CRD-C 24-01

Standard Test Method for Comparing Concretes on the Basis of the Bond Developed with Reinforced Steel

1. Scope

1.1 This test method covers comparison of concretes on the basis of the bond developed with reinforcing steel.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
C 143 Test Method for Slump of Portland Cement Concrete
C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 293 Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)
C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 617 Practice for Capping Cylindrical Concrete Specimens

3. Significance and Use

3.1 This test method is not intended either for use in tests in which the principal variable is the size or type of reinforcing bar or for establishing bond values for structural design purposes. This test method is adaptable to use for research purposes by varying the conditions as desired but no attempt to do so has been included in the method.

3.2 This test method may also be used to determine the conformance of a product or a treatment with a requirement relating to its effect on the bond developed between concrete and reinforcing steel.

4. Apparatus

4.1 *Molds for Bond Test Specimens*–Two types of molds will be required: for 6-in. or 150-mm concrete cubes each containing a vertically embedded bar, and for 6 by 6 by 12-in. or 50 by 150 by 300-mm prisms each containing two horizontally embedded bars. The molds preferably shall be made of metal, not less than 1/4 in. (6 mm) thick. If made of wood, they shall be lined with smooth sheet metal approximately 1/8 in. (3 mm) thick. The molds shall be watertight. With all-metal molds, watertightness may be accomplished by using grooved joints, or a sealing compound may be applied along the exteriors of the end joints after assembly. Particular care shall be taken to seal the openings where reinforcing bars extend through the molds. The molds shall be designed to hold the bars rigidly in place, including the free ends of projecting bars. The molds shall be constructed for easy removal without disturbance of embedded bars. Suitable molds are shown in Fig. 1.

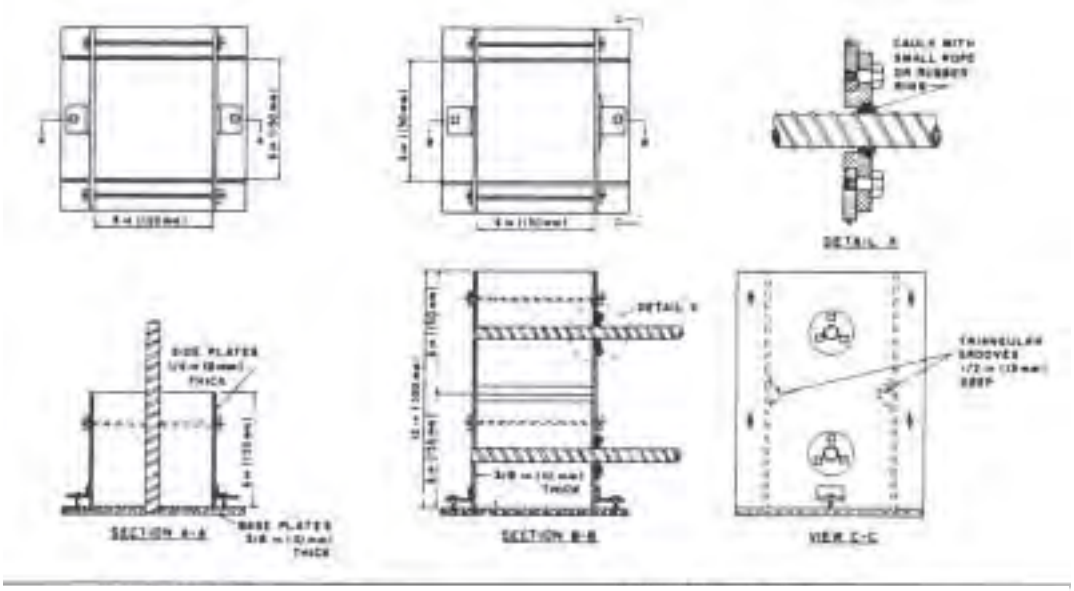

Fig. 1. Molds for Bond Test Specimens

4.2 *Measuring Apparatus–Apparatus* shall be provided for measuring the movement of the reinforcing bar with respect to the concrete at the loaded end of the bar. Dial gages shall be graduated in 0.001-in. (0.025-mm) units; a range of at least 0.5 in. (13 mm) shall be provided, and a range of 1.0 in. (25 mm) is desirable (Note 1).

