...Less Is More...

MATERIAL . ARCHITECTURE

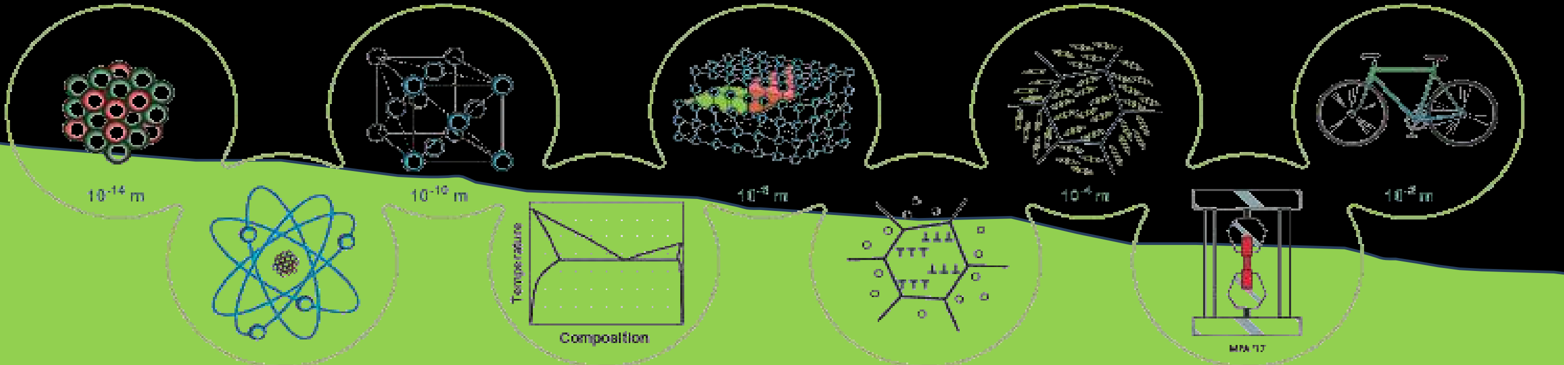
HONG KONG CONCRETE INSTITUTE ANNUAL CONCRETE SEMINAR 2020

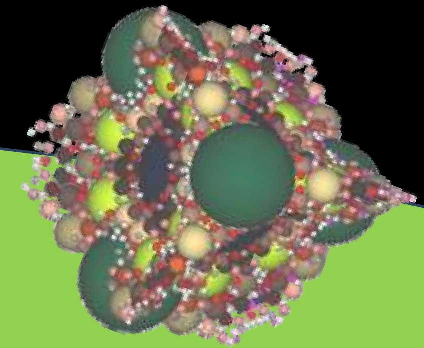
25/11/2020

A New Class Of Material

The New Technology Of Reinforced Concrete

Enablers Of Change



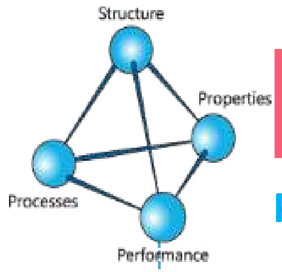


Structural MiC

Evolution in Concrete Morphology For Structural Formation

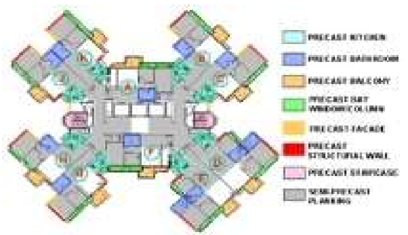
FLEXCRETE

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



R&D Chronology

Precast … Construction IT… Material … MiC



First
Structural Precast Volumetric Prefabrication
HK Fui Tei Residential Highrise Development

HKUST: Professor Chris Leung

First
Adoption of
ECC Concrete

First
Development of
Concrete Glue

Start
Extension of high performance
concrete technologies

Novel Steel-Concrete Sandwich Composite

2002 | 2005 | Architect : Calvin Wong | 2006 | 2012 | 2018 | 2019 | 2020

BxM • Virtual Construction• Mass Customization • Logistic

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

First
Innovative use of RFID in
HK Housing Authority Projects

“Yield-Plane
Work-Hardening”

Start
MustDo System
Development

Complete
MustDo System
Testing

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

Date : 25 Nov Year 2020

Prepared By Flexcrete Technology Limited

FLEXCRETE

Response
To
Market

Part -I : MustDo Composite Approach

Part -II : MustDo Composite Testing

Part -III : MustDo DfMA

Part -IV : Current Steel Concrete Types

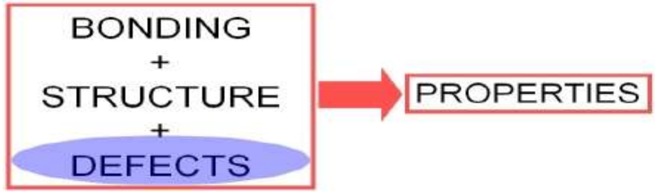
Architect - Engineer

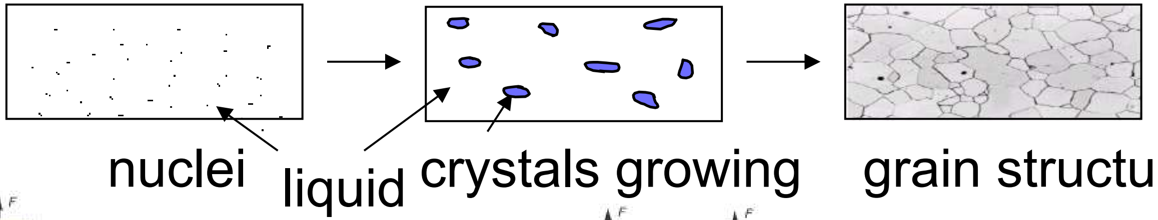
PART - I : APPROACH

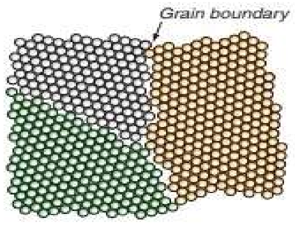
Evolution of RC Concrete
Architected Material
MustDo Composite

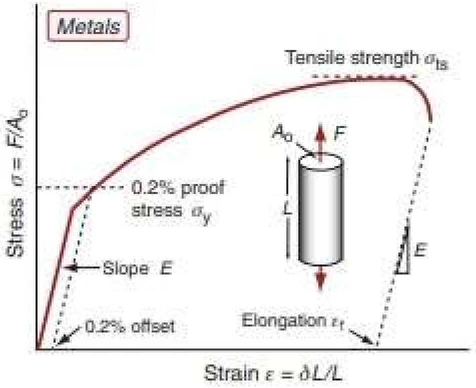
Towards A New Co-Creation Dynamics

Engineering Material Classes Strength & Ductility

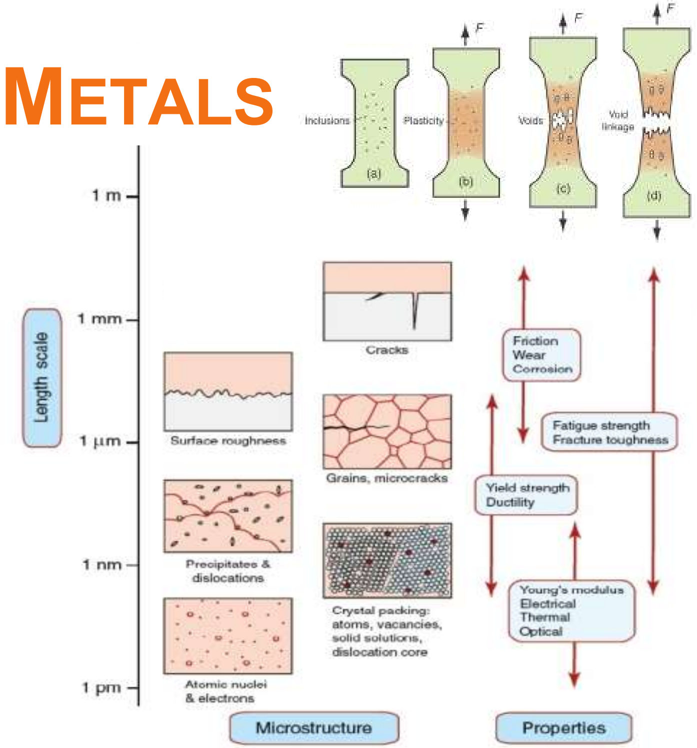




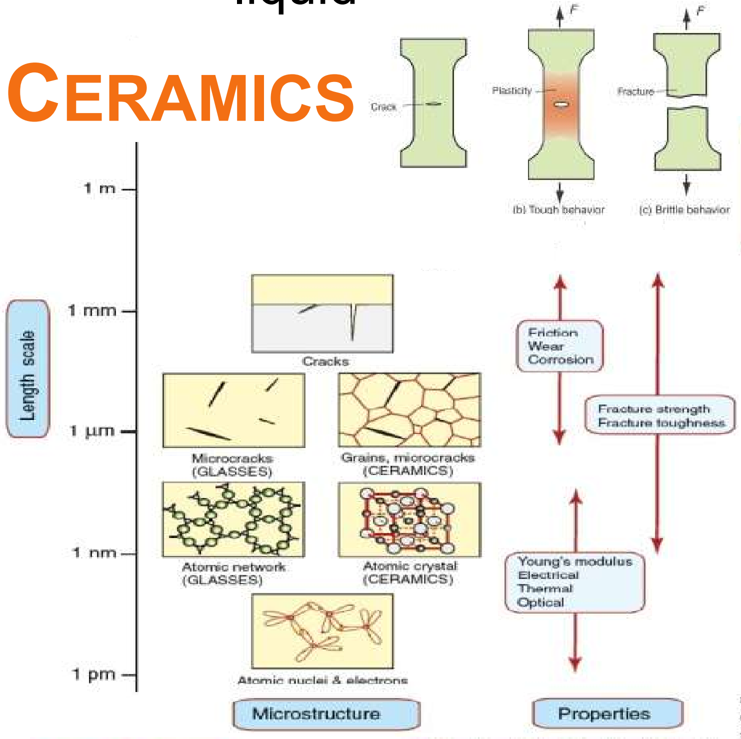




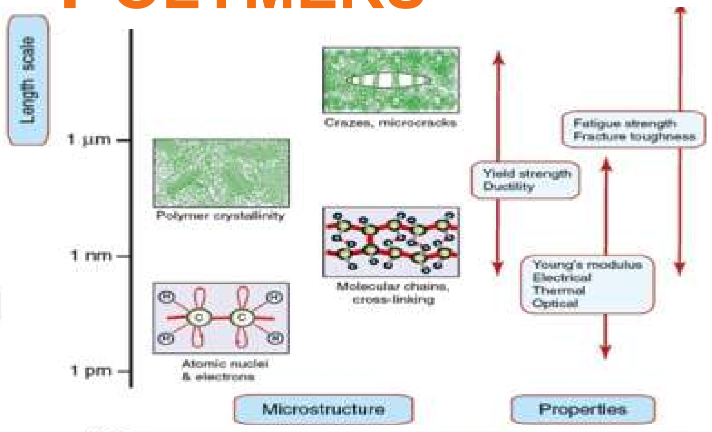
METALS

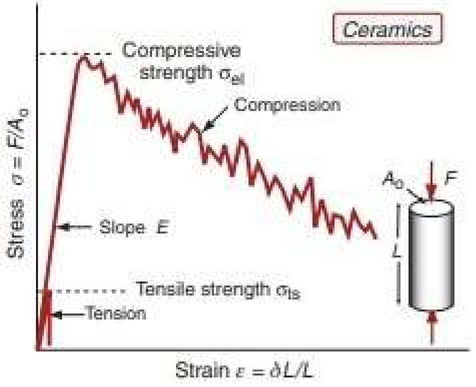


CERAMICS

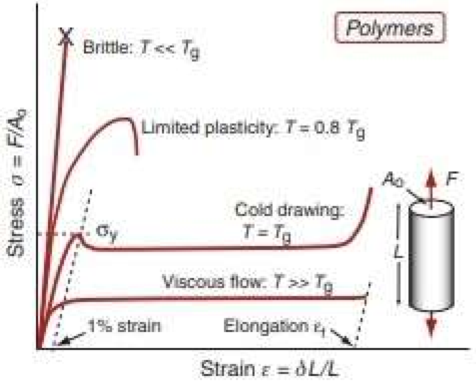


POLYMERS



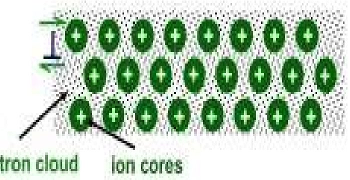


Organic Non-crystalline Structure



Metals:

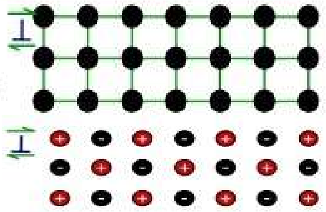
Dislocation motion easier.
- non-directional bonding
- close-packed directions for slip.



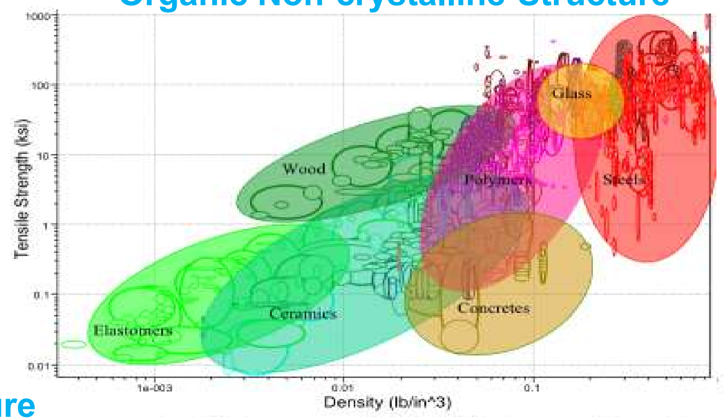
Inorganic Crystalline Structure

Covalent Ceramics (Si, diamond):
Motion hard.
-directional (angular) bonding

Ionic Ceramics (NaCl):
Motion hard.
-need to avoid ++ and - - neighbors.



Inorganic Crystalline/Non-crystalline Structure



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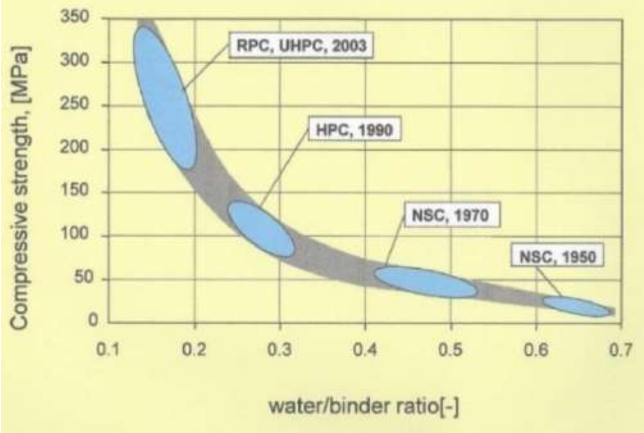
Evolution of Concrete Strength

Normal To High Performance Concrete

Ir. Prof. Albert K.H. Kwan



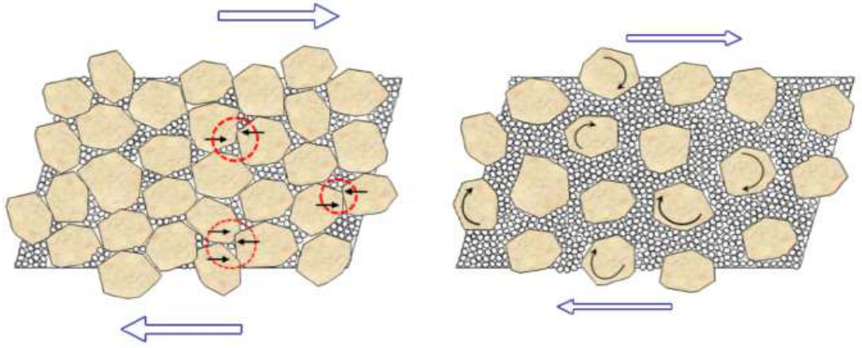
New theories

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

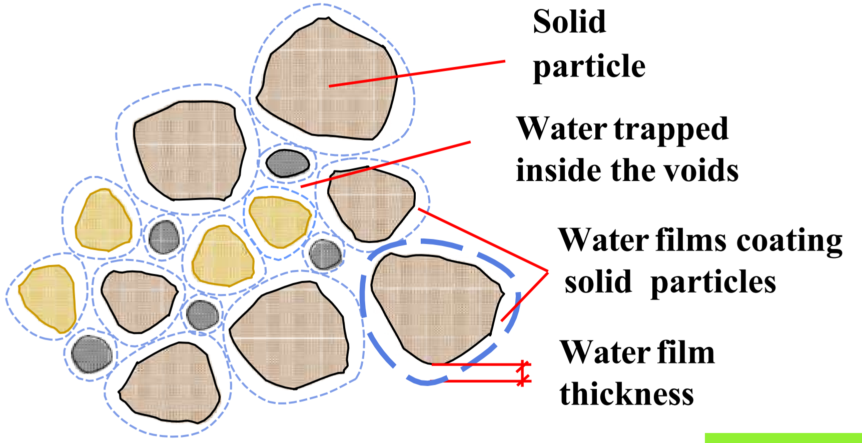
New technologies

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

Particle Interaction



Water Film Thickness



Ultra High Performance Concrete

Homogeneity Enhancement	Granular Mixture Optimization	Tensile & Toughness Enhancement Fibre/Matrix Bonding (LEFM)

Aggregate/Matrix E-Modulus

Meso-Effects

A low W/C ratio and a high cement / ultrafine content

- Reduction of the porosity
- High compressive strength and durability

Paste/Aggregate Interface

Macro-Effects

UHPC does not contain any coarse particle (≤ 2 mm)

- Homogeneity
- High compressive strength

Fibre as Toughening / Main Reinforcement

Matrix Toughness Tensile Strength

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

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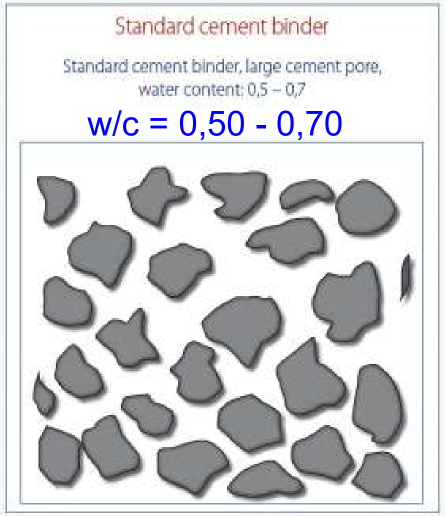
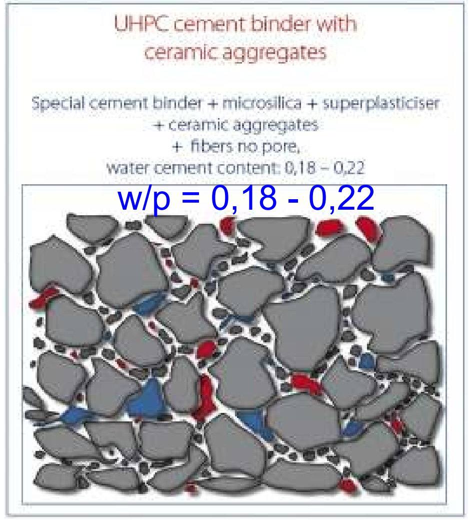
Evolution of Binder Paste Cementitious Binder



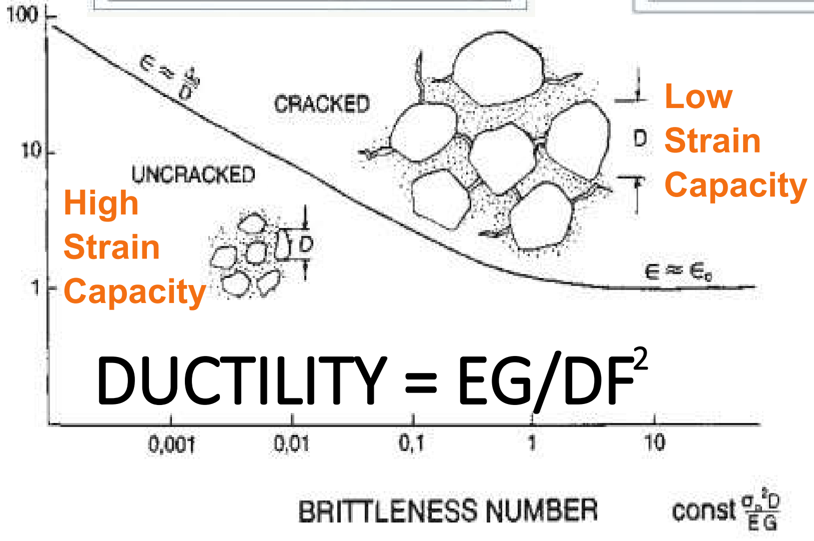


Fracture – Mechanical Properties (By Dr. Hans Henrik Bache)

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

The ductility is given by $D = \frac{\Delta}{\varepsilon_t L} \approx \frac{G E}{F_t^2 L}$ or $\approx \frac{G E}{f_t^2 D}$ where Δ is the deformation of the fracture zone in m, and f_t is the tensile strength in N/m^2. As it can be seen ε_t, G and E 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 $G = f_t \Delta$



E-Modulus of Elasticity
G-Fracture Energy

D-Size of Object
F-Tensile Strength

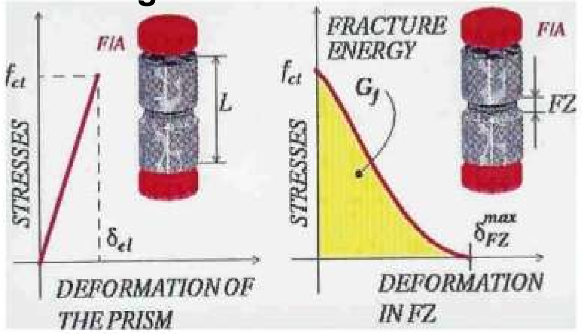
Particle Modification

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).

Softening Material- Concrete/Rock



G- Fracture Energy
Surface Energy-Bond Disruption

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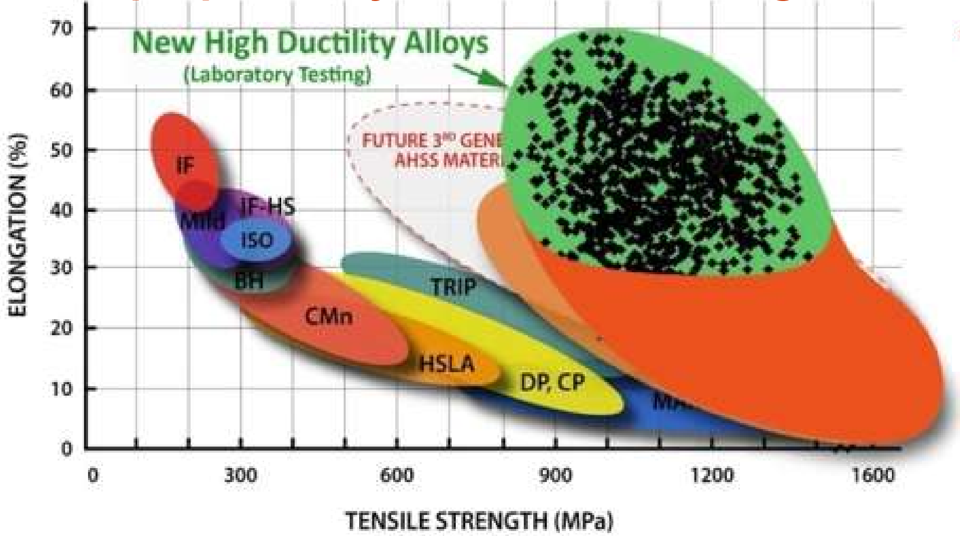
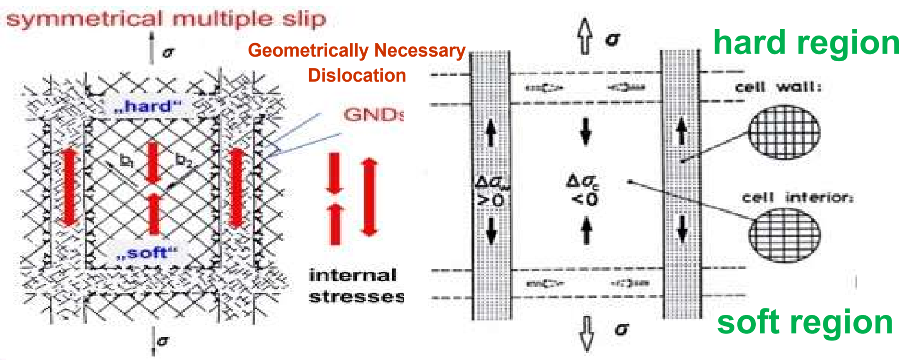
Evolution of Steel Strength

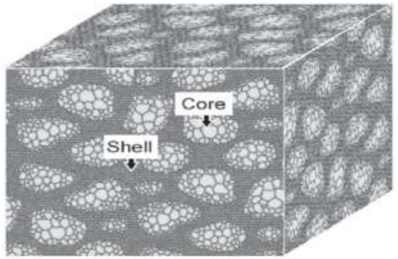
Grain Refining & Pinning

Superplasticity – Neck Free Elongation

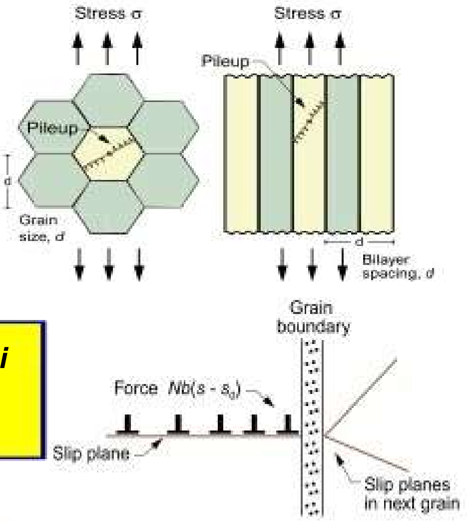


Strain Gradient Plasticity





Dislocation Cell Formation During Deformation

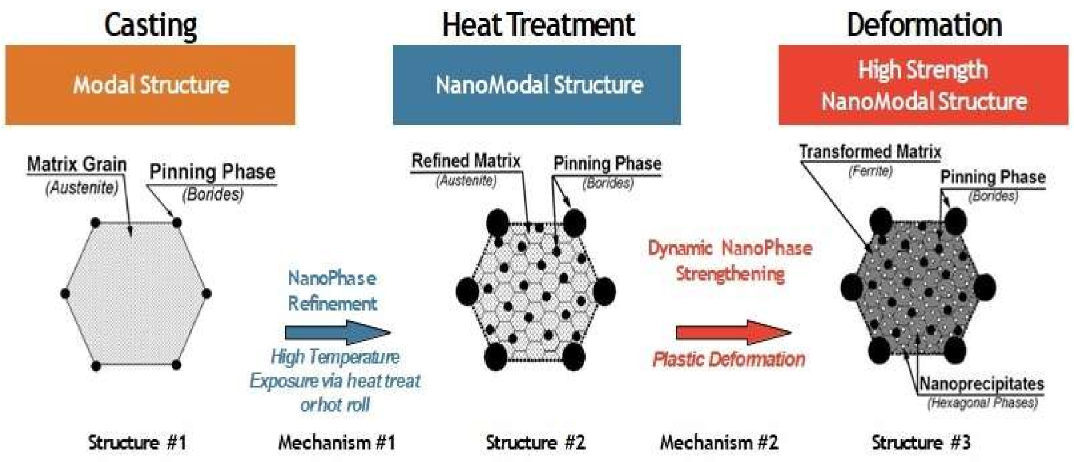


The deformation is:

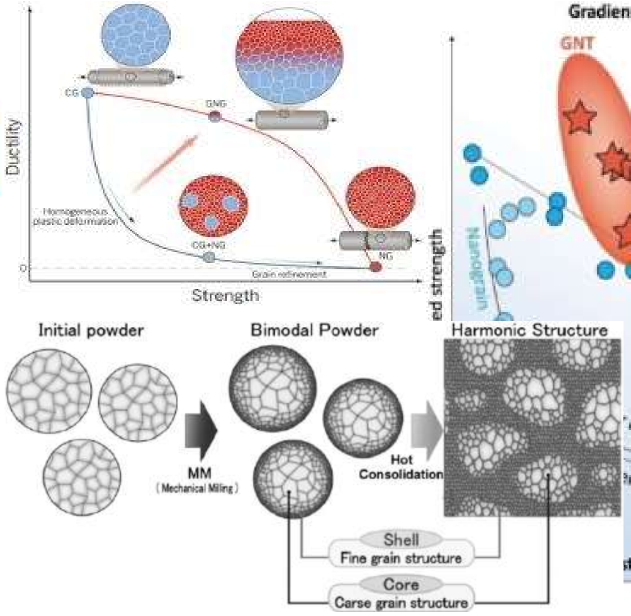
- macroscopically homogeneous, but
- microscopically heterogeneous: „Patterning"

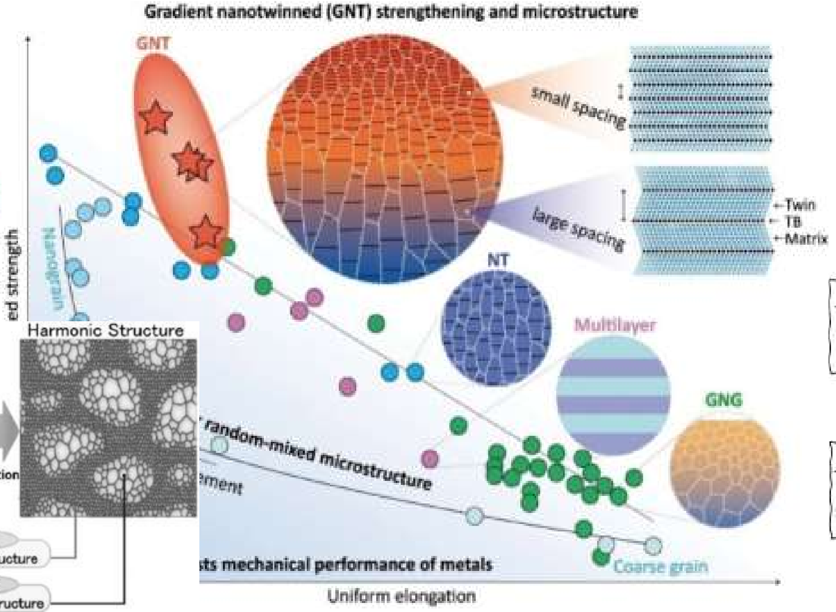
Hael Mughrabi

Structural Development Overview

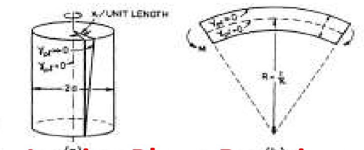


Grain-Size Strengthening **Pinning**

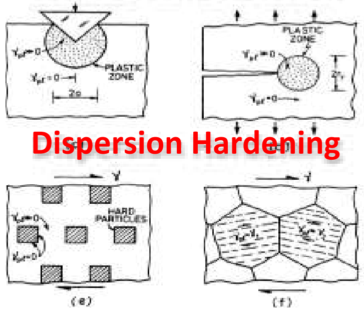




Lattice Plane Rotation



Dispersion Hardening



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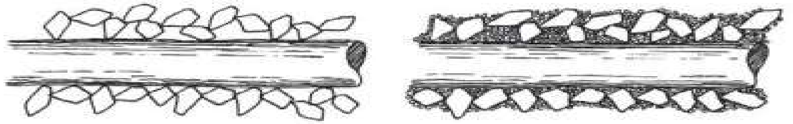
Evolution of Reinforced Concrete

Normal Reinforced

The assumption for the design of reinforced concrete include :



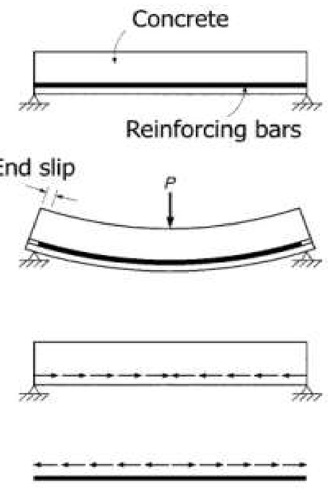
1. Perfect bonding between the concrete and steel exist, and
2. No slippage occur (strain in concrete and reinforcing steel is the same)
3. Moderate controlled cracks on the tensile side. (2-5% of yield strain of reinforcement)

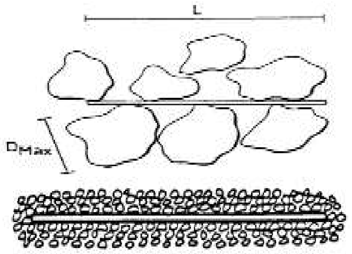
(a) beam before loading

(b) unrestrained slip between concrete and steel

(c) bond forces acting on concrete

(d) bond forces acting on steel



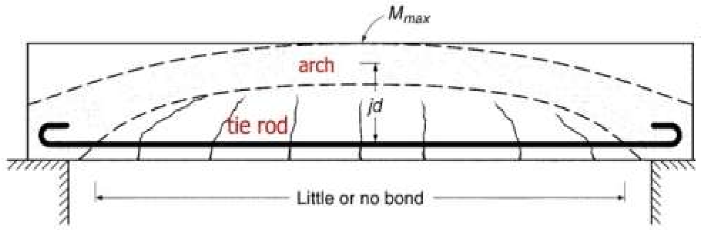


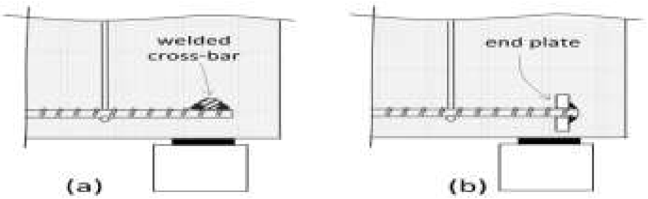
Normal Reinforced Concrete

R > 10 =L/D (smooth bar)

L = Development Length

D = Max. aggregate size





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.

