WHAT is Flexural Strength

Flexural strength is an indirect measure of the tensile strength of concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending. It is measured by loading 6 x 6-inch (150 x 150-mm) concrete beams with a span length at least three times the depth. Smaller beam specimens of cross-section 4 x 4-inch (100 x 100-mm) are also recognized as a standard size. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C78 (third-point loading) or ASTM C293 (center-point loading). The specimen size and type of loading do impact the measured flexural strength and comparisons or requirements should be based on the same beam size and loading configuration. The MR measured by third-point loading (ASTM C78) is lower than that determined by center-point loading (ASTM C293), sometimes by as much as 15 percent. It is also observed that a lower flexural strength will be measured with larger beam specimens.

Flexural strength is about 10 to 15 percent of compressive strength depending on the mixture proportions and type, size and volume of coarse aggregate used. For design of building members an estimate of the MR is obtained by:

\[ f_r = 7.5 \sqrt{f'_c} \]

where

\( f_r \) is the MR; \( f'_c \) is the specified compressive strength

When MR is critical to design, the best estimate is established from laboratory tests for specific mixtures and materials used.

WHY Measure Flexural Strength

Design of the thickness of concrete pavements are based on the flexural strength or MR. Factors include traffic loading and subgrade stiffness. Pavement designers often require validation that the proposed mixture will achieve the MR used in design. Concrete mixtures should be proportioned to achieve the MR as specified in contract documents. When acceptance in the field will be based on flexural strength tests, the concrete mixture should be appropriately designed to achieve a higher strength level that will reduce the risk of failing test results. Agencies that do not use MR for field control generally use compressive strength as it is more convenient and reliable to judge the quality of concrete as delivered. A pre-established relationship between compressive and flexural strength may be developed for this purpose. Flexural strength testing is not used for structural concrete.

HOW is Flexural Strength Used

Flexural strength is conservatively neglected in calculating the nominal flexural strength for design of structural members. The flexural strength, estimated from the empirical relationship, is used estimate the tensile stress that causes cracking of non-reinforced concrete and to evaluate deflections at service loads.

Most state highway agencies use compressive strength and not flexural strength tests for acceptance testing of road pavements. Flexural strength tests are useful in research and laboratory
evaluation of mixtures, but the sensitivity to testing variations does not lend itself to be used as a basis for acceptance or rejection of concrete in the field. Flexural strength tests for jobsite acceptance is commonly used for airfield pavements. Beam specimens must be prepared in accordance with ASTM C192 in the laboratory and ASTM C31 in the field. Consolidate by rodding or vibration, tap sides to release air pockets, and spade along the sides. Follow the temperature and moisture retention requirements for standard curing. 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 testing. Standard deviation for concrete flexural strength tests from subsequent loads for projects with good control range from about 40 to 80 psi (0.3 to 0.6 MPa). Standard deviation values exceeding 100 psi (0.7 MPa) may indicate problems with testing.

Where a correlation between flexural and compressive strength has been established, compressive strength of cores determined in accordance with ASTM C42 can be used. Reduced strength measured on cores should be taken into account. Sawing beams for flexural strength tests will show a greatly reduced measured flexural strength and should not be done. Splitting tensile strength of cores by ASTM C496 is sometimes used, but experience is limited.

Another procedure for in-place strength investigation uses compressive strength of cores calibrated by comparison with acceptable placements in proximity to the concrete in question.

### Method to Estimate Flexural Strength Using Compressive Strength of Acceptable Lots

<table>
<thead>
<tr>
<th></th>
<th>Lot 1</th>
<th>Lot 2</th>
<th>Lot 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR, psi</td>
<td>730 (OK)</td>
<td>688 (?)</td>
<td>731 (OK)</td>
</tr>
<tr>
<td>Core, psi</td>
<td>4492</td>
<td>4681</td>
<td>4370</td>
</tr>
</tbody>
</table>

Estimated Flexural Strength of Lot 2 =

\[
4681 \times \frac{730 + 731}{4492 + 4370} = 771 \text{ psi (OK)}
\]

### References