Products For Concrete

Scanfibre - Flexural Toughness Testing

INTRODUCTION

Scancem Materials have a reputation for the supply of advanced products for concrete backed by high-level technical support. They are also the leading supplier of steel fibres in Australia.

For the last 20 years the Scancem group's team of engineers have been studying the behaviour of steel fibres in concrete. Our knowledge has developed to a stage where we know:

- How fibres behave in concrete
- What fibre characteristics lead to performance in concrete
- How to apply limit state design principles to steel fibre slabs on grade

Our technology enables clients to achieve a high performance slab on grade at the minimum cost using specially developed steel fibres and a related guaranteed design approach.

Key to the use of fibres of any make is the performance they impart to concrete. This data sheet outline "toughness", the only performance measure appropriate for comparing steel fibres, as applied to slabs on grade. It outlines how toughness is measured, and what values are used for design.

TOUGHNESS DEFINITION

The principle effect of steel fibres in concrete is to enhance the concrete's post crack strength i.e. fibres only become effective after the concrete cracks and any design approach must therefore reflect this to be of any value.

Increases in concrete characteristic strength values such as compressive strength and flexural tensile strength are typically quite small at economic fibre dosage rates (<1% by volume or 80kg/m^3) and are not of significance for design purposes.

To benefit from the use of fibres, it is necessary to adopt a design procedure to take account of the strength after cracking i.e. away from the area of elastic behaviour on the load/deflection graph (Fig.1) and into the plastic or hinge forming area of the graph which permits a redistribution of stresses.

The area beneath this load/deflection graph is a measure of the energy required to achieve a certain deflection and is a measure of the ductility that a fibre reinforced composite possesses. The term "toughness" has been coined to convey the existence of the post cracking region of the load/deflection graph for a fibre reinforced concrete.

Toughness is the property that needs to be used in determining the load carrying capacity of steel fibre reinforced concrete (SFRC). Determining the load carrying capacity based on the uncracked section properties will not effectively differentiate between a plain concrete and a reinforced concrete, they both have essentially the same properties here and is the same reason that conventionally reinforced concrete is also designed on the basis of a cracked section.

The two countries, which have enjoyed the widest acceptance for toughness tests, are the USA and Japan who have introduced standards for this work.

Fig 1 – Load Deflection Curve

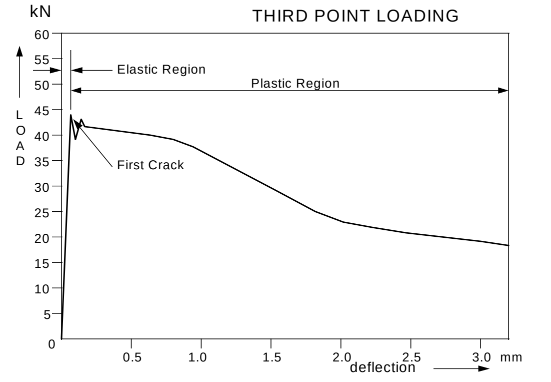
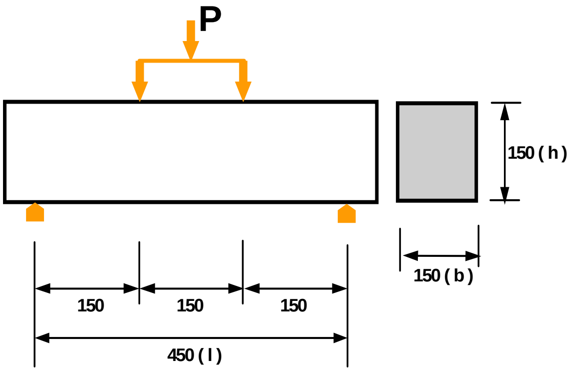


Fig 2 - Flexural Strength Test Set-up



USA Standard C1018 and Japanese Standard JCI-SF4 are both based on the third point loading of a beam of square cross section spanning a three times its depth (Fig. 2).

In subsequent procedures, the two codes differ in their approach.

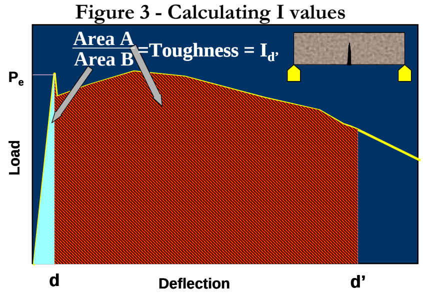
ASTM C1018 TOUGHNESS INDEX

This standard defines a toughness Index I as the ratio of the absorbed energy up to a given deflection to the absorbed energy up to first crack.

The standard toughness indices defined in ASTM C1018 are I5, I10 and I30 defined for deflections of 3δ, 5.5δ and 15.5δ where δ is the deflection at first crack. These indices are qualitative only and although not suitable for load capacity design can be used for comparative purposes

The accuracy of measurement of I is dependent on the ability to measure δ accurately, which typically for I5 (3δ) is around 0.05 - 0.1 mm. Apart from possible measuring errors, the deflection at first crack can rapidly increase past 3δ making the graph in this area dubious, and I5 values are seldom used.

Figure 3 - Calculating I values



JAPANESE STANDARD JSCE-SF4

This code provides numerical values for the purpose of design by defining an allowable "residual or effective" stress value up to a given deflection based on the load deflection graphs of standard beam tests for a particular SFRC sample.

From the area under the load/deflection graph up to a defined deflection value and using the physical characteristics of the standard beam test, it is possible to define an equivalent flexural strength (fe). It is in effect the average load value over the defined area of the load deflection graph expressed as a stress.

The equivalent flexural strength is a value that can be used directly for design. The value fe,3 which corresponds to a final deflection of :-

l/150 = 3mm

is often chosen as it reflects the strength at an acceptable deflection.

DEFLECTION

There need be no concern that the large cracks resulting in a beam at the high deflection (eg 3mm) used to determine effective stress values will also occur in the designed element. Suggestions that effective stress values should be determined at a lower deflection value to limit crack widths are thus erroneous.

Use of a toughness value and hence effective stress value determined at a high deflection is finding wide acceptance as a design value for the following reasons:-

- The equivalent flexural strength determined tends to decrease as the deflection value chosen increases. Hence, use of the toughness at a high (eg 3mm) deflection will give a lower design stress than would be derived at a lower deflection value and is thus more conservative. Lower applied stresses will also cause less cracking than using a higher allowable stress determined for a lower deflection toughness.
- The use of a performance characteristic at much higher deflections than occurs in practice is consistent with normal limit state design for RC sections. Conventional reinforcement is assumed to be yielding for capacity design.
- The limit state design approach is the only approach that takes account of post crack strength. As fibres only work after cracking it is a logical approach.
- The load capacity of full scale tests relates well to design values using the limit state approach at high deflections.
- At low deflections, near first crack, the toughness measurements are unstable and should not be used.

TESTING FACILITIES

Although the toughness test appears simple it is in fact difficult to undertake accurately. Scancem Materials have seen results from many laboratories claiming to be able to undertake toughness tests. Unfortunately most are totally unreliable. The following laboratories have proven reliable in testing steel fibre beams fro toughness.

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There can also be difficulty in making steel fibre samples. Only laboratories that have proven experience in making steel fibre samples should be used.

Figure 4 - Testing a beam for tougness