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.

Rule of play – conventional concrete, moderate quantity of reinforcement, good spacing between bars, large overlap length, moderate controlled cracks on the tensile side etc.,

<Normal reinforced concrete – ductile composite material designed in accordance with continuum mechanics>

Reinforcement can only be effectively used at the cost of the internal coherence of the concrete in the form of cracks passing the reinforcement.

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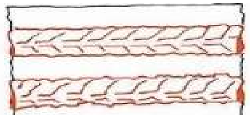
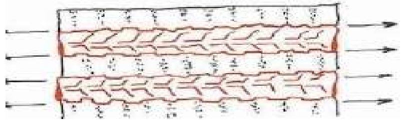
Evolution of Reinforced Concrete Super Reinforced

Crack Through Rebar

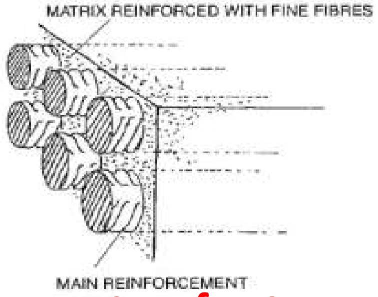
Crack In-between Rebar

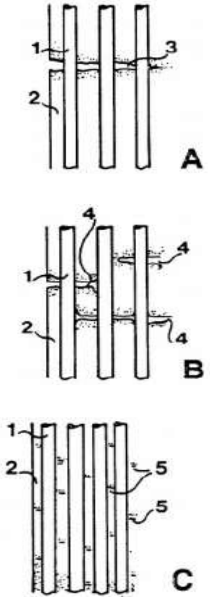


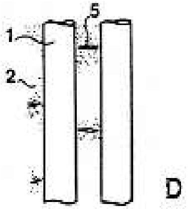
Subdivided Matrix



Distribution of
Multiple Crack Zone Deformation

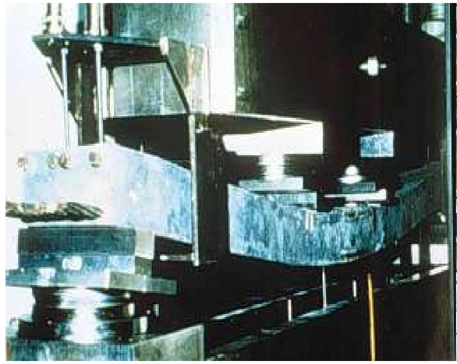


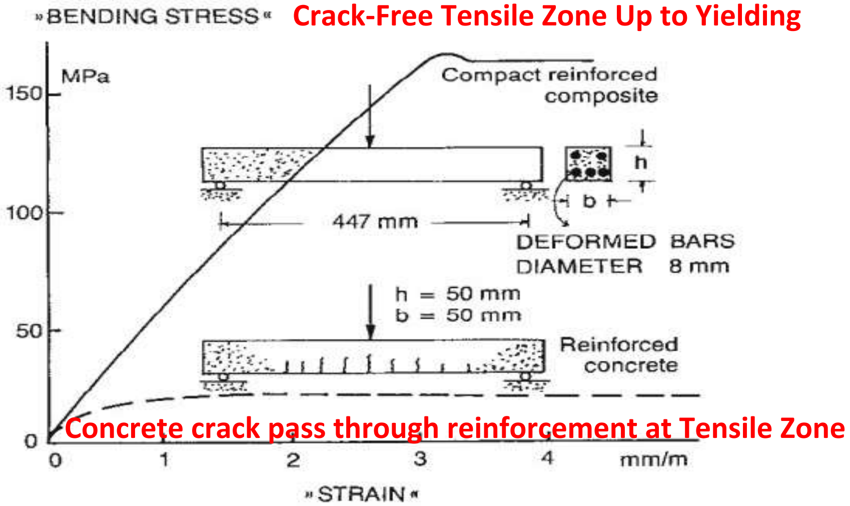




"Dr. Han Henrik Bache" - Multiple Crack Zone Deformation :
If a brittle material is placed in a configuration where it is fixed to rigid boundaries and thereby is subdivided into small individual fixed domains, the strain capacity of the material will be increased.

Crack-Free Tensile Zone Up to Yielding





Concrete crack pass through reinforcement at Tensile Zone

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.

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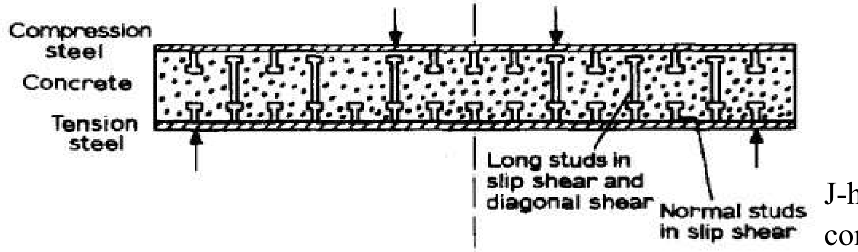
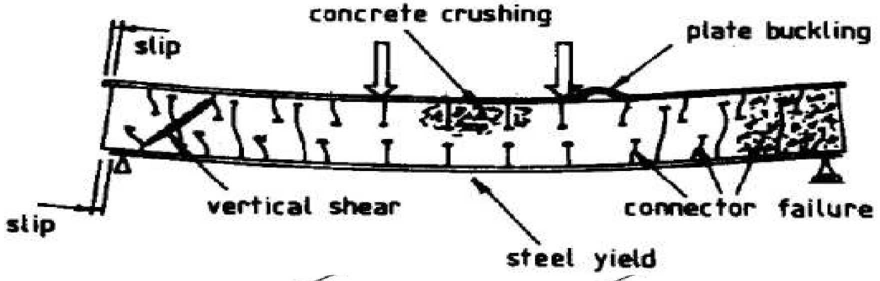
Evolution of Reinforced Concrete

Sandwich
Steel-Concrete-Steel

Steel – Concrete – Steel (Failure Modes)





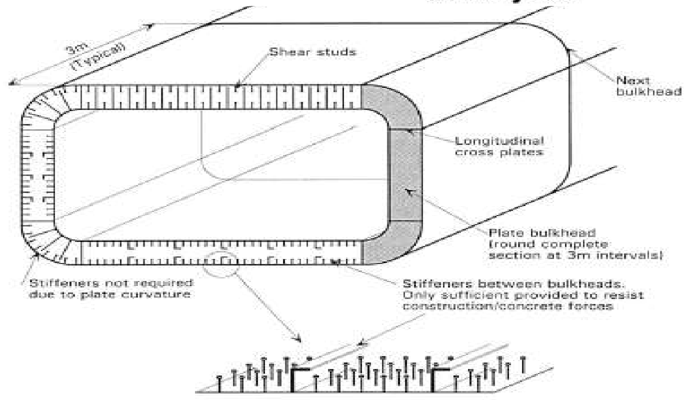
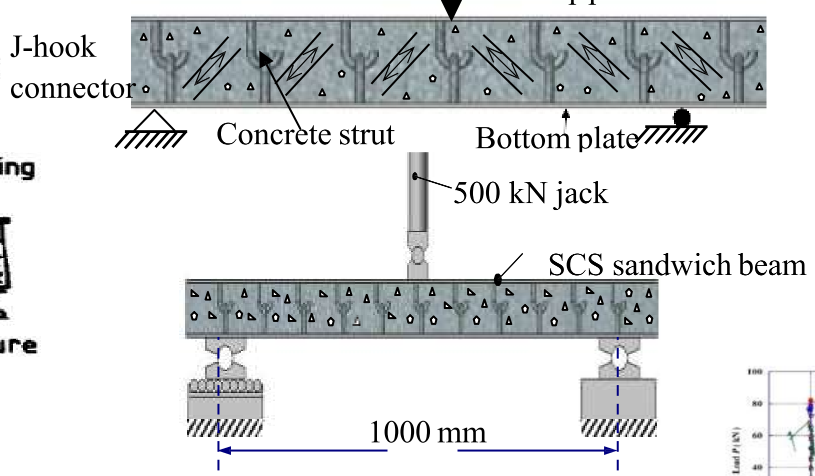


Fig. 1 Steel-Concrete-Steel (SCS) construction using shear studs.

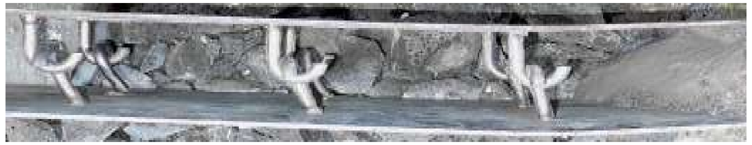


Typical crack pattern and sequence of appearance

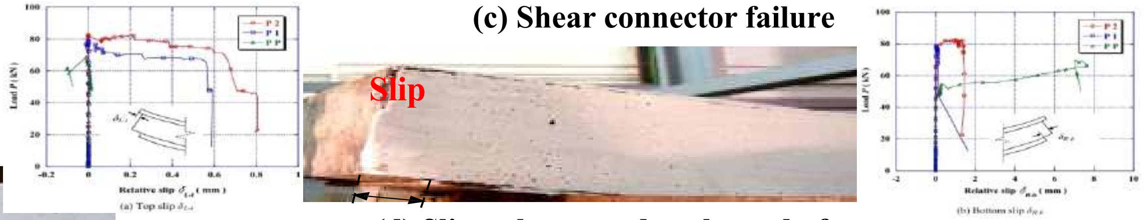
Sandwich Composite Using Shear Stud

(a) Flexural failure

(b) Concrete shear failure



(c) Shear connector failure



(d) Slip at beam end at the end of test

(e) Top plate buckling failure (beam SLCS)

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

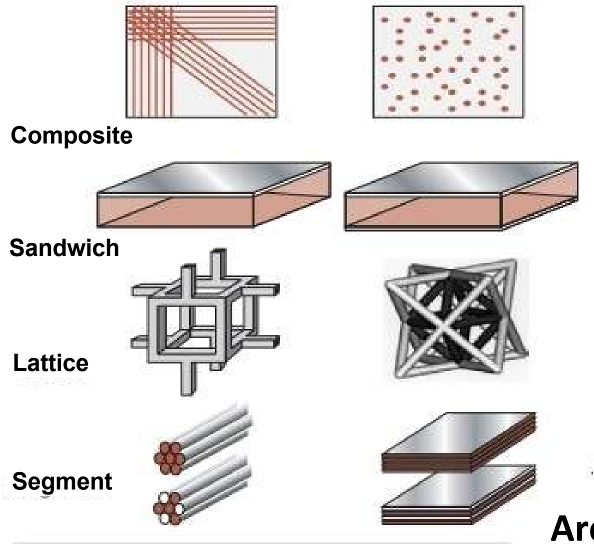
<Load Slip Behaviour between bottom steel plate and concrete core due to mismatch in curvatures result in debonding leading to shear cracks>

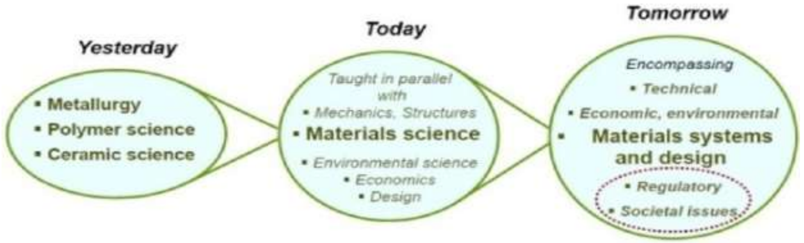
Date : 25 Nov Year 2020

Next >>Architected Materials *Strain Gradient & Topologies*

Prof. Mike Ashby
Granta Design, Cambridge (UK)

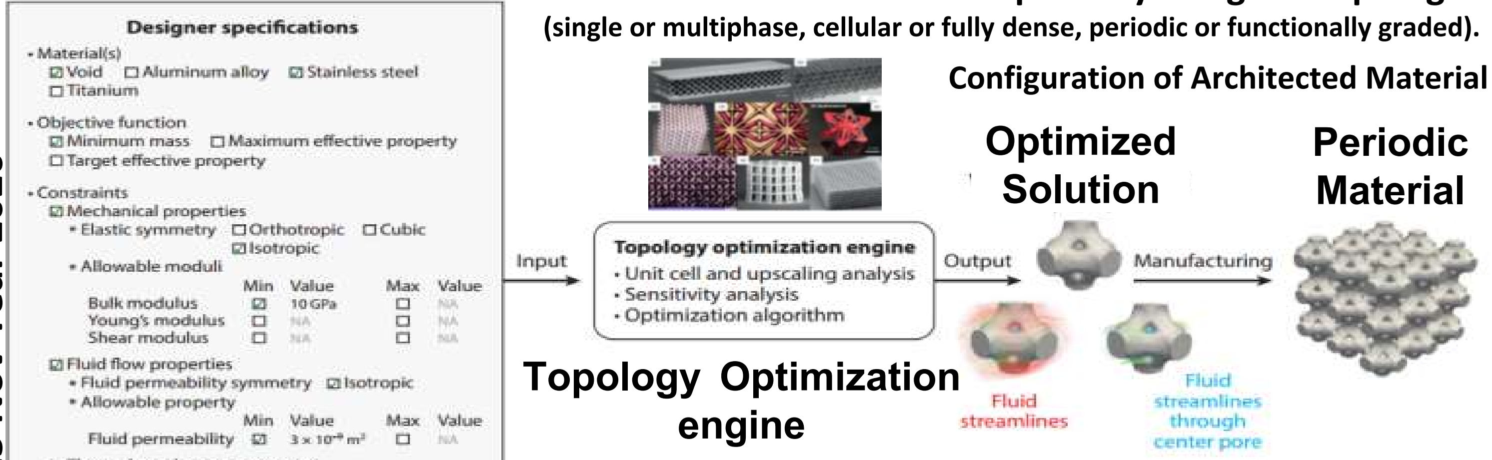
Architected Materials a class of materials that show new and/or customized behaviors by the interplay between material properties and geometry.





Adding Architecture to Materials

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



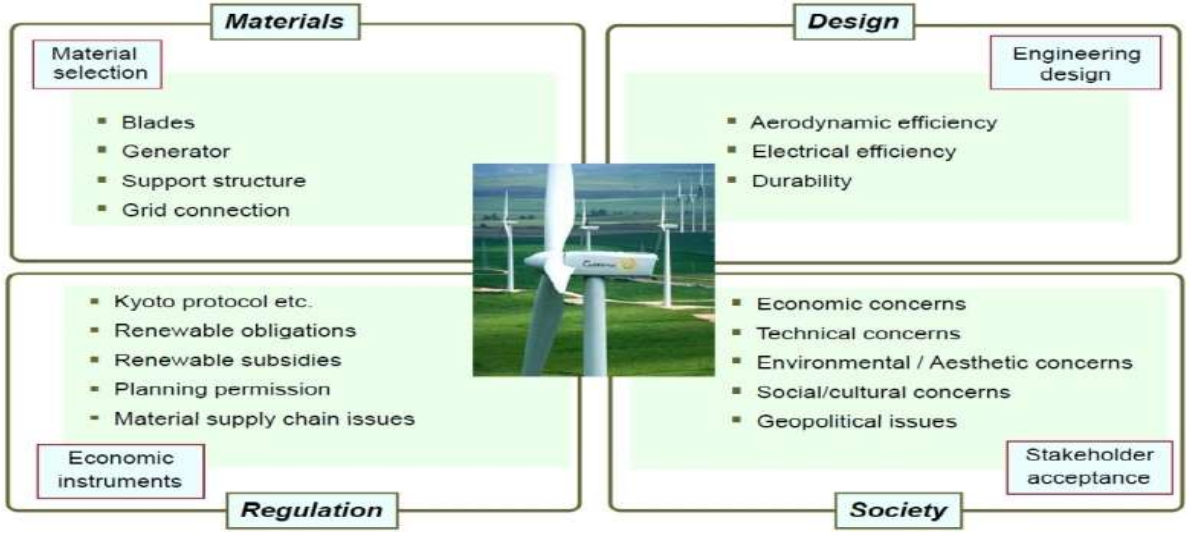
Topology optimization design framework for architected materials. The optimized unit cell architecture is then repeated in all directions and manufactured to form the bulk material.

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.**



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Next >>Composite Structures Reinforcement

Architected Materials

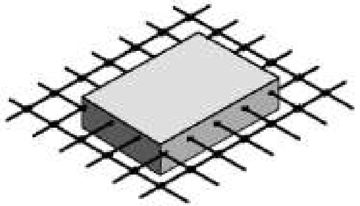
Triangular Interlocked Material

Inorganic Binder Types

Binder : Cementitious….Geopolymer

1D-Main Reinforcement — Steel — GRP

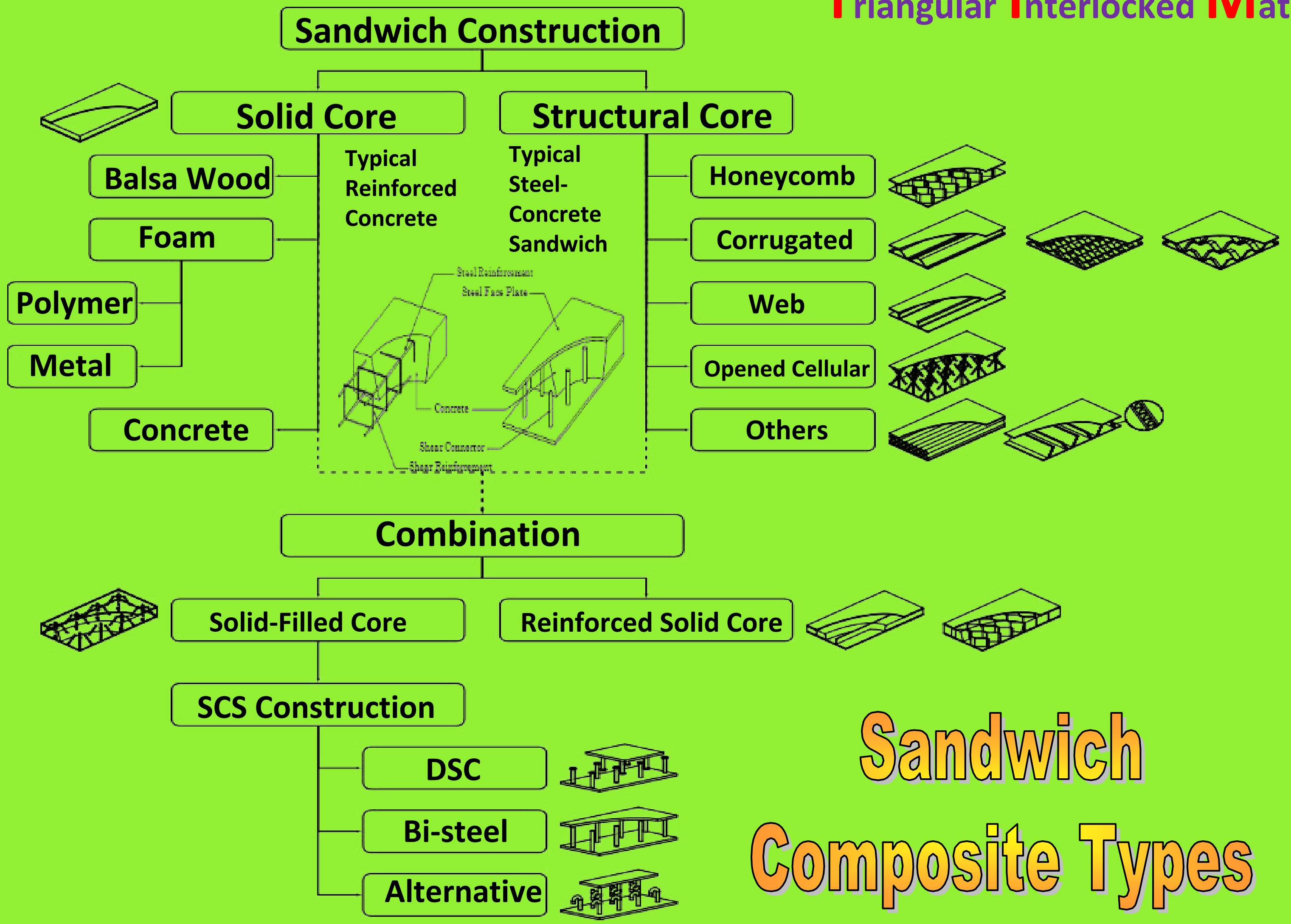
Welded Wire Fabric



2D/3D-Welded Main Reinforcement

Reinforcement Types

1D-Micro-Reinforcement … Fibres



Sandwich Composite Types

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 >

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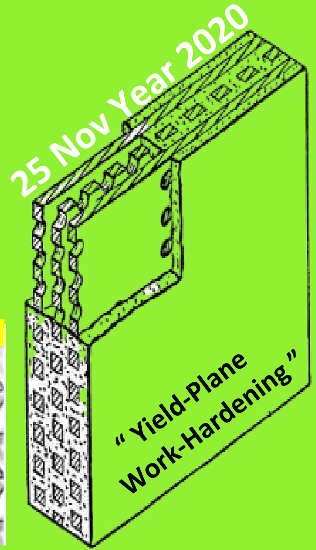
Thin Composite Design

R.T.M TEAM

Response To Market

MustDo

Metal Fabric Grid Reinforced Composite



Multi-layer

Uni-isogrid

Slurry-infiltration

Technology

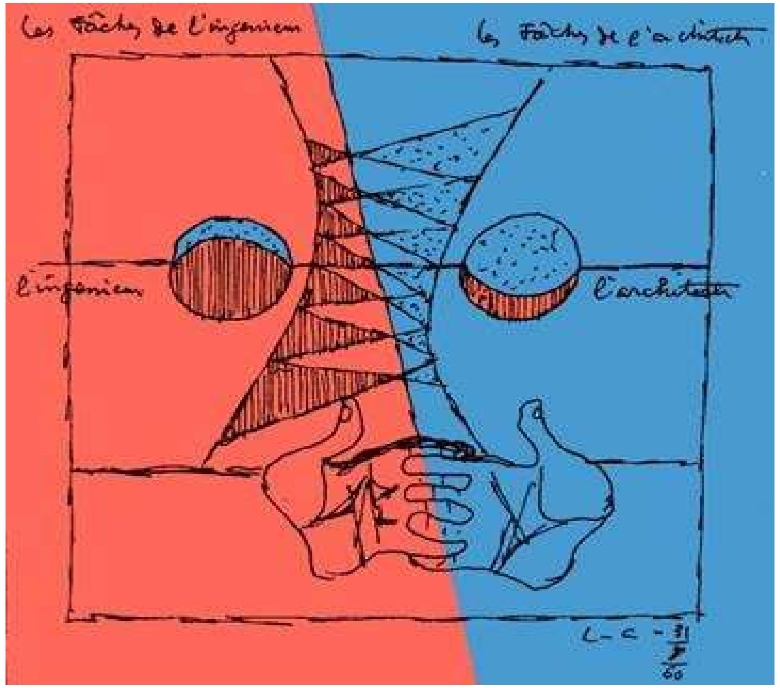
Development

Odm

3 - Dimensional Reinforcement Arrangement + Internal Tension Interlocked

Response To Market

Thin Steel-Concrete Composite Approach



Le Corbusier

- 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

Strength
+
Stiffness
+
Ductility

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, FIStructE

... 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

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

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

... 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*

MustDo Thin Composite

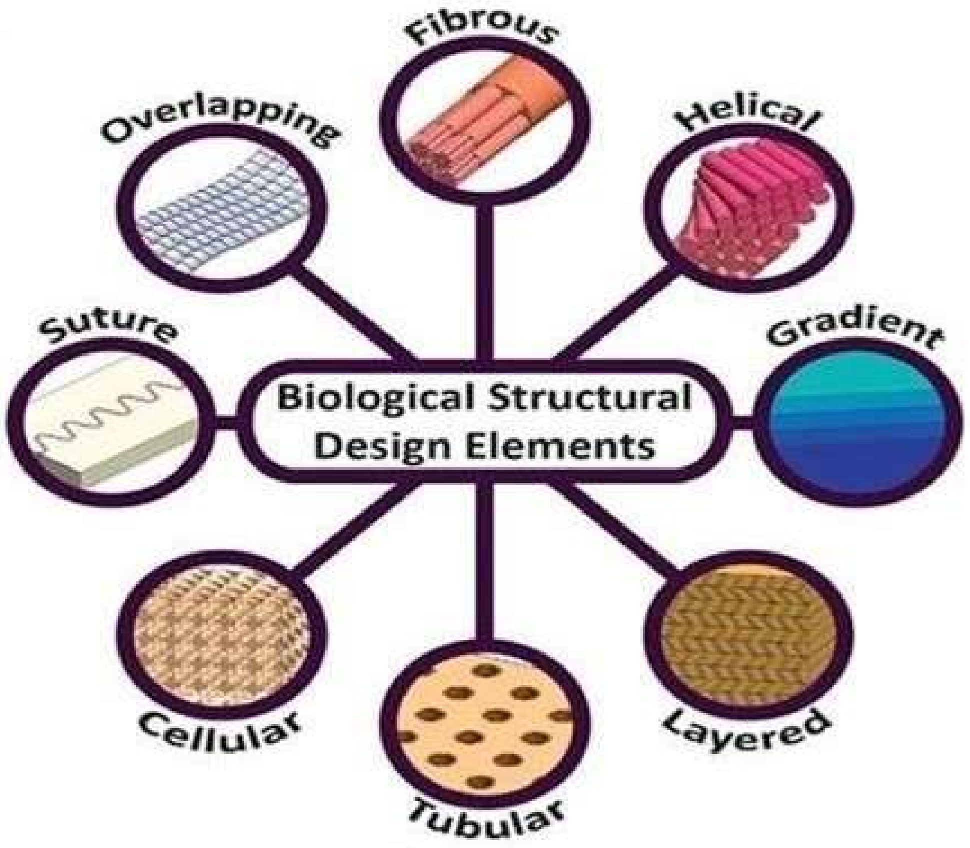
Rule of Mixture>> **Strain Partitioning**

... Localized-Strain-Zone (LSZ)...

... Bioinspired Structural Material...

Strength Heterogeneity
Domain Geometry
Interface Density
Domain Sizes

Multi-layer
Uni-isogrid
Slurry-infiltration
Technology
Development
ODM



→ Cellular

→ Layer

→ Tubular

Heterogeneous Lamella Structure

By utilizing hetero-zone interactions/couplings produce significant synergistic effect to control defect distribution. <Global Ductility–Localized Strain Zone Hardening>

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Composite Configuration Strategy :

Architected Material

LAYERED ............MODULUS.BOND.........CELLULAR.TUBULAR

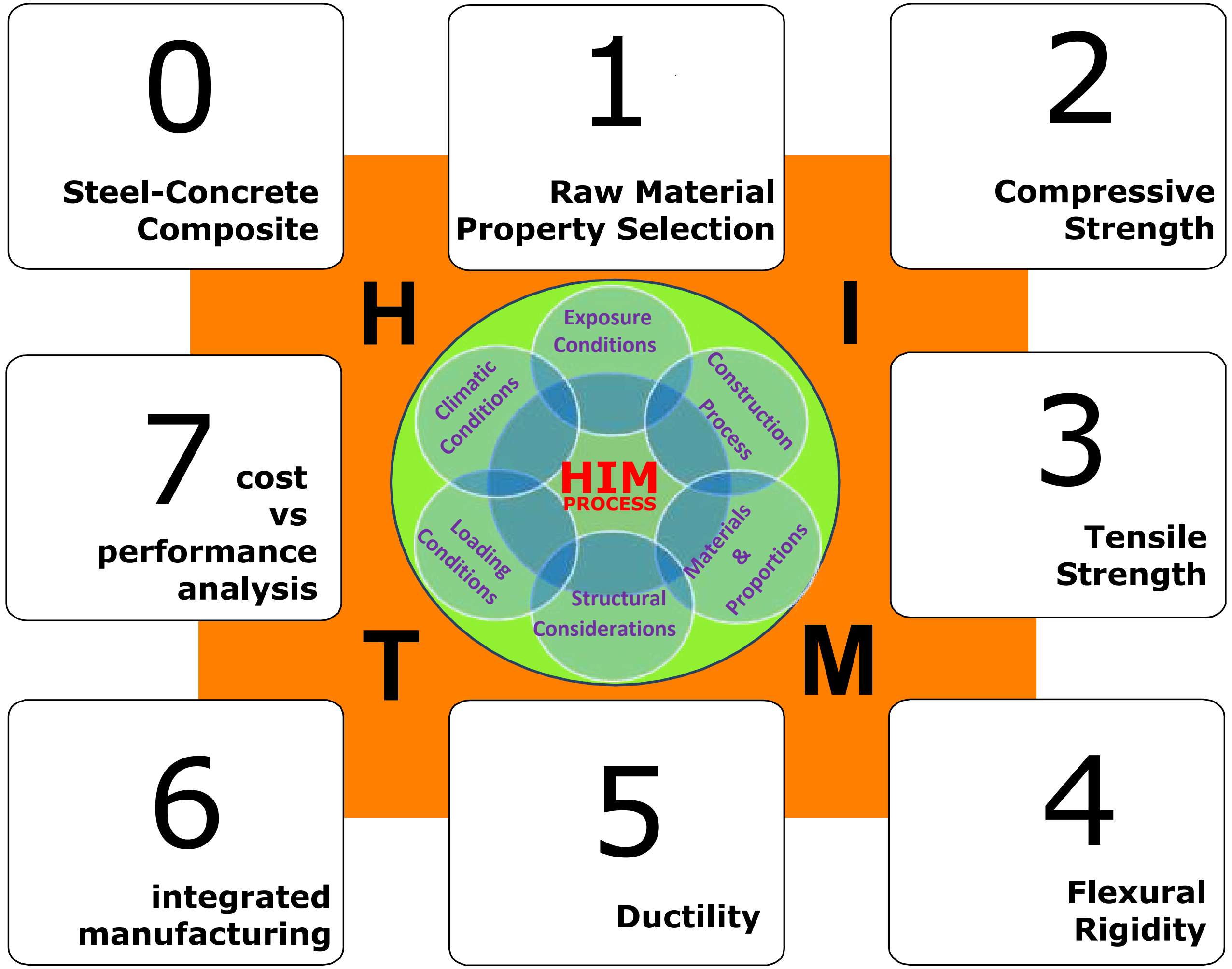
Flexural Rigidity ...High...	Strength ...High...	Ductility ...High...
Sandwich Structure	High Performance Concrete	Artificial Periodic Dislocation Networks
Eliminate Elastic Modulus Mismatch	Medium Yield Strength Steel	Triangular Unit Cells In Honeycomb Lattice

...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'



Strain Gradient Elasticity-Confinement-Back Stress Strengthening

HOLISTIC INTEGRATED MATERIAL TECHNOLOGY

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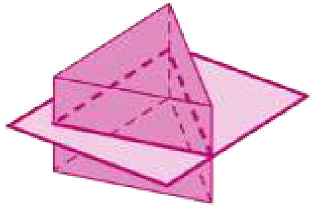
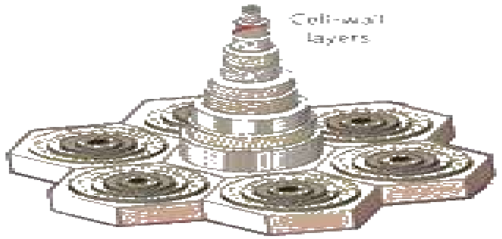


MustDo MIC Composite



R . T . M TEAM (Technology Elements of the FineScale Composite)

...New Topology...

