Test method T374

Determination of the toughness of a fibre reinforced shotcrete mix

OCTOBER 2012

Revision Summary

Ed/Rev Number	Clause Number	Description of Revision	Authorisation	Date
		New issue (Greg Forster)	D.Dash	May 1999
Ed 2/ Rev 0	All	Reformatted RMS template	J. Friedrich	October 2012

Note that Roads and Maritime Services is hereafter referred to as 'RMS'.

The most recent revision to Test method T374 (other than minor editorial changes) are indicated by a vertical line in the margin as shown here.

Test method T374

Determination of the toughness of a fibre reinforced shotcrete mix

Centrally loaded beam test

1. Scope

The purpose of this test method is to determine the toughness of a particular fibre reinforced shotcrete mix. It shall be assessed by measuring the amount of energy that can be absorbed by a beam when centrally loaded

2. Apparatus

Beams shall be tested in a stiff machine that can apply a central load to the specimen at a constant rate through an automatic servo-control mechanism. Such a machine is commonly described as a 'displacement controlled' test machine with an 'open loop' servo mechanism.

The load shall be applied through a central roller, capable of rotating about its own axis should the beam move during a test, which is sufficiently stiff to impose a load that is uniformly distributed across the beam width. One of the two lower rollers shall be fixed against rotation about an axis parallel to the longitudinal axis of the beam, whilst the other shall be free to rotate about this axis. The central roller shall be free to rotate about an axis parallel to the longitudinal axis of the beam (see Fig. 1). Such an arrangement of rollers will minimise torsion in the specimen arising from initial distortions in the surfaces of the specimen.

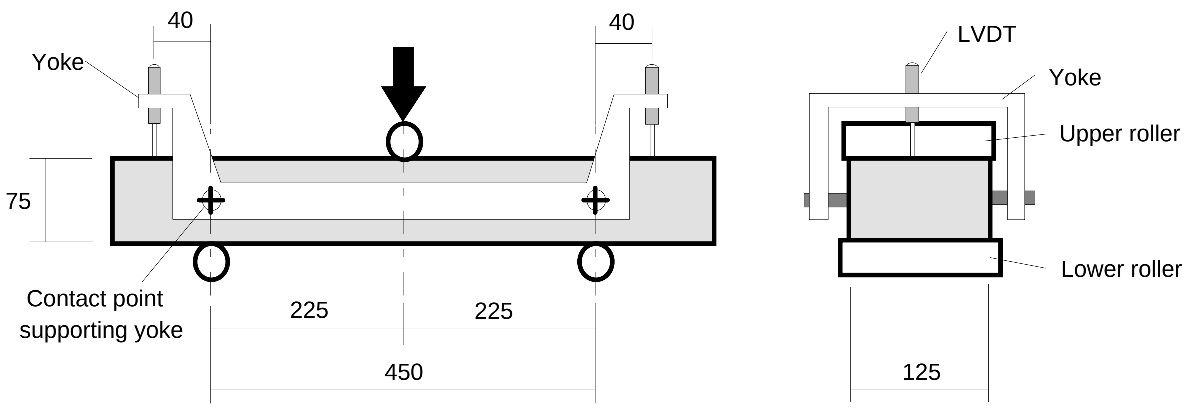

Fig. 1 - Typical fixture for centrally loaded beam test

Rotation of the ends of the beam shall be measured by displacement-recording devices (transducers) positioned so as to record displacement of the upper surface of the beam a distance at least 40 mm outboard of the supports, as shown in Fig. 1. Displacement transducers shall be fixed to a yoke that straddles the beam and is attached at mid-height immediately above the support points. The design of the yoke shall comply with the provisions of
ASTM C-1018-1994 to eliminate extraneous displacements from the measured record. In this way, the true rotation of each end of the beam relative to the supports can be determined.

3. Preparation of Test Specimens

(a) Moulding

Beams shall be cut from panels produced either during trial mixing or during production.

Forms shall comprise square melamine-coated formply constructed with inclined sides in such a manner that the base of the form measures 600 mm square, and the upper surface measures 800 mm square. The overall thickness of the panel produced by spraying concrete onto this form shall be at least 150 mm (see Fig. 2). The formply shall be at least 17 mm thick, but 25 mm ply may be used for the base to improve the flatness of the underside of the specimen and reduce the likelihood of vibration during spraying. The underside of the formply shall be stiffened with minimum 70×35 mm timber sections to ensure that the form maintains a close-to-flat base during spraying. Formply and stiffeners shall form a level and undistorted base.

