The New Technology Of Reinforced Concrete

Structural MiC

Evolution in Concrete Morphology For Structural Formation
R&D Chronology

First Structural Precast Volumetric Prefabrication
HK Fui Tei Residential Highrise Development

First Adoption of ECC Concrete
First Development of Concrete Glue
Start Extension of high performance concrete technologies


First Innovative use of 3D in
HK Housing Authority Commerce Complex
First Innovative use of RFID in
HK Housing Authority Projects


Head of The Team “MustDo System” : Ir. Prof. Albert K. H. Kwan

 HKUST: Professor Chris Leung

“Yield-Plane Work-Hardening”

Start MustDo System Development
Complete MustDo System Testing

Laminate with matrix material capable of following the strains of plate reinforcement.

Prepared By Flexcrete Technology Limited
Response To Market

Part -I : MustDo Composite Approach
Part -II : MustDo Composite Testing
Part -III : MustDo DfMA
Part -IV : Current Steel Concrete Types

PART - I : APPROACH
Evolution of RC Concrete
Architected Material
MustDo Composite
Towards A New Co-Creation Dynamics

Date : 25 Nov Year 2020
Engineering Material Classes

**METALS**
Inorganic Crystalline Structure
- Dislocation motion easier.
- Non-directional bonding
- Close-packed directions for slip.

**CERAMICS**
Inorganic Crystalline/Non-crystalline Structure
- Covalent Ceramics (Si, diamond):
  - Motion hard, non-directional bonding
- Ionic Ceramics (NaCl):
  - Motion hard, need to avoid + and - neighbors.

**POLYMERS**
Organic Non-crystalline Structure
- Stress & Ductility
- Compressive strength $\sigma_c$
- Tensile strength $\sigma_t$
- Fatigue strength & toughness

**BONDING + STRUCTURE + DEFECTS**

- Nuclei
- Liquid
- Crystals growing
- Grain structure
Evolution of Concrete Strength

Normal To High Performance Concrete

New theories
1. Packing of Solid Particles
2. Water Film Thickness
3. Particle Interaction
4. Reactive Agents

New technologies
4. Particuology for Concrete Science
5. Aggregate Treatment
6. Fillers
7. Superplasticizers

Ultra High Performance Concrete

Homogeneity
- Enhancement

Granular Mixture Optimization
- UHPC does not contain any coarse particle (≤ 2 mm)
- Homogeneity
- High compressive strength

Tensile & Toughness Enhancement
- Fibre as Toughening / Main Reinforcement
- Use of micro-fibres / mineral-fibres
  - Length 12/20mm and Ø=0.2/0.3 mm
    - Fibre Fracture, Fibre Pull-out
  - Tensile strength (fibre ratio depends on performance requirements)
  - Acicular Mineral fibre
    - Interfacial Debonding

Aggregate/Matrix E-Modulus
- A low W/C ratio and a high cement / ultrafine content
  - Reduction of the porosity
  - High compressive strength and durability

Paste/Aggregate Interface
- Meso-Effects
- Macro-Effects

Water Film Thickness
- Solid particle
- Water trapped inside the voids
- Water films coating solid particles
- Water film thickness

Date: 25 Nov Year 2020

Page.04
Fracture – Mechanical Properties

Particle Modification

Ductility of brittle material can be increased by incorporating particles, primarily in order to increase the modulus of elasticity (E) and the fracture energy (G). To achieve high fracture energy, the particles must be strong in relation to the matrix in order to force energy-consumption fracture around the particles.

Size Effect - Local Brittleness

The Brittleness Number – is a measure of the extent to which the object acts as a “small” object with good yield reserve and high carrying capacity (exhibiting ductile and plastic behaviour) or as a “large” one with little yield reserve and low carrying capacity (exhibiting brittle behaviour).

Evolution of Binder Paste

Cementitious Binder

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>Elastic Modulus (E) MN/m²</th>
<th>Tensile Strength (Ft) MN/m²</th>
<th>Fracture Energy (Gf) N/M</th>
<th>Crack Zone Deformation (CMOD) µM</th>
<th>Material Ductility (Lch) m</th>
<th>Stress Intensity Factor (K) MN/m³/²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Paste</td>
<td>7,000</td>
<td>4</td>
<td>20</td>
<td>5</td>
<td>0.01</td>
<td>0.4</td>
</tr>
<tr>
<td>Dense Silica Cement Mortar</td>
<td>50,000</td>
<td>20</td>
<td>100</td>
<td>20</td>
<td>0.0125</td>
<td>2.2</td>
</tr>
<tr>
<td>Concrete</td>
<td>30,000</td>
<td>3</td>
<td>60</td>
<td>20</td>
<td>0.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Compact Reinforced Composite</td>
<td>100,000</td>
<td>120</td>
<td>1,200,000</td>
<td>10,000</td>
<td>8.3</td>
<td>350</td>
</tr>
</tbody>
</table>

The ductility is given by:

\[ D = \frac{\Delta}{E} = \frac{G}{E} \frac{E}{F_t} \frac{L}{L^2} \]

where \( \Delta \) is the deformation of the fracture zone in m, and \( f_t \) is the tensile strength in N/m².

As it can be seen, \( E \) and \( G \) are material parameters, where \( L \) and \( D \) are characteristic quantities e.g., size of the structure, particle size of ultrafine particles, diameter of fibres and diameter of the reinforcement.

Where \( G \) is the fracture energy and is given by

\[ G = f_t \Delta \]

Softening Material - Concrete/Rock

G - Fracture Energy
Surface Energy-Bond Disruption
Evolution of Steel Strength

Superplasticity – Neck Free Elongation

Strain Gradient Plasticity

Dislocation Cell Formation During Deformation

The deformation is:
- macroscopically homogeneous, but
- microscopically heterogeneous: “Patterning”

Hael Mughrabi

Lattice Plane Rotation

Dispersion Hardening

Grain Refining & Pinning

Casting

Heat Treatment

Deformation

Structural Development Overview

Matrix Grain (Kustenite)

Pinning Phase (Secondary)

Rounded Matrix (Primary)

Plastic Deformation

High Strength NanoModal Structure

NanoParticles Strengthening

Dynamic NanoPhase Strengthening

Plastic Deformation

Transformed Matrix (Secondary)

NanoNecroplates (Mono-/Polyphase)

Matrix Grain (Kustenite)

Pinning Phase (Secondary)

Rounded Matrix (Primary)

Initial powder

Binodal Powder

Harmonic Structure

Gradient nanowinned (GNT) strengthening and microstructure

Metallurgical processing of metals

Uniform elongation

Pinning

Geoemtrically Necessary Dislocation

Symmetrical multiple slip

internal stresses

Geometrically Necessary Dislocation

Cell wall

Cell insertion

Grain refined α

Grain boundary

Force: \( F = \tau \cdot a \)

Gravity

Nanotwinned region

Nanocrystalline region

Nanometer grain structure

Hael Mughrabi

Date: 25 Nov Year 2020
Evolution of Reinforced Concrete

The assumption for the design of reinforced concrete include:

1. Perfect bonding between the concrete and steel exist, and
2. No slippage occur (strain in concrete and reinforcing steel is the same)
3. Moderate controlled cracks on the tensile side. (2-5% of yield strain of reinforcement)

(a) beam before loading
(b) unrestrained slip between concrete and steel
(c) bond forces acting on concrete
(d) bond forces acting on steel

In order for reinforced concrete to behave as intended, it is essential that “Bond Forces” be developed on the interface between concrete and steel, so as to prevent significant slip from occurring at the interface.