Plasticity Strain Gradient

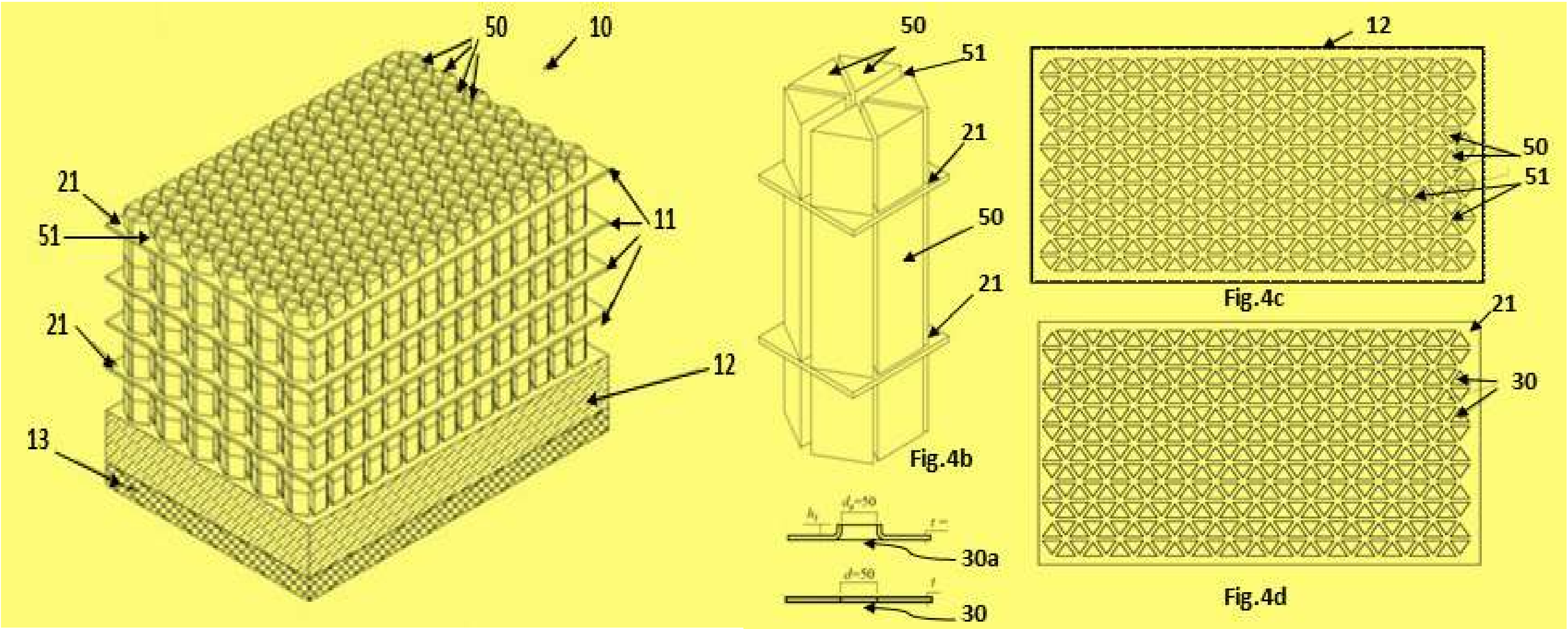
Architected Cellular Layers Material

Elastic Instabilities

Continuous Matrix Phase
<Cellular>

. Hard Phase
<Dowel-50>

.Soft Phase
<Honeycomb-51>



Continuous Reinforcing Phase
<Lattice>

. Perforated Plate
<Layers>

.Perforated Tube
<Interlayers>

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MustDo ISOGRID

Cellular . Layer . Tubular

Perforated Steel Plate

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Patent Pending

- 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

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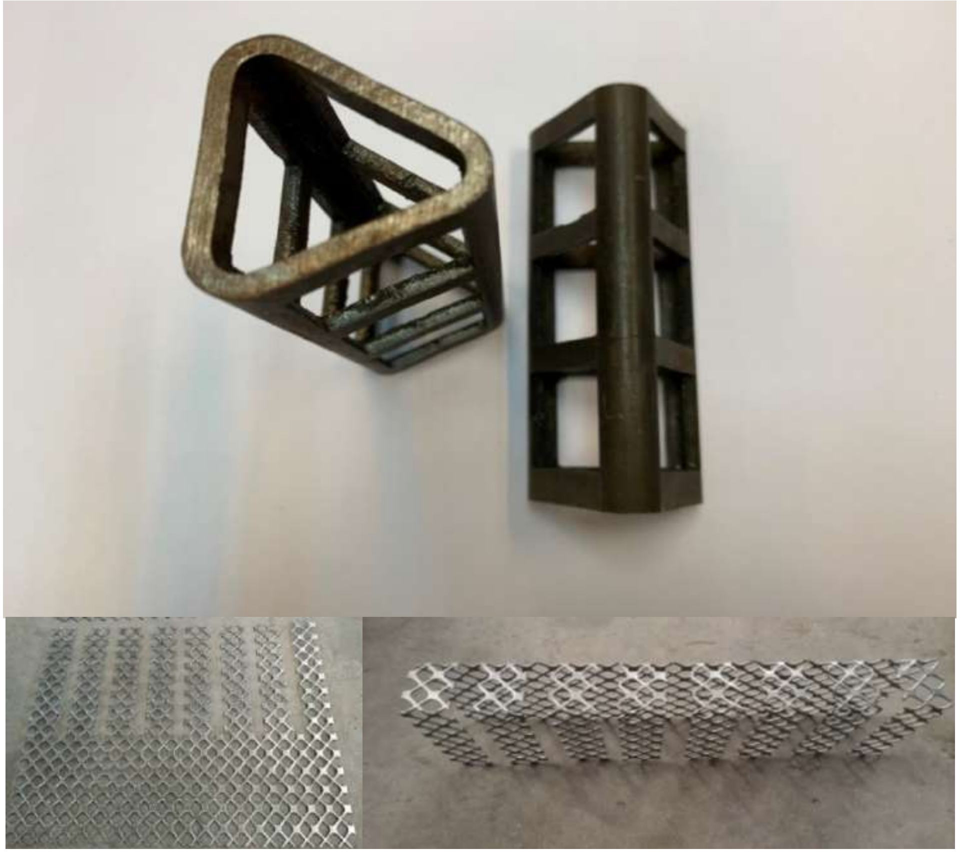
MustDo Connector



Cellular . Layer . Tubular

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

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Date : 25 Nov Year 2020

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FineScale Steel Concrete Composite

...Sandwich Family...

2 M.D. R.T.M TEAM U T 50

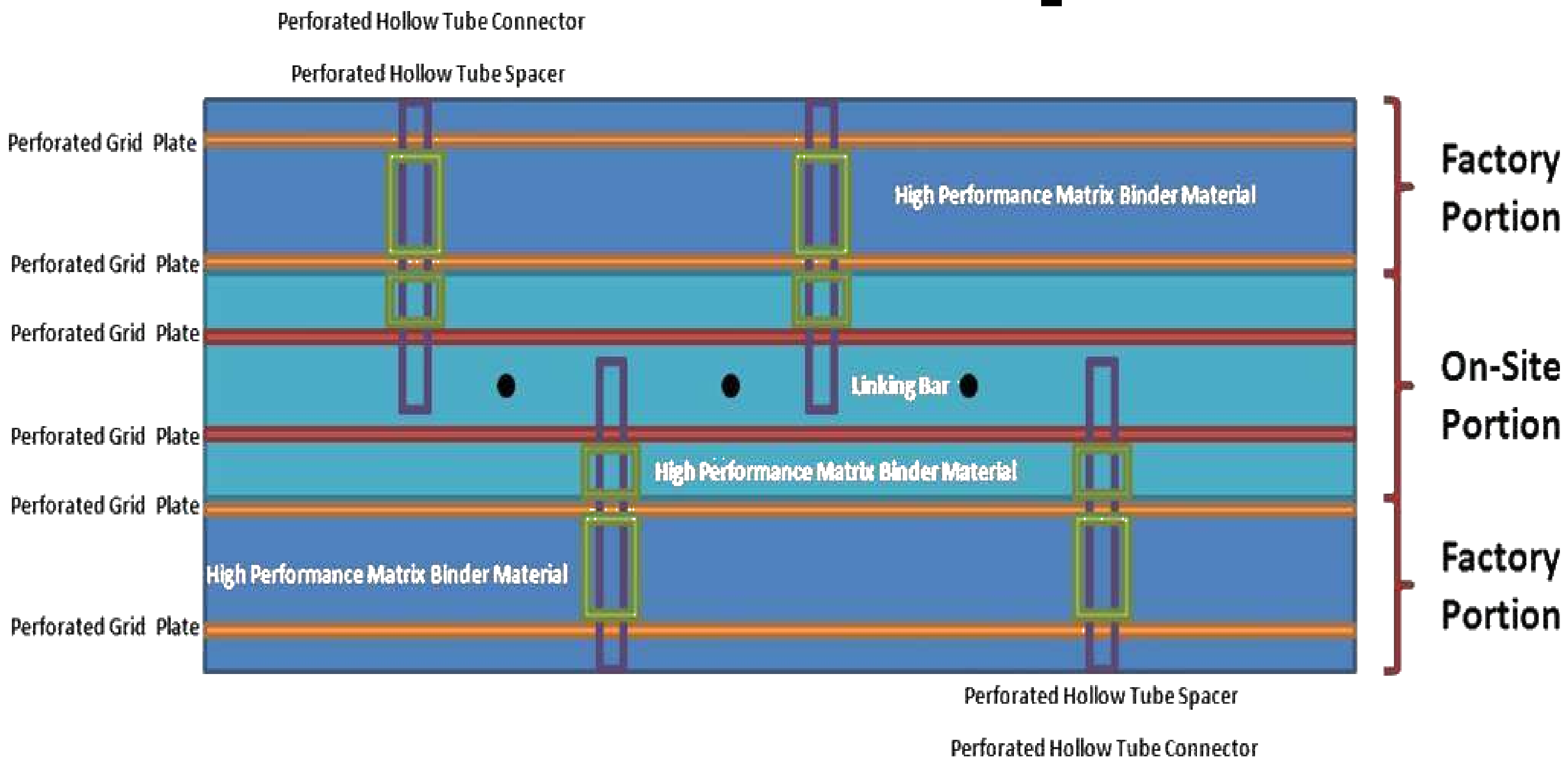
5 M.D. R.T.M TEAM U T 170

6 M.D. R.T.M TEAM U T 190

...Define...

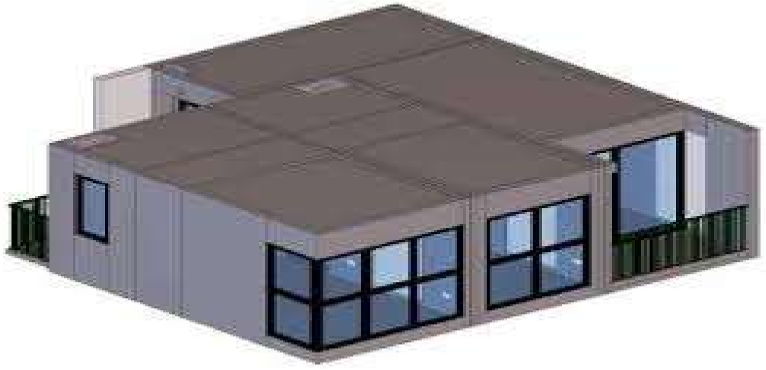
Isomesh Layers...

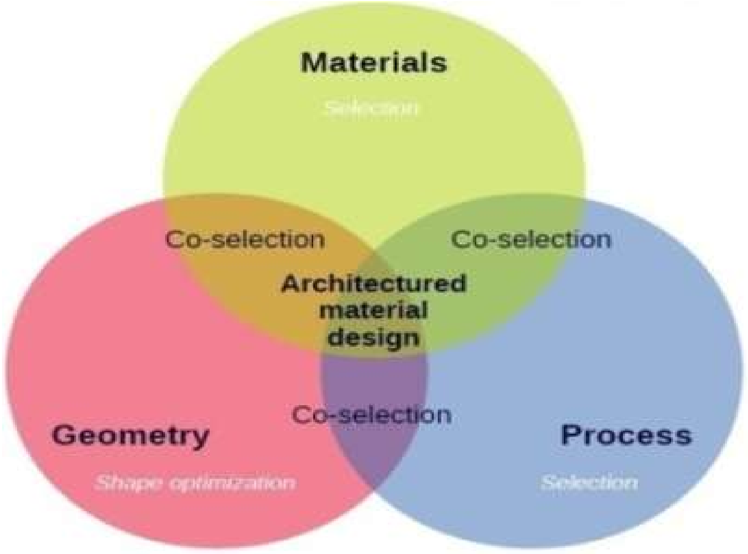
Composite Dimension...

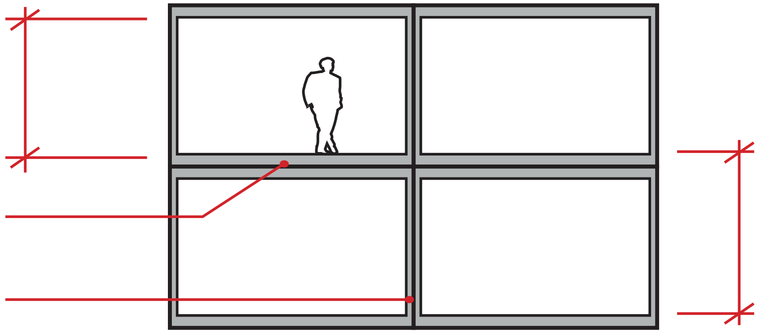


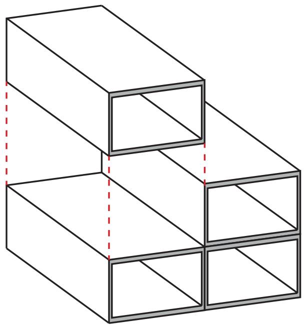
<Concrete> : Strength-Modulus<Steel> : Strength-Thickness

Concrete MIC Current State of Art









Double Slab

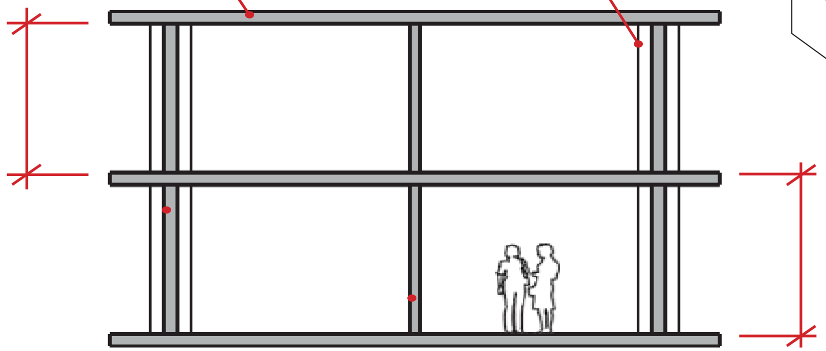
Double Wall

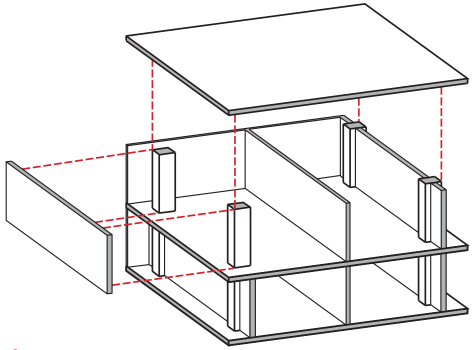
Current Concrete Modular Design

Current Cast In-situ Concrete

Single Slab

Single Wall





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MustDo MIC ...Lifting...

- MiC Box Size: 2500 x 6000 x 3500(h)
- MiC Box Weight: Approx. 11 Tons + 2KPa Imposed Load for Domestic Floors

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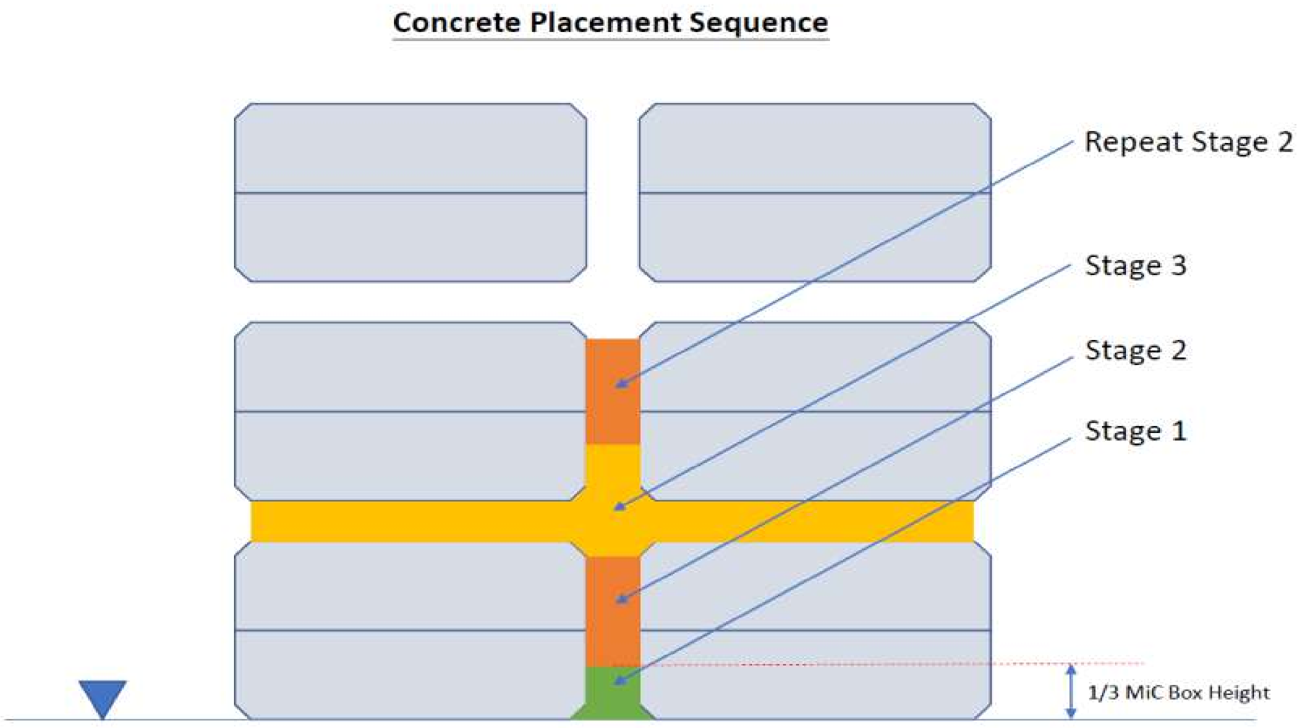
MustDo MIC ...Concrete Casting...



- In-situ Concrete Casting
- 3 Stages
- 1^{st} Stage: Fix the boxes in position. Less Pressure
- 2^{nd} Stage: Finish up wall casting
- 3^{rd} Stage: Horizontal structural Elements Concrete Casting

Date : 25 Nov Year 2020

Response
To
Market

Part -I : MustDo Composite Approach

Part -II : MustDo Composite Testing

Part -III : MustDo DfMA

Part -IV : Current Steel Concrete Types

Architect - Engineer

PART - II : TESTING

Work Inside Code FREEDOM

MustDo Composite Panel Casting

MustDo Composite Panel Testing

Performance Compliance Checking

Modular Layout Planning

Towards A New Co-Creation Dynamics

MustDo TIM Panel Design

Cellular-Layer-Tubular

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Composite Steel And Concrete Structure

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.

[Commentary] (1) The provisions of this chapter apply to members in which steel and concrete are mechanically composed to resist stress resultant. Such composite members include those where the structural steel is embedded inside concrete and those where the steel reinforcement is placed outside concrete.

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.

[Comments] 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/mm^2 are used.

Bond

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MustDo TIM Panel Design

Cellular-Layer-Tubular

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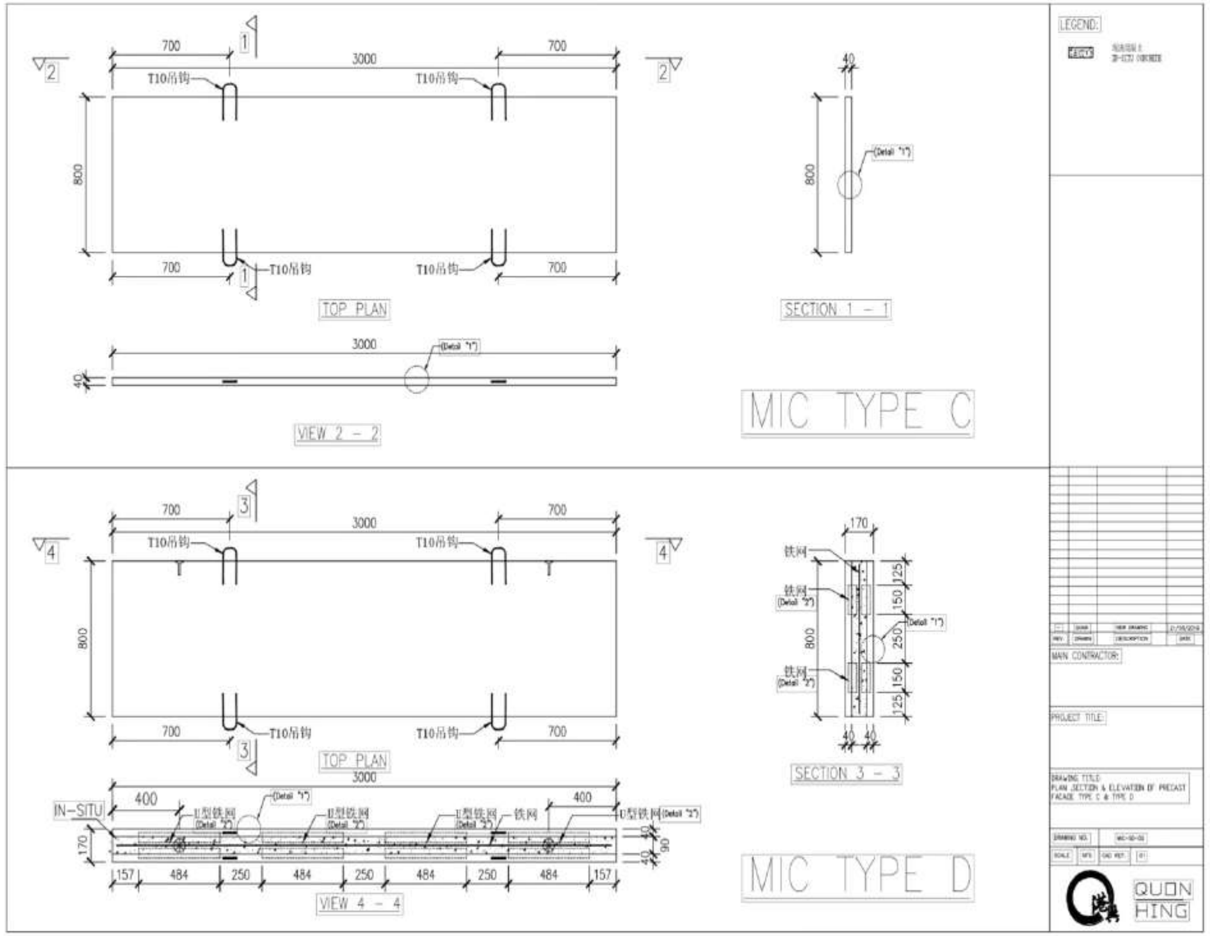
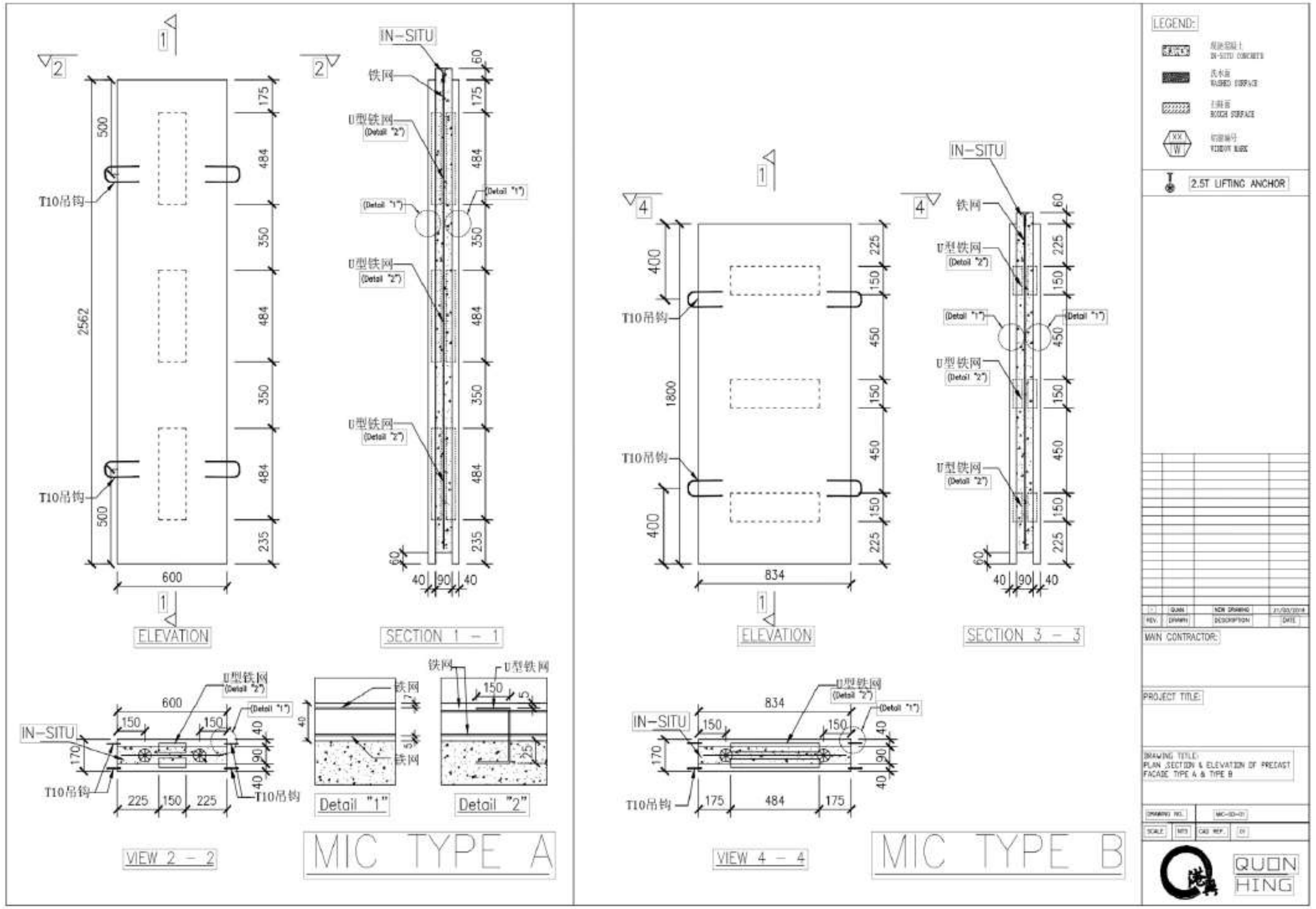
40 mm Composite Panel Drawings



