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Design of concrete-filled steel tubular (CFST) hybrid structures

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Foreword

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This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and prestressed concrete*.

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Introduction

Concrete-filled steel tubular (CFST) hybrid structures employ CFST members as their main members, and construct with steel or reinforced concrete members or components to act compositely. They consist of trussed CFST hybrid structures, concrete-encased CFST hybrid structures, etc. The economic and environmental benefits of CFST hybrid structures have made them one of the desirable structural types for constructions in relatively tough and harsh conditions, such as mountainous areas, earthquake-prone regions, corrosive environments, and less-developed regions. They can also be used in conventional structures, such as multi-storey residential buildings and relatively short-span bridges.

Design of concrete-filled steel tubular (CFST) hybrid structures

1 Scope

This document provides guidelines for the design, construction, and inspection of concrete-filled steel tubular (CFST) hybrid structures. These structures can be used as main structural components like columns, girders, piers, or arches in buildings, bridges, especially in high-rise structures, long-span spatial structures, and large-scale bridges.

CFST hybrid structures can employ CFST members with a circular cross-section as their chords, and they can also use square or rectangular CFST chords.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19338, *Performance and assessment requirements for design standards on structural concrete*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
concrete-filled steel tubular hybrid structure
CFST hybrid structure
structure in which concrete-filled steel tubular (CFST) members serve as its main members, and are in contact with and act compositely with steel or reinforced concrete members or components, including trussed CFST hybrid structure, concrete-encased CFST hybrid structure, etc.

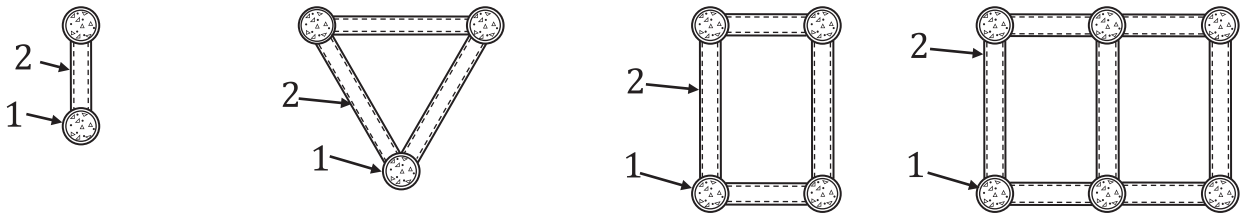
Note 1 to entry: CFST hybrid structures more frequently employ circular CFST members due to the higher confinement effect provided by circular hollow steel tubes to the core concrete; square or rectangular CFST members can also be used when design or construction conditions require. CFST members require full composite effects between steel tubes and the core concrete. Steel tubular members using infilled concrete to only enhance their stiffness are beyond the scope of this document.

3.2
trussed concrete-filled steel tubular (CFST) hybrid structure
trussed CFST hybrid structure
truss structure consisting of CFST chords and webs of steel tubes, CFST members or other steel profiles

Note 1 to entry: There are two-chord, three-chord, four-chord and six-chord trussed CFST hybrid structures (see Figures 1 and 2), and the chords are normally placed symmetrically. Trussed CFST hybrid structures generally serve as main structural members, such as truss girders, bridge piers or columns.

Note 2 to entry: During a typical construction process of cast-in-place trussed CFST hybrid structures, the steel components, such as the hollow steel tubes, are first erected; the core concrete in the chords is then placed (see Figure 3). Prefabricated CFST members can also be used in trussed CFST hybrid structures when construction conditions allow.

Note 3 to entry: For trussed CFST hybrid structure with rectangular CFST members, the CFST chords are generally placed to have the strong axes of their rectangular cross-sections all in parallel with the strong axis of the whole cross-section of the trussed CFST hybrid structure.

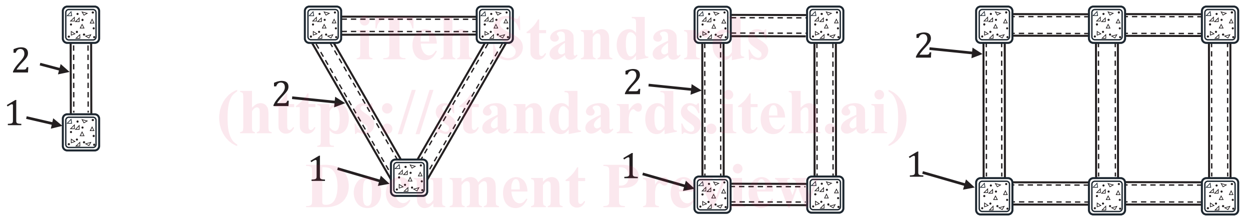


a) Two-chord **b) Three-chord** **c) Four-chord** **d) Six-chord**

Key

1	CFST chords
2	webs

Figure 1 — Cross-sections of trussed CFST hybrid structures with circular CFST members

