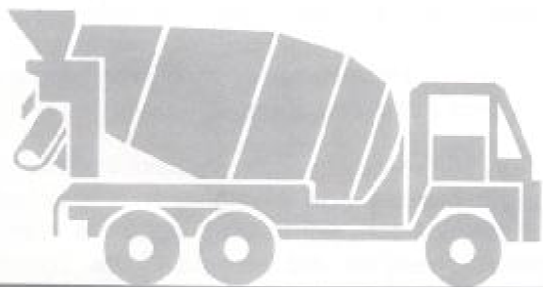


CONCRETE IN PRACTICE

CIP 16

What, Why, and How? Flexural Strength of Concrete

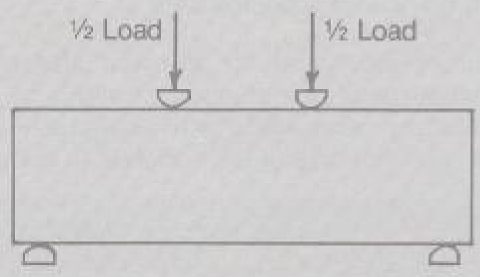
WHAT is Flexural Strength?

It is the ability of a beam or slab to resist failure in bending. It is measured by loading unreinforced 6 x 6 inch concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as "Modulus of Rupture" (MR) in psi.

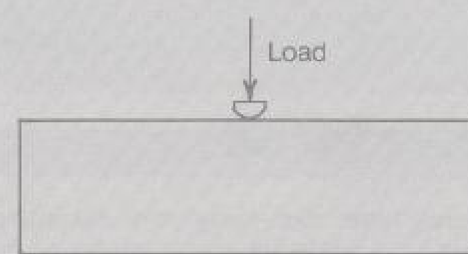
Flexural MR is about 12 to 20 percent of compressive strength. However, the best correlation for specific materials is obtained by laboratory tests.

WHY Test Flexural Strength?

Designers of pavements use a theory based on flexural strength. Therefore, laboratory mix design based on flexure may be required, or a cement content may be selected from past experience to yield the needed design MR. Some also use MR for field control and acceptance of pavements. Very few use flexural testing for structural concrete. Agencies not using flexural strength for field control generally find the use of compressive strength convenient and reliable to judge the quality of the concrete as delivered.[1]



ASTM C 78 — *Third-Point Loading,* half the load is applied at each third of the span length. MR so measured is lower than by C 293. Maximum stress is present over the center ⅓.



ASTM C 293 — *Center-Point Loading,* the entire load is applied at center span. The MR will be greater than C 78; the maximum stress is present only in the center of the span.

HOW to Use Flexural Strength

Beam specimens must be properly made in the field. Pavement concretes are stiff (½ to 2½ inch slump). Consolidate by vibration in accordance with ASTM C 31 and tap sides to release bubbles. For higher slump, after rodding, tap the molds to release bubbles and spade along the sides to consolidate. *Never allow the beam surfaces to dry at any time.* Immerse in saturated lime water for at least 20 hours before testing.

Specifications and investigation of apparent low strengths should take into account the higher variability of flexural strength results. Standard deviation for projects with good control range from about 40 to 80 psi. Values over 100 psi indicate testing problems, and there is a high likelihood that testing problems, or moisture differences within a beam, will cause low strength.

Where a correlation between flexural and compressive strength has been established, core strengths by ASTM C 42 can be used for compressive strength to check it against the desired value using the ACI 318 85 percent criteria. It is impractical to saw beams from a slab for flexural testing. Sawing beams will greatly reduce measured flexural strength and should not be done. Some use has been made of measuring indirect tensile strength of cores by ASTM C 496, but experience is lacking on how to apply the data.

Another procedure for in-place strength investigation uses compressive strength of cores calibrated by comparison with acceptable placements on either side of the concrete in question:

Method to Troubleshoot Flexural Strength Using Compressive Strength of Cores when Adjacent Lots are O.K.

Lot 1	Lot 2	Lot 3
MR = 730 (O.K.) CORE = 4492	688 (?) 4681	731 (O.K.) 4370

Estimate Flexural Strength of Lot 2 =

$$4681 \frac{(730 + 731)}{(4492 + 4370)} = 771 \text{ psi}$$

WHAT are the Problems with Flexure?

Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure. Beam specimens are very heavy, and allowing a beam to dry will yield lower strengths. Beams must be cured in a standard manner, and tested while wet.[2] *A short period of drying can produce a sharp drop in flexural strength.*

Many state highway agencies have used flexural strength but are now changing to compressive strength for job control of concrete paving. Cylinder strengths are also used for concrete structures.

> "The data point to a need for a review of current testing procedures. They suggest also that, while the flexural strength test is a useful tool in research and in laboratory evaluation of concrete ingredients and proportions, it is too sensitive to testing variations to be usable as a basis for the acceptance or rejection of concrete in the field."[3]

The CSI Spec-Data Sheet on Ready Mixed Concrete for Paving and Surfacing by NRMCA, the Municipal Concrete Pavement Manual by ACPA, ACI 325, and ACI 330 on Concrete Pavements, all point to the use of compressive strength as more convenient and reliable. The Pennsylvania DOT uses compressive strength of cylinders; 3750 psi is specified with 3000 psi for opening a pavement to traffic.

The concrete industry and inspection agencies are much more familiar with traditional cylinder compression tests for control and acceptance of concrete. Flexure can be used for design purposes, but the corresponding compressive strength should be used to order and accept the concrete. Any time trial batches are made, both flexural and compressive tests should be made so that a correlation can be developed for field control.

References

1. "How Should Strength be Measured for Concrete Paving?" by Richard C. Meininger, NRMCA TIL 420, and "Data Summary," NRMCA TIL 451.
2. "Significance of Tests and Properties of Concrete and Concrete-Making Materials," Chapter 12 on Strength, ASTM STP 169B.
3. "Studies of Flexural Strength of Concrete, Part 3, Effects of Variations in Testing Procedures," by Stanton Walker and D. L. Bloem, NRMCA Publication No. 75 (ASTM Proceedings, Volume 57, 1957).
4. "Variation of Laboratory Concrete Flexural Strength Tests," by W. Charles Greer, Jr., ASTM, Cement, Concrete and Aggregates, Winter, 1983.
5. "Concrete Mixture Evaluation and Acceptance for Air Field Pavements" by Richard C. Meininger and Norman R. Nelson, ASCE Air Field Pavement Conference, September, 1991. NRMCA Publication No. 178.

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