Coating the form with release agent prior to spraying may assist stripping, but can also make it difficult for the sprayed concrete to stick to the vertical form. Re-application of release agents after stripping and cleaning can extend the life of forms.

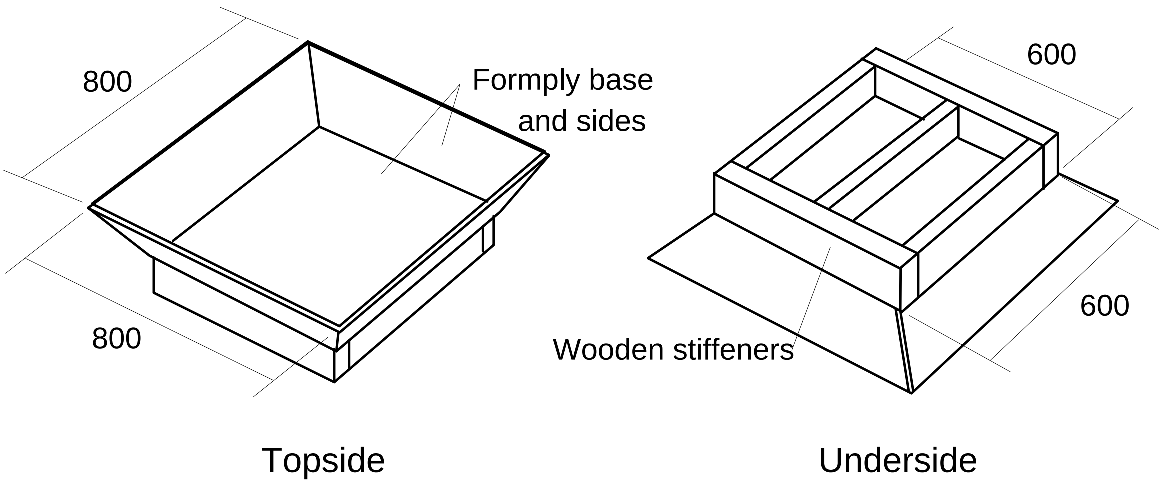

Fig. 2 - Square forms for panel production from which beam specimens are later cut.

The panels shall be sprayed to an overall thickness of at least 150 mm and do not need to be screeded to a uniform thickness as the unformed surface can be left rough.

(b) Cutting

After spraying the panel shall be left to harden for a period of 3 days adjacent to the finished structure. After this time has elapsed the panel shall be stripped and beams cut. The cutting of final beams directly from a panel is seldom satisfactory unless a rigid Bridge Saw, or equivalent, of sufficient size is used. In most circumstances it is preferable to initially cut rough over-sized beams from a panel and later trim these to the required final size. Regardless of which method is used, three beams measuring 75×125×550 mm shall be obtained from the same panel. These shall have smooth and parallel sides, and edges shall be perpendicular. Beams shall be cut and tested 'on the flat' such that the plane of bending in each beam coincides with the plane of bending in the panel (see Figs. 1 and 3). Following cutting, the beams shall be transferred to a laboratory for curing and testing. Beams shall be cured immersed in water at 23±2°C until the time of testing and tested wet.