NOTE l–One type of apparatus that has been found satisfactory is shown in Fig. 2. The dial gages are mounted on suitable yokes, which are attached to the concrete specimen with setscrews. At the loaded end of the bar, adjustment is accomplished by changing the height of the cap screws on the ends of the split-ring cross bar on which the stems of the dial gages bear.

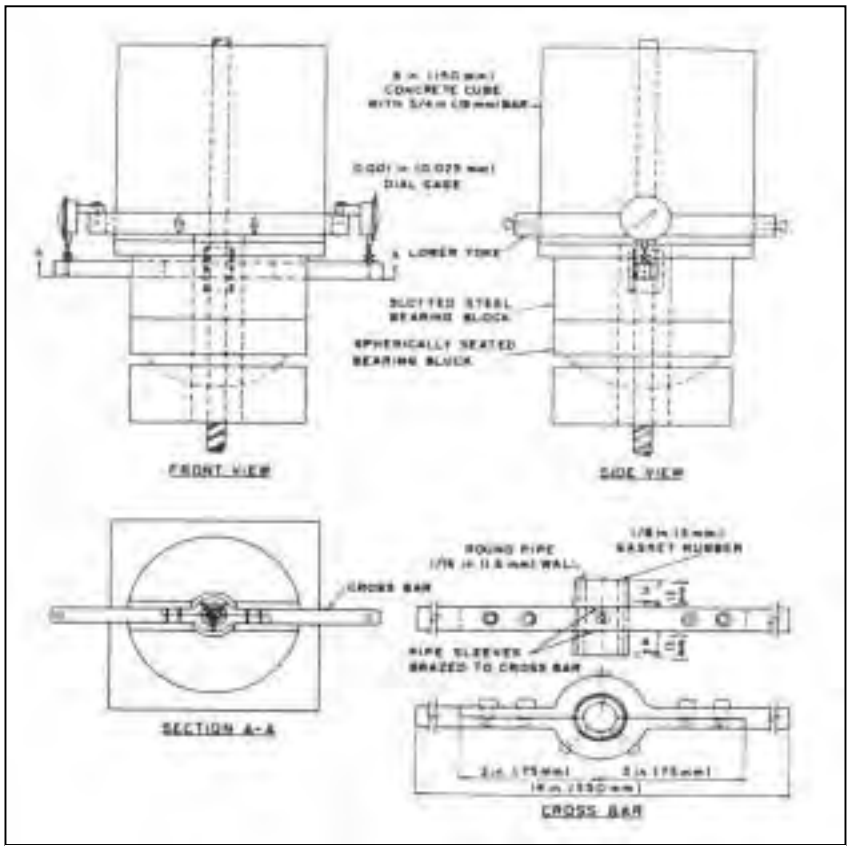

Fig. 2. Measuring and Testing Apparatus for Bond Test

The split-ring cross bar is attached to the reinforcing bar through four screws in the arms of the cross bar which bring the gasket rubber lining into firm contact with the reinforcing bar. The three setscrews as shown are used to ensure additional cross bar contact. The cross bar is located in a slot machined in the intermediate bearing plate, but is fastened to the reinforcing bar in such a way that no contact is made with the bearing plate during the test.

4.3 *Testing Apparatus*–The capped or bearing surface of the concrete cube shall be supported on a machined steel bearing plate at least 6 in. (150 mm) square and 3/4 in. (19 mm) thick, with a hole drilled through its center of sufficient diameter to accommodate the reinforcing bar. If a cross bar measuring apparatus similar to that shown in Fig. 2 is used, the bearing plate should be supported on a steel block at least 5 in. (125 mm) in diameter and 3 in. (75 mm) thick. This block should have a central hole to accommodate the reinforcing bar, and in addition, on its top side should have a diametral slot and central hole of dimensions sufficient to accommodate the cross bar. This slotted block shall rest in turn on a spherically seated bearing block at least 5 in. diameter and having a central hole at least 1-1/2 in. (38 mm) in diameter (Fig. 2).

5. Test Specimens

5.1 The test specimens shall be of two types: one containing one reinforcing bar embedded vertically, and the other containing two bars embedded horizontally. Three specimens of each type shall constitute a set of test specimens.