170 mm Composite Panel Drawings



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MustDo TIM Panel Design

Cellular-Layer-Tubular

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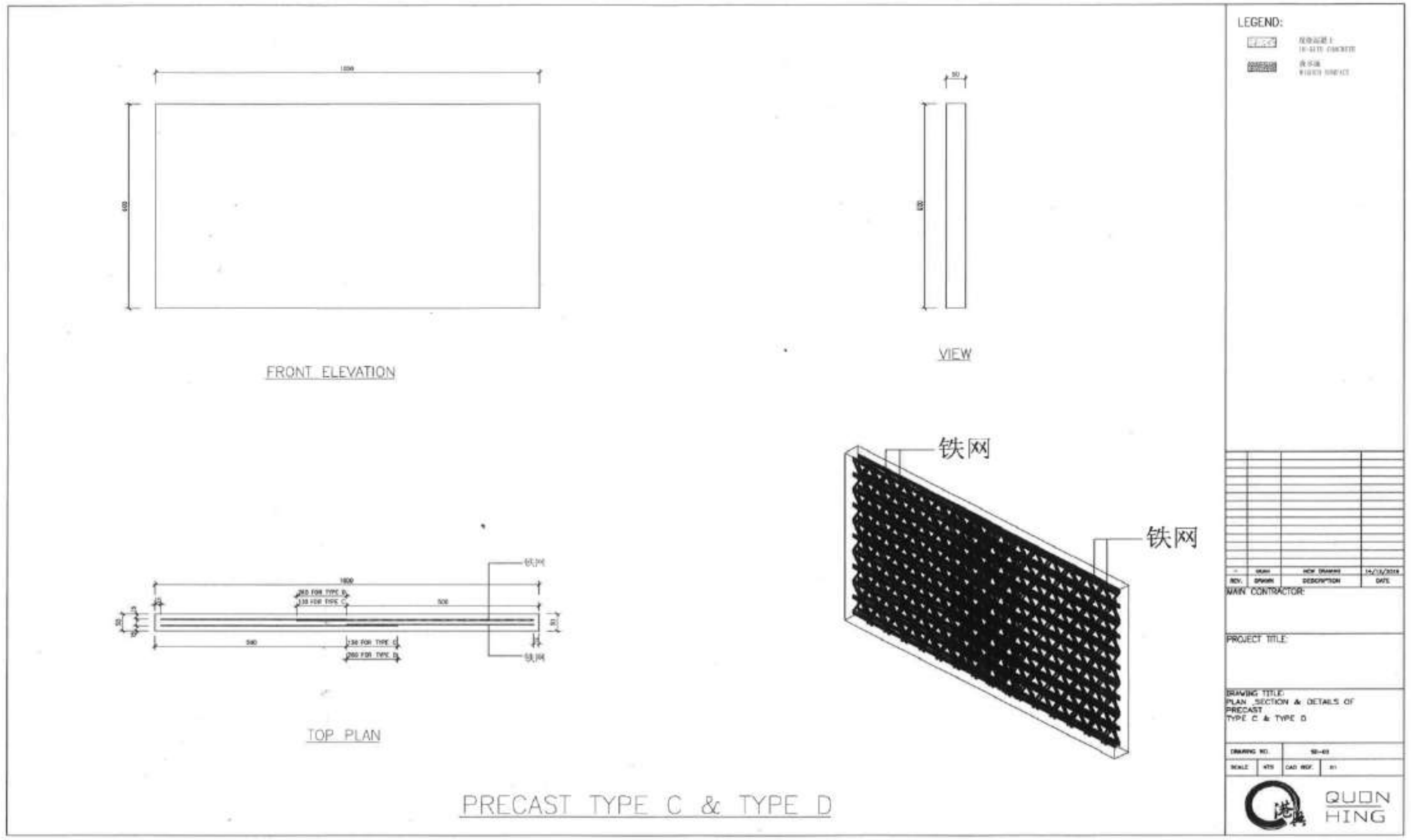
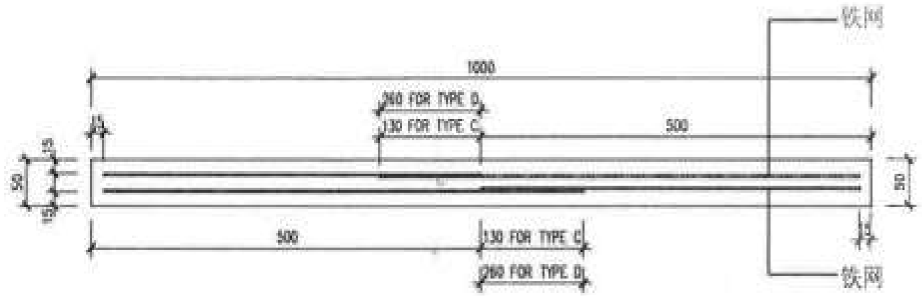
50 mm Composite Panel Drawings For 2-Holes & 4-Holes Lapping Testing





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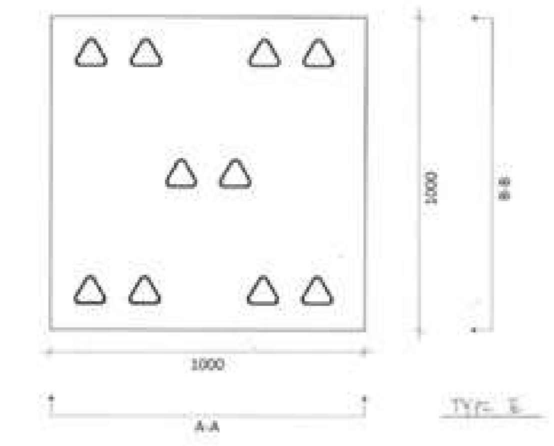
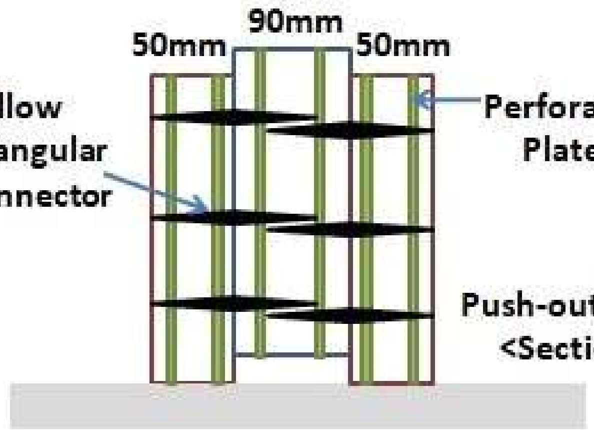
50 mm Composite Panel Drawings For Triangular Shear Connector

Push-Out Test for Triangular Shear Connector

Push-out Panel <Elevation>

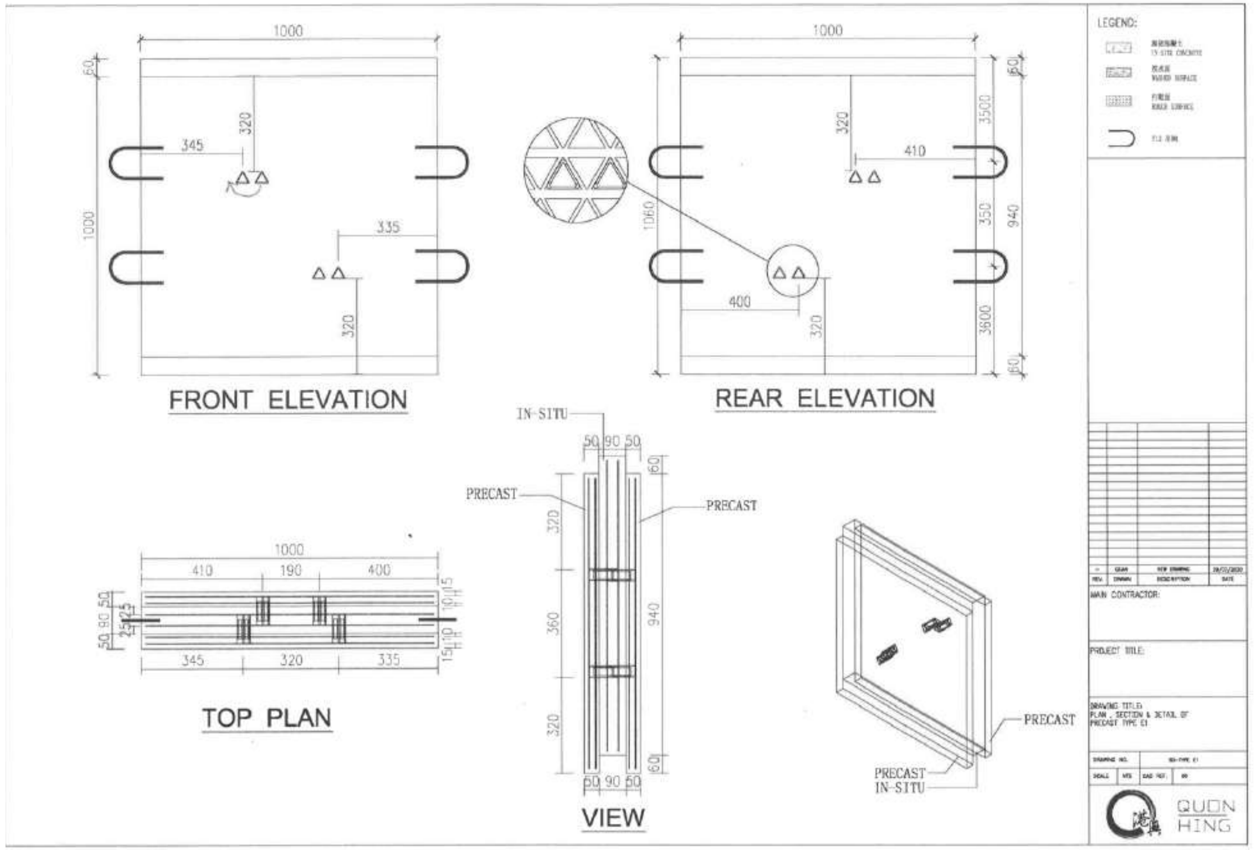
Shear Connector Push-Out Test Specimen Design
(Triangular Connector)





Hollow Triangular Connector <Plan>

Push Out Test in HKUST Civil Department Lab



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High Elastic Modulus Cementitious Matrix Development

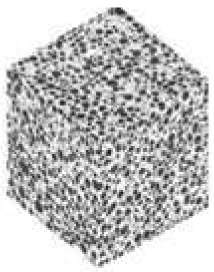
Desirable Properties

F.G.C(Fine Grain Concrete)

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 Heterogeneous material

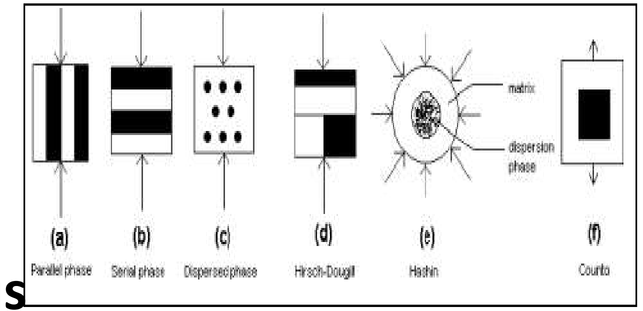
Geometrical with particles and aggregates of various sizes



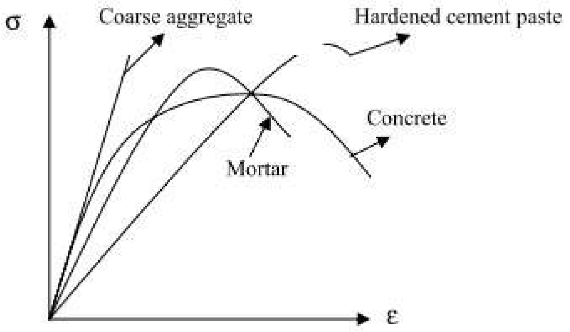
Mechanical with a different stiffness between aggregates and cement paste

Chemical shrinkage of the paste inside a rigid skeleton of aggregate

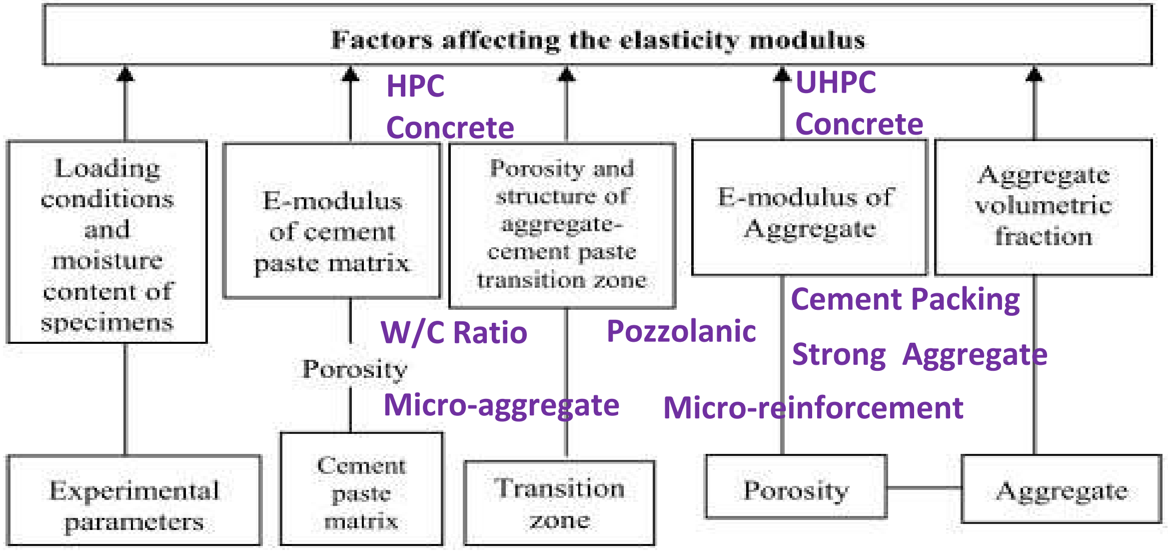
<Binary System> Particle Phase - Matrix Phase



E-Modulus Concrete Composite Models



Strain-Stress
Diagram of Concrete and its Components



Classification of Factors affecting E-modulus of Concrete

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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 Casting
Cellular-Layer-Tubular

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Air Curing of Trial Panels (Two-Stages Casting)

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MustDo TIM Panel Casting

Cellular-Layer-Tubular

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Casting of Volumetric Unit

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MustDo TIM Panel Testing

Cellular-Layer-Tubular

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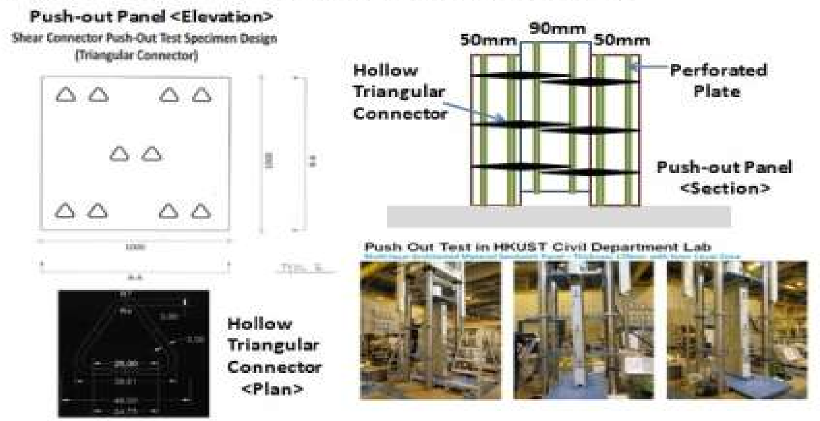
Test Done in HKUST Civil Department Lab

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

Push-Out Test for Triangular Shear Connector

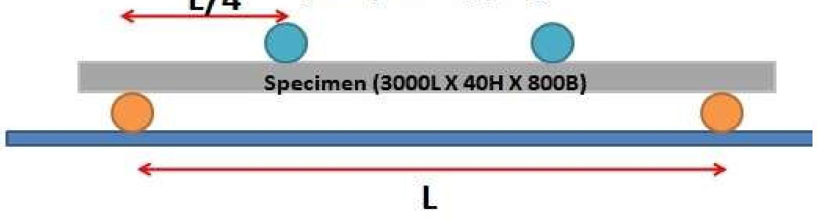


MustDo Slab Panel Flexural Behaviour Testing

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)

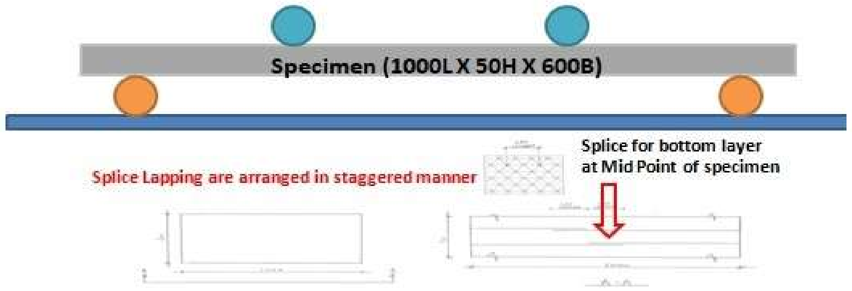


MustDo Slab Panel Flexural Behaviour Testing

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)

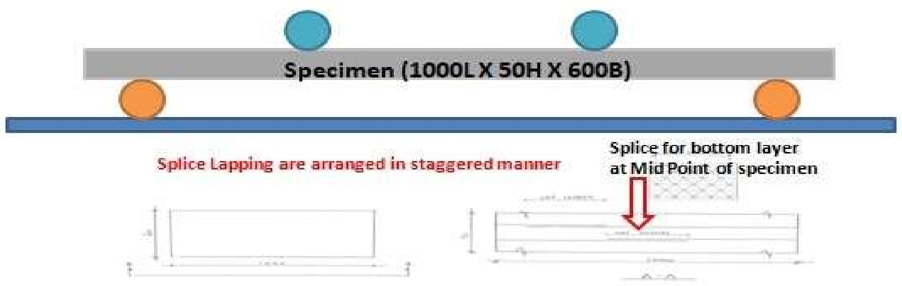


MustDo Slab Panel Flexural Behaviour Testing

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)



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MustDo TIM Panel Testing Push-Out

Cellular-Layer-Tubular

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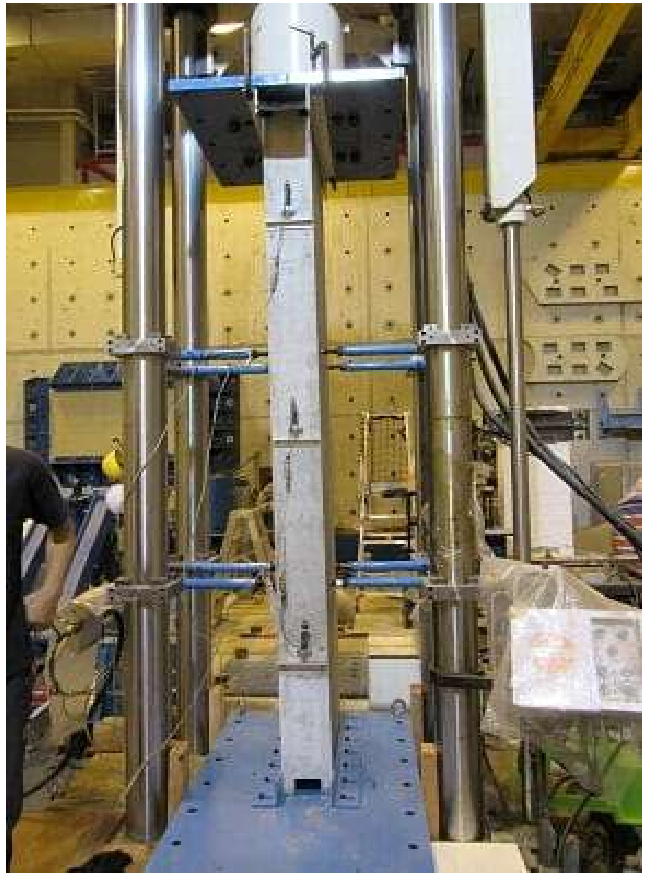
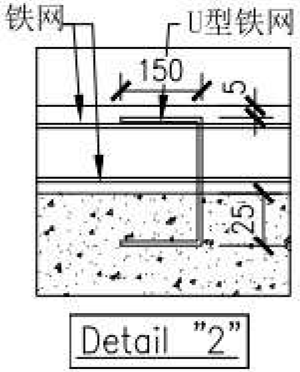
Push Out Test For Shear Connector in HKUST Lab

Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone



Testing Parameters



<A> Concrete Dowels & Metal Mesh As Shear Connectors

<B> Concrete Cover 5mm-7mm

<C> Structural Steel Plate Thickness 2.75mm-3mm

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MustDo TIM Panel Testing Push-Out

Cellular-Layer-Tubular

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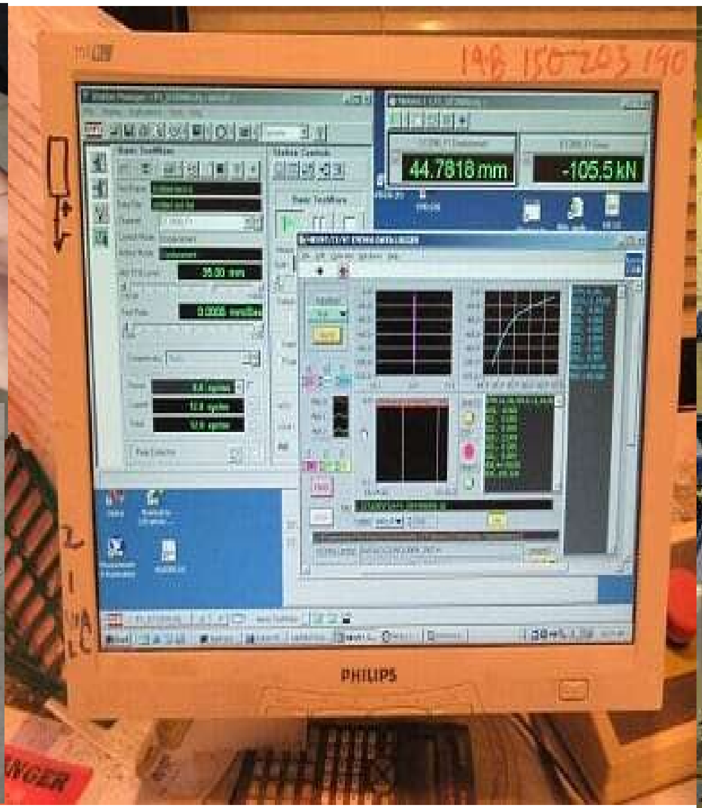
Push Out Test in HKUST Civil Department Lab

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



Reaching Maximum Test Machine Load Capacity 1800 KN

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

MustDo TIM Panel Testing Push-Out

Cellular-Layer-Tubular

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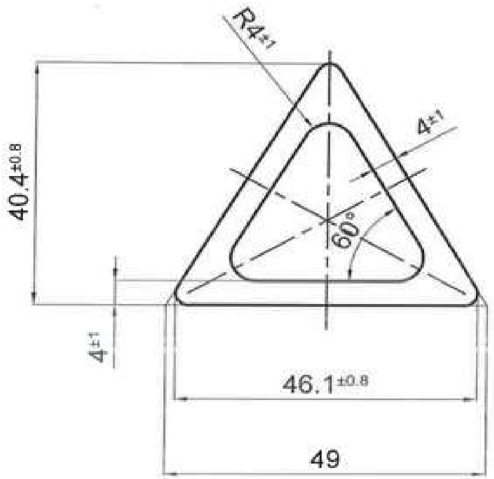
Patent Pending

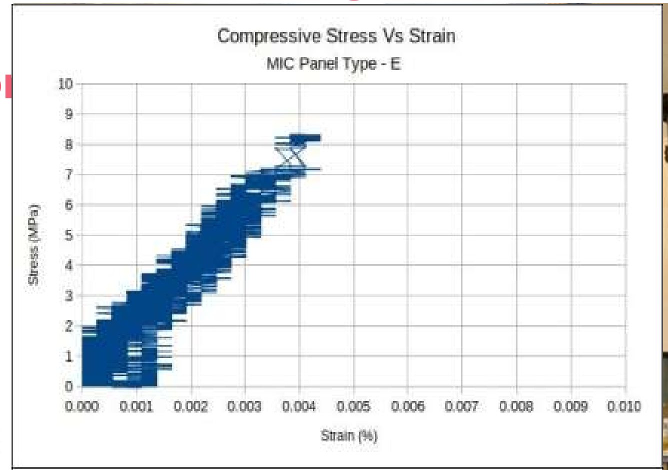
Push Out Test in HKUST Civil Department Lab

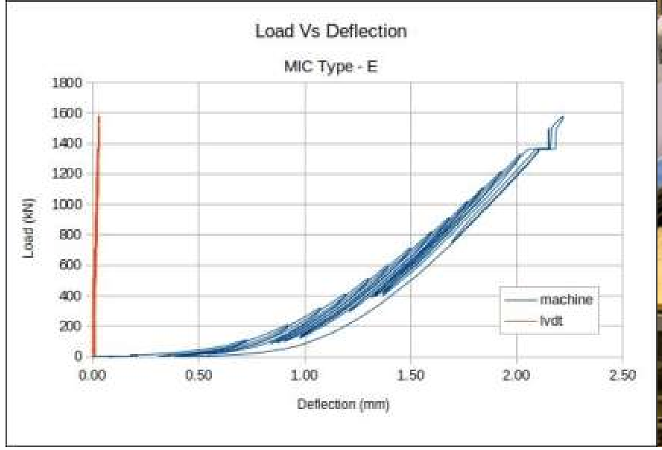
Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone (Two Stage Casting)

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 Bending

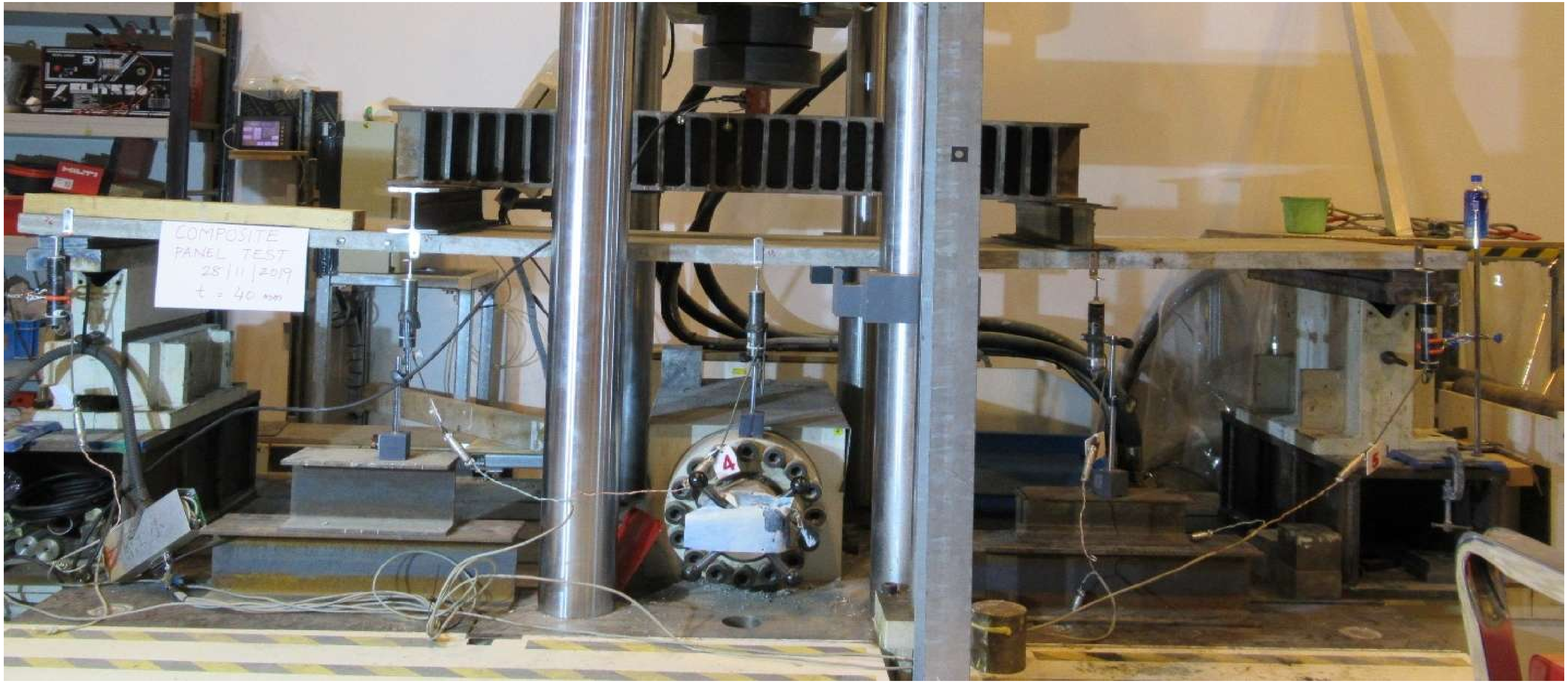
Cellular-Layer-Tubular

Confidential

Patent Pending

40mm Rigid Composite Test (Bending) in HKUST Civil Department Lab

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



Date : 25 Nov Year 2020

MustDo TIM Panel Testing Bending

Cellular-Layer-Tubular

FLEXCRETE

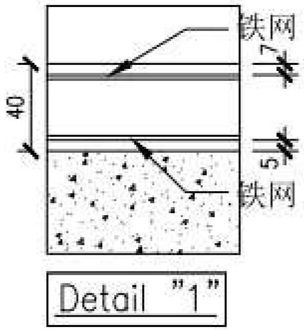
Confidential
Patent Pending

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)

Testing Parameters



<A> Concrete Dowels As Shear Connectors

<B> Concrete Cover 5mm-7mm

<C> Structural Steel Plate Thickness 2.75mm-3mm

Date : 25 Nov Year 2020

MustDo TIM Panel Testing Bending

Cellular-Layer-Tubular

FLEXCRETE

Confidential
Patent Pending

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

Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone

Date : 25 Nov Year 2020

MustDo TIM Panel Testing Bending

Cellular-Layer-Tubular

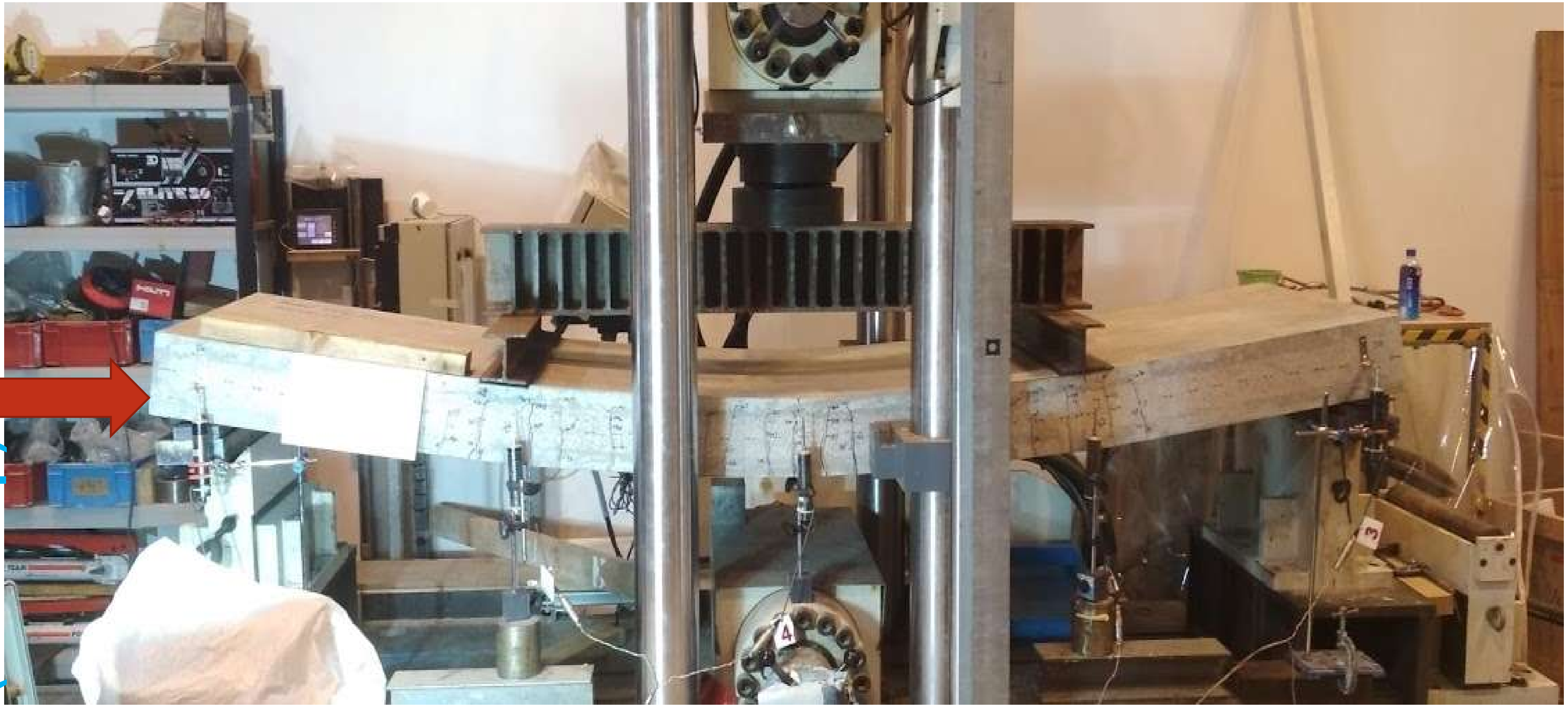
FLEXCRETE

Confidential
Patent Pending

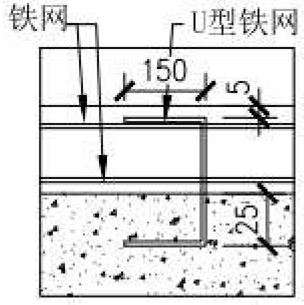
170mm Rigid Composite Test (Bending) in HKUST Civil Department Lab