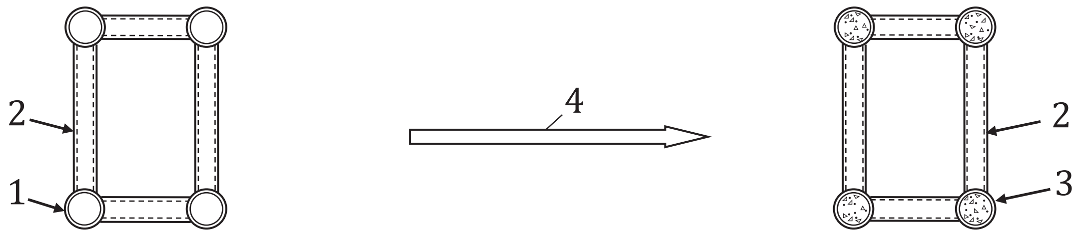


a) Two-chord **b) Three-chord** **c) Four-chord** **d) Six-chord**

Key

1	CFST chords
2	webs

Figure 2 — Cross-sections of trussed CFST hybrid structures with square or rectangular CFST members



a) As hollow steel tubular structure **b) As trussed CFST hybrid structure**

Key

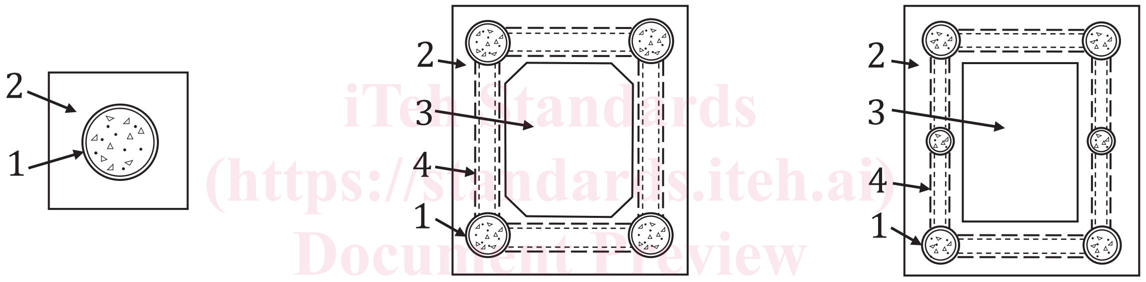
1 hollow steel tubular chords
2 webs
3 CFST chords
4 placement of core concrete in chords

Figure 3 — Typical construction process of a trussed CFST hybrid structure

3.3
concrete-encased concrete-filled steel tubular hybrid structure
concrete-encased concrete-filled steel tubular (CFST) hybrid structure

structure consisting of reinforced concrete encasement and one or more embedded CFST members

Note 1 to entry: The encased CFST member(s) in the concrete-encased CFST hybrid structure can be single or multiple, as shown in Figures 4 and 5, and are normally symmetrically placed. For the single-chord type, the CFST member is placed at the centre of the cross-section with a square or rectangular concrete encasement, forming a solid cross-section. For the multi-chord type, CFST chords are placed at the corners (four-chord type) and also mid-height of the cross-section (six-chord type) of the rectangular concrete encasement; steel tubes, or CFST or other steel profiles are used as webs to connect the CFST chords; to reduce self-weight, an internal hollow section, which is octagonal or rectangular, is generally formed. The multi-chord concrete-encased CFST hybrid structures are a derivation of the trussed CFST hybrid structures, and are generally used as columns, bridge piers, arches, etc.

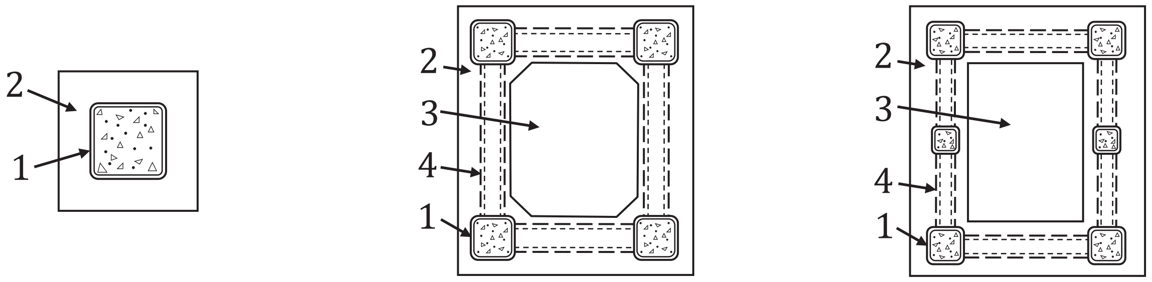


a) Single-chord, solid cross-section **b) Four-chord, with an internal hollow section** **c) Six-chord, with an internal hollow section**