5.2 *Specimens for Vertically Embedded Bar*–These specimens shall consist of concrete cubes, 6 in. or 150 mm on each edge with a single reinforcing bar embedded vertically along a central axis in each specimen. The bar shall project downward from the bottom face of the cube as cast a distance of about 3/8 in. (10 mm), and shall project upward from the top face whatever distance is necessary to provide sufficient length of bar to extend through the bearing blocks and the support of the testing machine and to provide an adequate length to be gripped for application of load (Fig. 1).

5.3 *Specimens for Horizontally Embedded Bars*–These specimens shall consist of concrete prisms 6 by 6 by 12 in. or 150 by 150 by 300 mm with the longer axes vertical. Two bars shall be embedded in each specimen, perpendicular to the long axis and parallel to and equidistant from the vertical sides of the prism (Fig. 1). In the vertical direction, one bar shall be located with its axis 3 in. (75 mm) from the bottom of the prism, and the other with its axis 9 in. (225 mm) from the bottom. Both bars shall project from the two ends of the specimen distances corresponding to those specified for specimens having a vertically embedded bar. A triangular groove or chamber shall be formed in each of the two opposite sides of the prism parallel to the axes of the bars and at midheight of the prism. These grooves shall be at least 1/2 in. (13 mm) deep, measured perpendicularly from the surface of the concrete. They are for the purpose of facilitating the breaking of the prism into two test specimens at this weakened plane prior to making the bond tests.

NOTE 2–To obtain the expected maximum effect on bond due to bleeding, settlement, and accumulation of air voids under the bars, the common plane of the two longitudinal ribs on each bar should be in a horizontal plane in the as-cast position.

5.4 *Reinforcing Bars*–The reinforcing bars shall be No. 6 deformed bars conforming to Specification A 615. Care shall be taken that all bars used in a given series of tests are of the same type and have the same size, shape, and pattern of deformations. The lengths of the individual bars shall be such as to meet the requirements of the test specimens.

NOTE 3–In consideration of the size of the test specimens and the consequent limited clearances between the reinforcing bars and the sides of the molds, and for standardization, it is recommended that the size of the coarse aggregate used in the concrete be not greater than 1 in. or 25.0 mm.

6. Mixing Concrete

6.1 The concrete shall be batched, machine mixed, molded, and cured in accordance with the applicable portions of Practice C 192 except as may be otherwise directed herein. Immediately after mixing, the slump of each batch of concrete shall be measured in accordance with Test

Method C 143. The air content of the freshly mixed concrete shall be determined in accordance with Test Method C 173 for lightweight aggregate concrete or Test Method C 231 for concrete containing relatively dense natural aggregate.

7. Casting Specimens

7.1 Prior to casting the test specimens, coat the inside surfaces of the molds with a thin film of mineral oil, petroleum jelly, or stearic acid paste. Clean the reinforcing bars of loose rust or scale with a wire brush, and clean off oil or grease by washing with a suitable solvent.

7.2 The manner of placing the concrete in the molds may in some cases be a variable in tests of bond. When this is not the case, use the following procedures for the respective types of specimens (Note 4).

7.2.1 For the 6-in. or 150-mm cubes, place the concrete in two layers of approximately equal thickness and rod each layer 25 times with the 5/8 in. (16 mm) diameter tamping rod.

7.2.2 For the 6 by 6 by 12-in. or 150 by 150 by 300-mm prisms, place the concrete in four layers of approximately equal thickness and rod each layer 25 times with the tamping rod (Note 5).

NOTE 4–If concrete of 1 in. (25 mm) slump or less, or under some conditions when the slump is between 1 in. (25 mm) and 3 in. (75 mm), consolidation by rodding may prove unsatisfactory. In such cases, internal vibration by means of a laboratory type, low amplitude, high-frequency vibrator is recommended. Care shall be taken not to vibrate the concrete excessively, unless this factor is being investigated in the tests.

NOTE 5–The first and third layers shall be of such thicknesses that the lower and then the upper horizontally embedded reinforcing bars, respectively, are completely covered by the consolidated concrete.

7.3 After the top layer has been consolidated, strike off the surface with a trowel and protect against evaporation of moisture by one of the acceptable methods described in paragraph 7.1, on Covering after Finishing, of Practice C 192. Take care that evaporation does not take place in the area adjacent to the protruding reinforcing bar for the vertically cast specimens.

7.4 Make at least three standard 6 by 12-in. or 150 by 300-mm or 4 by 8-in. or 100 by 200-mm control cylinders from each batch of concrete for determining compressive strength.