Due to the weakness of bond strength, end ANCHORAGE is provided in the form of HOOKS in addition to development length.

Where the length available for anchorage is small, MECHANICAL ANCHORAGES in the form of welded cross-bars or end plates may be used.

Rule of play – conventional concrete, moderate quantity of reinforcement, good spacing between bars, large overlap length, moderate controlled cracks on the tensile side etc.,
“Dr. Han Henrik Bache” - Multiple Crack Zone Deformation:
If a brittle material is placed in a configuration where it is fixed to rigid boundaries and thereby is subdivided into small individual fixed domains, the strain capacity of the material will be increased.

CRC object design base on two fracture-mechanical effects:
. Fibre strain hardening of the matrix (Local Ductility)
. Matrix strain hardening by fixation to closely spaced main reinforcement stiff frame (Global Ductility)

Main reinforcement function:
. Resisting tensile load (Reinforcement can be either thin or heavy)
. Distributing cracks in tensile zone (Reinforcement prefer thin)
. Improve local failure toughness (Reinforcement prefer heavy)

“Han Henrik Bache” – Good interaction between reinforcement and matrix depends on the matrix material being able to follow the deformations of the reinforcement as a coherent load-bearing material.
Evolution of Reinforced Concrete

Steel – Concrete – Steel (Failure Modes)

Sandwich Composite Using Shear Stud

- Flexural failure
- Concrete shear failure
- Shear connector failure
- Slip at beam end at the end of test
- Top plate buckling failure (beam SLCS)

Typical Steel-Concrete-Steel beam failure modes due to static load.

<Load Slip Behaviour between bottom steel plate and concrete core due to mismatch in curvatures result in debonding leading to shear cracks>
Architected Materials a class of materials that show new and/or customized behaviors by the interplay between material properties and geometry.

Examples of Architected Materials
- Random
- Ordered
- Ordered and Locally variable

Architected materials with optimally designed topologies (single or multiphase, cellular or fully dense, periodic or functionally graded).

Heterostructured and Gradient Materials (HGM)
1. HGM is characterized with large differences in mechanical behaviors among hetero-structured zones (back stress Soft zones and forward stress Hard zones).
2. Strong inter-zone interactions produce hetero-deformation induced (HDI) strengthening to enhance yield strength and extra HDI work hardening to retain ductility.
3. Interface engineering and interface-related phenomena such as strain banding, strain gradient near zone interfaces are critical factors for HGM material properties design.

Architected Materials Strain Gradient & Topologies

Next >>
An Architected Material: Combination of several simple materials, possibly involving open space, configured to reach performances not offered by any individual material. The term “architected material” was coined to make a link between the practice in architecture and structural engineering of topology optimization that has been employed to produce reliable, light, and elegant constructions. < Mike Ashby >
Metal Fabric Grid Reinforced Composite

3-Dimensional Reinforcement Arrangement + Internal Tension Interlocked
Response To Market

Thin Steel-Concrete Composite Approach

- Eliminate double wall & slab problem in MIC adoption
- Replicate in-situ reinforced concrete composite
- Achieve high strength/high rigidity/high ductility
- Work within current Codes
- Allow lighter and larger module to minimize joints
- Facilitate design freedom
MustDo Thin Composite

High Elastic Modulus Matrix = Increase stability against buckling with effective fixation to plate reinforcement

... High Strength Concrete Ductility...

Chief Advisor: Professor Albert Kwan

Improving flexural ductility of high-strength concrete beams

A. K. H. Kwan PhD, CEng, MICE, S. L. Chau MPhil and F. T. K. Au PhD, CEng, MICE, FStructE

Isogrid Plate Reinforcement = Increase stress distribution for higher load capacity (relative ductility)

Laminate Composite = Increase stiffness against local bending peeling and shear failure

... Confinement...

Theoretical study on effect of confinement on flexural ductility of normal and high-strength concrete beams

A. K. H. Kwan,*, F. T. K. Au* and S. L. Chau*

The University of Hong Kong

... Compressive Reinforcement...

Minimum flexural ductility design of high-strength concrete beams

J. C. M. Ho,*, A. K. H. Kwan* and H. J. Pam*

University of Hong Kong

High Strain Capacity = Increase strain capacity by geometrical yield-plane (rigid bodies + yield zones) while retaining good internal coherence of matrix

Date: 25 Nov Year 2020
By utilizing hetero-zone interactions/couplings produce significant synergistic effect to control defect distribution. <Global Ductility–Localized Strain Zone Hardening>
**Composite Configuration Strategy:**

- LAYERED .......... MODULUS.BOND ........ CELLULAR.TUBULAR
- Flexural Rigidity
- Sandwich Structure
- Eliminate Elastic Modulus Mismatch
- High Performance Concrete
- Medium Yield Strength Steel
- Triangular Unit Cells in Honeycomb Lattice
- Artificial Periodic Dislocation Networks

--- **New Topology...**

**Strain Gradient Structure** (Coherent Domain) ---(Mosaic Block) --- (Rigid Block)

Honeycomb Network

Geometry with Minimum Energy Configuration Corresponds to Symmetrical Position with Screw Dislocations of Equal Length.

**Triangular Interlocked Material ‘TIM’**

**Architected Material**

- **0**
  - Steel-Concrete Composite
  - Compressive Strength

- **1**
  - Raw Material Property Selection
  - Cost vs performance analysis

- **2**
  - Compressive Strength

- **3**
  - Tensile Strength

- **4**
  - Flexural Rigidity

- **5**
  - Ductility

- **6**
  - integrated manufacturing

- **7**
  - Overlap

Hetero-Interface Dislocation Induced Gradient Structure:


**Date: 25 Nov Year 2020**
MustDo MIC Composite

(Technology Elements of the FineScale Composite)

Architected Cellular Layers Material

Continuous Matrix Phase
<Cellular>

. Hard Phase
<Dowel-50>

. Soft Phase
<Honeycomb-51>

Plasticity Strain Gradient

Continuous Reinforcing Phase
<Lattice>

. Perforated Plate
<Layers>

. Perforated Tube
<Interlayers>

Elastic Instabilities

Date: 25 Nov Year 2020
MustDo ISOGRID

Perforated Steel Plate

- Typical welded steel fabric cannot realize ISOGRID
- Alternative form of Fabric Reinforcement (EN10080)
- Comply HK Steel Code using minimum 3mm thickness
- Realize internal confinement function
- Hole size optimize for concrete dowel effect
- Facilitate adoption of sandwich configuration
- Maximize non-contact lap advantage
MustDo Connector