Key

1 CFST members
2 concrete encasement
3 internal hollow section
4 webs

Figure 4 — Cross-sections of concrete-encased CFST hybrid structures with circular CFST members



a) Single-chord, solid cross-section **b) Four-chord, with an internal hollow section** **c) Six-chord, with an internal hollow section**

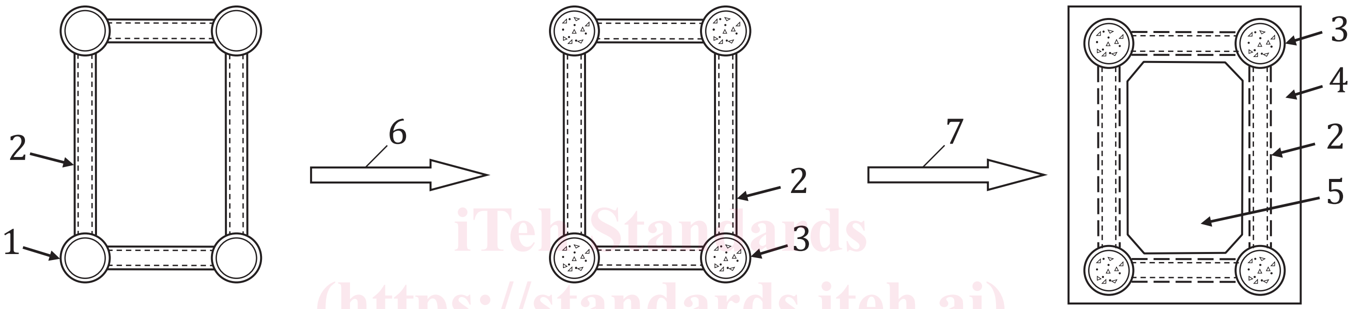
Key

1	CFST members
2	concrete encasement
3	internal hollow section
4	webs

Figure 5 — Cross-sections of concrete-encased CFST hybrid structures with square or rectangular CFST members

Note 2 to entry: A typical construction process for cast-in-place concrete-encased CFST hybrid structure consists of erection of hollow steel tubular chords and webs, placement of core concrete in chords, installation of reinforcement, and placement of concrete encasement, as shown in Figure 6. Prefabricated CFST members can also be used in concrete-encased CFST hybrid structures when construction conditions allow.

Note 3 to entry: For concrete-encased CFST hybrid structure with rectangular CFST members, the CFST chords are generally placed to have the strong axes of their rectangular cross-sections all in parallel with the strong axis of the whole cross-section of the concrete-encased CFST hybrid structure.



a) As hollow steel tubular structure

b) As trussed CFST hybrid structure

c) As concrete-encased CFST hybrid structure

Key

1	hollow steel tubular chords
2	webs
3	CFST chords
4	concrete encasement
5	internal hollow section
6	placement of core concrete in chords
7	placement of concrete encasement

Figure 6 — Typical construction process of a concrete-encased CFST hybrid structure

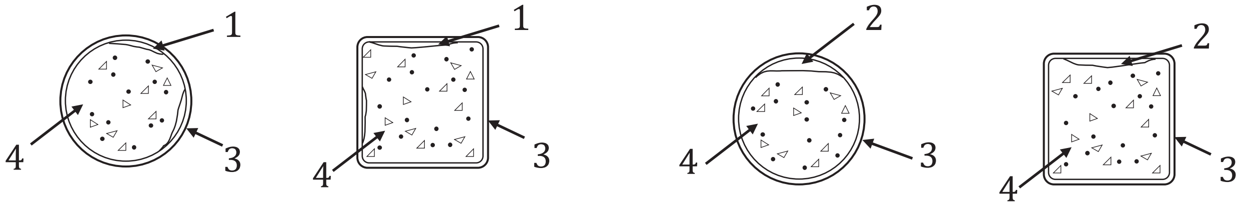
3.4
limiting value of initial stress in the steel tube

limiting value of the stress level in the steel tube before the steel tube and the core concrete in the CFST member can act together

3.5
limiting value of core concrete void in the steel tube

limiting value of the void ratio of the circumferential void, or the maximum height of the spherical-cap void between the steel tube and its core concrete in the CFST member

