing block was placed at the top. Grips were devised for the tension specimens so that when the load was applied the specimen would adjust itself to a direct pull and the pressure of the grips would be distributed equally on the specimen at all points.

The apparatus was designed to test any specimen up to the capacity of the machine, and it was found that it was somewhat unwieldy. A lighter apparatus was designed later. This will test specimens up to 20,000 lbs. total load, which is ample for any concrete that it is possible to make. The direct tension is assured with the apparatus by a welded eye from which the clip hanger allows a limited universal motion.

In order to determine what variation might be expected in the results of the tension tests four independent

Table I.—Results of an Independent Series of Tension Tests

Mix.	Tensile strength lb. per sq. in.	Maximum variation from avg., %
1 Cement: 3 Ottawa sand	202, 220, 216..Average 213	5.2
1 Cement: 3 Colorado River sand	264, 263, 294..Average 274	7.3
1 Cement: 2 Colorado River sand: 4 Colorado River gravel	275, 274, 275..Average 275	0.4
1 Cement: 1½ Colorado River sand: 3 Colorado River gravel	288, 304, 280..Average 291	4.0

series of tests were made, each series consisting of three specimens made on different days. Exceptions to this were the three tests made on the Ottawa sand briquettes, which were all made from the same batch. A different mix was used for each series. The results obtained from these series are given in Table I. From these results it is reasonable to assume that a single tension test would fall within 10 per cent. of the average. Results on other tests, not included here, indicate that the probable error on concrete specimens is much smaller, being closer to 5 than 10 per cent. The specimens were tested at the rate of 40 lbs. per square inch per minute.

In order to determine how closely the large 5-in. briquettes could be expected to check with the smaller 1-in. standard briquettes some 1:3 Ottawa sand mortar was made into briquettes of both sizes at the same time. The speed of the small tension testing machine was regulated to that of the large machine so that the rate per square inch of load would be the same. It was found that the smaller briquettes tested 12.4 per cent. higher than the larger briquettes when tested with the old apparatus, and 2.1 per cent. higher when the large briquettes were tested with the new apparatus. It is believed, however, that this difference is due to the variations that might enter in making and curing the specimens rather than in the apparatus. For instance, the mortar tested with the old apparatus was mixed with shovels on the floor, while that tested with the new apparatus was kneaded by hand, according to standard methods.

The abrasion test on the concrete rings was made in the standard brick rattler, having alternate staves removed. This was done in order to lighten the load on the pulley. The axis of the specimen was aligned with the axis of the barrel by driving wooden wedges between the staves and the specimen. After the shot were placed in the ring the moving head of the barrel was brought in contact with the specimen, holding it in place. The rattler revolved at the rate of 30 r.p.m., which was sufficient to cause the shot to ride up the specimen while it revolved. This permitted some of the shot to slide upon the concrete while others dropped from the top of the pile with a certain amount of impact. The charge used consisted of 139 cast-iron cubes measuring 1½ ins., with rounded edges. In addition there were six rectangular shot, 2⅝ x 2⅝ x 4½ ins., which brought the total weight of the charge up to 158 lbs.

Table II.—Abrasion Tests of Three Specimens

1 Part Cement : 2 Parts Colorado River Sand : 4 Parts Colorado River Gravel. Age, 28 Days.

First specimen lost	3.81%	by weight in	1,000	revolutions		
Second specimen lost	3.70%	"	"	"	"	"
Third specimen lost	2.88%	"	"	"	"	"
Average	3.45%	"	"	"	"	"

After each 500 revolutions the specimen was cleaned of all dust and weighed in order to determine what effect the number of revolutions would have on wear. It was found that the specimen lost approximately the same amount each 500 revolutions. The specimen was tested for 2,000 revolutions, but the percentage loss was calculated for 1,000 revolutions. The character of the surface of the specimens was carefully noted after each test. These observations furnish some of the most important features of these tests.

In the abrasion tests individual results show considerable variation from the average, as is apparent from the results of testing three specimens made of the same materials at different dates, given in Table II. The maximum variation from the average is 16.8 per cent. While this variation may seem excessive, it should be kept in mind that the chances for variation with a gravel specimen are larger than with crushed stone. This is due to the fact that a different number and size of the stones are knocked out of the surface of the gravel concrete in each of the specimens, while concrete made of ordinary crushed stone shows no such loss.