SS 674:2021
SS 812310:2014, MOD
(ICS 91.080.40; 91.100.30)

SINGAPORE STANDARD

Fibre concrete – Design of fibre concrete structures

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Fibre concrete – Design of fibre concrete structures

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BCSC set up the Technical Committee on Building Structures and Substructures to oversee the preparation of this standard. The Technical Committee consists of the following members:

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The Technical Committee set up the Working Group on Fibre concrete – Design of fibre concrete structures to prepare this standard. The Working Group consists of the following experts who contribute in their *individual capacity*:

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The organisations in which the experts of the Working Group are involved are:

Arup Singapore Pte Ltd
Association of Consulting Engineers Singapore
Bekaert MacCafferi Underground Solutions BVBA
Building and Construction Authority
Continental Steel Pte. Ltd.
CPG Consultants Pte Ltd
Housing & Development Board
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PUB, Singapore's National Water Agency
SETSCO Services Pte Ltd
Singapore Contractors Association Limited
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National Foreword

This Singapore Standard was prepared by the Working Group on Fibre concrete – Design of fibre concrete structures set up by the Technical Committee on Building Structures and Substructures under the purview of BCSC.

This standard is a modified adoption of SS 812310:2014, “Fibre concrete – Design of fibre concrete structures”, including its Amendment, published by the Swedish Institute for Standards.

In this standard, minor modifications have been made in Tables P.1 and Q.2 due to national requirements and the particular needs of the local industry. These technical deviations and additional information have been added directly to the clauses and are marked by a vertical bar on the left margin of the standard. The modifications are as follows:

a) Modification of requirements for Table P.1 – Properties to be determined during initial testing of fibre concrete, in addition to the requirements in SS EN 206:

   – Test method for residual flexural tensile strength at 28 days in EN 14651, the number of samples per test occasion was amended from 6 beams to 12 beams;

   – Test method for steel fibre distribution in fresh concrete in EN 14721, the number of samples per test occasion was amended from 1 to 3;

   – Test method for polymer fibre distribution in fresh concrete in EN 14488-7, the number of samples per test occasion was amended from 1 to 3.

b) Modification of requirements for Table Q.2 – Test frequency for the execution control of fibre concrete:

   – Test method for fibre content in SS-EN 14721 (steel fibres) and SS-EN 14488-7 (polymer fibres):

      - Under execution class 2, was amended from 1 per 300 m^3 or 1 per pour to 1 per 100 m^3 or 3 per pour; and

      - Under execution class 3, was amended from 1 per 100 m^3 or 1 per pour to 3 per 100 m^3 or 3 per pour.

   – Test method for residual flexural tensile strength in SS-EN 14651, under execution class 3, was amended from 1 per 100 m^3 or 1 per pour to 2 per 100 m^3 or 2 per pour;

   – Note 1 – Amended from 6 beams to 12 beams.

The following changes, including some minor edits, were also made within the body of this standard:

– Amended the standards in the normative references and bibliography from SS-EN (Swedish Standards) to SS EN (Singapore Standards) or BS EN where applicable;

– Amended SS 812310 to SS 674.

In Singapore, the following practices are adopted:

– The fibre orientation factor η_f is taken as 1 for horizontally cast members such as slabs and tunnel segments. For other cases, η_f is taken as 0.5.

– The magnification factor η_{det} is generally taken as 1.

– Fibres are used together with bar reinforcement in beams and other structural members subjected to significant tensile stresses.

NOTE – Where numerical values are expressed as decimals, the comma is read as a full point.

Attention is drawn to the possibility that some of the elements of this Singapore Standard may be the subject of patent rights. Enterprise Singapore shall not be held responsible for identifying any or all of such patent rights.

Introduction

This Standard has been prepared in order to provide National guidelines on how to design fibre concrete structures in accordance with SS EN 1992-1-1. SS 674 is not a Eurocode but it is complement to SS EN 1992-1-1. Both documents should be read in conjunction with each other for a full comprehension of the subject.