Note 1 to entry: The compactness of the core concrete in a CFST member is crucial to ensure that the steel tube and its core concrete act together. However, due to concrete shrinkage and construction issues, circumferential void [see Figure 7 a)] and spherical-cap void [see Figure 7 b)] will possibly develop in the cross-sections of vertical members and horizontal members, respectively. When the void is within a limiting value, its influence on the structural resistance is negligible. Therefore, the concept of limiting value of core concrete void in the steel tube is proposed.



a) Circumferential void

b) Spherical-cap void

Key

1	circumferential void
2	spherical-cap void
3	steel tube
4	core concrete

Figure 7 — Schematic diagram of core concrete voids in CFST members

3.6
confinement factor

ratio of the nominal compressive strength of cross-section of the steel tube to that of the core concrete in a CFST member

Note 1 to entry: Confinement factor is a representative parameter that reflects the interaction between steel tube and core concrete of the CFST member. Within the parametric ranges in this document, with the increase of the confinement factor, the steel tube provides stronger confinement to its core concrete during loading, and the strength and ductility of the CFST member increases, and vice versa. In other words, the confinement factor represents the degree of composite effects between the steel tube and its core concrete.

3.7
equivalent slenderness ratio

slenderness ratio converted from a trussed CFST hybrid structure to a CFST member when calculating its global stability in axial compression

4 Symbols

The following symbols are used generally throughout the document.

Factored actions, action effects and resistances		
Symbol	**Explanation**	**Unit**
M	factored bending moment	N·mm
M_u	bending resistance	N·mm
N	factored axial force	N
N_0	resistance of cross-section of the CFST hybrid structure to compression	N
N_c	resistance of cross-section of the CFST chord to compression	N

N_{cfst}	resistance of cross-section of the encased CFST member to compression	N
N_{rc}	resistance of cross-section of the concrete encasement to compression	N
N_{t}	resistance of cross-section of the CFST chord to tension	N
N_{u}	resistance of the CFST hybrid structure in axial compression	N
V	factored shear force	N
V_{cfst}	shear resistance of the encased CFST member	N
V_{rc}	shear resistance of the concrete encasement	N
V_{u}	shear resistance of the CFST hybrid structure	N
Material properties		
Symbol	**Explanation**	**Unit**
E_{c}	modulus of elasticity of concrete	MPa
$E_{\mathrm{c,c}}$	modulus of elasticity of the core concrete in the CFST member	MPa
$E_{\mathrm{c,oc}}$	modulus of elasticity of the concrete slab or concrete encasement	MPa
E_{s}	modulus of elasticity of steel	MPa
f	design tensile, compressive and flexural strength of steel	MPa
f_{c}	design compressive cylinder strength of concrete	MPa
f_{ck}	characteristic compressive cylinder strength of concrete	MPa
$f_{\mathrm{c,oc}}$	design compressive strength of the concrete encasement	MPa
f_{l}	design tensile strength of the longitudinal reinforcement	MPa
f_{sc}	design compressive strength of the CFST cross-section	MPa
f_{scy}	characteristic compressive strength of the CFST cross-section	MPa
f_{sv}	design shear strength of the CFST cross-section	MPa
f_{y}	characteristic yield strength of steel	MPa
$f_{\mathrm{y}l}$	characteristic yield strength of steel reinforcement	MPa
$G_{\mathrm{c,c}}$	shear modulus of the core concrete in the CFST member	MPa
$G_{\mathrm{c,oc}}$	shear modulus of the concrete slab or concrete encasement	MPa
G_{s}	shear modulus of steel	MPa
Geometric parameters		
Symbol	**Explanation**	**Unit**
A_{c}	cross-sectional area of the core concrete in the CFST member	mm^2
A_{l}	cross-sectional area of the longitudinal reinforcement	mm^2
A_{oc}	cross-sectional area of the concrete slab or concrete encasement	mm^2
A_{s}	cross-sectional area of the steel tube	mm^2
A_{sc}	cross-sectional area of the CFST member	mm^2
A_{sv}	total cross-sectional area of stirrups	mm^2
A_{v}	cross-sectional area of stirrup-confined concrete	mm^2
b	width of the CFST hybrid cross-section	mm
B	width of the square or rectangular CFST member	mm
d_{r}	mean width of the circumferential void	mm
d_{s}	maximum height of the spherical-cap void	mm
D	outside diameter of the circular CFST member	mm
D_{i}	diameter of the core concrete in the CFST member	mm
h	height of the CFST hybrid cross-section	mm
h_{i}	distance along the cross-sectional height between the centroids of compression and the tension chords	mm