TENSILE TESTS OF SPLICES OF REINFORCING BARS.

In constructing the walls of the Washington Street tunnel in Chicago the method of drifting by successive levels necessitated the introduction of vertical reinforcing rods of short lengths, cut according to the height of the drift. The walls were built underground and in sections six or eight feet high.

As it was not deemed prudent to rely entirely on the bonding strength of the concrete to transmit stress from one rod to another, tests were made under the direction of the Board of Supervising Engineers on 1-in. twisted steel rods spliced with one or more simple V[4] clamps. These were placed in tension and the load applied at the rate of 1,000 lbs. per minute. As the keys left in the concrete face of each drift allowed a minimum of 8 ins. overlap, this length of splice was used in all tests. A description of the tests is given in the third annual report of the Board of Supervising Engineers, from which we abstract this information

Methods of Testing.—The tests were made with one, two and three clamps as follows:—

(1) Single clamp 8 ins. overlap.

(2) Two clamps fastened on opposite sides.

(3) Three clamps, two fastened on one side and one from the opposite side.

The result showed that in general the two-clamp type was the best to use in construction work. This type, when the clamp was tightened enough—slightly enough to bend the plate—showed a resistance of 6,400 lbs. with ⅛-in. slip. When put under further load there was no movement until the load reached 13,690 lbs., when a sudden slip occurred of 3/16 in. in the strap of one of the clamps and ⅛ in. slip in the rods. The rocks then began to pull apart at this or a lower stress.

The single clamp allowed the bars to twist practically as soon as any stress was applied, and showed a slip of ⅛ in. at 4,000 lbs. stress, increasing to ¼ in. slip at 5,600 lbs.

With three clamps a slip of ⅛ in. occurred in the bars with a stress of 6,760 lbs. The strap started at 10,730 lbs., 11,690 lbs. and 18,330 lbs., respectively, with a total slip at this time of ½ in. At 25,580 lbs. there was a sudden slip of the bars and one clamp became entirely loose so that no further load could be applied.

In general, the tendency of this type of lap splice is to offer a fairly uniform resistance to tensile stress up to a point where the clamps become dislocated and lose their grip, when complete failure occurs. The effect of tension on the unconcreted joint also appears to hasten the dislocation of the clamps, and consequently decreases the apparent strength of the plain joint.

The working stress used in all concrete designs provided for 16,000 lbs. per square inch tension in the steel. In these tests the resistance was about 7,000 lbs. up to the first slip. This resistance, however, would be much greater when the rods were embedded in concrete, so it was decided to use a splice of the type with two clamps and rely on the bonding stress of the concrete to supply the deficiency between the resistance of the splice and the stress in the steel.

In estimating this additional strength two forces were relied on: First, a surface adhesion taken conservatively at 100 lbs. per sq. in., which directly augments the net tensile strength of the splice; second, a bonding effect, which prevents the bars from twisting, and consequently defers the displacement of the clamps. By this method the full tensile strength of the bar (16,000 lbs.) could be realized.

In various drift levels the key was about 12 ins. in depth, which always provided at least 8 ins. overlap as previously stated. This made it fairly easy to apply the clamps in position.

A second series of tests as indicated on Fig. 2 were made as follows:—

(1) With a two U-clamp splice with ½-in. plate and no concrete.

(2) Two U-clamp splices embedded in a concrete block and tested when the concrete block was seven days old. (Two tests.)

(3) Two U-clamp splices as above, except with concrete 28 days old.

The first test on the plain joint was in the nature of a check on the previous tests, and a maximum of 27,000 lbs. was reached with the first slip at 8,810 lbs. and a total slip of 2¼ ins.

The mixture of the concrete was 1:2:4 with Portland cement, sand and ½ to ¾ in. crushed limestone. The blocks were each 12-in. cubes, thus embedding the 8-in. lap splice 2 ins. at each end, and in this respect the test could not hope to reveal the full bonding strength of a continuous concrete monolith.

The points of measurement of slippage between bars was necessarily outside the cube, so that the combined effect of unrestricted torsion and stretch in these outer sections of the bars undoubtedly decreased the ultimate strength of the joint as put under test, so that the results here recorded may be regarded in every respect as conservative.

The first seven-day cube took a slowly increasing load up to 23,080 lbs., when a movement of ⅛ in. occurred and the concrete cracked on four sides. No further load could be applied until the total slip increased to ¼ in., from which the load was carried up to a maximum of 31,220 lbs. with continual slipping and a total displacement of 1.29 ins. The second seven-day cube failed practically the same as the first, except that the first slip occurred at 19,400 lbs., and a maximum of 34,120 lbs. was carried with a gradual slipping of 1.33 ins.

The test on 28-day concrete showed a slight movement at 13,550 lbs., holding to 21,000 lbs., and then a gradual stretch up to a maximum of 30,480 lbs. with 3/32 in. total slip. In Fig. 2 a vertical movement represents stress without slip, and conversely, inclination represents a continuous pulling apart with increasing load.

Conclusions.—(1) In all cases the strength of the splicing seems to be dependent upon the strength of the concrete, and there is comparatively little margin between the first evidence of distress and complete failure.

(2) The 28-day concrete specimen took about 50 per cent. more stress at complete failure than the average of the two seven-day specimens.

(3) When such splices are used, the concrete would fail before the splice.

(4) This method of splicing reinforcing bars is safe for a working stress of approximately 16,000 lbs. per square inch in the steel.

Figure 2 shows the curious fact that the three-clamp splice without concrete has less strength than the two clamps at lower loads, but as higher loads are applied the third clamp becomes effective. This anomaly is undoubtedly due to the difficulty of securing an equal bearing between bars and clamps until sufficient load has been applied to start abrasive action.

PERSONAL.

MR. JAMES A. BELL, engineer of the township of Dunwich, Ont., has resigned his position and MR. A. S. COLE, O.L.S., has been appointed as his successor.