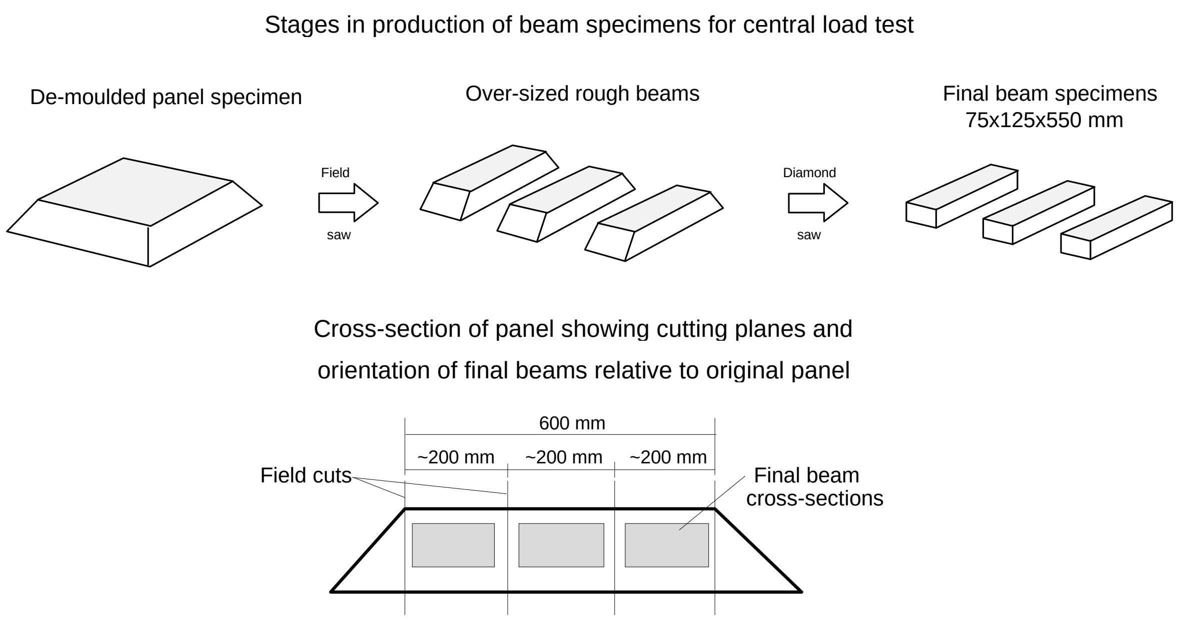

Fig. 3 - Production of beam specimens.

4. Test Procedure

1. Mark the centre of the beam with ink at the midpoint between the two supports.
2. Impose a load at the centre of the beam using a rate of displacement of 0.25 □□ 0.025 mm / min.
3. Record the applied load (P Newtons) and displacement of the two end transducers (d_1 , d_2) at intervals of 0.01 mm displacement of the central transducer (d_3).
4. Note the displacement (d_3) at which the beam cracks. If more than one crack appears discard the test.
5. Measure the width (b_1 and b_2 mm) and thickness (h_1 and h_2 mm) of the beam immediately adjacent to, and on either side of the crack.
6. Measure the distance (x_1, x_2 mm) that each end of the crack is offset from the centre of the beam.
7. Plot a graph of the corrected moment (normalised to a width of 125 mm) versus crack rotation.
8. Determine the area under the moment / crack rotation graph from 0 to 0.05 radians rotation. This value is the energy absorbed in Joules.
9. Determine the peak flexural stress reached during the test.
10. A minimum of three beams shall be tested and averaged to determine the mean energy absorption up to 0.05 radians of crack rotation.

5. Calculations

(a) Rotation, $R = \dfrac{d}{\ell}$ (radians)

where d = vertical displacement at beam end (mm)
ℓ = distance from support at beam end (mm)

(b) Total rotation, $R_t = R_1 + R_2$ (radians)

where R_1, R_2 are the rotations of each end of the beam

(c) Pre-crack rotation, R_p (radians)

(d) Crack rotation, $R_c = R_t - R_p$ (radians)

(e) Moment, $M = \frac{PL}{4}$ (Nmm)

where P = applied force (N)
L = distance between supports (mm)

(f) Corrected Moment, $M' = M\,(1 - \frac{2x}{L})$ (Nmm)

where x = offset of crack from centre of beam
$= (x_1 + x_2)/2$ (mm)

(g) Corrected Normalised Moment,

$$M_n = M' \frac{125}{b}$$ (Nmm)

where b = mean beam width (mm) $= (b_1 + b_2)/2$

(h) Read the peak moment Y (Nmm) from the graph of corrected normalised moment vs rack rotation.

(i) Section modulus, $Z = \frac{bh^2}{6}$ (mm^3)

Where h = mean beam thickness (mm) $= (h_1 + h_2)/2$

(j) Peak flexural stress $\sigma_p = \frac{Y}{Z}$ (MPa)

6. Reporting of Results

The following results for a single point beam test shall be reported:

(a) Specimen identification

(b) Location, position, time, and date of spraying, and name of nozzle operator

(c) Curing conditions, and age at testing

(d) Identification of testing laboratory

(e) The two measured beam widths and thicknesses, and mean values

(f) Moment-crack rotation curve as calculated from recorded data

(g) Peak stress achieved (in MPa)

(h) Energy absorption up to 0.050 radians of crack rotation (in Joules)

(i) Number of cracks formed during test