Multi-layer Architected Material Sandwich Panel – Thickness 170mm with 5mm Cover Zone

Full Composite Action (Non-Slip)



Testing Parameters



Detail "2"

<A> Concrete Dowels & Metal Mesh As Shear Connectors

<B> Concrete Cover 5mm-7mm

<C> Structural Steel Plate Thickness 2.75mm-3mm

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

Date : 25 Nov Year 2020

MustDo TIM Panel Testing Lapping

Cellular-Layer-Tubular

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Patent Pending

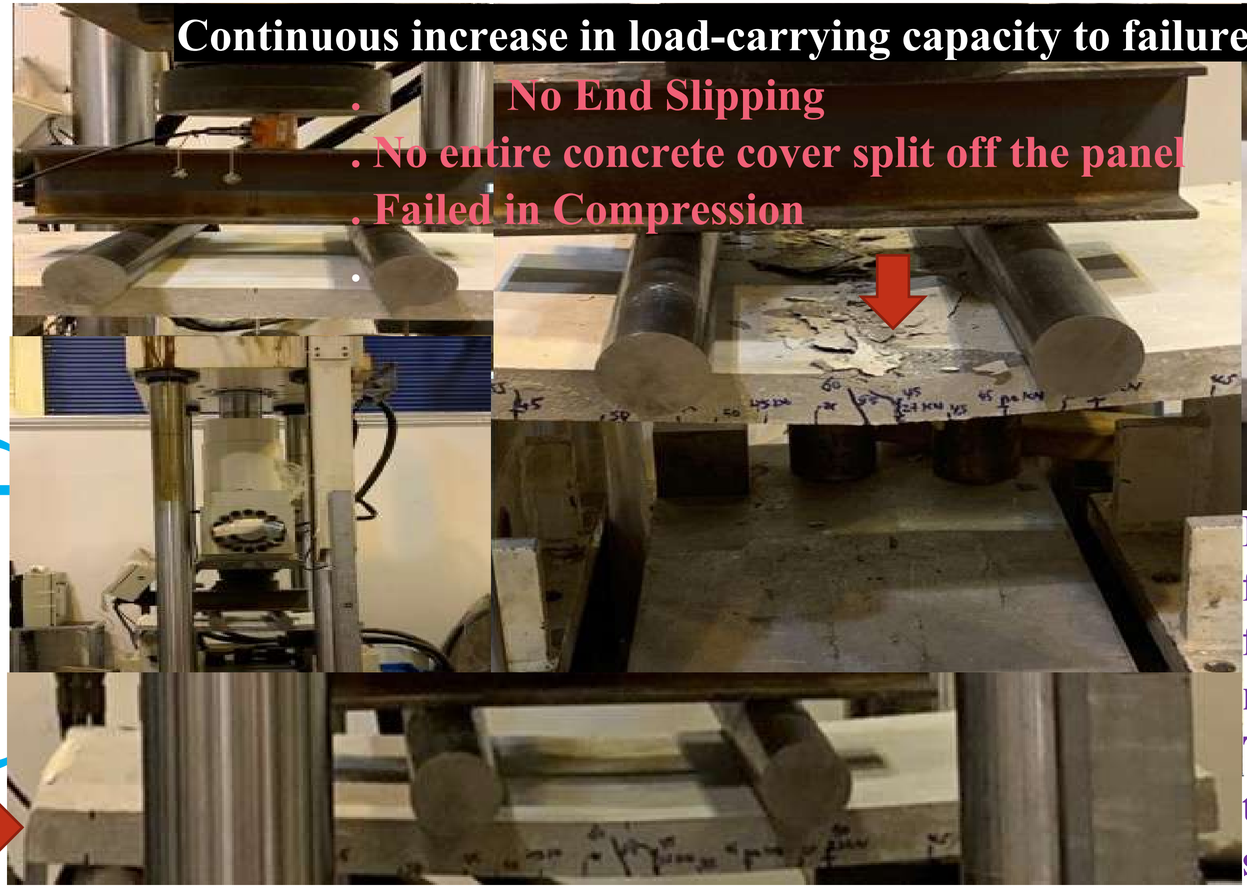
Tension Contact Lap Splices Test (Bending) in HKUST Civil Department Lab

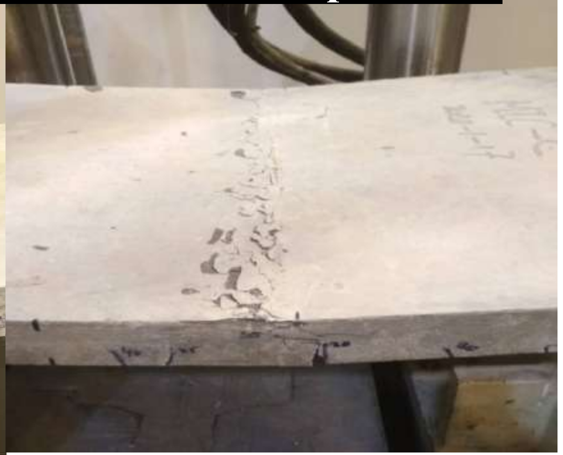
Mono-layer Architected Material Sandwich Panel – Thickness 50mm

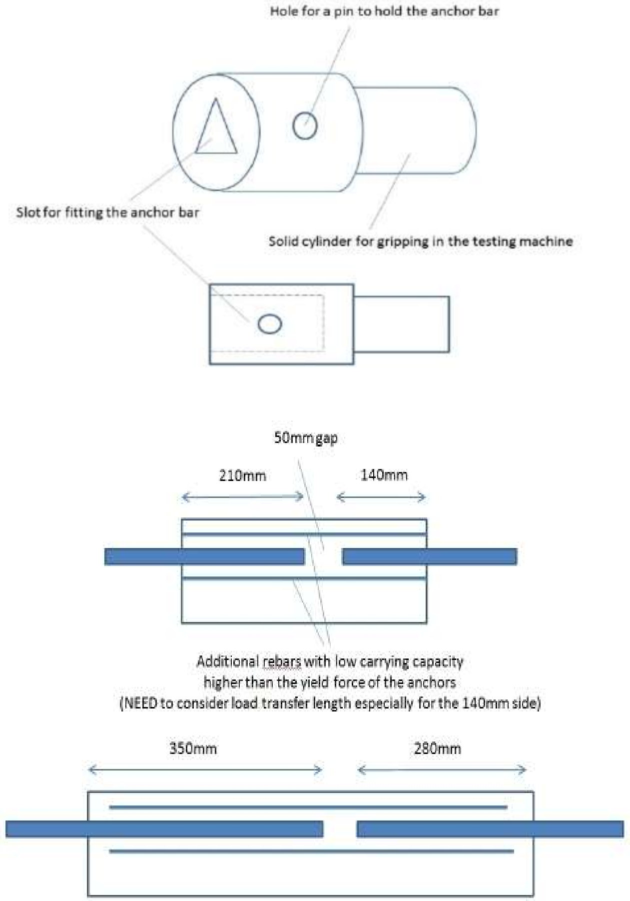
Perforated Triangular Hollow Tube Rebar

Bending Test Setup   < 4 holes Lapping>   <2 holes Lapping>

Full Composite Action (Non-Slip)







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.

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>

Date : 25 Nov Year 2020

MustDo TIM Panel Testing Anchorage

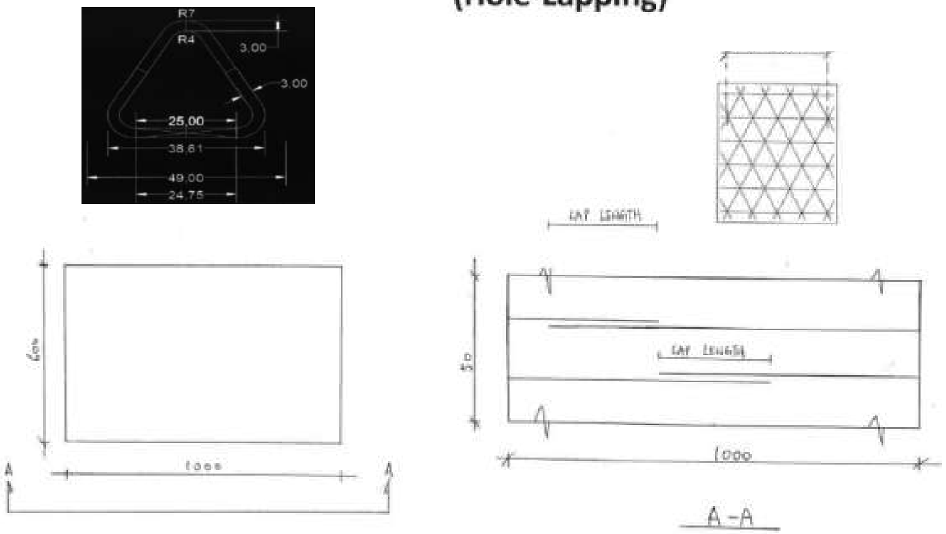
Cellular-Layer-Tubular

FLEXCRETE

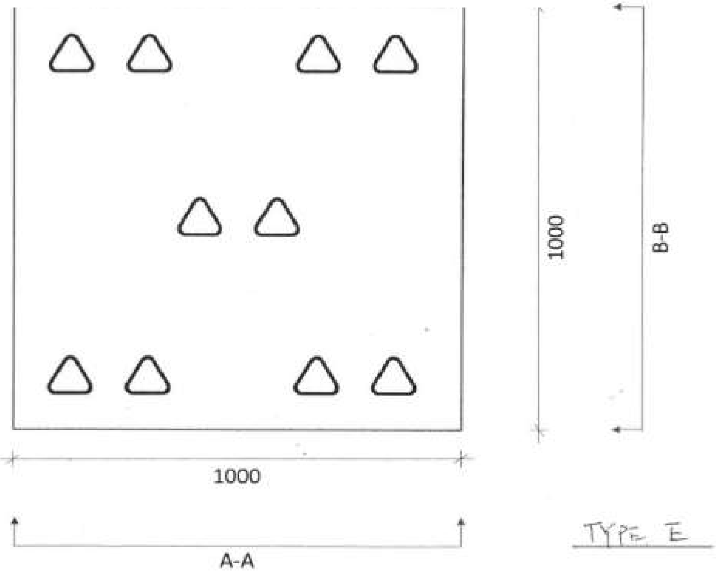
Confidential
Patent Pending

Perforated Structural Plate - Lapping

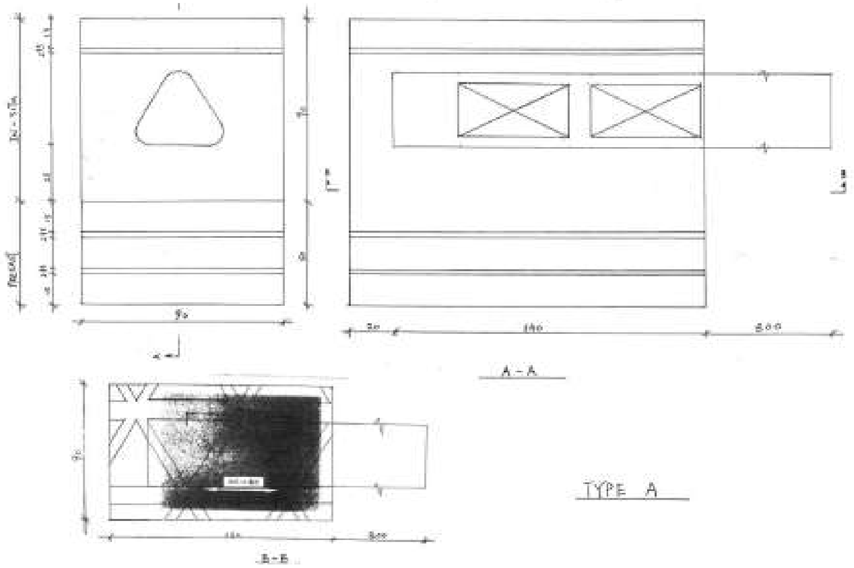
Isogrid Mesh Splice Test Specimen Design (Hole-Lapping)

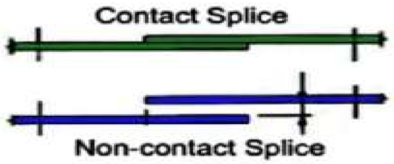


Shear Connector Push-Out Test Specimen Design (Triangular Connector)

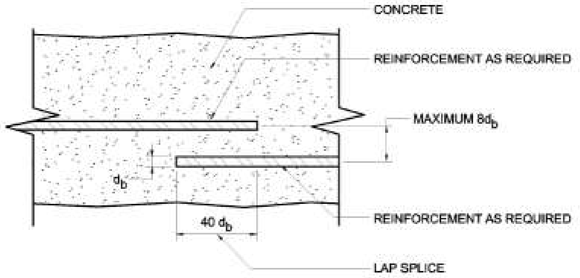


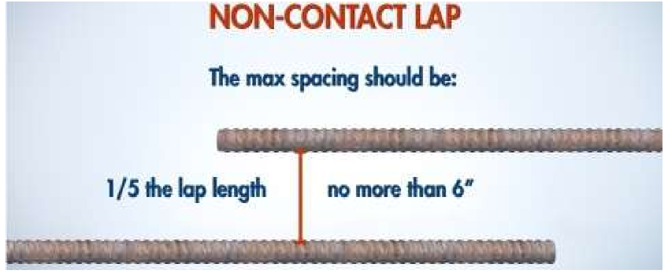
Triangular Headed Bar Anchorage Test Specimen Design (Bond Strength In Tension)

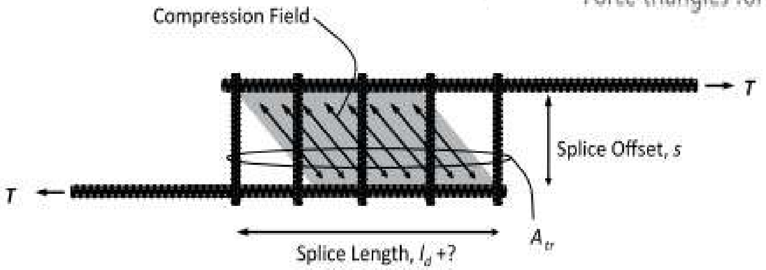




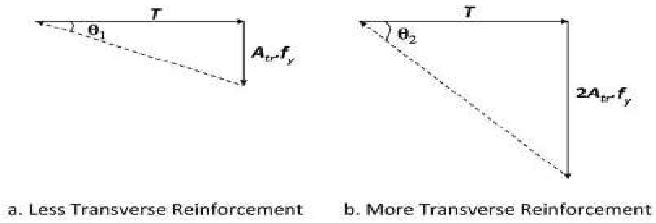
Traditional Rebar - NonContact Splice Lap (Spacing: Max. 1/5 lap length)







Force triangles for noncontact splice: influence of transverse reinforcement.



Spacing Restriction Relaxed with Transverse Reinforcement

Date : 25 Nov Year 2020

Plain Welded Wire Fabric Splice Lapping

BS EN 1992-1-1:2004
EN 1992-2-2:2004 (E)

8.6 Anchorage by welded bars

(1) Additional anchorage to that of 8.4 and 8.5 may be obtained by transverse welded bars (see Figure 8.6) bearing on the concrete. The quality of the welded joints should be shown to be adequate.

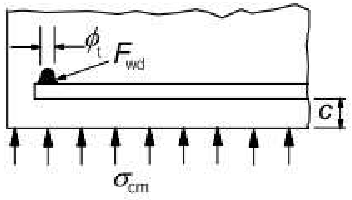


Figure 8.6: Welded transverse bar as anchoring device

(5) 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:

$$F_{btd} = F_{wd} \le 16 A_s f_{cd} \phi_t / \phi_l \quad (8.9)$$

where:

F_{wd} design shear strength of weld (see 8.6 (2))

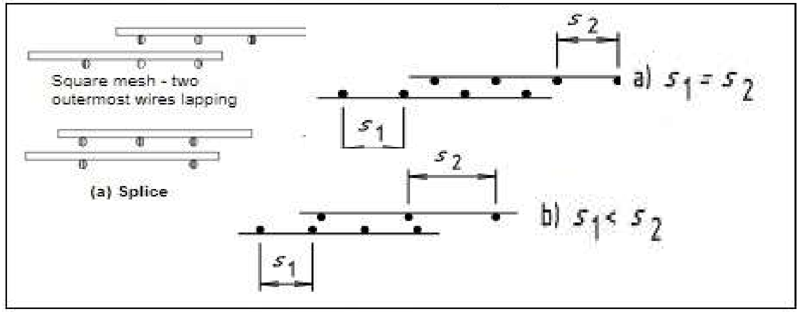
ϕ_t nominal diameter of transverse bar: $\phi_t \le 12$ mm

ϕ_l nominal diameter of bar to anchor: $\phi_l \le 12$ mm

If two welded cross bars with a minimum spacing of ϕ_t are used, the anchorage length given by Expression (8.9) should be multiplied by a factor of 1,41.

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).

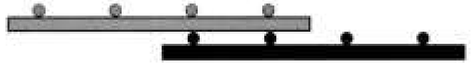
Reinforced Concrete Design
in accordance with AS 3600—2009



Full Yield Strength Layered Lap

- The most common type lapping used.
- Transfer the full yield strength of the reinforcement.
- Too great an accumulation of laps can be avoided by staggering the sheet arrangement.

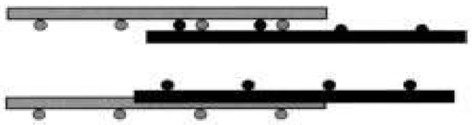
Full Yield Layered Lap



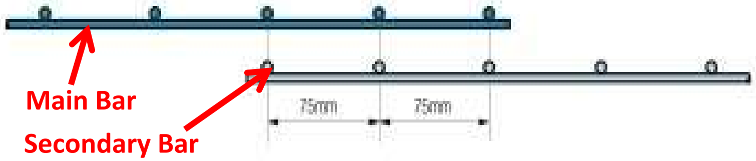
Reversed or Nested-in-Plane Lap

- Particularly useful in situations of maximum stress to maintain the lapped reinforcement in the same plane.

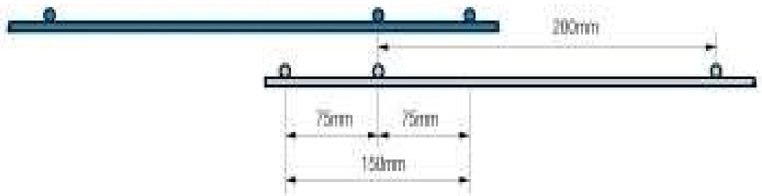
Nested-in-Plane Lap



Two Welded Intersection Overlapping



One Welded Intersection Overlapping



Specification No & Title :	Parameter	Value
BS:4483 & BS:4482 Steel fabric for the reinforcement of concrete & Steel wire for the reinforcement of concrete products	UTS	1.05 times Yield Stregth
	Yield – 0.2% Proof Strength	500 MPa
	Total Elongation at Peak force on 5D GL	2.5%
	Weld Shear Strength (125 Mpa)	Min. 25% of Yield Strength of Thicker Dia
ASTM A185 & A82 Steel Welded Wire Fabric Plain For Reinforcement & Steel Wire, Plain, for Concrete Reinforcement - Grade 60 & Grade 80 (80000Psi)	UTS Grade 80 / Grade 60	620 MPa Min / 515 Mpa
	Yield – 0.35% Proof Strength	550Mpa Min / 450 MPa
	Reduction in Area (after Failure)	30% Min
	Weld Shear Strength (250 Mpa)	Min. 50% of Yield Strength of Thicker Dia

Date : 25 Nov Year 2020

Compliance Checking:

Steel for the Reinforcement of Concrete HK (Constr) Reg. & HK CS2

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.

Construction Standard CS2:2012

Steel Reinforcing Bars for the Reinforcement of Concrete

STEEL FABRIC allow good freedom for Concrete Reinforcement

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.

MustDo TIM Panel Performance Reinforcement Type

Cellular-Layer-Tubular

BS EN 1992-1-1:2004
EN 1992-1-1:2004 (E)

Compliance Checking:

Steel for the Reinforcement of Concrete EN 1992-1-1:2004

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 EN10080, 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_e, which relates to the characteristic, minimum and maximum values based on the long-term quality level of production. In contrast f_{yk} is the characteristic yield stress based on only that reinforcement used in a particular structure. There is no direct relationship between f_{yk} and the characteristic R_e. However the methods of evaluation and verification of yield strength given in EN 10080 provide a sufficient check for obtaining f_{yk}.

(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.

ANNEX C (Normative)

Properties of reinforcement suitable for use with this Eurocode

Table C.2N: Properties of reinforcement

Product form		Bars and de-coiled rods			Wire Fabrics			Requirement or quantile value (%)
Class		A	B	C	A	B	C	-
Fatigue stress range (MPa) (for N ≥ 2 x 10^6 cycles) with an upper limit of βf_{yk}		≥150			≥100			10,0
Bond: Minimum relative rib area, $f_{R,min}$	Nominal bar size (mm) 5 - 6 6,5 to 12 > 12	0,035 0,040 0,056						5,0

Nominal Bar Size Relate To Bond Strength with Concrete

Plain Bar Size in Lattice Girders

ISO 10544 or BS 4482 :2005

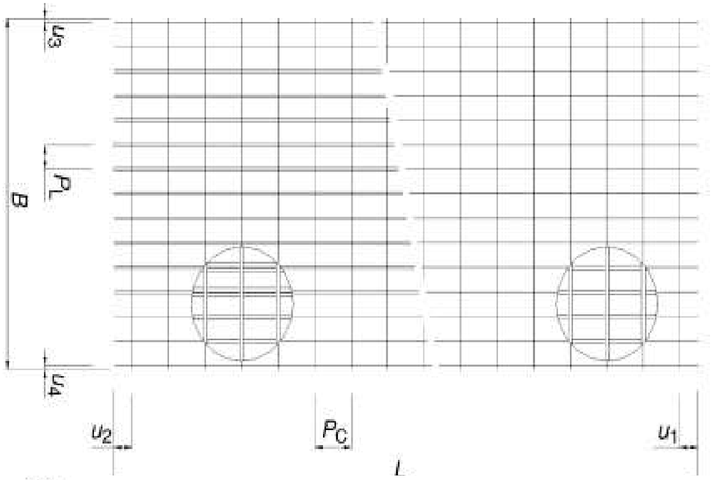
Date : 25 Nov Year 2020

MustDo TIM Panel Performance Reinforcement Type

Cellular-Layer-Tubular

Compliance Checking:

Steel for the Reinforcement of Concrete EN 10080 : 1999/2005



Key

N_L number of longitudinal wires
P_L pitch of longitudinal wires
d_L diameter of longitudinal wires
N_C number of transverse wires
P_C pitch of transverse wires
d_C diameter of transverse wires
L length of longitudinal wire
B length of transverse wire
u_1 overhang of the longitudinal wires
u_2 overhang of the longitudinal wires
u_3 overhang of the transverse wires
u_4 overhang of the transverse wires

Figure 1 — Geometrical characteristics of purpose made welded fabric

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 prEN10080:1999.
The values are given in the following table.

Property	Specified characteristic value		
Steel grade	B450C	B500B	B500A
Yield strength Re (N/mm²)	≥ 450	≥ 500	≥ 500
Ratio Rm/Re	≥ 1.15 and ≤ 1.35	≥ 1.08	≥ 1.05
Elongation Agt (%)	≥ 7.5	≥ 5.0	≥ 2.5

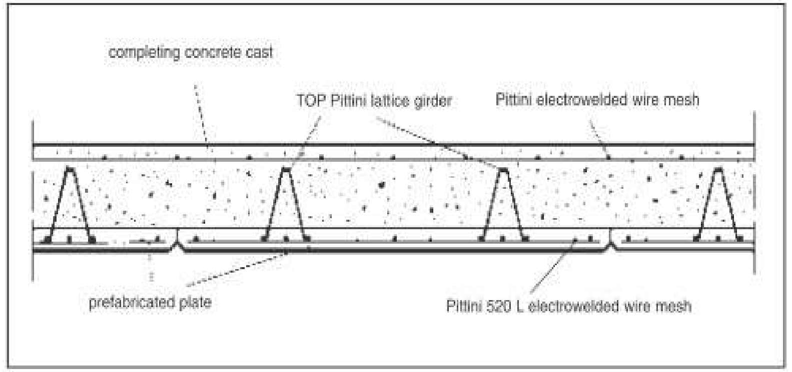
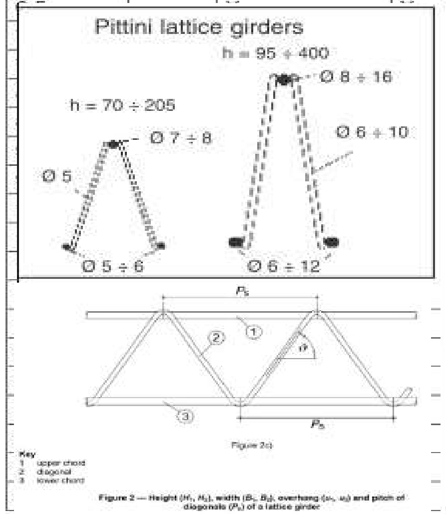
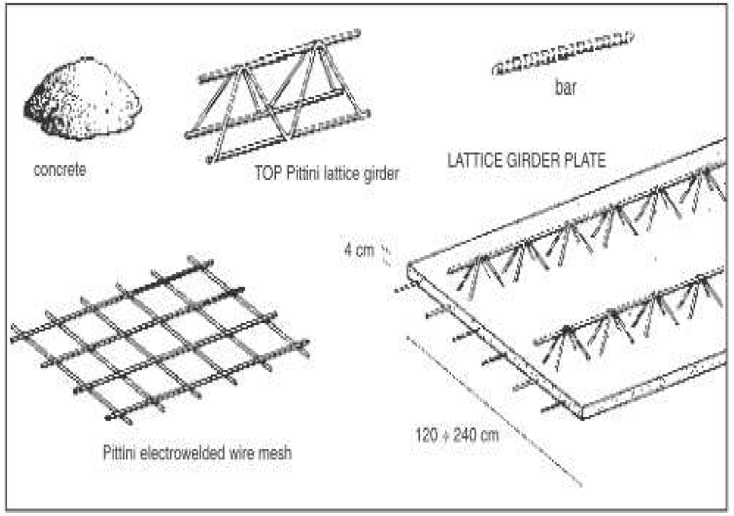


Table 6 — Preferred nominal diameters, cross-sectional areas and masses per metre

Nominal diameter mm	Bars	Coils and De-coiled products	Welded fabric	Lattice girders	Nominal cross sectional area mm²	Nominal mass per metre kg/m
4,0		×		×	12,6	0,099
4,5		×		×	15,9	0,125
5,0		×	×	×	19,6	0,154
5,5		×	×	×	23,8	0,187
6,0	×	×	×	×	28,3	0,222





NON WELDED steel fabric reinforcement can follow the Nominal Cross-sectional Area Requirements recommended in EN 10080 : 2005

Date : 25 Nov Year 2020

MustDo TIM Panel Performance

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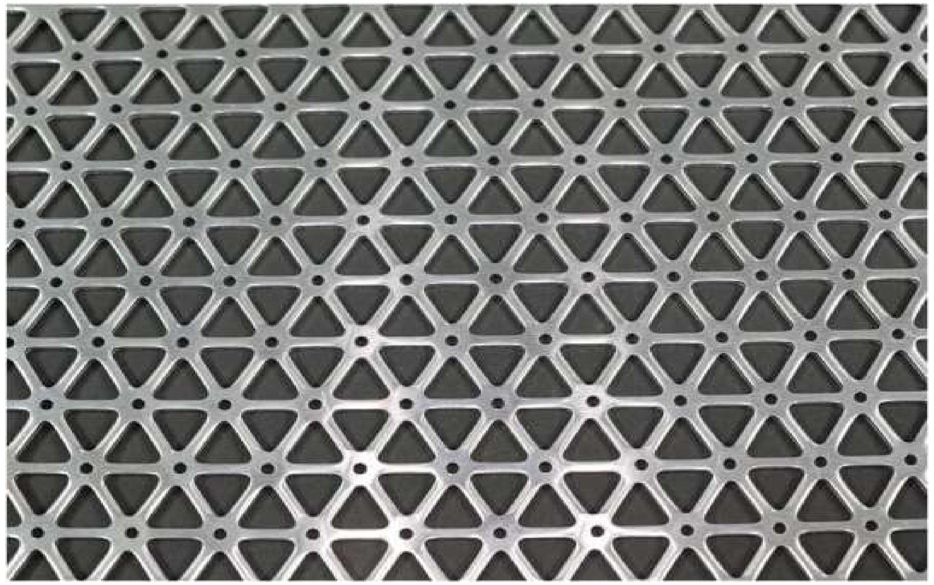
Compliance Checking: Reinforcement Type

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 .

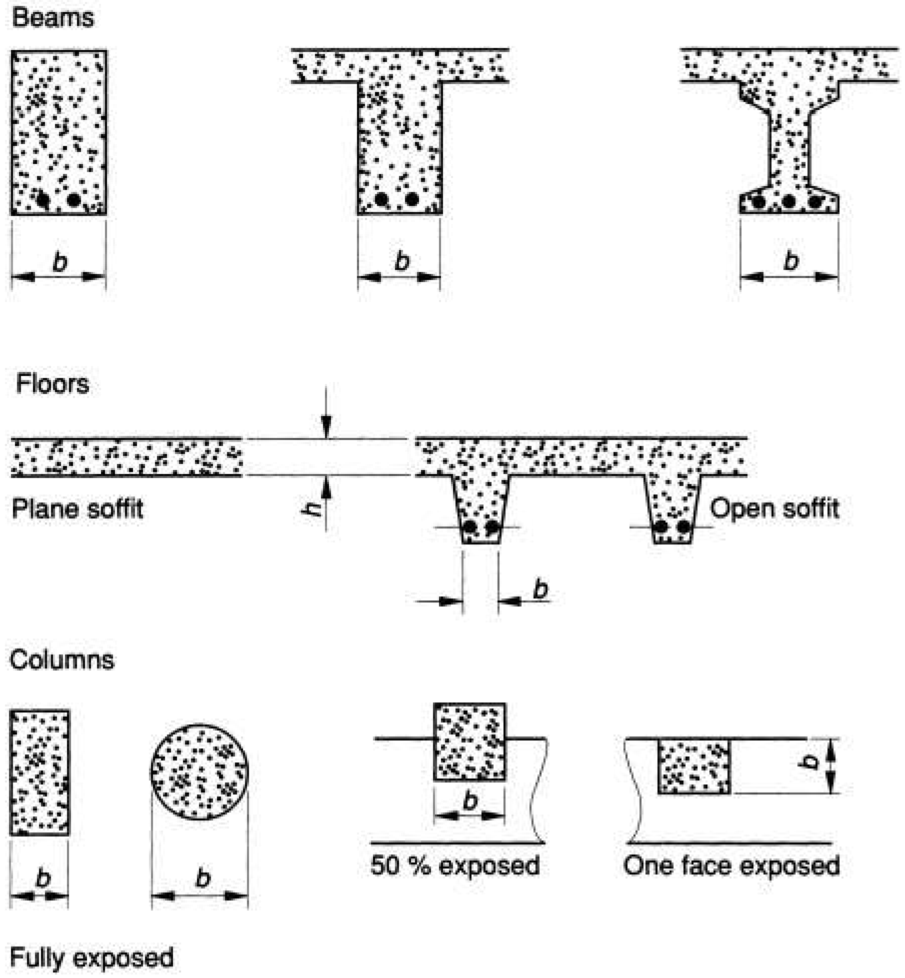
Date : 25 Nov Year 2020

MustDo TIM Panel **Performance** Concrete Cover

Cellular-Layer-Tubular

Compliance Checking: BS 8110-1: 1997

Concrete Structural Elements



Minimum Elements Thickness

Minimum dimensions of reinforced concrete members for fire resistance

Fire resistance h	Minimum beam width (b) mm	Rib width (b) mm	Minimum thickness of floors (h) mm	Column width (b)			Minimum wall thickness		
				Fully exposed mm	50 % exposed mm	One face exposed mm	$p < 0.4$ % mm	0.4 % $< p <$ 1 % mm	$p > 1$ % mm
0.5	200	125	75	150	125	100	150	100	75
1	200	125	95	200	160	120	150	120	75
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	—	160	100
3	240	150	150	400	300	200	—	200	150
4	280	175	170	450	350	240	—	240	180

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.