8. Curing Specimens

8.1 Remove the molds from the specimens not earlier than 20 h after casting. Take extreme care to prevent striking or otherwise disturbing the reinforcing bars.

NOTE 6 –If the method of sealing the openings around the reinforcing bars shown in Fig. 1 is used, remove the packing around the bar first: then unbolt the collar from the side of the mold

and carefully remove from the bar. The bottom of the mold may then be slipped easily over the projecting bar.

8.2 Immediately after removing the molds, cure the specimens in a room in accordance with Specification C 511 until the time of test. Test the specimens at an age of 28 days.

9. Specimen Preparation

9.1 When the specimens are between 7 and 14 days old, break the 6 by 6 by 12-in. or 150 by 150 by 300-mm prisms in half in flexure to form two 6-in. or 300-mm cubes. Do this by arranging the specimen as a simple beam with center-point loading in accordance with Test Method C 293 with the two triangular grooves in the upper and lower faces of the beam at midspan. Apply the load to a 3/4-in. (19-mm) diameter bar laid in the upper groove and continue until fracture occurs. Take care not to strike or otherwise disturb the reinforcing bars during the operation.

9.2 Cap the surface of the 6-in. or 300-mm cube containing the vertically embedded bar, which is to be utilized as the bearing surface in the pull-out test. The applicable portions of Practice C 617 relative to capping materials and procedures shall be used.

NOTE 7–The recommended procedure for capping the specimens with vertically cast bars is as follows: Align the reinforcing bar vertically by use of a carpenter's level. Placing the specimens on the base of the mold with facilitate the use of shims generally required to align bars. Oil the 3/4 in. (19 mm) drilled steel plate used in the pull-out operation and use as the capping plate. After a sufficient quantity of capping material has been placed on the specimen, slip the plate over the reinforcing bar and press firmly on the capping material until it extrudes at all edges of the plate. Level the plate with carpenter's level. Removal of material that extrudes through the drilled hole in the plate before it hardens will aid in removing the plate without damage to the cap. Unless machined molds are used for specimens containing horizontally cast bars, it is recommended that they also be capped in the same manner.

10. Procedure

10.1 Mount the specimen in the testing machine so that the surface of the cube from which the long end of the bar projects is in contact with the bearing block assembly shown in Fig. 2. The spherically seated bearing block shall rest on a support which transfers the reaction from this block to the weighing table of the testing machine. The projecting reinforcing bar shall extend through the bearing block assembly and the support, and be gripped for tension by the jaws of the testing machine.

10.2 In assembling the testing apparatus on the specimen, carefully measure, to the nearest 0.1 in. (2.5 mm), and record the distance between the bearing face of the concrete and the horizontal plane passing through the point on the reinforcing bar where the cross bar of the device for measuring slip plus elongation is attached so that the elongation of the reinforcing bar over this distance may be calculated and deducted from the measured slip plus elongation.

10.3 Apply the load to the reinforcing bar at a rate not greater than 5000 lbf/min (22 kN/min), or at the no-load speed of the testing machine head of not greater than 0.05 in./min (1.27 mm/min), depending on the type of testing machine used and the means provided for ascertaining or controlling speeds.

10.4 Read and record the applied load and the two dial gage readings, at a sufficient number of intervals throughout the test to provide at least 15 readings by the time a slip of 0.010 in. (0.25 mm) has occurred at the loaded end of the bar. Record the dial-gage readings to an estimated 0.1 of the least division of the dial (Note 8).

10.5 Continue the loading and readings at appropriate intervals until (*1*) the yield point of the reinforcing bar has been reached, (*2*) the enclosing concrete splits, or (*3*) a slippage of at least 0.10 in. (2.5 mm) has occurred at the loaded end.

NOTE 8–The operation or applying the load and reading and recording the two dial gages is best performed by a crew of five: the machine operator, two people to read the dial gages, and two to record. The machine operator calls "Read" as the first 500 lbf (2.2 KN) of load is applied and as each 1000-lbf (4.4 KN) increment of load is applied. On this signal the dial gage readers call out the restrictive readings to the crew member recording for the respective dial gages. The readings are taken and recorded simultaneously without stopping the application of load.