This Standard follows the same Section configuration as SS EN 1992-1-1 and provides additional paragraphs and amended text where necessary to aid fibre concrete design, plus relevant figures, tables and equations.

Repetition of text from SS EN 1992-1-1 has been avoided as far as possible and is only included when absolutely necessary for the comprehension of this Standard. Figures, tables and equations are numbered according to the separate Sections, i.e. the first figure in Section 3 is notated as 3.1, the second figure 3.2 and so on.

This Standard deals mainly with fundamental requirements concerning general issues, basis of design, materials, structural analysis, ultimate limit state, and serviceability limit state (Sections 1, 2, 3, 5, 6, and 7). Durability is treated equally for fibre concrete and conventionally reinforced concrete and is covered in SS EN 1992-1-1, Section 4. This Standard addresses Section 8.2 *Spacing of bars* and both Sections 9.2 *Beams* and 9.3 *Solid slabs* with regards to minimum flexural reinforcement. There is no need for changes to SS EN 1992-1-1 Section 10 *Additional rules for precast concrete elements and structures* or Section 12 *Plain and lightly reinforced concrete structures*. This standard for fibre concrete covers creep and shrinkage, members not requiring design shear reinforcement, and punching in Section 11.

This Standard covers fibre concrete structures. The term “fibre concrete” instead of “steel fibre concrete” or “steel fibre reinforced concrete” has been selected deliberately since the intention is to develop a standard that is material-independent regarding the fibre material. However, the scientific basis for the Standard is predicated on numerous test results and literature references primarily devoted to steel fibre concrete and secondly, but to a much lesser degree, polymer fibre concrete. Despite the fact that the fibre concrete material properties and equations given are defined or derived from proposed fibre material-independent tests it is emphasized that the polymer fibres currently available in the market may either lead to very low values of strength, moment capacity and/or stiffness of the fibre concrete or mixes needing such high fibre amounts that they will be difficult to cast outside the laboratory.

1 General

1.1 Scope

This Standard applies to the design of buildings and other civil engineering works in concrete with steel fibres and or polymer fibres according to BS EN 14889-1 and BS EN 14889-2. The Standard does not cover glass, carbon, basalt or any other type of fibres.

This Standard is intended to be used in conjunction with SS EN 1992-1-1 Eurocode 2: Design of structures – Part 1-1: General rules and rules for buildings.

NOTE SS 674 is not a Eurocode.

The following subjects are dealt with in this Standard:

Section 1: General
Section 2: Basis of design
Section 3: Materials
Section 5: Structural analysis
Section 6: Ultimate limit states (ULS)
Section 7: Serviceability limit states (SLS)
Section 8: Detailing of reinforcement and prestressing tendons - General
Section 9: Detailing of members and particular rules
Section 10: No section 10 in SS 812310
Section 11: Lightweight aggregate concrete structures

Annex O: Calculation of strains and stresses in bending
Annex P: Production and conformity control of fibre concrete
Annex Q: Execution control of fibre concrete
Annex R: Expected Coefficient of Variation for beam tests according to BS EN 14651
Annex S: Fibre concrete, statically indeterminate structures, and magnification factors

1.2 Normative references

The following normative documents contain provisions which, through references in this text, constitute provisions of this Standard. For dated references, subsequent amendments to or revisions of any of these publications do not apply. However, parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the normative document referred to applies.

SS EN 206:2014, *Concrete — Specification, performance, production and conformity*

BS EN 14488-7, *Testing sprayed concrete — Part 7: Fibre content of fibre reinforced concrete*

BS EN 14651, *Test method for metallic fibre concrete — Measuring the flexural tensile strength (limit or proportionality (LOP), residual)*

BS EN 14721, *Test method for metallic fibre concrete — Measuring the fibre content in fresh and hardened concrete*

BS EN 14889-1, *Fibres for concrete — Part 1: Steel fibres — Definitions, specifications and conformity*

BS EN 14889-2, *Fibres for concrete — Part 2: Polymer fibres — Definitions, specifications and conformity*

SS EN 1992-1-1:2008, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*

1.5 Definitions

1.5.2 Additional terms and definitions used in this Standard

1.5.2.5 Fibre concrete

Structural or non-structural concrete members in which the concrete matrix provides compressive strength and protection of the fibres, whereas the fibres provide tensile strength and ductility after cracking. For structural members the fibre has to fulfil the requirements in BS EN 14889-1 (steel fibres) and BS EN 14889-2 (polymer fibres).