Perforated Triangular Steel Tube

- Typical shear stud cannot apply in ISOGRID plate
- Alternative form of Extruded Tubular Shear Connector
- Comply HK Steel Code using minimum 3mm thickness
- Perforation to realize internal confinement function
- Hole size optimize for concrete anchorage effect
- Facilitate adoption of sandwich configuration
- Avoid fatigue welding problem by using insertion
Steel Concrete Composite

<Concrete> : Strength-Modulus
<Steel> : Strength-Thickness

Date: 25 Nov Year 2020
MiC Box Size: 2500 x 6000 x 3500(h)

MiC Box Weight: Approx. 11 Tons + 2KPa Imposed Load for Domestic Floors
In-situ Concrete Casting

3 Stages
1\textsuperscript{st} Stage: Fix the boxes in position. Less Pressure
2\textsuperscript{nd} Stage: Finish up wall casting
3\textsuperscript{rd} Stage: Horizontal structural Elements Concrete Casting
Response To Market

Part - I : MustDo Composite Approach
Part - II : MustDo Composite Testing
Part - III : MustDo DfMA
Part - IV : Current Steel Concrete Types

Date : 25 Nov Year 2020
STANDARD SPECIFICATIONS FOR CONCRETE STRUCTURES – 2007
"Design" JSCE Guidelines for Concrete No.15

16.1 General

(1) This chapter lays down specifications for design of structural members made using a combination of concrete and structural steel. Provisions are given for design of such members, including the limit states defined for checking durability, safety, and seismic performance procedure for examination of such limit states and structural details that are prerequisite for the examination.

(2) The provisions given here apply to following types of composite (i) steel reinforced members, (ii) concrete-filled steel columns, and (iii) steel-concrete sandwich members.

Reinforced and prestressed concrete members made using conventional steel reinforcement are not considered ‘composite members’ as far as the provisions in this chapter are concerned. Apart from the three types mentioned in this chapter, several types of composite member have been proposed to date, and it can be expected that newer proposals will continue to be made in the future also.

16.2 General requirements for composite structures

Composite members defined in this chapter shall satisfy the following requirements:

(1) There is a perfect bond between the concrete and structural steel, and the bond remains throughout the period when the structure is in service.

(2) Structural steel embedded in concrete does not buckle.

(3) The durability of composite members should be comparable to that of conventional reinforced concrete members. In cases when structural steel is placed outside the concrete in the composite members, the steel should be provided with an appropriate anti-corrosion coating, etc. depending upon the environment to which the structure or member is exposed.

(4) For structural steel arranged outside the concrete, appropriate fire-resistant cover etc. should be provided if the structure or member is likely to be exposed to very high temperatures such as in the event of fire.

16.3 Design Method

16.3.1 Selection of steel

In addition to steel generally used, steel developed especially for composite structures may be also used as the steel in plates and bar reinforcement.

[Commentary] To have an adequately proportioned cross-section in the composite structure at both the safety and serviceability limit state, steels which have similar mechanical properties, such as yield strength and yield strain, should be used in the main elements of the composite member. Steel plates with protrusions or perforations may be used to augment the bond between the steel and concrete, or to disperse cracking. The provision of the present specification does not apply when materials such as carbon fibers or high strength steel with a yield stress in excess of 700-800 N/mm² are used.
MustDo TIM Panel

50 mm Composite Panel Drawings For 2-Holes & 4-Holes Lapping Testing
50 mm Composite Panel Drawings For Triangular Shear Connector

Push-Out Test for Triangular Shear Connector

Push-out Panel <Elevation>
Shear Connector: Push-Out Test Specimen Design (Triangular Connector)

Push-out Panel <Section>

50mm 90mm 50mm
Hollow Triangular Connector
Perforated Plate

Top Plan

Push Out Test in HKUST Civil Department Lab

Hollow Triangular Connector
<Plan>
High Elastic Modulus Cementitious Matrix Development

Desirable Properties
1. High Compressive Strength
2. Moderate Cement Content + Filler
3. Small Sized Aggregate with High Elastic Modulus
4. Low Water Cement Ratio But High Workability
5. Low Viscosity
6. Low Volumetric Sensitivity

Concrete is a natural Geometrical with particles and aggregates of various sizes
Heterogeneous material
Mechanical with a different stiffness between aggregates and cement paste
Chemical shrinkage of the paste inside a rigid skeleton of aggregate

HPC
UHPC
Concrete

Strain-Stress Diagram of Concrete and its Components
Casting of Trial Panels

Concrete Properties
1. Limitation of aggregate size and maximize paste ratio
2. Enhancement of paste properties with a Young modulus closer to the aggregate skeleton
3. Paste content sufficient between the aggregate to avoid rigid skeleton
MustDo TIM Panel

Air Curing of Trial Panels (Two-Stages Casting)
MustDo TIM Panel

Casting of Volumetric Unit
MustDo TIM Panel Testing
Cellular-Layer-Tubular

Test Done in HKUST Civil Department Lab

1. Triangular Headed Bar Anchorage Test.
2. Uni-Isogrid Splice Lapping Test
3. Triangular Connector Push-Out Test

Date: 25 Nov Year 2020

MustDo Slab Panel Flexural Behaviour Testing
Status: Already Done in HKUST Lab
<EN 1994-1-1:2004(E)> 4-point static loading

Four Point Flexural Test on 40mm Thick Slab Panel.
(No Splice Lapping)
Specimen (3000LX 40H X 800B)

L/4

L

MustDo Slab Panel Flexural Behaviour Testing
Status: To Be Done in HKUST Lab (Type-C)
<4-point static loading>

Four Point Flexural Test on 50mm Thick Slab Panel.
(With Two Holes Splice Lapping)
Specimen (1000LX 50H X 600B)

Splice for bottom layer at Mid Point of specimen

Splice Lapping are arranged in staggered manner

MustDo Slab Panel Flexural Behaviour Testing
Status: To Be Done in HKUST Lab (Type-D)
<4-point static loading>

Four Point Flexural Test on 50mm Thick Slab Panel.
(With Four Holes Splice Lapping)
Specimen (1000LX 50H X 600B)

Splice Lapping are arranged in staggered manner

Splice for bottom layer at Mid Point of specimen
Push Out Test For Shear Connector in HKUST Lab
Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone

Testing Parameters

- Concrete Dowels & Metal Mesh as Shear Connectors
- Concrete Cover: 5mm-7mm
- Structural Steel Plate Thickness: 2.75mm-3mm

Date: 25 Nov Year 2020
Push Out Test in HKUST Civil Department Lab
Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone (Two Stage Casting)

Result: In full compliance with the assumption for the emulation of in-situ casted reinforced concrete.
Perfect Bonding & No Slippage Occur

Reaching Maximum Test Machine Load Capacity 1800 KN
Push Out Test in HKUST Civil Department Lab

Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone (Two Stage Casting)

Reaching Maximum Test Machine Load Capacity Still In Elastic Stage

Perforated Triangular Tube Shear Connector

Result: In full compliance with the assumption for the emulation of in-situ casted reinforced concrete.

