

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
5900 Folsom Blvd.
Sacramento, California 95819-4612



METHOD OF TEST FOR FLEXURAL STRENGTH OF RAPID STRENGTH CONCRETE

A. SCOPE

This test method describes the procedure used for determining the flexural strength or modulus of rupture of Rapid Strength Concrete (RSC) by the use of a simple beam with third point loading.

Rapid Strength Concrete is used on projects where short construction windows (6 to 55 h) require rapid curing (typically 3 to 24 h). This test method is typically used to fabricate and test samples at the jobsite to meet traffic-opening criterion.

B. REFERENCES

ASTM E 4 - Force Verification of Testing Machines
ASTM C 78/C 78M - Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)
California Test 539 - Sampling Fresh Concrete

C. APPARATUS

1. Testing Machine:

The testing machine shall conform to the requirements of Sections 16, 17, and 18 of ASTM E 4 and Section 4 of ASTM C 78/C 78M.

2. Beam molds:

- a. Molds shall be made of plastic or other material with a low coefficient of thermal conductivity and be non-reactive with concrete containing hydraulic cements.
- b. Molds shall maintain their dimensions and shape under all testing conditions.
- c. Molds shall be mortar tight during use. A suitable sealant, such as sealing caulk, heavy grease, modeling clay, or micro-crystalline wax shall be used where necessary to prevent leakage through the joints.
- d. Molds shall be lightly coated with mineral oil or another suitable non-reactive release material before use.
- e. The molds shall be 6 in. × 6 in. in cross section and a minimum of 20 in. in length. Maximum variation from the nominal cross section shall not exceed $\frac{1}{8}$ in.
- f. The surface of the molds shall be smooth and free from blemishes.

- g. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warping.
- 3. Vibrators: Internal vibrators shall be used. The vibrating frequency shall be at least 7000 vibrations per minute [150 Hz] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one third ($\frac{1}{3}$) the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the form by at least 3 in.
- 4. Small tools: Items such as shovels, scoops, pails, trowels, wooden floats, rubber hammers, sponges, and tachometers.
- 5. Insulating blankets.
- 6. Lime saturated water bath at $73^{\circ}\text{F} \pm 3^{\circ}\text{F}$ or moist cure room or sand pit as required by the contract documents.
- 7. Calipers (Vernier, dial or digital), U.S. Standard, 0 to 8 in. minimum range, calibrated.
- 8. Metal combination square, complete with metal rule with U.S. Standard graduations, 20 in. minimum length.
- 9. Copy of the approved mix design with the final set time clearly indicated.

D. CALIBRATION OF APPARATUS

All devices used for calibration shall be traceable to the National Institute of Standards and Technology (NIST).

- 1. Vibrators:
Verify vibrator frequency using a suitable calibrated tachometer at least once per shift.
- 2. The beam breaking machine:
Calibrate the beam breaking machine in accordance with the manufacturer's recommended procedure or ASTM E 4 at least once every 12 months. The span length of the load applying and support blocks shall be measured and recorded. The span length shall be 18 in. $\pm \frac{1}{16}$ in.

E. PREPARATION OF TEST SPECIMENS

- 1. Sampling fresh concrete:
 - a. Obtain a sample of concrete from the mass during the placing operation of sufficient mass, to fabricate three (3) beams of the size of beams selected for each testing age required. Sampling shall be in accordance with California Test 539.
 - b. Always remix the sample with a shovel on a nonabsorbent surface to assure that there is no segregation of the concrete.

- c. Beams must be cast immediately adjacent to the slab they represent within 10 min of sampling and prior to the loss of plasticity.
2. Molding test specimens:
- a. Beams shall be fabricated in sets of three (3) beams for each test age. Extra beams may be required if the contract documents require averaged test results of multiple beams. In this case, extra material may be required during sampling.
 - b. Before each use, apply a release agent such as a light coat of fresh oil to all inside surfaces of the mold.
 - c. Place concrete in the molds in one layer. Place the concrete in the molds so that it is uniformly distributed without segregation.
 - d. Vibrate the concrete. Maintain a uniform time period for the duration of vibration for the mold size and the type of vibrator used. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Sufficient vibration has been achieved when the surface of the concrete appears relatively smooth and no air bubbles are seen on the surface. Over vibration will cause segregation. The vibrator shall not be allowed to rest on the bottom or the sides of the mold.
 - e. Spade the concrete along the sides and ends of the beam molds with a trowel or other suitable tool to remove air voids if necessary.
 - f. Strike off surplus concrete and finish the surface with a wood float.
 - g. Finish the surface of the specimens with a minimum of manipulation necessary to provide a flat even surface that is level with the rim of the mold.
 - h. Record the beam fabrication time (nearest 15 min), date, weather conditions, ambient temperature, and number of beams fabricated for each age to be tested.
3. Curing test specimens:
- a. Apply the same curing medium to the top surface of the test beam as is applied to the pavement. Do not delay the application of the curing compound.
 - b. Upon application of the curing compound and as soon as the concrete slab is set (when it can take foot traffic) place the beams directly on the slab.
 - c. Cover the beams with an insulating blanket to hold the heat and moisture in the beams while they cure.
 - d. Transport beams, for 7 d or greater flexural strength test, with care to the laboratory. Cover with wet towels or other suitable material when transporting. See Note at the end of Section E.3.
 - e. Carefully remove the beam from the base plate and place in a lime water bath or moist curing room or sand pit for proper curing. The water bath

shall be maintained at $73^{\circ}\text{F} \pm 3^{\circ}\text{F}$. Store the specimens in the lime water bath or moist room or sand pit until the time of testing.