1.5.2.6 Steel fibre

Straight or deformed pieces of cold-drawn steel wire, straight or deformed cut sheet fibres, melt extracted fibres, shaved cold drawn wire fibres and fibres milled from steel blocks which are suitable to be homogeneously mixed into concrete or mortar.

[BS EN 14889-1 Section 3.1]

1.5.2.7 Polymer fibre

Straight or deformed pieces of extruded, oriented and cut material which are suitable to be homogeneously mixed into concrete or mortar.

[BS EN 14889-2 Section 3.2]

1.5.2.8 Designed concrete

Concrete for which the required properties and additional characteristics if any are specified to the producer who is responsible for providing a concrete conforming to the required properties and additional characteristics.

[BS EN 206 Section 3.1.1.4]

1.5.2.9 Prescribed concrete

Concrete for which the composition of the concrete and the constituent materials to be used are specified to the producer who is responsible for providing a concrete with the specified composition.

[SS EN 206 Section 3.1.1.10]

1.6 Symbols

For the purposes of this standard, the following symbols apply.

NOTE All other relevant symbols for comprehension of this standard can be found in SS-EN 1992-1-1.

Latin upper case letters

C_i	Residual strength factor
R_{ax}	Factor defining the degree of external axial restraint provided by elements attached to the element considered or by friction with the soil

Latin lower case letters

$f_{ct,L}^{f}$	Limit of proportionality as obtained from beam testing in accordance with BS EN 14651
$f_{R,1}$	Characteristic residual flexural tensile strength of a fibre concrete of class R_1
$f_{R,3}$	Characteristic residual flexural tensile strength of a fibre concrete of class R_3
$f_{R,4}$	Characteristic residual flexural tensile strength of a fibre concrete of class R_4
$f_{R,1,i}$	Individual test results for residual flexural tensile strength of a fibre concrete of class R_1
$f_{R,3,i}$	Individual test results for residual flexural tensile strength of a fibre concrete of class R_3
$f_{R,1m}$	Mean residual flexural tensile strength of a fibre concrete of class R_1
$f_{R,3m}$	Mean residual flexural tensile strength of a fibre concrete of class R_3
$f_{ctk,0.05}$	Characteristic value of the tensile strength for the concrete matrix in accordance to the current codes
$f_{ft,R1}$	Characteristic residual tensile strength of a fibre concrete of class R_1
$f_{ft,R3}$	Characteristic residual tensile strength of a fibre concrete of class R_3
$f_{ftd,R1}$	Design residual tensile strength of a fibre concrete of class R_1
$f_{ftd,R3}$	Design residual tensile strength of a fibre concrete of class R_3
k_n	Statistical factor
k_f	Factor to consider the ratio between the residual tensile strength and the tensile strength
l_{cs}	Characteristic length
w_u	Ultimate crack opening

Greek lower case letters

γ_f	Partial factor for fibre concrete
η_f	Fibre orientation factor
η_{det}	Factor considering the degree of indeterminacy
ε_{ct}	Tensile cracking strain
ε_{ftu}	Ultimate tensile strain in fibre concrete
$\phi_{s,f}$	Modified reinforcement bar size for fibre reinforced concrete

2 Basis of design

2.3 Basic variables

2.3.2 Material and product properties

2.3.2.1 General

(3) Provisions for fibre concrete are given in Section 3.

(4) Structural components designed with this Standard shall have structural system stability (system equilibrium) in ultimate limit state after a fully developed crack system. This requires that one of the following conditions is fulfilled:

— stress redistribution is possible in a statically indeterminate system

— conventional steel bar reinforcement or pre-tensioned steel reinforcement in combination with fibre concrete is used

— external normal forces maintain equilibrium.