

ISO 16521:2024-09 (E)

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

| Contents | | Page |
|--------------------|---|-------------|
| Foreword | | vii |
| Introduction | | viii |
| 1 | Scope | 1 |
| 2 | Normative references | 1 |
| 3 | Terms and definitions | 1 |
| 4 | Symbols | 5 |
| 5 | Materials | 7 |
| 5.1 | General | 7 |
| 5.2 | Concrete | 8 |
| 5.2.1 | Cement | 8 |
| 5.2.2 | Aggregates | 8 |
| 5.2.3 | Water | 8 |
| 5.2.4 | Admixtures | 8 |
| 5.2.5 | Additions | 8 |
| 5.2.6 | Concrete mixture specification | 8 |
| 5.3 | Steel tubes | 8 |
| 5.4 | Steel reinforcement | 9 |
| 5.4.1 | Deformed reinforcement | 9 |
| 5.4.2 | Plain reinforcement | 9 |
| 5.5 | Other materials | 9 |
| 5.5.1 | Welding consumables | 9 |
| 5.5.2 | Fasteners | 9 |
| 5.5.3 | Protective paint systems | 9 |
| 5.6 | Storage of materials | 9 |
| 6 | Design and construction procedure | 9 |
| 7 | General guides | 11 |
| 7.1 | Limitations | 11 |
| 7.1.1 | CFST members | 11 |
| 7.1.2 | Trussed concrete-filled steel tubular (CFST) hybrid structures | 12 |
| 7.1.3 | Concrete-encased concrete-filled steel tubular (CFST) hybrid structures | 12 |
| 7.2 | Limit states | 13 |
| 7.3 | Ultimate limit state design format | 14 |
| 7.3.1 | General | 14 |
| 7.3.2 | Factored load effects | 14 |
| 7.3.3 | Design resistances | 14 |
| 7.4 | Serviceability limit state design format | 15 |
| 8 | Specific guides | 15 |
| 8.1 | Design working life | 15 |
| 8.2 | Selections of materials, structural plans and detailing | 15 |
| 8.3 | Seismic design requirements | 15 |
| 8.4 | Selections of constructional methods and techniques | 15 |
| 9 | Actions (loads) | 16 |

| | | |
|--------|--|----|
| 9.1 | General | 16 |
| 9.2 | Dead loads | 16 |
| 9.3 | Live loads | 16 |
| 9.4 | Snow loads | 16 |
| 9.5 | Wind forces | 16 |
| 9.6 | Earthquake forces | 16 |
| 9.7 | Thermal forces | 17 |
| 9.8 | Load partial factors and load combinations | 17 |
| 10 | Analysis | 17 |
| 10.1 | General | 17 |
| 10.1.1 | Structural analysis purpose | 17 |
| 10.1.2 | Structural analysis methods | 17 |
| 10.1.3 | Structural analysis requirements | 17 |
| 10.1.4 | Loading cases | 18 |
| 10.1.5 | Construction stage analysis | 18 |
| 10.2 | Stress-strain relationships for materials | 18 |
| 10.2.1 | General | 18 |
| 10.2.2 | Concrete | 19 |
| 10.2.3 | Steel | 26 |
| 10.3 | Indices for the strength and stiffness of CFST hybrid structures | 28 |
| 10.3.1 | CFST cross-section | 28 |
| 10.3.2 | CFST hybrid structures | 30 |
| 11 | Ultimate limit states of trussed concrete-filled steel tubular (CFST) hybrid structures | 31 |
| 11.1 | General | 31 |
| 11.2 | Resistances to compression and bending | 31 |
| 11.2.1 | Axial compression | 31 |
| 11.2.2 | Bending | 34 |
| 11.2.3 | Combined compression and bending | 35 |
| 11.2.4 | Resistances of CFST chords | 39 |
| 11.2.5 | Resistances of webs | 45 |
| 11.3 | Resistance to shear | 46 |
| 11.3.1 | With horizontal webs | 46 |
| 11.3.2 | With diagonal webs | 46 |
| 12 | Ultimate limit states of concrete-encased concrete-filled steel tubular (CFST) hybrid structures | 46 |
| 12.1 | General | 46 |
| 12.2 | Resistances of single-chord structures | 46 |
| 12.2.1 | Axial compression | 46 |
| 12.2.2 | Combined compression and bending | 47 |
| 12.2.3 | Tension | 50 |
| 12.3 | Resistances of four-chord structures | 51 |
| 12.3.1 | Axial compression | 51 |
| 12.3.2 | Combined compression and bending | 51 |
| 12.4 | Resistances of six-chord structures | 55 |
| 12.4.1 | Axial compression | 55 |
| 12.4.2 | Combined compression and bending | 55 |
| 12.5 | Resistances of slender structures | 59 |
| 12.5.1 | Axial compression | 59 |
| 12.5.2 | Combined compression and bending | 60 |
| 12.6 | Resistance subjected to long-term loading | 60 |
| 12.7 | Resistance to shear | 60 |
| 12.8 | Resistance to combined axial force, bending and shear | 62 |
| 13 | Serviceability limit states of concrete-filled steel tubular (CFST) hybrid structures | 62 |
| 13.1 | Calculation of structural response | 62 |
| 13.2 | Serviceability limitations | 62 |
| 14 | Protective design | 62 |