Date : 25 Nov Year 2020

Concrete Cover Requirements Under HK Building Regulations

Concrete Cover Requirement Checking

<Durability, Fire, & Bond Requirements>

$$C_{nom} = C_{min} + C_{dev}$$

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 prescribed FRP as per element type)
5. **Add Deviation/Tolerance factor** (check for in-situ or precast)

Building (Construction) Regulations

(Cap. 123 sub. leg. B)

MINIMUM THICKNESS OF CONCRETE COVER TO REINFORCEMENT

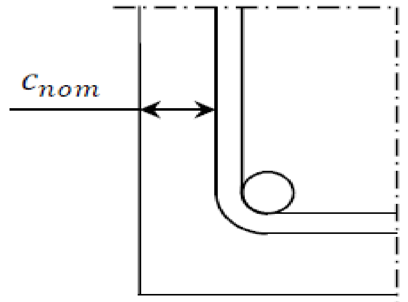
Specified grade strength	Reinforced concrete Conditions of exposure		Prestressed concrete Conditions of exposure		Slabs and walls in enclosed buildings
	Moderate	Severe	Moderate	Severe	
	mm	mm	mm	mm	mm
20	30	-	-	-	20
25	30	40	-	-	20
30	30	35	30	35	20
35	25	30	25	30	15
40	25	30	20	25	15
45	25	30	20	25	15

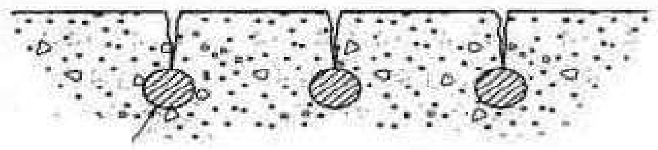
Date : 25 Nov Year 2020

Concrete Cover Requirements In General

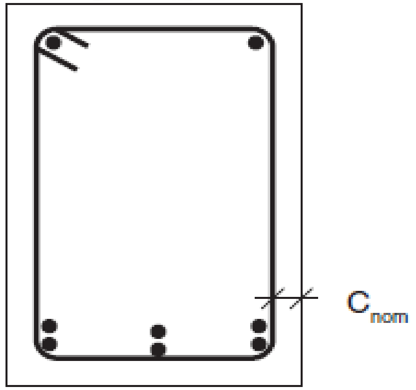
Durability and Cover

1. Exposure Classes
2. Structural Classes
3. Cover
4. Detailing of Members / Reinforcement



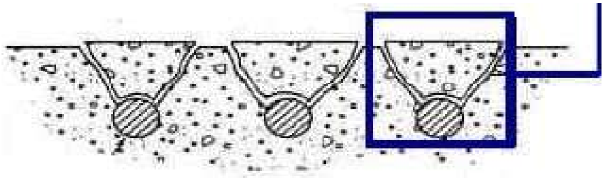


The cover is the distance between the surface of the reinforcement closest to the nearest concrete surface.



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.



Date : 25 Nov Year 2020

Concrete Cover Requirements Under EUROCODE 2

- Concrete cover is the primary means of ensuring durability:
  - Nominal cover is defined as a minimum cover c_{min} plus an allowance in design for deviation Δc_{dev}

    $c_{nom} = c_{min} + \Delta c_{dev}$
  - Minimum concrete cover c_{min} shall ensure:
    - Adequate transmission of bond forces
    - Protection of steel from corrosion
    - Adequate fire resistance

$c_{min} = \max\{c_{min,b};\ c_{min,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add};\ 10\ mm\}$

Where:

$c_{min,b}$	minimum cover for bond requirements
$c_{min,dur}$	minimum cover for environmental requirements
$\Delta c_{dur,\gamma}$	additive safety element
$\Delta c_{dur,st}$	reduction of minimum cover for stainless steel
$\Delta c_{dur,add}$	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_{min}, plus an allowance in design for deviation to all steel reinforcement, Δc_{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 pairs or bundles of three or more bars) plus Δc_{dev}. Where no links are present the nominal cover should be at least equal to this size of the bar) plus Δc_{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. ⬅ Aggregate Size

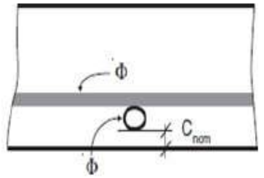
- Nominal cover c_{nom}

- $c_{min,b}$: minimum cover due to bond requirement ⬅ Rebar Size

- 1 bar

  $c_{min,b} = \phi$

  $c_{min,b} = \phi + 5\ mm$ (if $d_g > 32$)



Date : 25 Nov Year 2020

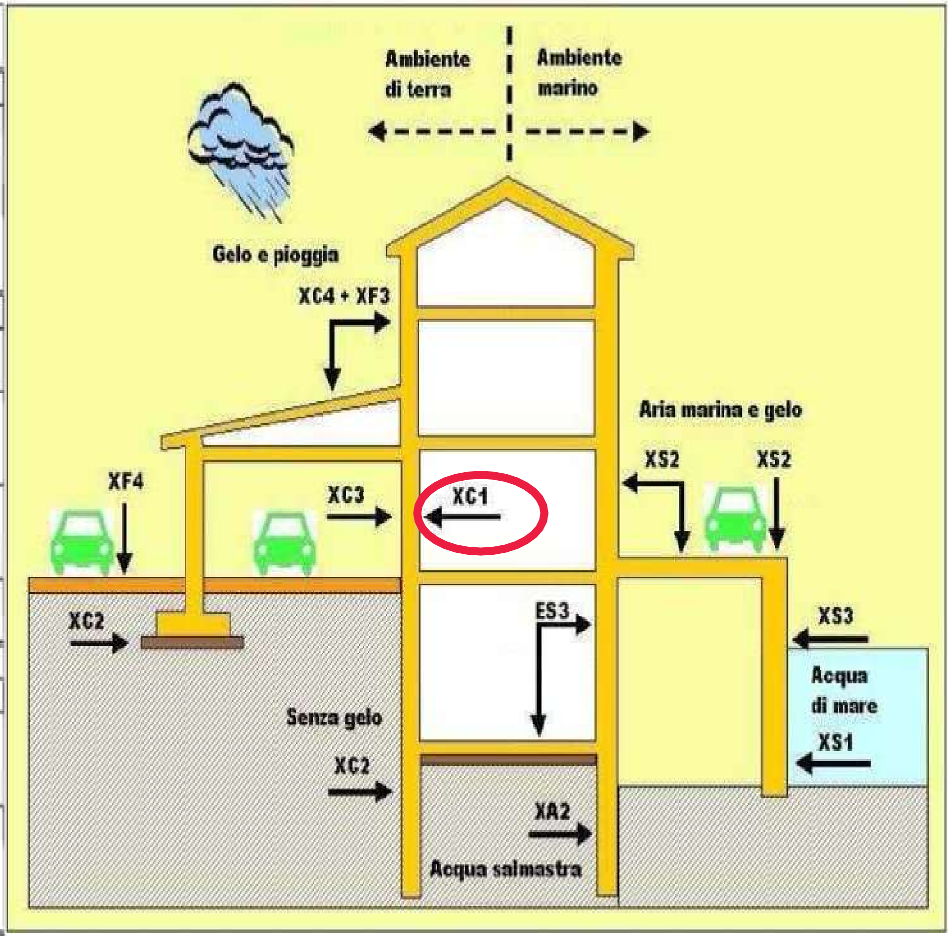
MustDo TIM Panel Performance Concrete Cover

Cellular-Layer-Tubular

Concrete Cover Provision for MustDo Sandwich Panel

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

Class designation	Description of the environment	Informative examples where exposure classes may occur
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity
2 Corrosion induced by carbonation		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2
3 Corrosion induced by chlorides		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete components exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs



EN 13369

Common rules for precast concrete products

Table 4 — Deviations

Target dimension mm	Cross-section Δb, Δh [a] mm	Concrete cover [a b] Δc_{dev} mm
$L \leq 150$	+10/− 5	±5
$L = 400$	+15/− 10	+ 15/− 10
$L \geq 2\,500$	±30	+25/− 10

[a] Linear interpolation for intermediate values.

[b] According to EN 1992-1-1:2004, 4.4.1.1:

$c_{nom} = c_{min} + \Delta c_{dev}$ (use the numerical value for $-\Delta c_{dev}$). Δc_{dev} 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 Δc_{dev} than given in the National Annex by taking the appropriate measures.

Date : 25 Nov Year 2020

MustDo TIM Panel Performance Concrete Cover

Cellular-Layer-Tubular

Concrete Cover Provision for MustDo Sandwich Panel

1.Exposure Classes | **2. Structural Classes** | 3. Cover | 4. Detailing for members

Criterion	Exposure Class						
	XO	XC1	XC2, XC3	XC4	XD1 / XS1 / XA1	XD2 / XS2 / XA3	XD3 / XS3 / XA3
Design working life	100 years, Increase class by 2						
	25 years and less, Reduce class by 1						
Strength Class	C 30/37	C 30/37	C 30/37	C 35/45	C 40/50	C 40/50	C45/55
	If the strength is greater, Reduce class by 1						
	C 50/60	C 50/60	C 55/67	C 60/75	C 60/75	C 60/75	C 70/85
	If the strength is greater, Reduce class by 2						
Binder type	-	C 35/45	C35/45	C 40/50	-	-	-
		Concrete with CEM I with fly ashes					
	-				-	-	-
		Reduce class by 1					
Compact Cover	Reduce class by 1						

Criterion	Exposure classification according to table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1 / XA1 [3]	XD2 / XS2 / XA2 [3]	XD3 / XS3 / XA3 [3]
Design working life	100 years: increased by 2	100 years: increased by 2	100 years: increased by 2	100 years: increased by 2	100 years: increased by 2	100 years: increased by 2	100 years: increased by 2
	25 years and less: reduced by 1	25 years and less: reduced by 1	25 years and less: reduced by 1	25 years and less: reduced by 1	25 years and less: reduced by 1	25 years and less: reduced by 1	25 years and less: reduced by 1
Resistance classification [1]	≥ C30/37 and < C50/60: reduced by 1	≥ C30/37 and < C50/60: reduced by 1	≥ C30/37 and < C55/67: reduced by 1	≥ C35/45 and < C60/75: reduced by 1	≥ C40/50 and < C60/75: reduced by 1	≥ C40/50 and < C60/75: reduced by 1	≥ C45/55 and < C70/85: reduced by 1
	≥ C50/60: reduced by 2	≥ C50/60: reduced by 2	≥ C55/67: reduced by 2	≥ C60/75: reduced by 2	≥ C60/75: reduced by 2	≥ C60/75: reduced by 2	≥ C70/85: reduced by 2
Type of matrix cement		Concrete of class≥ C35/45 base of CEM I without fly ash: reduced by 1	Concrete of class≥ C35/45 base of CEM I without fly ash: reduced by 1	Concrete of class≥ C40/50 base of CEM I without fly ash: reduced by 1			
Compactness of cover [2]	Reduced by 1	Reduced by 1	Reduced by 1	Reduced by 1	Reduced by 1	Reduced by 1	Reduced by 1

1) For the sake of simplicity, the resistance class here is an indicator of durability. It may be judicious to adopt, on the basis of more fundamental indicators of durability and of associated threshold values, a specific justification of the structural classification adopted, by referring to the AFGC guide "Design of concretes for a given life of structures", or to standards documents based on the same principles

2) This criterion applies only in the case of elements for which a good compactness of the covers can be guaranteed, namely:
- Formwork face of element plans (easily assimilated to slabs, possibly ribbed), cast horizontally on industrial formworks.
- Elements industrially prefabricated: elements extruded or drawn, or formwork faces of elements cast into metal frameworks.
- Under face of flagstones of bridge, possibly ribbed, subject to accessibility of bottom of framework with vibration devices.

3) For exposure classifications XAi, this correspondence is indicative subject to a justification of the nature of the aggressive agent.

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MustDo TIM Panel Performance Concrete Cover

Cellular-Layer-Tubular

Procedure for calculating the minimum concrete cover under EUROCODE 2

	Concrete cover		
	Parameters	Suggest	User defined
1	Exposure class		XC1
2	Strength class		C70/85
3	Max agg diam. (mm)		10
4	Service life		50
5	Slab or similar?		YES
6	Quality control?		YES
7	Max bar diam. (mm)		3
8	$\Delta c_{dur,st}$		0
9	$\Delta c_{dur,\gamma}$		0
10	$\Delta c_{dur,add}$		0
11	$\Delta c_{c,dev}$		5
12	Structural class		S2
13	$c_{min,dur}$		10
14	$c_{min,b}$		3
15	c_{min}		10
16	c_{nom}		15

Minimum Nominal Concrete Cover Required for MustDo Panel is 15mm.

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

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

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1 *(Eurocode 2)*						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

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MustDo TIM Panel Performance Steel Ratio

Cellular-Layer-Tubular

Equivalent Area

TABLE A SPECIFICATION FOR WELDED WIRE FABRIC

STANDARD SPECIFICATIONS - SHEETS

		Main Wire		Cross Wire		Cross Sectional		Area Mass Per
SS32 Ref. No.	BS4483 Ref. No.	Size (mm)	Spacing (mm)	Size (mm)	Spacing (mm)	Main mm^2/m	Cross mm^2/m	Unite Area kg/m^2
SQUARE MESHES								
A 13	-	13	200	13	200	664	664	10.42
A 12	-	12	200	12	200	566	566	8.89
A 11	-	11	200	11	200	475	475	7.46
A 10	A 393	10	200	10	200	393	393	6.16
A 9	-	9	200	9	200	318	318	4.99
A 8	A 252	8	200	8	200	252	252	3.95
A 7	A 193	7	200	7	200	193	193	3.03
A 6	A 142	6	200	6	200	142	142	2.22
A 5	A 98	5	200	5	200	98	98	1.54
D 13	-	13	100	13	100	1327	1327	20.83
D 12	-	12	100	12	100	1131	1131	17.76
D 11	-	11	100	11	100	950	950	14.91
D 10	-	10	100	10	100	785	785	12.32
D 9	-	9	100	9	100	636	636	9.98
D 8	-	8	100	8	100	503	503	7.90
D 7	-	7	100	7	100	385	385	6.04
D 6	-	6	100	6	100	283	283	4.44
D 5	-	5	100	5	100	196	196	3.08
RECTANGULAR MESHES								
B 13	-	13	100	10	200	1327	393	13.50
B 12	B 1131	12	100	8	200	1131	252	10.90
B 11	-	11	100	8	200	950	252	9.43
B 10	B 785	10	100	8	200	785	252	8.14
B 9		9	100	8	200	636	252	6.97
B 8	B 503	8	100	8	200	503	252	5.93
B 8A	-	8	150	7	200	335	193	4.14
B 7	B 385	7	100	7	200	385	193	4.53
B 6	B 283	6	100	7	200	283	193	3.73
B 5	B 196	5	100	7	200	196	193	3.05
STANDARD SPECIFICATIONS - ROLLS (48X2.4m)								
A 6	A 142	6	200	6	200	142	142	2.22
A 5	A 98	5	200	5	200	98	98	1.54

TABLE B SUBSTITUTION OF FABRIC FOR MILD STEEL BARS

BARS			SUBSTITUTION OF FABRIC FOR MILD STEEL BARS		
DIAMETER (mm)	SPACING (mm)	AREA (mm^2/m)	EQUIVALENT AREA (mm^2/m)	RECOMMENDED FABRIC REF NO. (mm^2/m)	
10	75	1047	540	D9 B9 (636)	
	100	786	405	D8 B8 (503)	
	125	628	324	B8A (335)	A10 (393) B7 (385)
	150	524	270	D6 B6 (283)	A9 (318)
	175	449	231	A8 (252)	
	200	393	203	A8 (252)	
	250	314	162	A7 (193)	D5 B5 (196)
	300	262	135	A6 (142)	
13	75	1770	912	D11 B11 (950)	
	100	1327	684	D10 B10 (785)	
	125	1062	547	D9 B9 (636)	
	150	885	456	D8 B8 (503)	
	175	759	391	A10 (393)	
	200	664	342	D7 B7A B7 (385)	
	250	531	274	D6 B6 (283)	A9 (318)
	300	442	228	A7 (193)	

* Equivalent Area = $\frac{As \times fy \text{ (steel bar)}}{fy \text{ (fabric)}}$

where As = Area of steel bar

fy (steel bar) = 250 N/mm^2 for mild steel bar

fy (fabric) = 485N/mm^2 for hard-drawn steel wire

TABLE C SUBSTITUTION OF FABRIC FOR HIGH TENSILE STEEL BARS

BARS			SUBSTITUTION OF FABRIC FOR HIGH TENSILE STEEL		
DIAMETER (mm)	SPACING (mm)	AREA (mm^2/m)	EQUIVALENT AREA (mm^2/m)	RECOMMENDED FABRIC REF NO. (mm^2/m)	
10	75	1047	993	D12 B12 (1131)	
	100	785	745	D10 B10 (785)	
	125	628	596	D9 B9 (636)	
	150	524	497	D8 B8 (503)	
	175	449	426	D8 B8 (503)	
	200	393	373	D7 B7 (385)	A10 (393)
	250	314	298	A9 (318)	B8A (335)
	300	262	248	A8 (252)	D6 B6 (283)
13	75	1770	1679	Nil	
	100	1327	1259	D13 B13 (1328)	
	125	1062	1007	D12 B12 (1131)	
	150	885	839	D11 B11 (950)	
	175	759	720	D10 B10 (785)	
	200	664	630	D9 B9 (636)	
	250	531	504	D8 B8 (503)	
	300	442	419	D8 B8 (503)	
16	75	2681	2543	Nil	
	100	2011	1907	Nil	
	125	1609	1526	Nil	
	150	1341	1272	D13 B13 (1328)	
	175	1149	1090	D12 B12 (1131)	
	200	1005	953	D11 B11 (950)	
	250	804	763	D10 B10 (785)	
	300	670	635	D9 B9 (636)	

* Equivalent Area = $\frac{As \times fy \text{ (steel bar)}}{fy \text{ (fabric)}}$

where As = Area of steel bar

fy (steel bar) = 460 N/mm^2 for high tensile bar

fy (fabric) = 485N/mm^2 for hard-drawn steel wire

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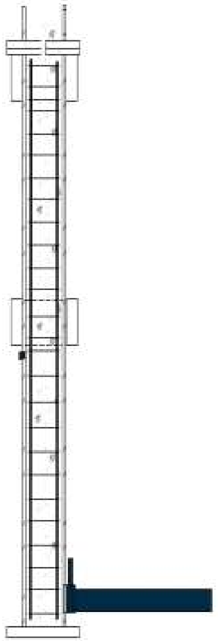
MustDo TIM Panel Performance Self Compacting

Cellular-Layer-Tubular

In-situ Concreting: Trial Arrangement



Hole in cap plate to allow concrete through

Bottom-up SCC Casting

2.1.1 電気暗渠の試験工事

(1) 施工・載荷実験[1)]

表 2 に示すように高充填性コンクリートの配合を一定にし，函軸方向ウェブの開口面積率をパラメータに施工実験を実施した。混和材に高粉末度（6,000cm²/g）の高炉スラグを使用し，商業用コンクリートプラントで製造した。コンクリートの品質管理はスランプフロー値により行い，その値を60±5cm に設定した。

図 4 に型枠，図 5 に充填方法の概要を示す。バイブレーター等の

表 2 高充填性コンクリートの配合

水結合材比*1 W/(C+Sg) (%)	細骨材率 s/a (%)	単位量 (kg/m³) 水 W	セメント C	スラグ Sg	細骨材 S	粗骨材*2 G
31.5	49.1	178	179	385	807	788

*1 高性能減水剤添加量=(C+Sg)×2.5%

*2 粗骨材（砕石）の最大寸法20mm

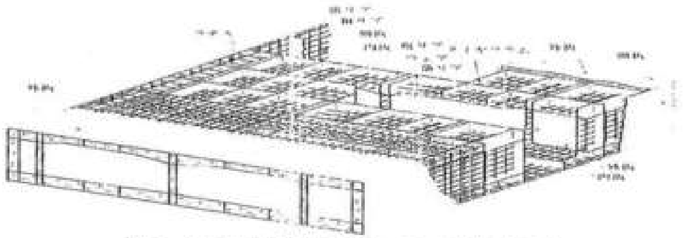


図 3 合成構造沈埋函(A-タイプ)構造概要図

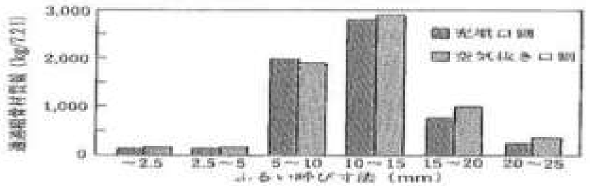
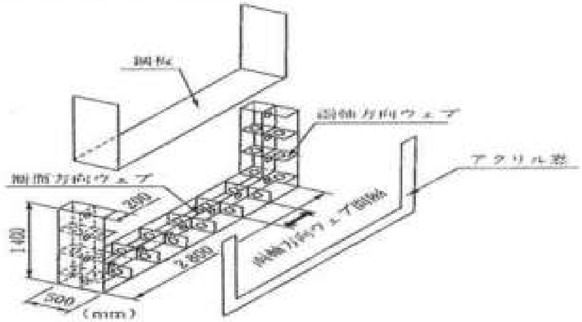


図 6 ふるい試験結果の一例

図 (mm)	100φ	125φ	140φ
開口面積率	16.3%	25.2%	31.4%



寸法	1 400mm × 2 800mm × 500-200mm
内容積	0.52m³
断面方向ウェブ	開口形状：100mmφの円形
	開口間隔：400mm(基準)

図 4 二重鋼殻型枠の概要

表 3 充填実験結果

(a) 横置き

函軸方向ウェブ開口面積率	函軸方向ウェブ間隔 400mm	600mm	∞ (ウェブナシ)
16.3% (100mmφ)	●	●	○
25.2% (125mmφ)	●	○	
31.4% (140mmφ)	○		

(b) 縦置き

函軸方向ウェブ開口面積率	函軸方向ウェブ間隔 400mm	600mm	∞ (ウェブナシ)
16.3% (100mmφ)	●	●	○
25.2% (125mmφ)	○	○	
31.4% (140mmφ)	○		

●：充填不能 ○：充填可能

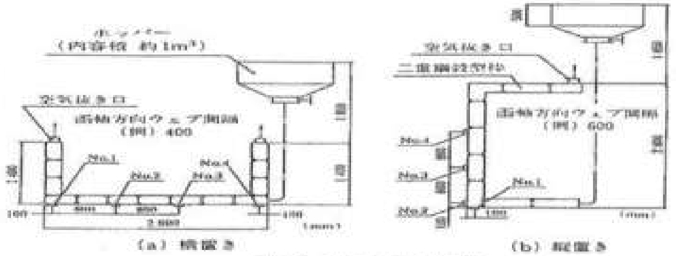
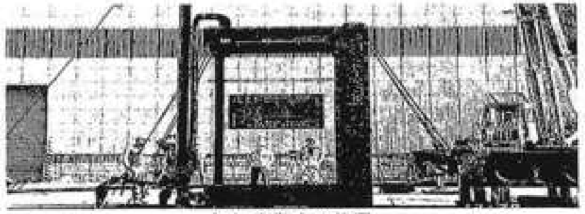
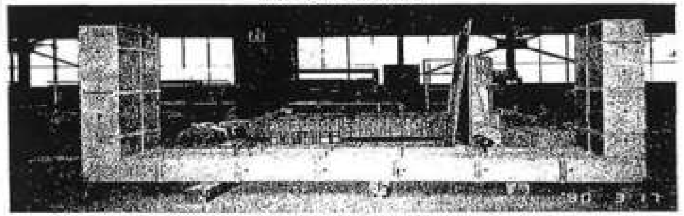


図 5 充填方法の概要



(a) 充填中の状況



(b) 木製型枠脱型後

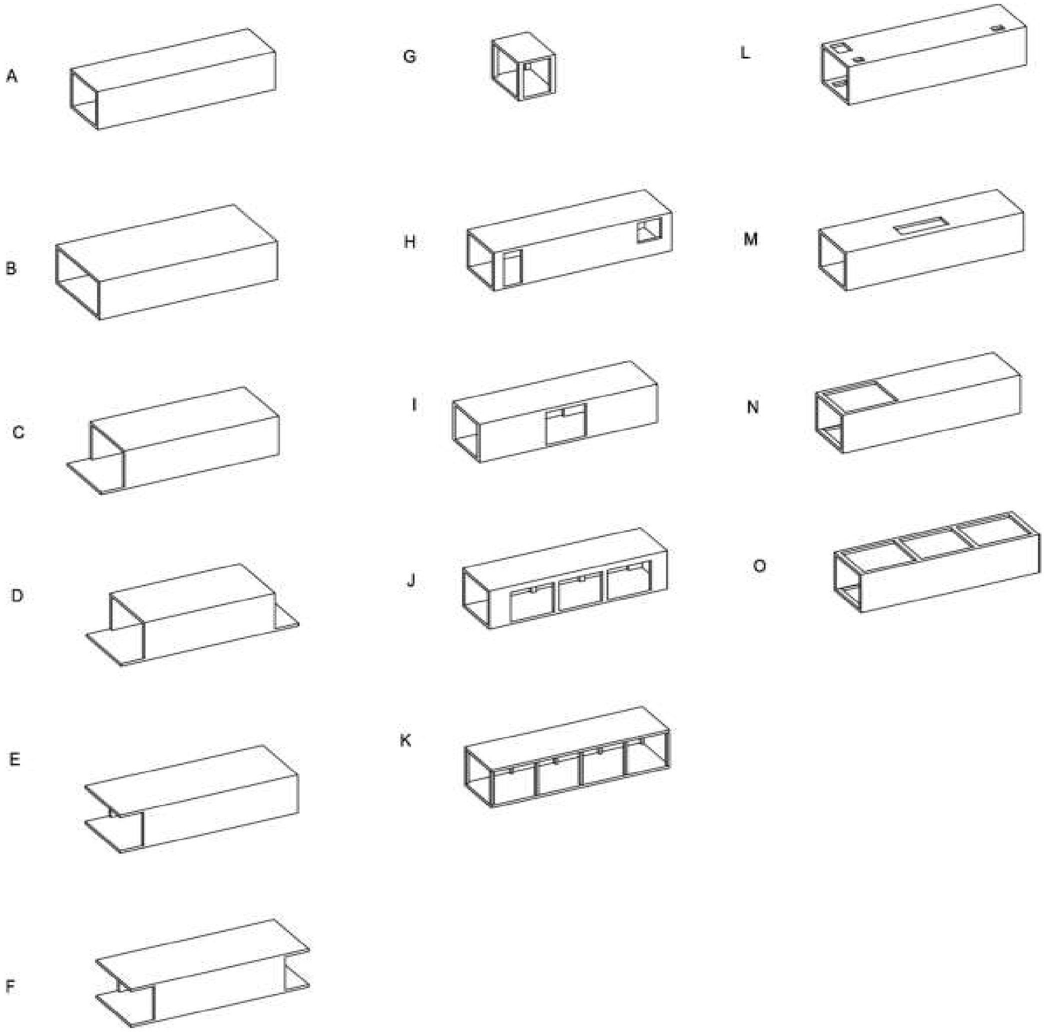
写真 1 充填実験状況

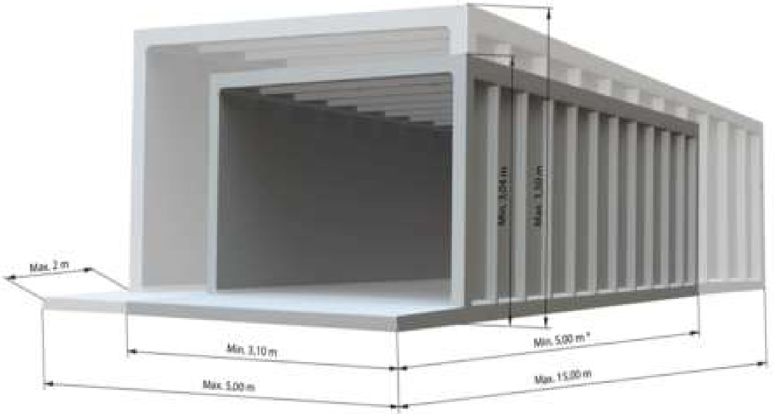
In-situ Sandwich Casing

Date : 25 Nov Year 2020

MustDo TIM Panel Modular Planning

Cellular-Layer-Tubular





Modular Topology Approach

Date : 25 Nov Year 2020

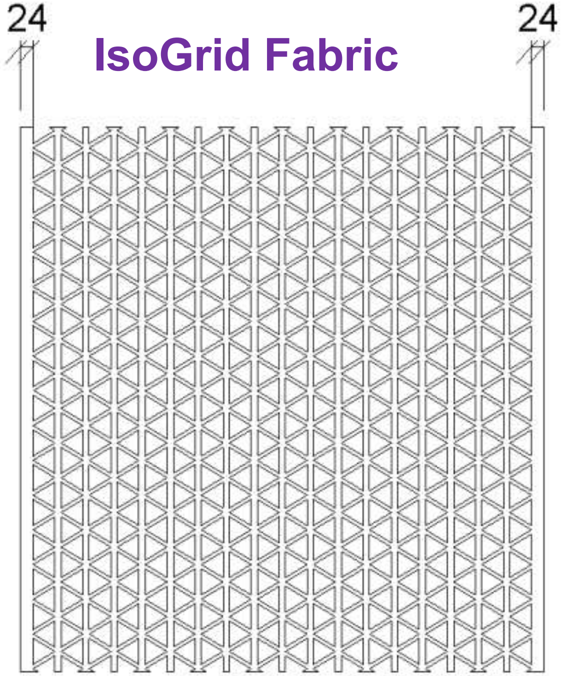
MustDo TIM Panel Modular Planning

Cellular-Layer-Tubular

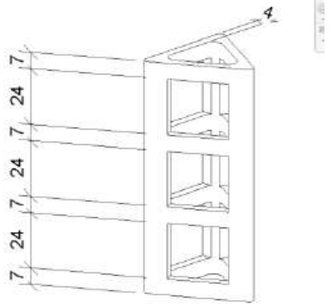
FLEXCRETE

Confidential
Patent Pending

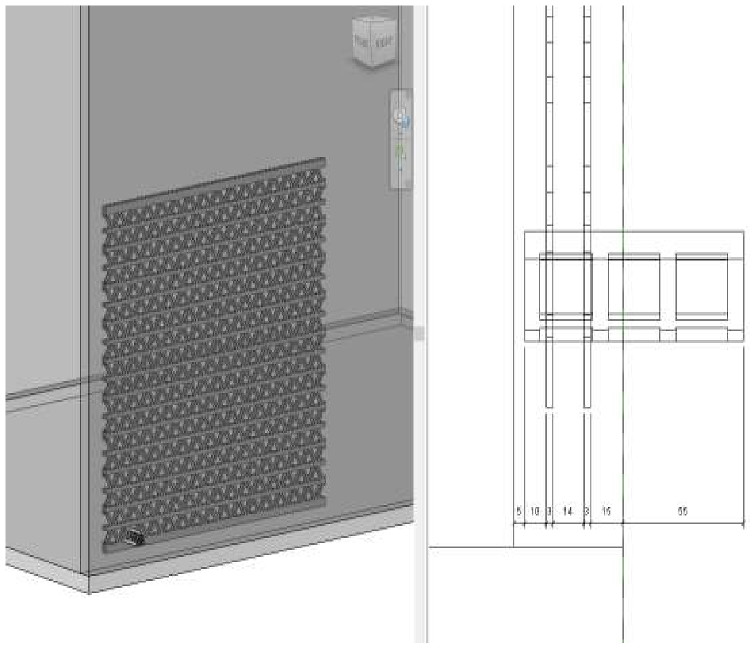
IsoGrid Fabric



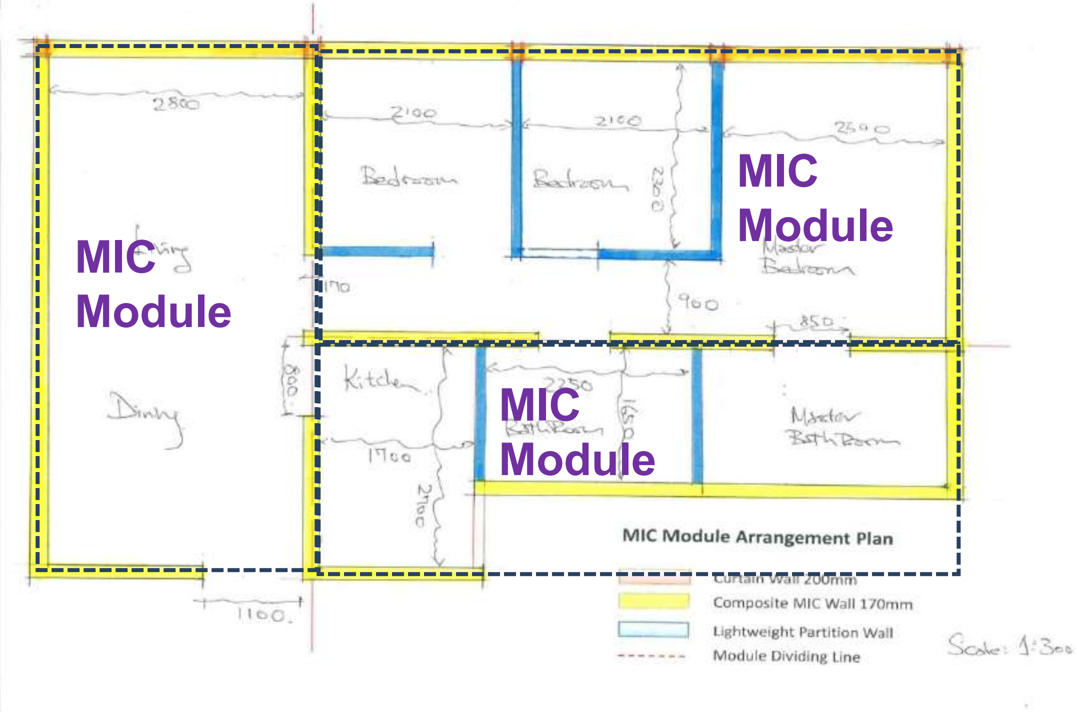
Tubular Connector



MustDo Wall Assembly Design



Modular Planning



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Response
To
Market

Part -I : MustDo Composite Approach

Part -II : MustDo Composite Testing

Part -III : MustDo DfMA

Part -IV : Current Steel Concrete Types

Architect - Engineer

PART - III : DfMA

Steel Plate Production
Steel Tube Extrusion
Steel Plate Hole Forming
Modular Manufacturing