<Perfect Bonding & No Slippage Occur>

Date: 25 Nov Year 2020

MustDo TIM Panel Testing Cellular-Layer-Tubular Push-Out
MustDo TIM Panel Test (Bending) in HKUST Civil Department Lab
Mono-layer Architected Material Sandwich Panel – Thickness 40mm with 5mm Cover Zone

Date: 25 Nov Year 2020
40mm Rigid Composite Test (Bending) in HKUST Civil Department Lab

Mono-layer Architected Material Sandwich Panel – Thickness 40mm with 5mm Cover Zone

Full Composite Action (Non-Slip)

Date: 25 Nov Year 2020

MustDo TIM Panel

Testing Parameters

A> Concrete Dowels As Shear Connectors

B> Concrete Cover 5mm-7mm

C> Structural Steel Plate Thickness 2.75mm-3mm
MustDo TIM Panel

170mm Rigid Composite Test (Bending) in HKUST Civil Department Lab

Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone
170mm Rigid Composite Test (Bending) in HKUST Civil Department Lab
Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone

Result: In full compliance with the assumption for the design of reinforced concrete.
<Perfect Bonding & No Slippage Occur>

Testing Parameters

- **<A>** Concrete Dowels & Metal Mesh As Shear Connectors
- **<B>** Concrete Cover 5mm-7mm
- **<C>** Structural Steel Plate Thickness 2.75mm-3mm
MustDo TIM Panel

Tension Contact Lap Splices Test (Bending) in HKUST Civil Department Lab
Mono-layer Architected Material Sandwich Panel – Thickness 50mm
Perforated Triangular Hollow Tube Rebar

Bending Test Setup

Continuous increase in load-carrying capacity to failure with Ductile response.
No End Slipping
No entire concrete cover split off the panel
Failed in Compression

Result: In full compliance with 40’D’ Lap Length Requirement Or “Two” Welded Intersection Overlapping as Plain Welded Wire Fabric <‘D’ = Thickness of Steel Plate>

Both test panels with flexural failure occurred instead of failing in bond within the splice region.
This verify that the strength of the splice exceeds the flexural strength of the panel.

Date: 25 Nov Year 2020

Testing (Non-Slip)
Cellular-Layer-Tubular
Lapping
Perforated Structural Plate - Lapping

Traditional Rebar - NonContact Splice Lap (Spacing: Max. 1/5 lap length)

Spacing Restriction Relaxed with Transverse Reinforcement
Plain welded wire fabric (plain WWF) bonds to concrete by the positive mechanical anchorage at each intersection. According to SS:32, the minimum weld shear stress requirement for plain WWF is 250 MPa and deformed WWF is 140 MPa. Based on this requirement, a lap splice with two welded intersection overlapping is sufficient to transfer the full yield strength for plain WWF. Slip resistance of WWF embedded in concrete is dependent on the ability of the welded transverse wire to provide anchorage. Thus the most important variables are the size ratio between the transverse and longitudinal wire of the fabric and the quality of the weld connecting them (shear stress).

### Two Welded Intersection Overlapping

Main Bar

Secondary Bar

### One Welded Intersection Overlapping

**Table:**

<table>
<thead>
<tr>
<th>Specification No &amp; Title</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS4483 &amp; BS4482</td>
<td>UTS</td>
<td>1.05 times Yield Strength</td>
</tr>
<tr>
<td></td>
<td>Yield — 0.2% Proof Strength</td>
<td>592 MPA</td>
</tr>
<tr>
<td></td>
<td>Total Elongation at Peak force on SD GL</td>
<td>2.5%</td>
</tr>
<tr>
<td></td>
<td>WeldedShear Strength (125 Mpa)</td>
<td>Min. 25% of Yield Strength of Thicker Bar</td>
</tr>
<tr>
<td>ASTM A315 &amp; A28</td>
<td>UTS Grade 80 / Grade 86</td>
<td>670 MPA Min / 515 Mpa</td>
</tr>
<tr>
<td></td>
<td>Yield — 0.2% Proof Strength</td>
<td>550 Mpa Min / 450 Mpa</td>
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<tr>
<td></td>
<td>Reduction in Area (after Failure)</td>
<td>30% Min</td>
</tr>
<tr>
<td></td>
<td>WeldedShear Strength (250 Mpa)</td>
<td>Min. 50% of Yield Strength of Thicker Bar</td>
</tr>
</tbody>
</table>

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**Figure 8.6:** Welded transverse bar as anchoring device

For nominal bar diameters of 12 mm and less, the anchorage capacity of a welded cross bar is mainly dependent on the design strength of the welded joint. It may be calculated as follows:

\[
F_{\text{req}} = \frac{F_{\text{tot}} \times 16 \times A_{\text{tot}}}{\phi} \\
\text{where:} \\
F_{\text{req}} \quad \text{design shear strength of weld (see 8.6 (2))} \\
A_{\text{tot}} \quad \text{nominal diameter of transverse bar: } \phi \leq 12 \text{ mm} \\
\phi \quad \text{nominal diameter of bar to anchor: } \phi \leq 12 \text{ mm}
\]

If two welded cross bars with a minimum spacing of \( \phi \) are used, the anchorage length given by Expression (8.9) should be multiplied by a factor of 1.41.
Compliance Checking: Steel for the Reinforcement of Concrete

Building (Construction) Regulations
(Cap. 123 sub. leg. B)

54. Reinforcement
Reinforcement for concrete shall be hot rolled steel bars, cold reduced steel wire or steel fabric of suitable composition, manufacture, and chemical and physical properties.

This Construction Standard

Review of the CS2 comprises two stages. Stage 1 of the review is to update the technical specification and quality assurance system for steel reinforcing bars to align with the quality and performance levels as stipulated in the latest international standards, with due consideration of the conditions and practices of the local industry. Stage 2 of the review will include the requirements for product certified steel reinforcing bars.

This Construction Standard relates to Stage 1 of the review with regard to non-product certified steel reinforcing bars.

CS2:1995 was prepared by making reference to BS 4449:1988, which has been superseded by subsequent versions in 1997 and 2005. This Construction Standard makes reference to the latest version of BS 4449, viz. BS 4449:2005+A2:2009 for ribbed steel reinforcing bars, and BS 4482:2005 for plain steel reinforcing bars up to 12 mm diameter. It does not cover steels delivered in the form of coils and decoiled products, and plain steel reinforcing bars of grade 250 with diameter larger than 12 mm, for which other standards should be referred to.

This Construction Standard provides full material specifications for grade 250 (for steel reinforcing bars up to 12 mm diameter), grade 500B and grade 500C steel reinforcing bars, including requirements on mass per metre, chemical composition, mechanical properties and bond property. The local requirements for certification of Quality Assured (QA) Stockists and the purchasers testing have been updated in Sections 4 and 5 of this Construction Standard.