| | | |
|--------|---|----|
| 14.1 | General | 62 |
| 14.1.1 | Corrosion resistance | 62 |
| 14.1.2 | Fire resistance | 63 |
| 14.1.3 | Impact resistance | 63 |
| 14.2 | Design of corrosion resistance | 63 |
| 14.2.1 | Anti-corrosion measures | 63 |
| 14.2.2 | Corrosion resistance calculation | 63 |
| 14.3 | Design of fire resistance | 64 |
| 14.3.1 | Load ratio during fire | 64 |
| 14.3.2 | Fireproof coating | 64 |
| 14.3.3 | Fire resistance ratings | 65 |
| 14.3.4 | Detailing requirements | 65 |
| 14.4 | Design of impact resistance | 66 |
| 14.4.1 | Bending resistance under impact | 66 |
| 14.4.2 | Dynamic increase factor for circular CFST chords under impact | 66 |
| 14.4.3 | Deformation of circular CFST chords under impact | 67 |
| 15 | Connections | 67 |
| 15.1 | General | 67 |
| 15.2 | Joints of trussed concrete-filled steel tubular (CFST) hybrid structures | 67 |
| 15.2.1 | General requirements | 67 |
| 15.2.2 | Typical forms of joints | 68 |
| 15.2.3 | Welding requirements | 69 |
| 15.2.4 | Detailing requirements of webs | 69 |
| 15.2.5 | Inserted plate connections | 70 |
| 15.2.6 | Gusset plate connections | 70 |
| 15.2.7 | Intersecting welded plane K-joints and N-joints | 71 |
| 15.2.8 | Plane T-joints, Y-joints and X-joints | 74 |
| 15.2.9 | Multiplanar joints | 74 |
| 15.3 | Joints of concrete-encased concrete-filled steel tubular (CFST) hybrid structures | 74 |
| 15.3.1 | Steel beam-to-column ring plate joints | 74 |
| 15.3.2 | Reinforced concrete beam-to-column joints | 75 |
| 15.3.3 | Detailing requirements of beam-to-column joints | 76 |
| 15.3.4 | Connections between steel tubes | 77 |
| 15.4 | Column bases and supporting connections | 78 |
| 15.4.1 | Column bases and supporting connections of trussed CFST hybrid structures | 78 |
| 15.4.2 | Column bases of concrete-encased CFST hybrid structures | 82 |
| 15.5 | Fatigue design of joints | 83 |
| 15.5.1 | General requirements | 83 |
| 15.5.2 | Design methods | 83 |
| 15.5.3 | Hot spot stress ranges under constant amplitude fatigue | 84 |
| 15.5.4 | Hot spot stress ranges under variable amplitude fatigue | 84 |
| 15.5.5 | Detailing requirements | 85 |
| 16 | Construction and acceptance | 86 |
| 16.1 | General | 86 |
| 16.2 | Fabrication and erection of steel tubes | 86 |
| 16.2.1 | General | 86 |
| 16.2.2 | Documents | 86 |
| 16.2.3 | Fabrication | 86 |
| 16.2.4 | Surface protection | 87 |
| 16.2.5 | Transportation and erection | 87 |
| 16.3 | Construction of core concrete | 87 |
| 16.3.1 | General | 87 |
| 16.3.2 | General requirements | 87 |
| 16.3.3 | Mixture design | 88 |
| 16.3.4 | Requirements of self-compacting concrete | 88 |
| 16.3.5 | Use of cement plaster | 88 |
| 16.3.6 | Placement preparation | 88 |
| 16.3.7 | Placement methods | 88 |
| 16.3.8 | Placement process | 88 |

| | | |
|--|--|----|
| 16.3.9 | Treatment of post-placement holes on steel tubes | 88 |
| 16.3.10 | Requirements of limiting values of core concrete void in steel tubes | 88 |
| 16.4 | Construction of concrete encasement | 90 |
| 16.4.1 | General | 90 |
| 16.4.2 | Construction preparation | 90 |
| 16.4.3 | Workability of concrete | 90 |
| 16.4.4 | Construction order | 90 |
| 16.5 | Inspection and acceptance | 90 |
| 16.5.1 | General | 90 |
| 16.5.2 | Steel structures | 91 |
| 16.5.3 | Core concrete | 91 |
| 16.5.4 | Concrete encasement | 91 |
| 16.5.5 | Documents and records | 91 |
| Annex A (informative) Long-term load coefficients for concrete-encased circular CFST hybrid structures | | 92 |
| Annex B (informative) Fire resistance ratings of single-chord concrete-encased circular CFST hybrid structures | | 96 |
| Bibliography | | 97 |