Towards A New Co-Creation Dynamics

MustDo Materials DfMA Hot Rolled Steel Plate

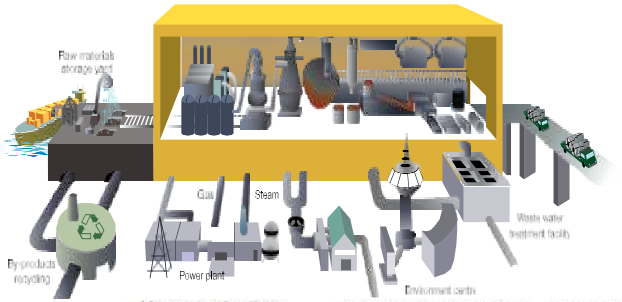
Hot Rolled Steel Plate Production Sizing

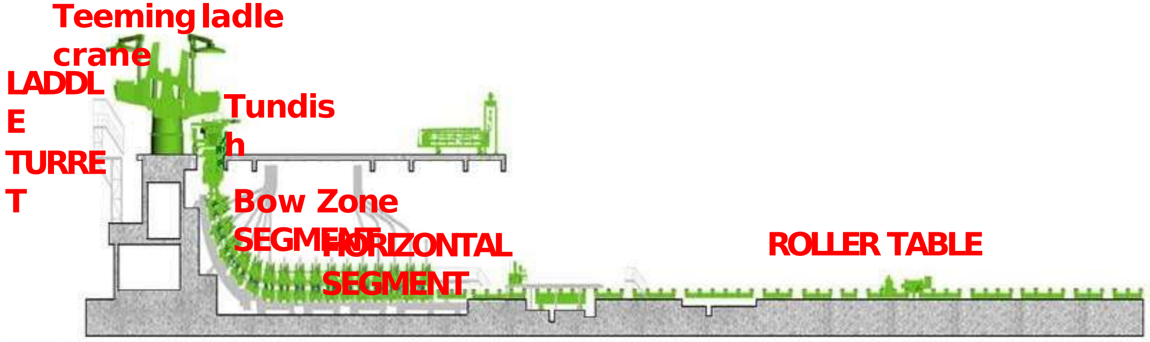
按厚度分根据GB/T15574-1995《钢产品分类》的规定

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)。

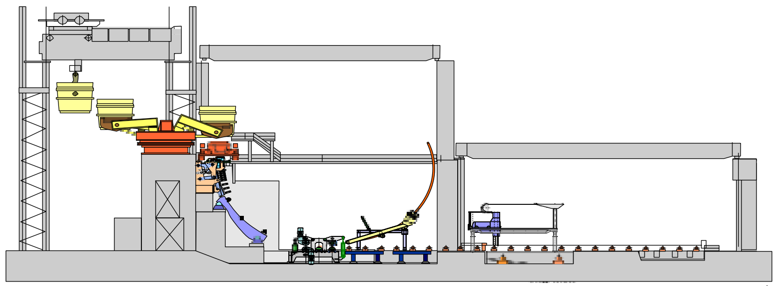
2) 厚钢板：厚度大于3(4)mm的钢板。在实际工作中，厚钢板又称中厚钢板，其划分是： (1)中板：厚度3(4)-20mm的钢板。

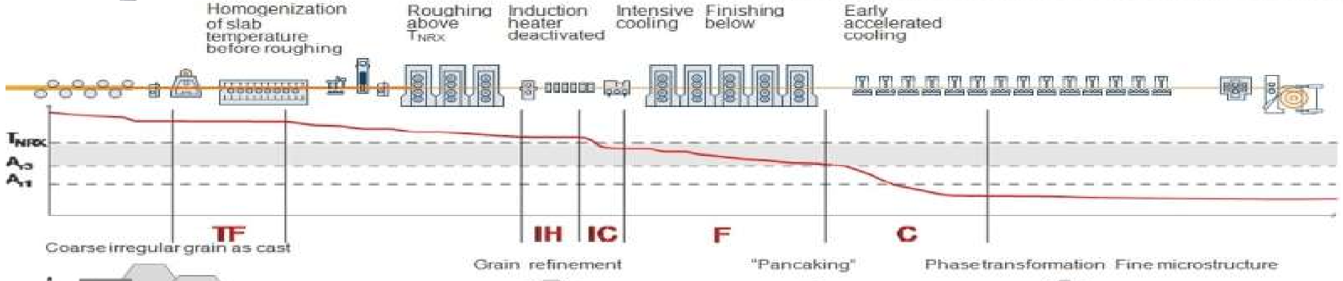
Steel Making Facility

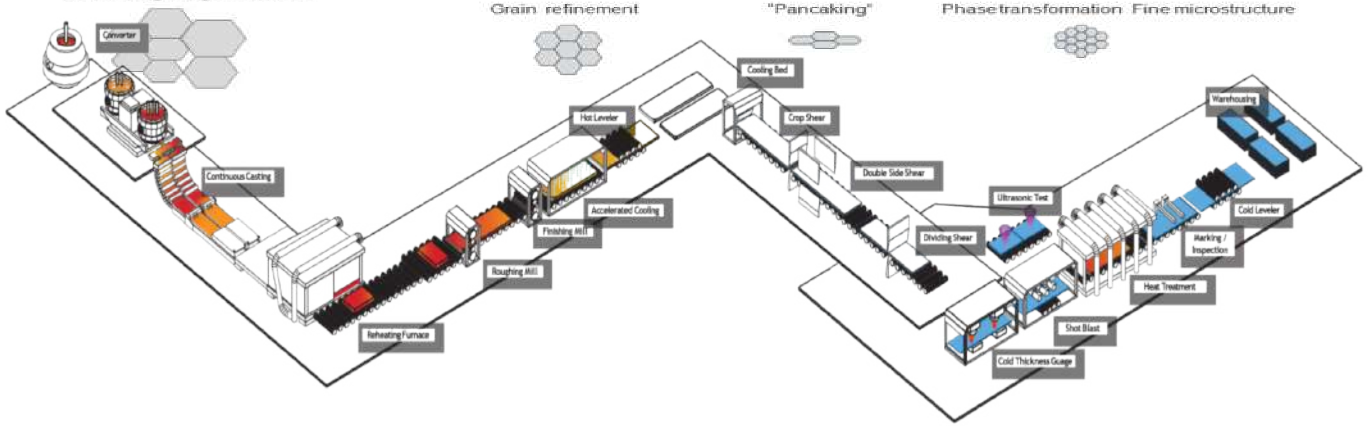




Continuous Casting Machine







2 Dimensions

Quard at present is supplied in the following range:

	Thickness	Width
Quard 400	4 - 50 mm	1500 - 3100 mm
Quard 450	3,2 - 64 mm	
Quard 500	4 - 40 mm	
Quard 550	6 - 20 mm	

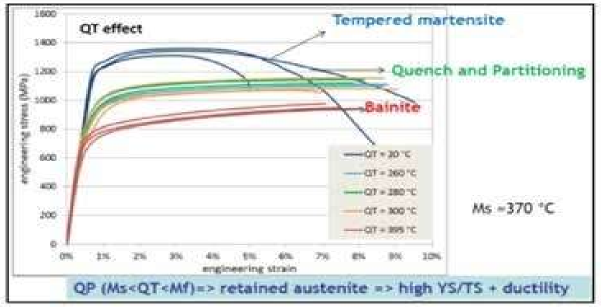
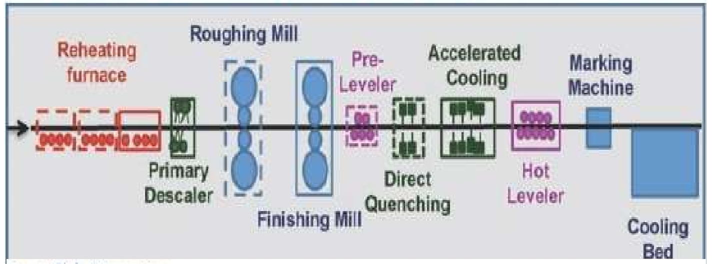


PLATE MILL TECHNOLOGICAL LAYOUT

4.3 METER WIDE FOUR HIGH SINGLE STAND REVERSING MILL



Input Slab Dimension:

Thickness (mm)	Width (mm)	Length (mm)	Weight (Ton)
210-300	1200-2400	2600-4100	23.2 max.

Output Plate Dimension:

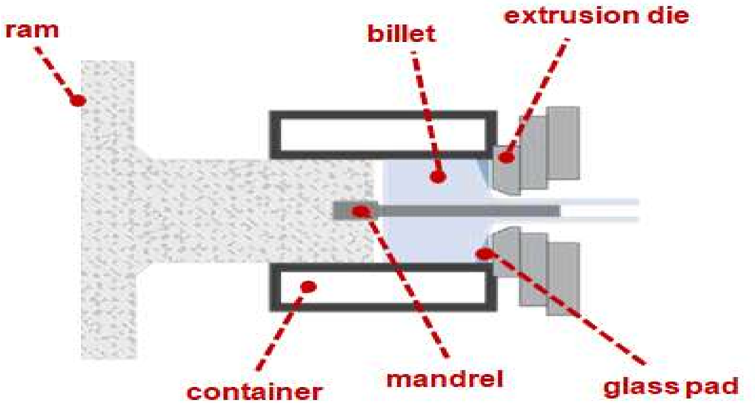
Thickness (mm)	Width (mm)	Length (mm)	Finished Length (mm)
6-100	1500-4200	7000-42000	6300-15000

Date : 25 Nov Year 2020

MustDo Materials DfMA Hot Extrusion Steel Profiles

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

- CREATIVITY

- 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.

CARBON STEEL

STAINLESS STEEL AND DUPLEX

STEEL TITANIUM

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.

DIMENSIONS	**Fit in a circle of max Ø 255** | Inside diameter for hollow profiles: from 20 mm to 160 mm Minimum thickness: **4 mm**
LENGTHS	Up to c. 16 800 mm
WEIGHT PER METER	Up to max. c. 110 kg/m
TOLERANCES	Depending on profile cross section and material
MATERIALS	Nearly all quality - all required heat treatments are available

Date : 25 Nov Year 2020

MustDo Materials DfMA Steel Plate & Tube Machining

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).

PROCESS	KERF WIDTH (mm)	HAZ WIDTH (mm)
Flame Cutting	0.9	1.5
Plasma Cutting	3.2	0.5
Laser Cutting	0.3	0.2

切割效果极佳

采用普锐特冶金技术固态激光技术能够达到极佳的切割效果，避免了机械剪切引起的带钢变形，而且切割能力不受钢种强度的限制。在LW21L(连续镀锌线，连续退火线，重卷线，检验线)和LW21H(酸洗线，酸洗冷轧联合机组)两种类型的应用中，整个带钢厚度范围内切割的质量和可靠性都已得到验证。

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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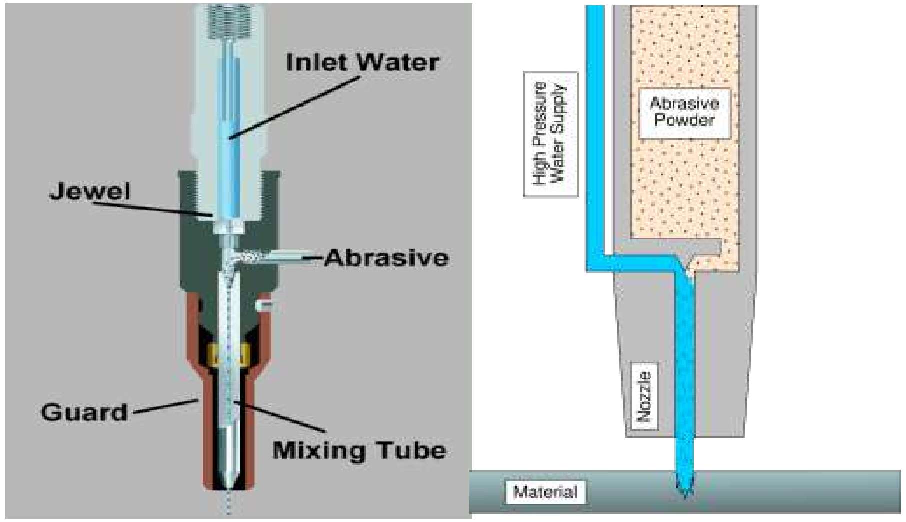
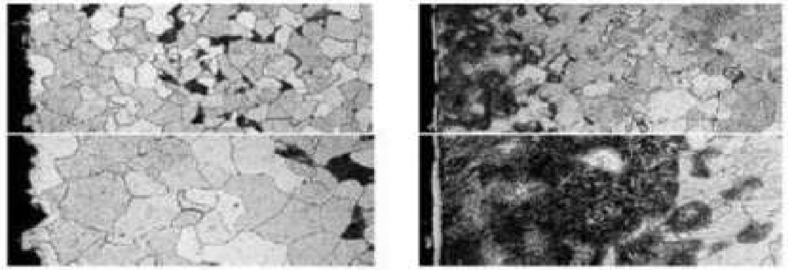
Abrasive Waterjet Machining

- 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

Abrasive WJ Cutting



20 mm mild steel,
cut with the abrasive water jet (left) And the laser jet (right)



- **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**

After plasma cutting

After laser cutting

After waterjet cutting

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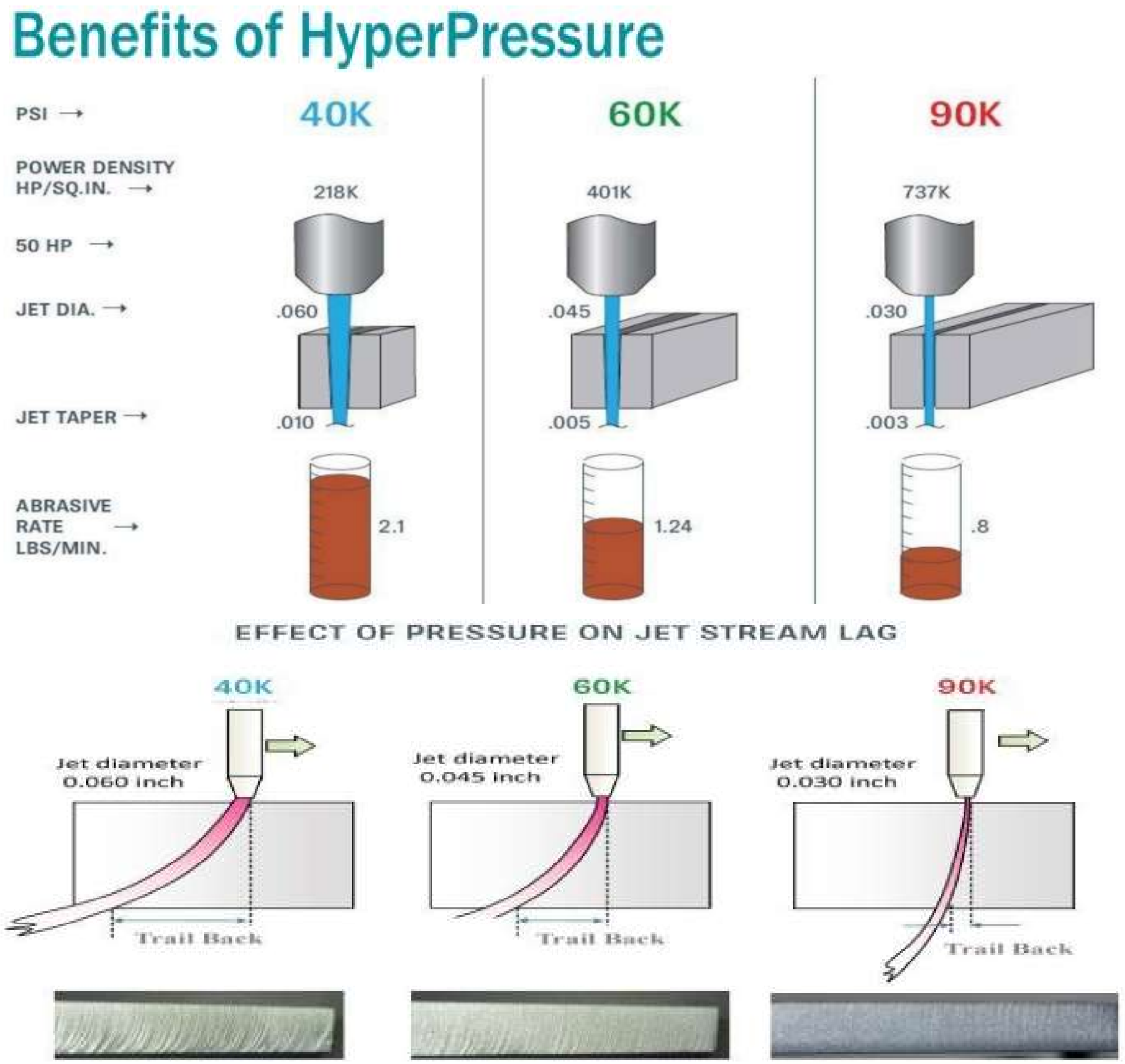
MustDo Materials DfMA Steel Plate & Tube Machining

Abrasive Waterjet Machining



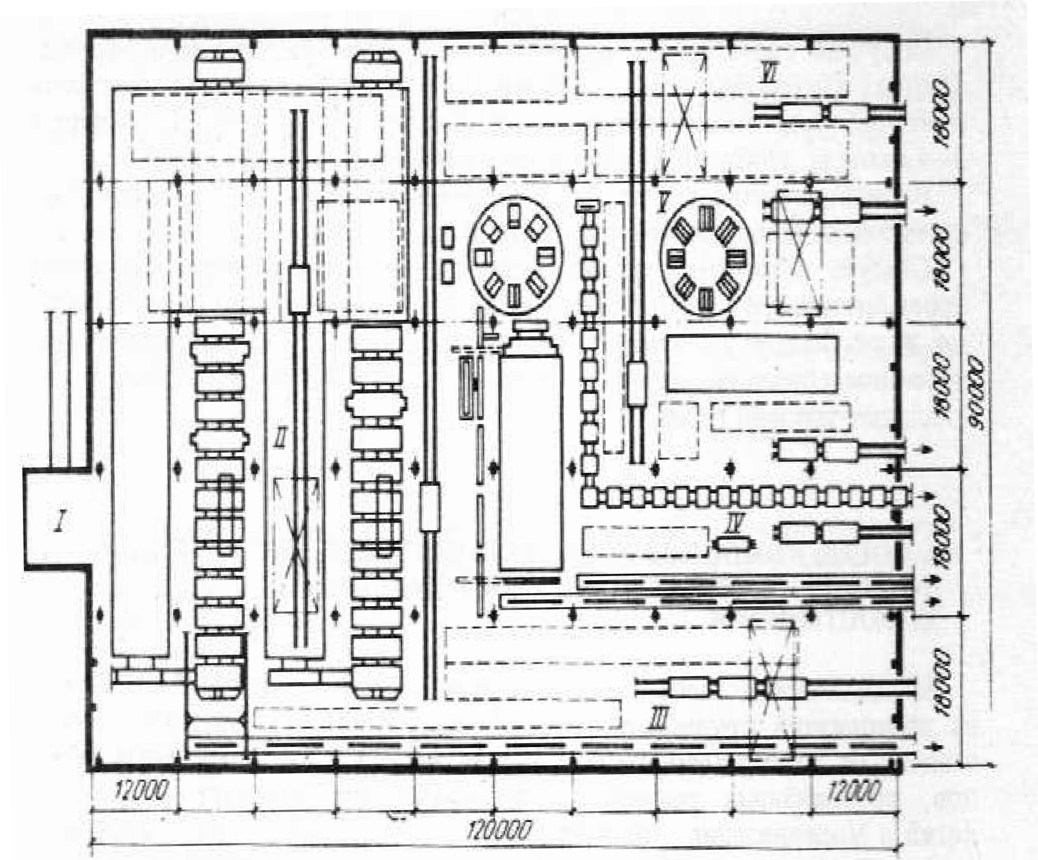
Punching

Date : 25 Nov Year 2020

MustDo Materials DfMA Volumetric Concrete Production

Automatic Isogrid Plate Production

Concrete Modular Units Production : Factory Cell



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.

Common rules for precast concrete products

EN 13369 : 2018

DECLARATION OF PERFORMANCE

Issue No: xxxx

1. Product code: Xxxx
2. Type: Xxxxxx
3. Intended use or uses: xxxxxx
4. Manufacturer: xxxxxxxxxxxx

5. System of AVCP: 2+
6. Harmonised Standard: EN 14992:2007+A1:2012 – Annex ZA.1a
7. Notified Body: BSI
8. Certificate No: 0086-CPD-600388
9. Declared performance:

Essential characteristics	Performance	Harmonised technical spec
Concrete: Compressive Strength	40 N/mm²	EN 13369:2018
Pre-stressing steel: Ultimate Tensile Strength	1670 N/mm²	EN 13369:2018
Pre-stressed steel: Tensile Yield Strength	1400 N/mm²	EN 13369:2018
Mechanical Resistance	NPD	EN 13369:2018
Detailing	Class B	EN 14992:2007+A1:2012
Durability	High (XD1-XS1)	EN 1992-1-1 (EN2016 : 2013)

Signed for and on behalf of the manufacturer by:

xxxxxxxxx– Managing Director

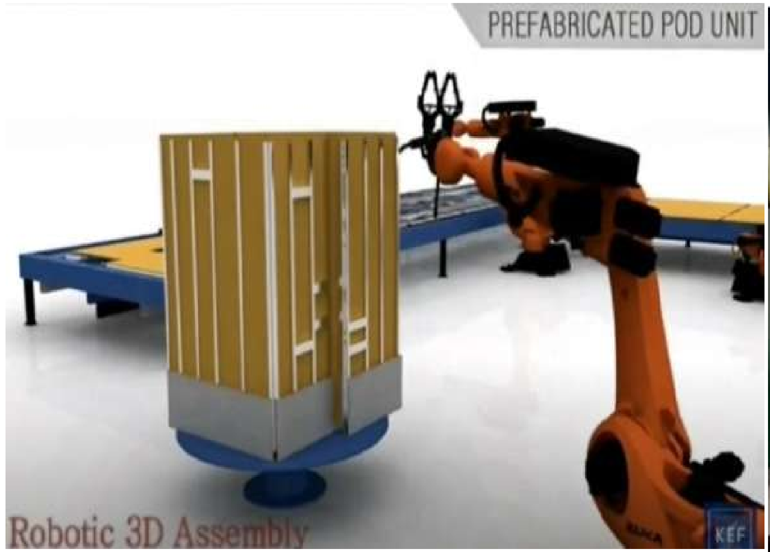
Date:.................................... Signature:....................................

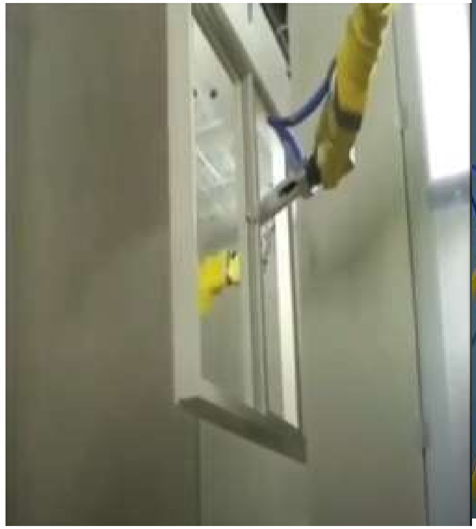
Revision No	1	2	3
Date of Issue			
Author			

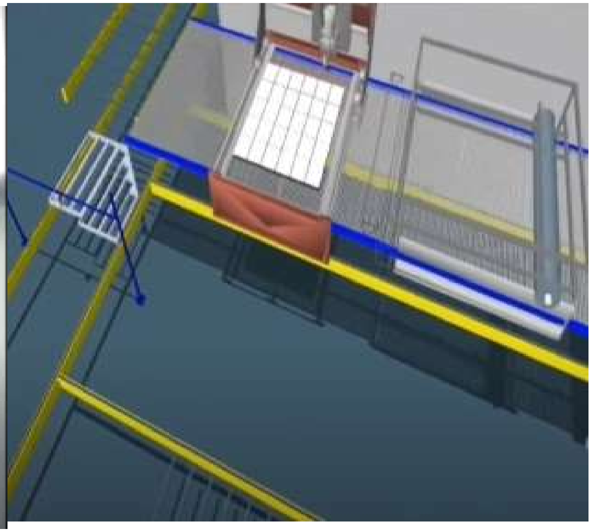
Date : 25 Nov Year 2020

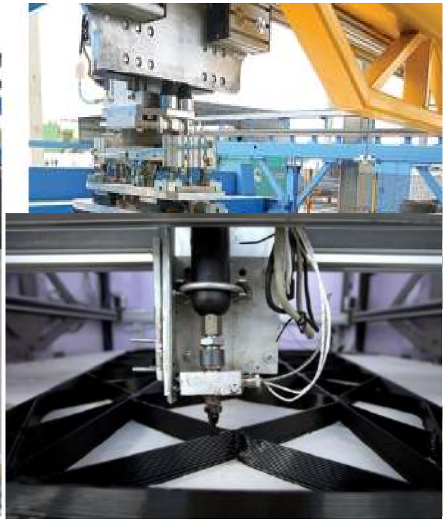
MustDo Materials DfMA Volumetric Concrete Production

Volumetric Production – Concrete Module Process Flow *Automatic Robotic Production*