STEEL FABRIC allow good freedom for Concrete Reinforcement.
3.2 Reinforcing steel

3.2.1 General

(1)\(^P\) The application rules of this Eurocode apply to reinforcement which is in the form of bars, de-coiled rods and welded fabric in accordance with EN 10080. They do not apply to specially coated bars.

(2)\(^P\) The requirements for the properties of the reinforcement are for the material as placed in the hardened concrete. If site operations can affect the properties of the reinforcement, then those properties shall be verified after such operations.

(3)\(^P\) Where other steels are used, which are not in accordance with EN 10080, the properties shall be verified to be in accordance with this Eurocode.

(4)\(^P\) The required properties of reinforcing steels given in Table 3.3 are fulfilled if the testing procedures and results are in accordance with EN 10080.

(5)\(^P\) EN 10080 refers to a yield strength \(R_y\), which relates to the characteristic, minimum and maximum values based on the long-term quality level of production. In contrast, \(f_y\) is the characteristic yield stress based on only that reinforcement used in a particular structure. There is no direct relationship between \(f_y\) and the characteristic \(R_y\). However the methods of evaluation and verification of yield strength given in EN 10080 provide a sufficient check for obtaining \(f_y\).

(6)\(^P\) The application rules relating to lattice girders apply only to those made with ribbed bars. The use of lattice girders made with other types of reinforcement/steel (e.g. plain bars) shall be in accordance with separate special rules or documentation of the results of tests to show that the application rules apply. Lattice girders made with other types of reinforcement shall be in accordance with the appropriate European Technical Approval.

### Table C.2N: Properties of reinforcement

<table>
<thead>
<tr>
<th>Product form</th>
<th>Bars and de-coiled rods</th>
<th>Wire Fabrics</th>
<th>Requirement or quantile value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Fatigue stress range (MPa) (for (N \geq 2 \times 10^5) cycles) with an upper limit of (f_y)</td>
<td>≥150</td>
<td>≥100</td>
<td>10,0</td>
</tr>
<tr>
<td>Bond:</td>
<td>Nominal bar size (mm)</td>
<td>5 - 6</td>
<td>6,5 to 12</td>
</tr>
<tr>
<td>Minimum</td>
<td>0,035</td>
<td>0,040</td>
<td>0,056</td>
</tr>
<tr>
<td>relative rib area, (f_{y,\text{rel}})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nominal Bar Size Relate To Bond Strength with Concrete

Plain Bar Size in Lattice Girders

ISO 10544 or BS 4482 :2005
Compliance Checking:
Steel for the Reinforcement of Concrete

Properties of the reinforcing steel
The reinforcing steels manufactured in Ferriere Nord S.p.A., company of Pittini Group, are delivered in bars, coils, welded fabric and lattice girders conforms the standard prEN 10080:1999.

Table 6 — Preferred nominal diameters, cross-sectional areas and masses per metre

<table>
<thead>
<tr>
<th>Nominal diameter mm</th>
<th>Bars</th>
<th>Coils and De-coiled products</th>
<th>Welded fabric</th>
<th>Lattice girders</th>
<th>Nominal cross-sectional area mm²</th>
<th>Nominal per metre mass kg/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>12.6</td>
<td>0.099</td>
</tr>
<tr>
<td>4.5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>16.9</td>
<td>0.125</td>
</tr>
<tr>
<td>5.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>19.6</td>
<td>0.154</td>
</tr>
<tr>
<td>5.5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>23.5</td>
<td>0.187</td>
</tr>
<tr>
<td>6.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>28.3</td>
<td>0.222</td>
</tr>
</tbody>
</table>

Figure 1 — Geometrical characteristics of purpose made welded fabric.

NON WELDED steel fabric reinforcement can follow the Nominal Cross-sectional Area Requirements recommended in EN 10080 : 2005
Compliance Checking: IsoGrid Steel Fabric for the Reinforcement of Concrete

By reference to the equivalent steel cross sectional as adopted in welded steel fabric reinforcement, all Current RC code can be employed for engineering calculation, checking and approval.

PERFORATED STEEL PLATE as fabric reinforcement to augment the bond between the steel and concrete.
MustDo TIM Panel

Compliance Checking: BS 8110-1: 1997

Concrete Structural Elements

Minimum Elements Thickness

Minimum dimensions of reinforced concrete members for fire resistance

<table>
<thead>
<tr>
<th>Fire resistance</th>
<th>Minimum beam width (b) mm</th>
<th>Rib width (b) mm</th>
<th>Minimum thickness of floors (b) mm</th>
<th>Column width (b) mm</th>
<th>Minimum wall thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>200</td>
<td>125</td>
<td>75</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>125</td>
<td>95</td>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>1.5</td>
<td>200</td>
<td>125</td>
<td>110</td>
<td>250</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>125</td>
<td>125</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>240</td>
<td>150</td>
<td>150</td>
<td>400</td>
<td>300</td>
</tr>
<tr>
<td>4</td>
<td>280</td>
<td>175</td>
<td>170</td>
<td>450</td>
<td>350</td>
</tr>
</tbody>
</table>

NOTE 1  These minimum dimensions relate specifically to the covers given in Table 3.4 and Table 4.9.

NOTE 2  p is the area of steel relative to that of concrete.
Concrete Cover Requirements Under HK Building Regulations

Concrete Cover Requirement Checking

<Durability, Fire, & Bond Requirements>

\[ C_{\text{nom}} = C_{\text{min}} + C_{\text{dev}} \]

1. Reinforcement Bond  (Not smaller than rebar thickness)

2. Aggregate Size  (Not smaller than maximum aggregate size)

3. Durability  (Not smaller than exposure class/strength class)

4. Fire Resistance  (Not smaller than prescribed FRP as per element type)

5. Add Deviation/Tolerance factor  (check for in-situ or precast)

Date: 25 Nov Year 2020
Concrete Cover Requirements In General

Durability and Cover

1. Exposure Classes
2. Structural Classes
3. Cover

4. Detailing of Members / Reinforcement

The cover is the distance between the surface of the reinforcement closest to the nearest concrete surface.