11. Calculation

11.1 Calculate the nominal average bond stress as the load on the bar as recorded at any stage in the test divided by the nominal surface area of the entire embedded length of the bar. For No. 6 deformed bars having an embedded length of 6 in. (150 mm), the surface area to be used in this calculation may be taken as 14.14 in. (90 cm).

11.2 Calculate the slip of the bar as the average of the readings of the two dial gages. Corrected for the elongation or the reinforcing bar in the distance between the bearing surface of the concrete cube and the point on the reinforcing bar where the measuring device was attached. For calculating this elongation, the nominal cross-sectional area of a No. 6 bar may be taken as 0.44 in. (284 mm), and the modulus of elasticity may be assumed to be 29×106 psi (200 GPa). Theoretically, a similar correction is required for the compression of the concrete between the bearing surface and the location at which the yoke holding the dials is attached if the apparatus illustrated in Fig. 2 is used. This movement, however, is usually very small and may be eglected.

12. Report

12.1 The report shall include such of the following data as are pertinent to the variables or combinations of variables studied in the tests:

12.1.1 *Properties of the Concrete Mixture:*

12.1.1.1 Type and proportions of hydraulic cement, mineral admixtures, fine aggregate, coarse aggregate (including nominal maximum size and grading or designated grading indexes), and net water-cement ratio of the concrete.

12.1.1.2 Type and proportion of any admixture used.

12.1.1.3 Twenty-eight day compressive strength of control cylinders as determined by Test Method C 39.

12.1.1.4 Air content or freshly mixed concrete, indicating whether the Volumetric Method (Test Method C 173) or the Pressure Method (Test Method C 231) was used.

12.1.1.5 Unit weight of the concrete as determined by Test Method C 138.

12.1.1.6 Slump of the concrete as determined by Test Method C 143.

12.1.2 *Properties of Reinforcing Bars:*

12.1.2.1 Nominal diameter or designation of reinforcing bars, and measured mass per foot of length.

12.1.2.2 Measured values of deformation characteristics including spacing, height, inclination, and gap determined as specified in Specification A 615. If possible, a photograph or drawing of the bar, showing the pattern of surface deformation, shall be included.

2.1.2.3 Yield point of bars, determined in accordance with Test Methods and Definitions A 370.

12.1.3 *Mixing Concrete and Casting Specimens:*

12.1.3.1 *Method of Mixing*–If the standard method of mixing referred to in the section on mixing concrete is not used, describe the method actually used in detail, giving data on the order of adding and mixing the various ingredients and a time table of the various steps in the process.

12.1.3.2 *Method of Casting*–If the method of casting the specimens differs from that specified previously, describe the method used in detail.

12.1.4 *Curing:*

12.1.4.1 Age at which molds were removed.

12.1.4.2 Environment of specimens during curing if different from that specified, and length of time in environment.

12.1.5 *Procedure:*

12.1.5.1 The capping material used and the capping procedure, if different from that described. Distance from the bearing face of the concrete cube to the point on the reinforcing bar where the measuring apparatus was attached.

12.1.5.2 Type of testing machine used.

2.1.5.3 Rate at which load was applied in the test, and how measured.

12.1.6 *Results:*

12.1.6.1 It is recommended that the results of each test, or the average of the results obtained in tests of three companion specimens, be presented by plotting the nominal average bond stress as the ordinate, and the slip (between the reinforcing bar and the concrete) as the abscissa. The results of tests on the three types of specimens (vertical and horizontal at two depths of cover) shall not be averaged together.

12.1.6.2 It is recommended that comparisons between different values of the variables be based primarily on the relation of nominal average bond stress to the slip. For such comparisons, the nominal average bond stress measured at five equal intervals of slip, taken from the bond stress curves, shall be used. The values of slip to be used shall be from 0 to some specified limit which, in general, should not exceed 0.01 in. (0.25 mm).

12.1.6.3 For the horizontally embedded bars, the orientation of the longitudinal ribs on the reinforcing bars should be stated. Preferably, the two ribs of a bar should be in a common horizontal plane as cast. Also, results for the lower bar should be compared with results for the upper bar.

13. Precision and Bias

13.1 *Precision*–No data are known to exist that might serve as a basis for preparing a precision statement. Such data are being sought by the Subcommittee.

13.2 *Bias*–This test method has no bias because the values determined can be defined only in terms of the test method.

14. Keywords

14.1 Concrete bond; reinforcing steel