- f. The beams are to be placed in a lime water bath or moist cure room or sand pit (as required by the contract documents) between 5 and 10 times final set time or 24 hr, whichever is earlier of the RSC slab material being used.
- g. Sand pit option: Keep the sand surrounding the test specimens damp at all times, and cover with a tarpaulin to prevent the cooling effect of excessive evaporation. Place test specimens in a water bath 24 hr \pm 6 hr before testing. The water bath shall be $73^{\circ}\text{F} \pm 3^{\circ}\text{F}$. Store specimens in the water bath until the time for testing.

NOTE: Keep the beams thoroughly damp throughout the curing period. Even a few minutes exposure of beams to drying can seriously reduce the strength gain.

F. BEAM BREAKING METHOD

- 1. Procedure
 - a. Position the testing machine on a firm foundation well removed from the influence of jars and vibration caused by passing traffic.
 - b. Set the span length to 18 in. \pm $\frac{1}{16}$ in.
 - c. Using the combination square and metal rule, mark the locations of the load applying blocks. This will assist in measuring and determining if the fracture has occurred within the middle third of the span. It may be necessary to continue the marks completely around the beam, post break. Use the combination square to extend the marks.
 - d. Turn the test specimen on its side with respect to its position as molded, and center it on the bearing blocks.
 - e. Center the loading system in relation to the applied force.
 - f. Bring the load applying blocks in contact with the surface of the specimen at the third points between the supports. Check that "full contact" is obtained between the specimen and the loading blocks and supports. When there is not full contact, grind or cap the contact surfaces of the specimen, or shim with leather strips. (See notes below.)
 - g. Apply the load continuously at a rate that constantly increases the extreme fiber stress from 125 to 175 psi/min, until rupture occurs.

NOTES:

"Full contact" is obtained when no more than $\frac{3}{4}$ in. of load bearing block length has a gap in excess of 0.004 in.

It is recommended that grinding surfaces of the specimens be minimized as it may change the physical characteristics of the specimens and thereby affect the test results.

Use leather shims only when the specimen surfaces in contact with the blocks or supports depart from a plane by not more than 0.015 in. Leather shims shall have

a nominal thickness of $\frac{1}{4}$ in., shall be $\frac{3}{4}$ to 2 in. wide, and shall extend across the full width of the specimens.

If fracture occurs at a capped section, include the cap thickness in the measurement.

2. Measurement and Calculations

- a. Using the calipers, measure and record to the nearest $\frac{1}{16}$ in. the width of the beam at the tension side of the plane of fracture, and record this width as the value of "b."
- b. Using the calipers, measure and record to the nearest $\frac{1}{16}$ in. the depth of the beam at three points across the plane of fracture.
- c. Take the average of these three measurements as the depth, and record as the value of "d."
- d. When the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = 1.05 \frac{Pl}{bd^2}$$

Where: R = Modulus of rupture, psi

P = Maximum applied load indicated by the testing machine, lbf

l = Span length, in.

b = Width of specimen, in.

d = Average depth of specimen, in.

- e. Using the metal rule, measure and record the distance to the plane of fracture from the plane of load.
- f. When fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = 3.15 Pa/bd^2$$

Where: a = Average distance from line of fracture to the nearest support measured on the tension surface of the beam, in.

- g. If fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, discard the results of the test.

G. REPORT

The report shall include the following:

1. Identification number

2. Measured width to the nearest $\frac{1}{16}$ in.
3. Measured depth to the nearest $\frac{1}{16}$ in.
4. Span length, in.
5. Maximum applied load, lb
6. Test method used (e.g., CT 524)
7. Modulus of rupture calculated to the nearest 10 psi
8. Curing history and apparent moisture condition of the specimens at the time of test
9. If specimens were capped, ground or if leather shims were used
10. Defects in specimens including number of beams discarded when the fracture occurred in the tension surface outside of the middle third of the span length by more than 5 % of the span length
11. Age of specimens at testing time to the nearest 15 min, date, time, weather conditions, and ambient temperature

H. PRECISION AND BIAS

Difference in the individual test results of beams aged per contract requirement and Section E.3 above, tested by the same operator, must not exceed 16 %. When tested at two other laboratories, the results must not exceed 19 %.

Since there presently is no accepted standard for determining bias in this test method, no statement on bias is made.

I. PRECAUTIONS

Portland cement, when mixed with water, makes an alkaline solution. Contact with the skin can cause drying and cracking or dermatitis. Take care to prevent skin contact by wearing impervious gloves. If skin contact occurs, wash promptly with soap and water.

Fabricating and testing concrete specimens often involves lifting and stooping. Use proper lifting practices to prevent injury.

J. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

End of Text
(California Test 524 contains 6 pages)