It should be sufficient in order to guarantee:

- the protection of the steel against corrosion;
- the safe transmission of bond forces;
- an adequate fire resistance.
Concrete Cover Requirements Under EUROCODE 2

- Concrete cover is the primary means of ensuring durability:
  - Nominal cover is defined as a minimum cover $c_{\text{min}}$ plus an allowance in design for deviation $\Delta c_{\text{dev}}$
    \[ c_{\text{nom}} = c_{\text{min}} + \Delta c_{\text{dev}} \]
  - Minimum concrete cover $c_{\text{min}}$ shall ensure:
    - Adequate transmission of bond forces
    - Protection of steel from corrosion
    - Adequate fire resistance

\[ c_{\text{min}} = \max\{c_{\text{min}, b}, c_{\text{min}, \text{dur}} + \Delta c_{\text{dur}, \gamma} - \Delta c_{\text{dur}, \text{st}} - \Delta c_{\text{dur}, \text{add}}, 10 \text{ mm}\} \]

Where:
- $c_{\text{min}, b}$: minimum cover for bond requirements
- $c_{\text{min}, \text{dur}}$: minimum cover for environmental requirements
- $\Delta c_{\text{dur}, \gamma}$: additive safety element
- $\Delta c_{\text{dur}, \text{st}}$: reduction of minimum cover for stainless steel
- $\Delta c_{\text{dur}, \text{add}}$: reduction of minimum cover for additional protection

Nominal cover (EC2, Clause 4.4.1.1): Nominal cover is the cover specified by the Designer and shown on the structural drawings. Nominal cover is defined as the minimum cover, $c_{\text{min}}$, plus an allowance in design for deviation to all steel reinforcement, $\Delta c_{\text{dev}}$. It should be specified to the reinforcement nearest to the surface of the concrete (e.g., links in a beam).

The nominal cover to a link should be such that the resulting cover to the main bar is at least equal to the size of the main bar (or to a bar of equivalent size in the case of masts or bundles of three or more bars) plus $\Delta c_{\text{dev}}$. Where no links are present the nominal cover should be at least equal to this size of the bar) plus $\Delta c_{\text{dev}}$.

Where special surface treatments are used (e.g., bush hammering), the expected depth of treatment should be added to the nominal cover.

Nominal covers should not be less than the maximum (nominal) aggregate size.
Concrete Cover Provision for MustDo Sandwich Panel

Exposure classes related to environmental conditions in accordance with EN 206-1

<table>
<thead>
<tr>
<th>Class designation</th>
<th>Description of the environment</th>
<th>Informative examples where exposure classes may occur</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>Dry or permanently wet</td>
<td>Concrete inside buildings with very low air humidity. Concrete permanently submerged in water.</td>
</tr>
<tr>
<td>C22</td>
<td>Wet, rainy dry</td>
<td>Concrete surfaces subject to long-term water contact. Water foundations.</td>
</tr>
<tr>
<td>C23</td>
<td>Moderate humidity</td>
<td>Concrete inside buildings with moderate or high air humidity. Concrete permanently submerged in water.</td>
</tr>
<tr>
<td>C24</td>
<td>Cyclic wet and dry</td>
<td>Concrete surfaces subject to water contact, not within exposure class C22.</td>
</tr>
</tbody>
</table>

EN 13369
Common rules for precast concrete products

<table>
<thead>
<tr>
<th>Table 4 — Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target dimension (mm)</td>
</tr>
<tr>
<td>L ≤ 150</td>
</tr>
<tr>
<td>L = 400</td>
</tr>
<tr>
<td>L ≥ 2,500</td>
</tr>
</tbody>
</table>

a) Linear interpolation for intermediate values.

b) According to EN 1992-1-1:2004, 4.4.1.1: 

\[
g = c_{a} + \Delta_{c} \delta_{c} \]  

[use the numerical value for \( \Delta_{c} \delta_{c} \)]. \( \Delta_{c} \delta_{c} \) is a Nationally Determined Parameter; hence other values may be valid in the place of use. A manufacturer may achieve and declare smaller values for \( \Delta_{c} \delta_{c} \) than given in the National Annex by taking the appropriate measures.
## Concrete Cover Provision for MustDo Sandwich Panel

<table>
<thead>
<tr>
<th>Exposure Class</th>
<th>100 years: increased b by 2</th>
<th>100 years: increased b y 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>XO</td>
<td>Reduces class by 1</td>
<td>Reduces class by 1</td>
</tr>
<tr>
<td>XC1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XC2, XC3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XC4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XD1 / XS1 / XA1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XD2 / XS2 / XA2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XD3 / XS3 / XA3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Design Working Life
- 25 years and less: Reduces class by 1
- ≥ C30/37 and < C50/60: Reduced by 1
- ≥ C50/60: Reduced by 1

### Strength Class
- C 50/60: Reduced by 1
- C 35/45: Reduced by 1

### Type of Matrix Cement
- Concrete of class: C35/45 base of CEM 1 without fly ash: Reduced by 1
- Concrete of class: C35/45 base of CEM 1 with fly ash: Reduced by 1
- Concrete of class: C40/50 base of CEM 1 without fly ash: Reduced by 1
- Concrete of class: C40/50 base of CEM 1 with fly ash: Reduced by 1

### Composition of Cover
- Reduces by 1
- Reduces by 1
- Reduces by 1
- Reduces by 1

### Compact Cover
- Reduces by 1
- Reduces by 1
- Reduces by 1
- Reduces by 1

---

1. For reasons of simplicity, the resistance class here is an indicator of variability. It may be advisable to refer to the above or fundamental indicators of durability and associated threshold values, as specific information on the structural classification indicated, referring to the AFPC guideline "Design of structures for a given lifetime of structures", to standards documents based on the same principles.
2. This criterion applies only to the case of elements for which a good compactness of the cover can be guaranteed, namely:
   - Frameworks of elements that are easily accessible (cavities, accessible, possible ribbed) of horizontal or vertical frameworks.
   - Elements industrially prefabricated or elements extruded or drawn, or framework sections of elements cast into metal frameworks.
   - Under base of flat roof, possibly ribbed, subject to accessibility of bottom of framework with vibration devices.
3. For exposure classifications XA1, this criterion is indicative of the compactness of the cover, subject to the conditions of the aggressive agent.
**Procedure for calculating the minimum concrete cover under EUROCODE 2**

**Final determination of $c_{\text{min,dur}} (1)$**

The value $c_{\text{min,dur}}$ is finally determined as a function of the structural class and the exposure class:

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Exposure Class according to Table 4.1 (Eurocode 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X0</td>
</tr>
<tr>
<td>S1</td>
<td>10</td>
</tr>
<tr>
<td>S2</td>
<td>10</td>
</tr>
<tr>
<td>S3</td>
<td>10</td>
</tr>
<tr>
<td>S4</td>
<td>10</td>
</tr>
<tr>
<td>S5</td>
<td>15</td>
</tr>
<tr>
<td>S6</td>
<td>20</td>
</tr>
</tbody>
</table>

**Concrete cover**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Suggest</th>
<th>User defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Exposure class</td>
<td></td>
<td>XC1</td>
</tr>
<tr>
<td>2 Strength class</td>
<td>C70/85</td>
<td></td>
</tr>
<tr>
<td>3 Max agg diam. (mm)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4 Service life</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>5 Slab or similar?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>6 Quality control?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>7 Max bar diam. (mm)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>8 $\Delta c_{\text{dur,cat}}$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9 $\Delta c_{\text{dur,cel}}$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 $\Delta c_{\text{dur,add}}$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11 $\Delta c_{\text{dur,dev}}$</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>12 Structural class</td>
<td>S2</td>
<td></td>
</tr>
<tr>
<td>13 $c_{\text{min,dur}}$</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>14 $c_{\text{min,b}}$</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>15 $c_{\text{min}}$</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>16 $c_{\text{nom}}$</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

**Environmental Requirement for $c_{\text{min,dur}}$ (mm)**

- **Structural Class**: S1, S2, S3, S4, S5, S6
- **Exposure Class**: X0, XC1, XC2 / XC3, XC4, XD1 / XS1, XD2 / XS2, XD3 / XS3

Minimum Nominal Concrete Cover Required for MustDo Panel is 15mm.
### Table A  
**Specification for Welded Wire Fabric**  
**Standard Specifications - Sheets**

<table>
<thead>
<tr>
<th>Steel Ratios of</th>
<th>Main Wire</th>
<th>Cross Wire</th>
<th>Cross Sectional</th>
<th>Area Mass Per</th>
<th>Uncoiled Area</th>
<th>kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.S.M. Ref. No.</td>
<td>mm (mm)</td>
<td>mm (mm)</td>
<td>mm (mm)</td>
<td>mm²/m²</td>
<td>mm²/m²</td>
<td></td>
</tr>
<tr>
<td>20-13</td>
<td>13 300</td>
<td>13 300</td>
<td>464 664</td>
<td>10.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-10</td>
<td>10 300</td>
<td>10 300</td>
<td>475 475</td>
<td>7.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35-7</td>
<td>7 300</td>
<td>7 300</td>
<td>511 511</td>
<td>9.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-5</td>
<td>5 300</td>
<td>5 300</td>
<td>566 566</td>
<td>9.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-3</td>
<td>3 300</td>
<td>3 300</td>
<td>630 630</td>
<td>11.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-2</td>
<td>2 300</td>
<td>2 300</td>
<td>705 705</td>
<td>13.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80-1</td>
<td>1 300</td>
<td>1 300</td>
<td>800 800</td>
<td>15.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-0.8</td>
<td>0.8 300</td>
<td>0.8 300</td>
<td>900 900</td>
<td>16.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120-0.6</td>
<td>0.6 300</td>
<td>0.6 300</td>
<td>1000 1000</td>
<td>17.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150-0.45</td>
<td>0.45 300</td>
<td>0.45 300</td>
<td>1100 1100</td>
<td>19.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200-0.3</td>
<td>0.3 300</td>
<td>0.3 300</td>
<td>1600 1600</td>
<td>23.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-0.2</td>
<td>0.2 300</td>
<td>0.2 300</td>
<td>2400 2400</td>
<td>34.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400-0.15</td>
<td>0.15 300</td>
<td>0.15 300</td>
<td>3600 3600</td>
<td>49.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-0.1</td>
<td>0.1 300</td>
<td>0.1 300</td>
<td>5000 5000</td>
<td>62.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Equivalent Area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>114 114</td>
<td>114 114</td>
<td>2088 2088</td>
<td>30.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Date:</strong> 25 Nov Year 2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B  
**Substitution of Fabric for Mild Steel Bars**

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Spacing (mm)</th>
<th>Area (mm²/m)</th>
<th>Equivalent Area (mm²/m)</th>
<th>Recommended Ref. No. (mm²/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>75</td>
<td>1947</td>
<td>540</td>
<td>D9 B361</td>
</tr>
<tr>
<td>14</td>
<td>75</td>
<td>2147</td>
<td>518</td>
<td>D9 B305</td>
</tr>
<tr>
<td>18</td>
<td>75</td>
<td>2258</td>
<td>493</td>
<td>D9 B306</td>
</tr>
<tr>
<td>22</td>
<td>75</td>
<td>2370</td>
<td>464</td>
<td>D9 B307</td>
</tr>
<tr>
<td>25</td>
<td>75</td>
<td>2473</td>
<td>438</td>
<td>D9 B308</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
<td>2576</td>
<td>409</td>
<td>D9 B309</td>
</tr>
<tr>
<td>35</td>
<td>75</td>
<td>2680</td>
<td>382</td>
<td>D9 B310</td>
</tr>
<tr>
<td>40</td>
<td>75</td>
<td>2784</td>
<td>355</td>
<td>D9 B311</td>
</tr>
<tr>
<td>50</td>
<td>75</td>
<td>2888</td>
<td>328</td>
<td>D9 B312</td>
</tr>
<tr>
<td><strong>Steel Ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
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<tr>
<td>150</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
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</tr>
<tr>
<td>300</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
</tbody>
</table>

### Table C  
**Substitution of Fabric for High Tensile Steel Bars**

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Spacing (mm)</th>
<th>Area (mm²/m)</th>
<th>Equivalent Area (mm²/m)</th>
<th>Recommended Ref. No. (mm²/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>75</td>
<td>3623</td>
<td>958</td>
<td>D9 B361</td>
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<td>D9 B350</td>
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<td>3828</td>
<td>967</td>
<td>D9 B351</td>
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<td>4244</td>
<td>987</td>
<td>D9 B355</td>
</tr>
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<td>75</td>
<td>4348</td>
<td>992</td>
<td>D9 B356</td>
</tr>
<tr>
<td>50</td>
<td>75</td>
<td>4452</td>
<td>997</td>
<td>D9 B357</td>
</tr>
<tr>
<td><strong>Steel Ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
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<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
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<tr>
<td>200</td>
<td>114</td>
<td>2088</td>
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<td></td>
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<tr>
<td>300</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>114</td>
<td>2088</td>
<td>3050</td>
<td></td>
</tr>
</tbody>
</table>

*Equivalent Area* = Area of steel bar

Where:  
- As = Area of steel bar
- fy (tensile bar) = 460 N/mm² for high tensile bar
- fy (fabric) = 485 N/mm² for hand-drawn steel wire

*Equivalent Area* = Area of steel bar

Where:  
- As = Area of steel bar
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In-situ Concreting: Trial Arrangement

Date: 25 Nov Year 2020

Hole in cap plate to allow concrete through

Bottom-up SCC Casting

In-situ Sandwich Casing
MustDo TIM Panel

Modular Topology Approach
MustDo TIM Panel

Modular Planning

Cellular-Layer-Tubular

IsoGrid Fabric

MustDo Wall Assembly Design

Modular Planning

Tubular Connector

MIC Module

MIC Module
Part - I: MustDo Composite Approach

Part - II: MustDo Composite Testing

Part - III: MustDo DfMA

Part - IV: Current Steel Concrete Types

Towards A New Co-Creation Dynamics
按厚度分根据GB/T15574-1995《钢产品分类》的规定
1) 薄钢板：厚度小于或等于3mm的钢板称为薄钢板(但按照我国传统的分法，一般是小于或等于4mm)。
2) 厚钢板：厚度大于3(4)mm的钢板。在实际工作中，厚钢板又称中厚钢板，其划分是：(1)中板：厚度3(4)-20mm的钢板。
HOT EXTRUDED SPECIAL STEEL PROFILES

THE FORMING TECHNOLOGY KNOWN AS HOT EXTRUSION CAN BE USED TO PRODUCE PROFILED BARS AND TUBES WITH COMPLEX GEOMETRIES.

TECHNICAL PARAMETERS

<table>
<thead>
<tr>
<th>STEEL TYPE</th>
<th>DIMENSIONS</th>
<th>LENGTHS</th>
<th>WEIGHT PER METER</th>
<th>TOLERANCES</th>
<th>MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBON STEEL</td>
<td>Fit in a circle of max Ø 255</td>
<td>Up to c. 16 800 mm</td>
<td>Up to max. c. 110 kg/m</td>
<td>Depending on profile cross section and material</td>
<td>Nearly all quality - all required heat treatments are available</td>
</tr>
<tr>
<td>STAINLESS STEEL AND DUPLEX</td>
<td>Minimum thickness: 4 mm</td>
<td>Up to c. 16 800 mm</td>
<td>Up to max. c. 110 kg/m</td>
<td>Nearly all quality - all required heat treatments are available</td>
<td></td>
</tr>
</tbody>
</table>

DURING HOT EXTRUSION, A PRE-HEATED BILLET IS PLACED IN A CHAMBER AND PUSHED THROUGH A SPECIAL DIE OPENING THAT GIVES THE DESIRED CROSS SECTION TO THE FINISHED BAR.

CREATIVITY IS AN ATTITUDE. IT IS A MINDSET. IT IS THIS ATTITUDE THAT DRIVES THE DESIRE IN ONE TO PRODUCE SOMETHING NEW RATHER THAN REPRODUCE EXISTING TRIED AND TESTED IDEAS.
MustDo Materials

Cutting Operation

Hot Cutting

• Flame Cutting (Oxy-LPG and Oxy-acetylene)
• Plasma Cutting
• Laser Cutting

FLAME CUTTING

Correct selection of nozzle size for the plate thickness being cut is important to ensure efficient cutting and to minimise the width of the heat affected zone (HAZ).

PLASMA CUTTING

The heat affected zone from a plasma cut is narrower than that produced from flame cutting but peak hardnesses are generally higher.

LASER CUTTING

The laser cutting process is unlike other thermal cutting in so far as the material is essentially vapourised from the kerf rather than melting and removal by kinetic energy.

The laser concentrates its energy into a focused beam resulting in low levels of excess heat. This results in very small HAZ areas (0.05 - 0.15 mm) and small kerfs (0.3 mm).

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>KERF WIDTH (mm)</th>
<th>HAZ WIDTH (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame Cutting</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Plasma Cutting</td>
<td>3.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Laser Cutting</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Cold Cutting

• Punching Cutting
• Waterjet Cutting
• Power Sawing

WATERJET CUTTING

A key advantage of water jet cutting is that it leaves the surface free of HAZ. Cutting without heat protects against metallurgical changes in the plate, ensuring original plate mechanical properties are maintained.

The waterjet cut shows no change in material structure at the edge of the cut. The laser cut edge shows a distinct change in structure to a depth of 0.2 mm.

Both laser cutting and waterjet cutting are industrial processes which should be considered by structural designers and fabricators as alternate means to avoiding problems associated with fit up, cut edge squareness, shape precision, dross and gross HAZ’s which can occur with conventional thermal cutting processes.

PUNCHING FORMING

The guillotine blades should be very sharp and set with a clearance of 0.25 - 0.40 mm. Note, the maximum limiting thickness for cold punching are approximately half the cold shearing values.

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MustDo Materials DfMA Steel Plate & Tube Machining

**Abrasive Waterjet Machining**

- Fastest growing machining process
- One of the most versatile machining processes
- Compliments other technologies such as milling, laser, EDM, plasma and routers
- True cold cutting process – no HAZ, mechanical stresses or operator and environmental hazards
- Not limited to machining – food industry applications

Water jet cutting is a cold process, so there is no structural influence. The heat transfer during laser, plasma and flame cutting changes the structure.
MustDo Materials

Abrasie Waterjet Machining

DfMA Steel Plate & Tube Machining

Punching
I - concrete mixing unit; II - production of outer wall panels; III - finishing and export of finished products; IV - production of inner wall panels and floor slab panels; V - production of room (box) units; VI - reinforcement production.
Volumetric Production — Concrete Module Process Flow

Automatic Robotic Production
Architect - Engineer

Part - I: MustDo Composite Approach
Part - II: MustDo Composite Testing
Part - III: MustDo DfMA
Part - IV: Current Steel Concrete Types

Date: 25 Nov Year 2020

PART - IV: REFERENCE
Steel Concrete Composite
Shear Connector Types
Micro-reinforced Concrete
Metal mesh fabric Beam

Towards A New Co-Creation Dynamics
Sandwich Model With Crack Membrane

Steel Concrete Arrangement

Steel Encased Sections

Concrete Encased Sections

Prefabricated Cage Sections
Application of Steel-Concrete-Steel Composite Wall

No Upper Steel Ratio Limit – Steel on the outside of the composite

Double Skin – Steel Concrete Steel Sandwich Composite
Ferrocement Shear Connectors

Three kinds of mechanical shear connectors.

1. concrete-headed Studs,
2. Perfobond connectors,
3. new Burring connectors <B6-6>.

Relationship between Load and Slip of Shear Connector

Failure Modes of Concrete Dowel Shear Connector

Date : 25 Nov Year 2020
High Performance Concrete

ECC Reinforced Slab (135mm thick)

UHPC Application Code

Micro-reinforced Concrete

Slurry infiltrated mat concrete

Bendable Concrete
Concrete Beam Web Using Micro-reinforced Thin Wall
Concrete Beam Web Using Micro-reinforced Thin Wall

Q3 – Mikrobewehrter Beton
- Mikrobewehrung Ø1/20 – $\rho_w = 1.5\%$
- feines Rissbild
- Sekundäres Betonversagen
Concrete Beam Web Using Welded Metal Mesh

A novel means of improving the performance of reinforced concrete beams using the welded wire mesh as core zone reinforcement

The present practice of using shear reinforcement in the form of stirrups, which go round near to the periphery in reinforced concrete beams, leaves the core zone of the cross section, where there is existence of high shear stress, un-reinforced. This leads to sudden appearance and propagation of cracks, leading to brittle failures under shear.

This paper presents a novel means of using prefabricated mesh either as transverse reinforcement in place of conventional stirrups or as longitudinal core reinforcement apart from stirrups/ties, which not only reinforces the core zone of reinforced concrete cross section but also provide resistance against diagonal tension due to shear in continuous manner.
Concrete Beam Web Using Welded Metal Mesh

- **R-160**: Stirrup Rebar As Transverse Reinforcement
- **M-160**: Prefabricated Mesh As Transverse Reinforcement
- **L-160**: Prefabricated Mesh As Longitudinal Reinforcement

Date: 25 Nov Year 2020
Thank you very much for your interest!

Date: 25 Nov Year 2020