Date : 25 Nov Year 2020

Response
To
Market

Part -I : MustDo Composite Approach

Part -II : MustDo Composite Testing

Part -III : MustDo DfMA

Part -IV : Current Steel Concrete Types

Architect - Engineer

PART - IV : REFERENCE

Steel Concrete Composite

Shear Connector Types

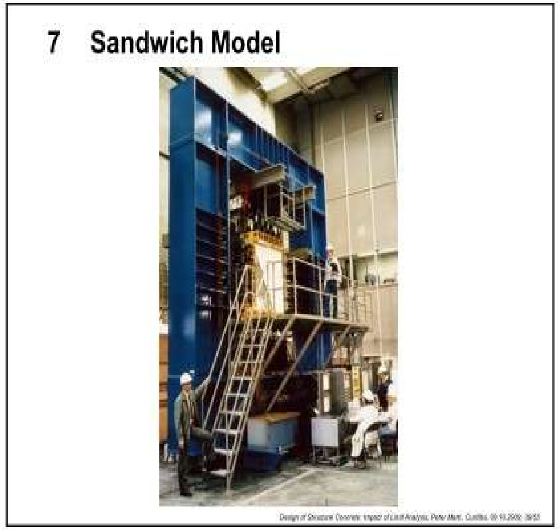
Micro-reinforced Concrete

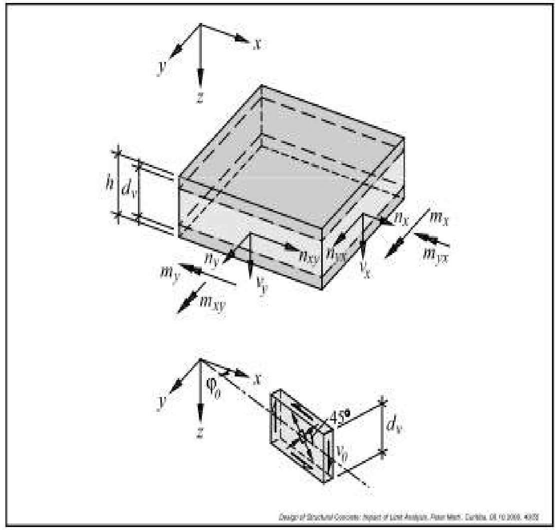
Metal mesh fabric Beam

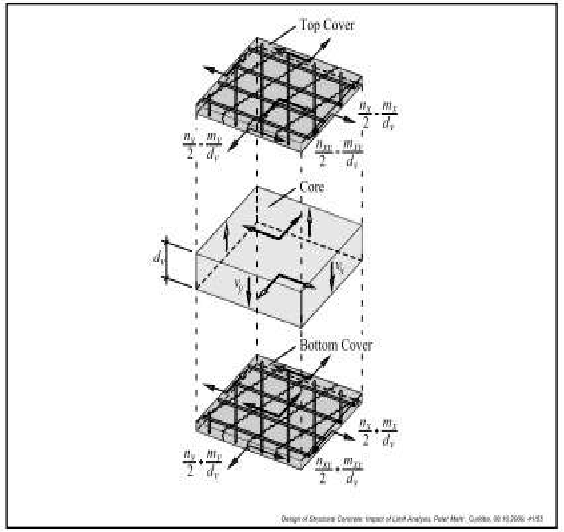
Towards A New Co-Creation Dynamics

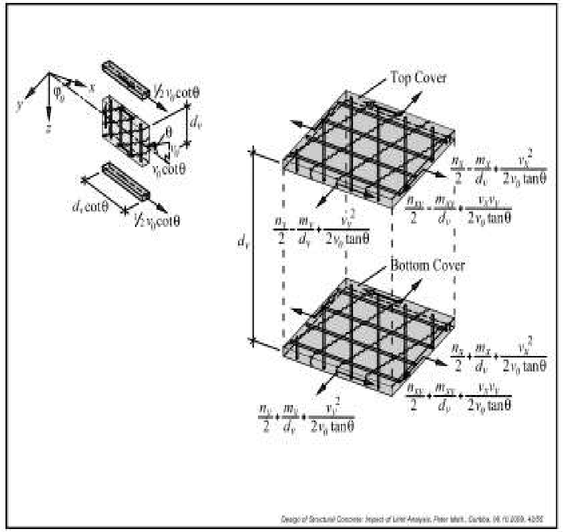
Date : 25 Nov Year 2020

Sandwich Model With Crack Membrane

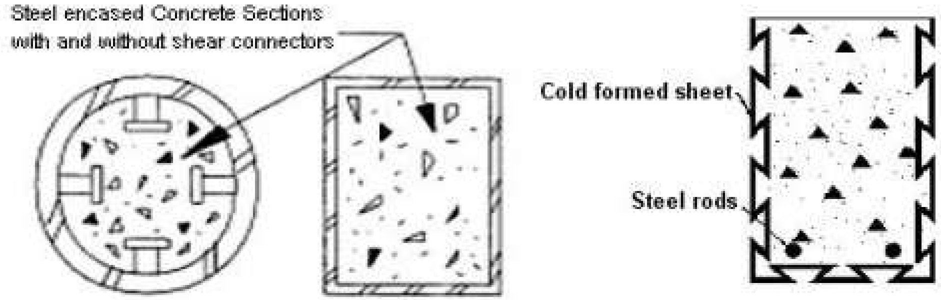




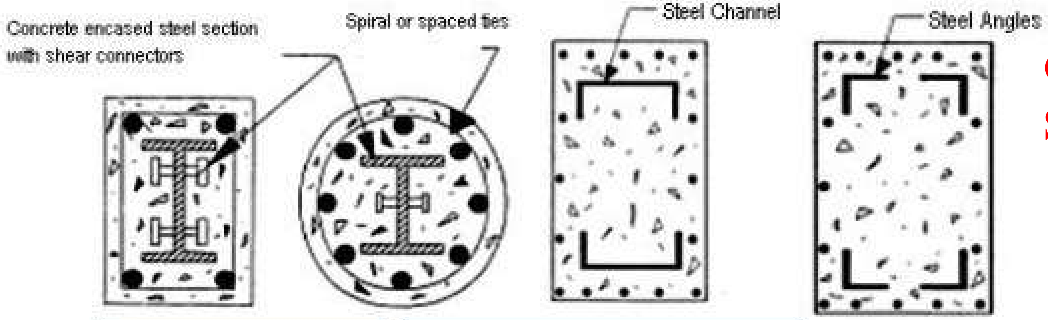




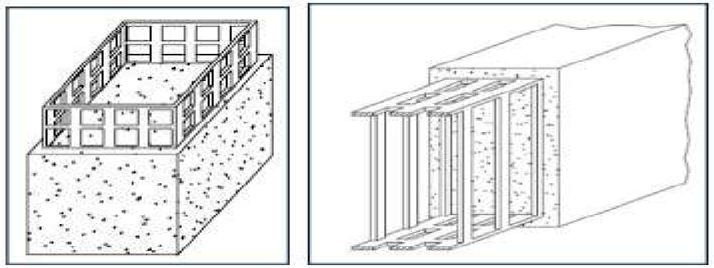
Steel Concrete Arrangement



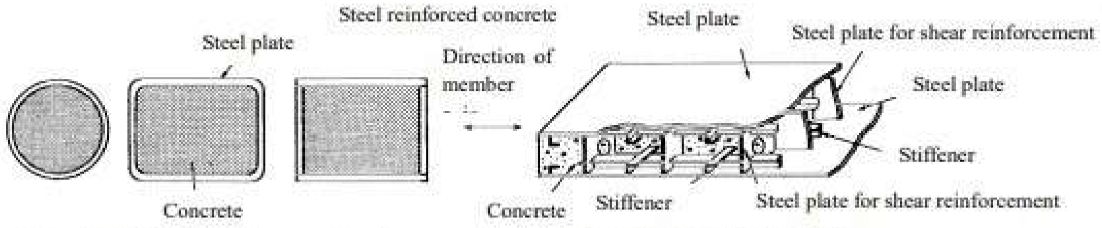
Steel Encased Sections



Concrete Encased Sections



Prefabricated Cage Sections



Concrete-filled columns (cross sections)

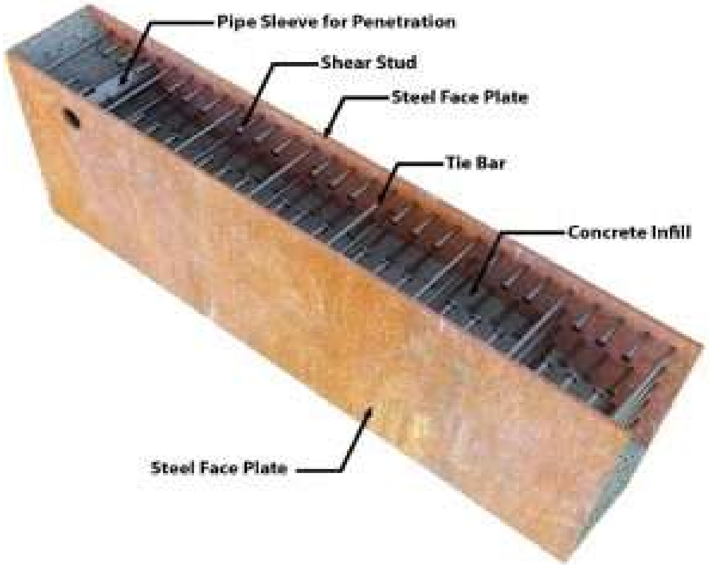
Steel-concrete sandwich structure

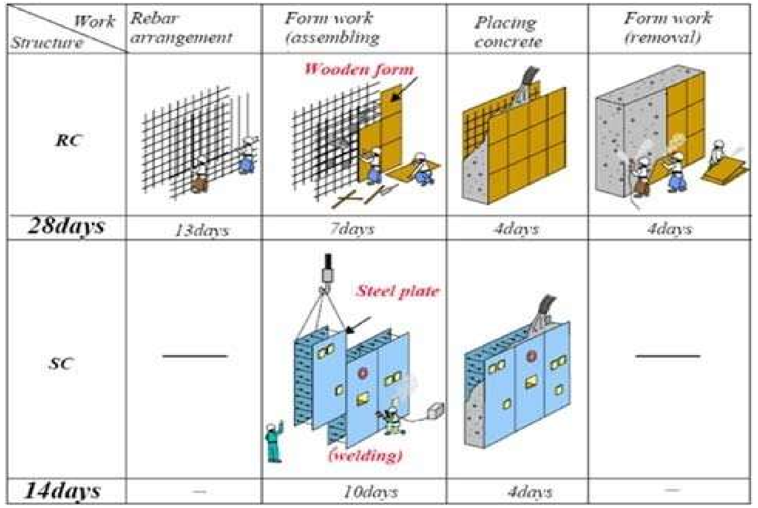
Date : 25 Nov Year 2020

Application of Steel-Concrete-Steel Composite Wall

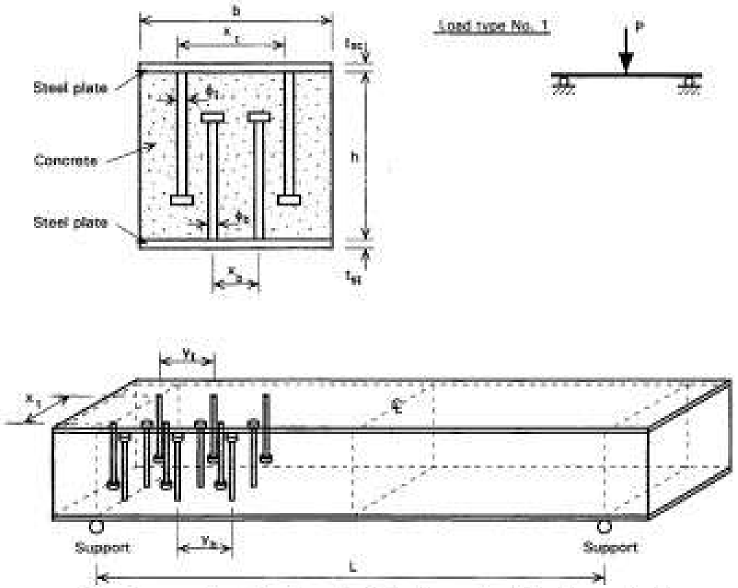
No Upper Steel Ratio Limit – Steel on the outside of the composite

Schematization of a SCS sandwich tunnel element

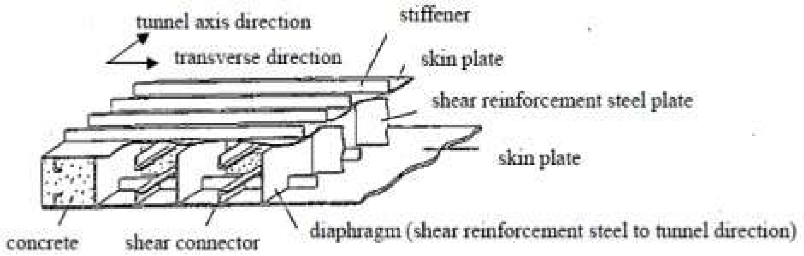




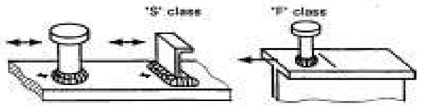
Structure \ Work	Rebar arrangement	Form work (assembling)	Placing concrete	Form work (removal)
RC		Wooden form		
28days	13days	7days	4days	4days
SC	—	Steel plate (welding)		—
14days	–	10days	4days	–



Steel concrete steel sandwich element with shear studs



Schematization of a SCS sandwich tunnel element with all members



Class 'F' and 'S' failure modes as defined in BS5400:Part 10

Double Skin – Steel Concrete Steel Sandwich Composite

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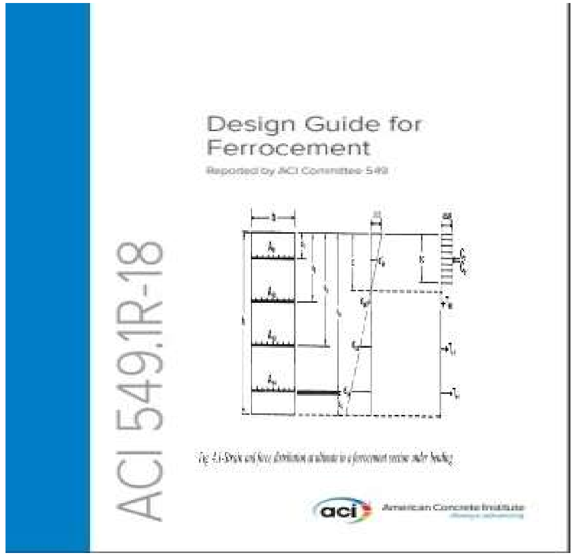
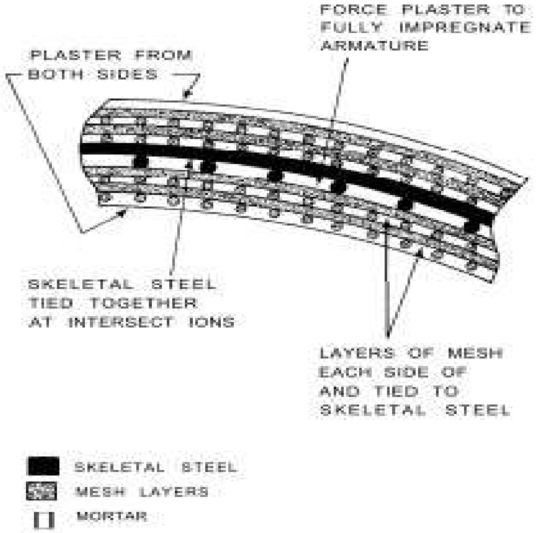
Ferrocement Shear Connectors



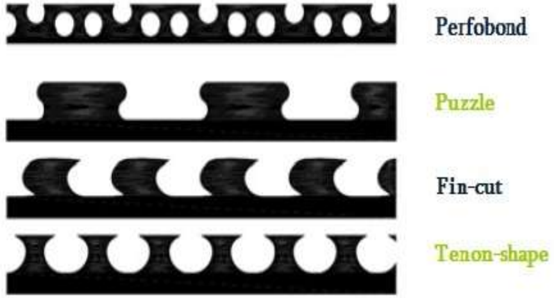


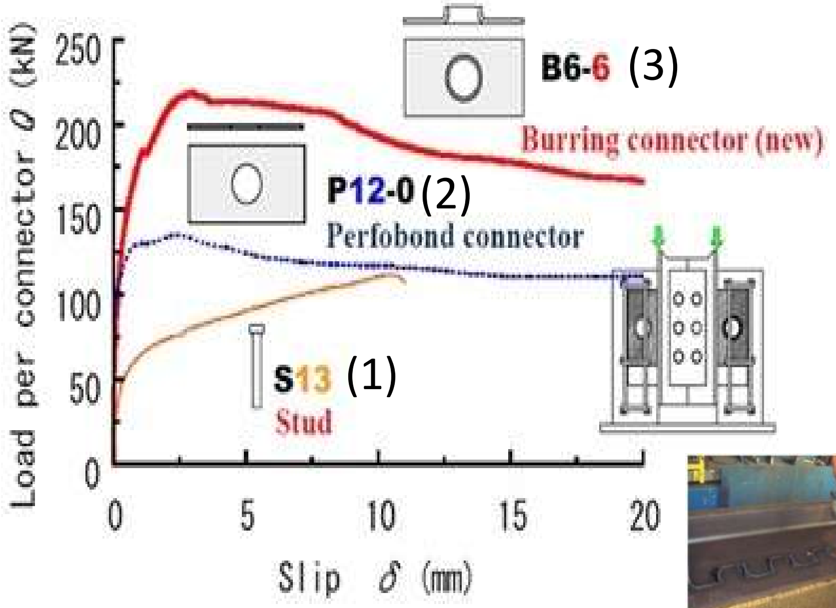
Three kinds of mechanical shear connectors.

(1) concrete-headed Studs,

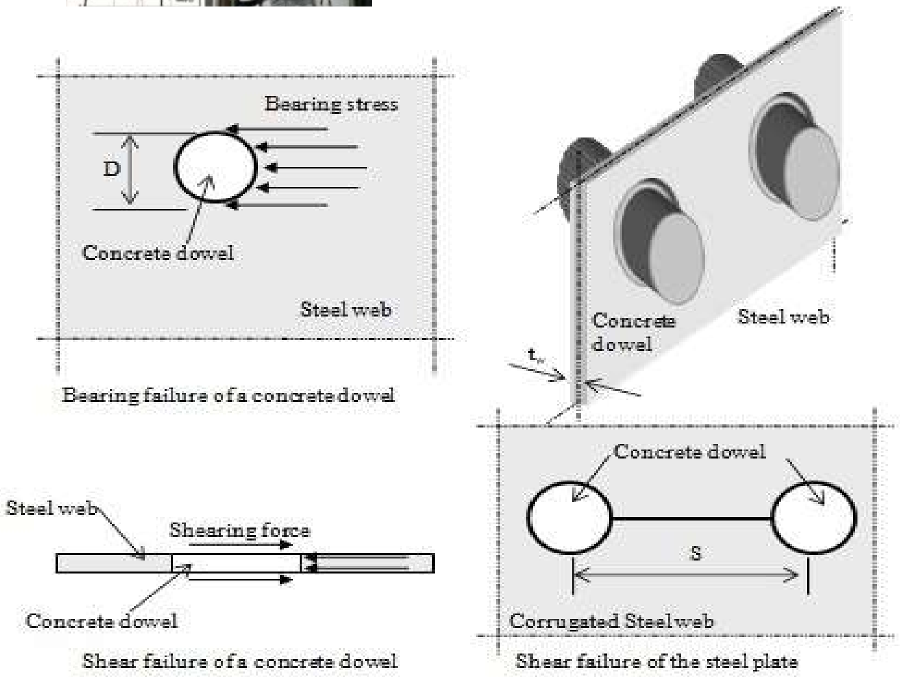
(2) Perfobond connectors,

(3) new Burring connectors <B6-6>.





Relationship between Load and Slip of Shear Connector



Failure Modes of Concrete Dowel Shear Connector

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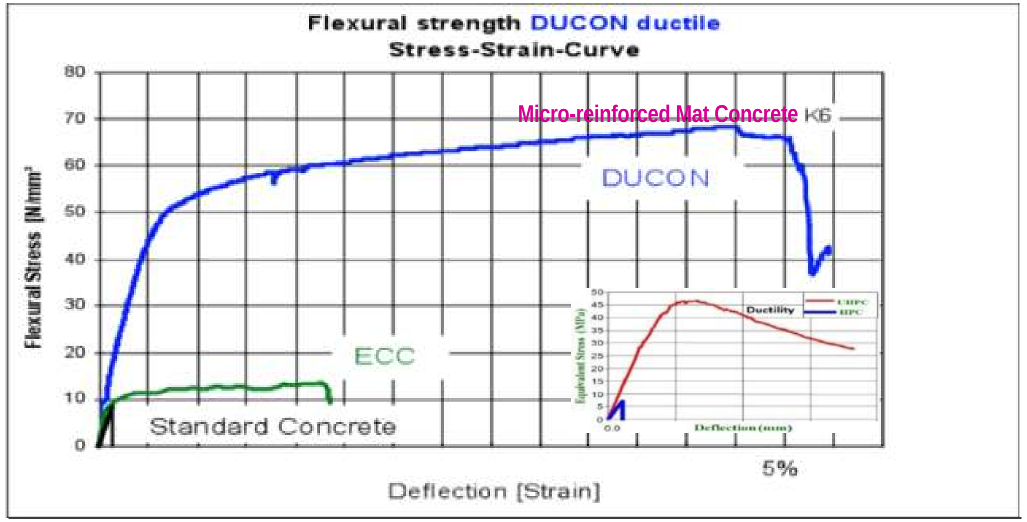
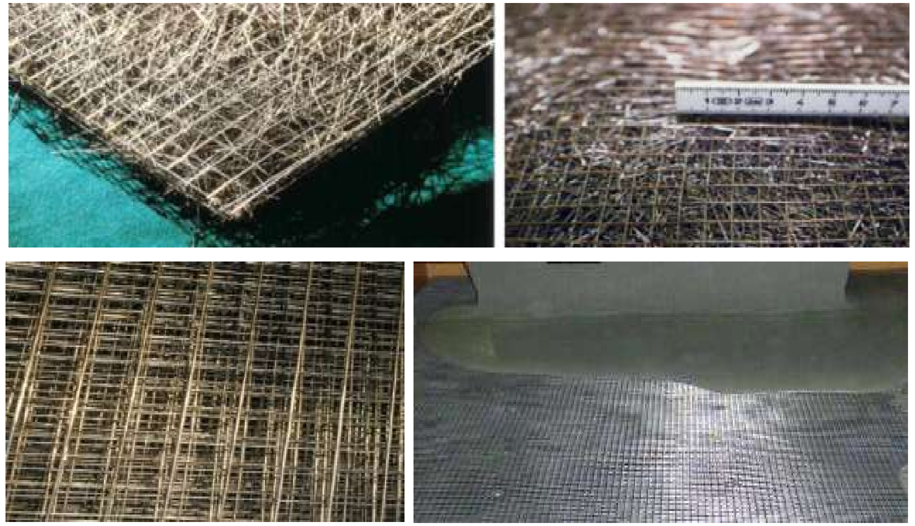
High Performance Concrete Micro-reinforced Concrete



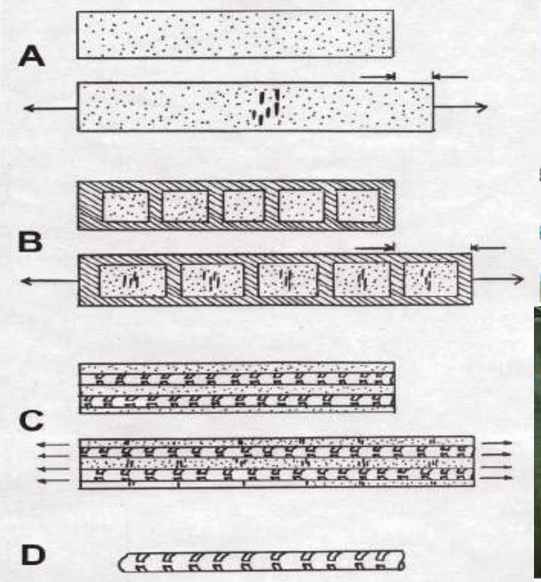


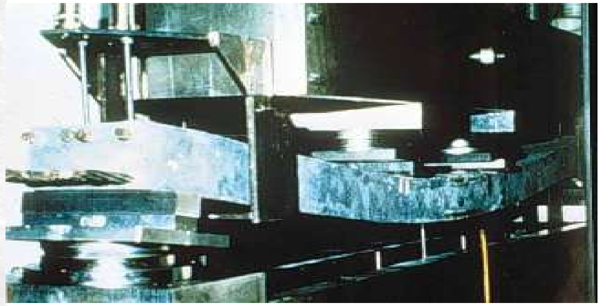
Slurry infiltrated mat concrete

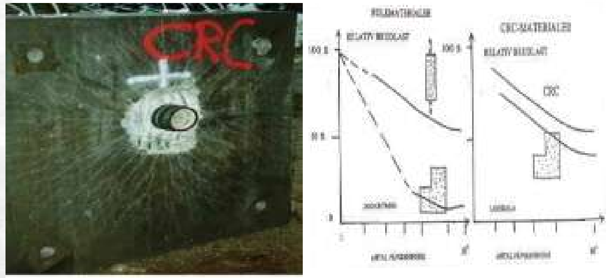
ECC Reinforced Slab (135mm thick)


Setra
Association Française de Génie Civil
AFGC
Documents scientifiques et techniques
Bétons fibrés à ultra-hautes performances
Ultra High Performance Fibre-Reinforced Concretes
Recommandations provisoires
Interim Recommendations

UHPC Application Code

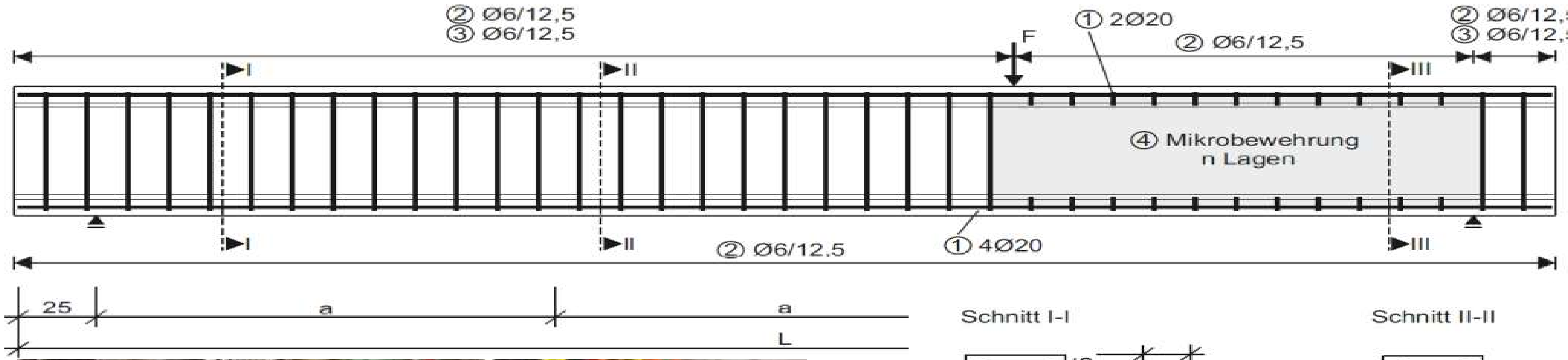


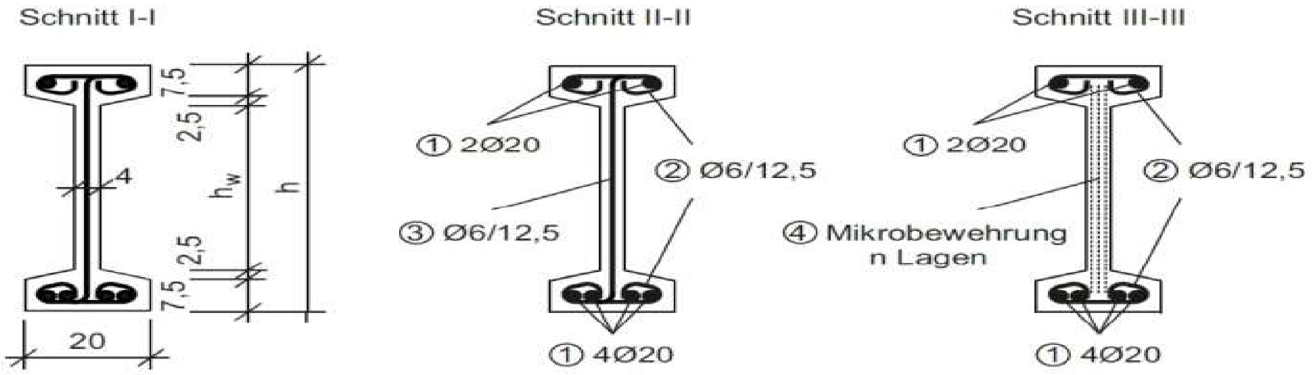


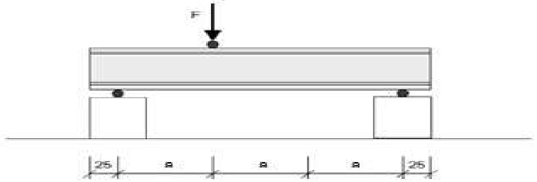


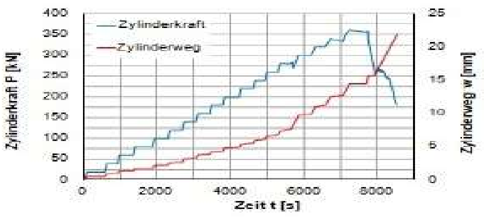
Date : 25 Nov Year 2020

Concrete Beam Web Using Micro-reinforced Thin Wall







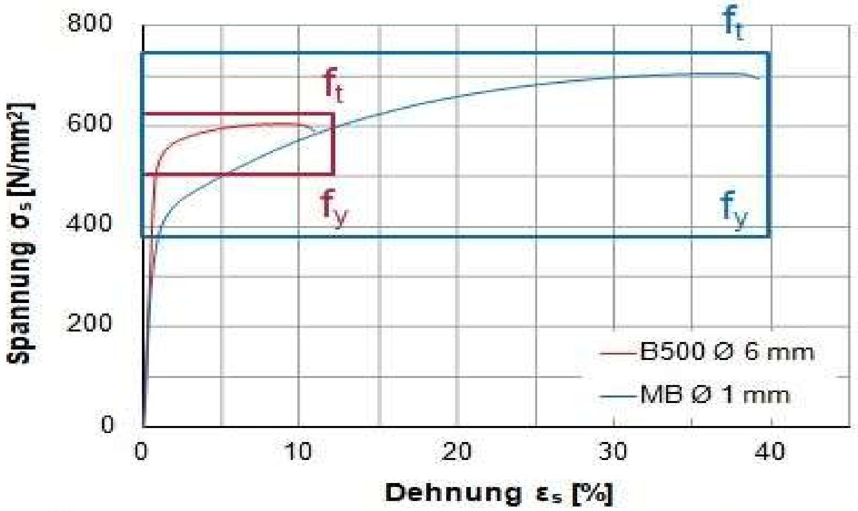


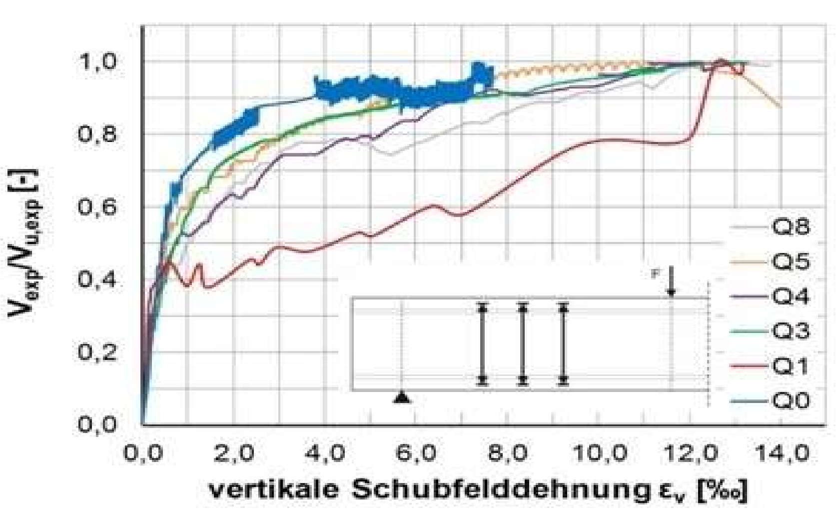
Date : 25 Nov Year 2020

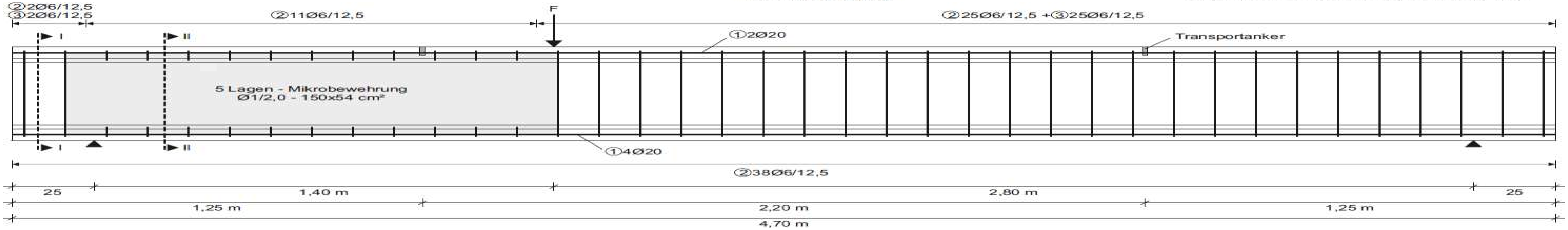
Concrete Beam Web Using Micro-reinforced Thin Wall

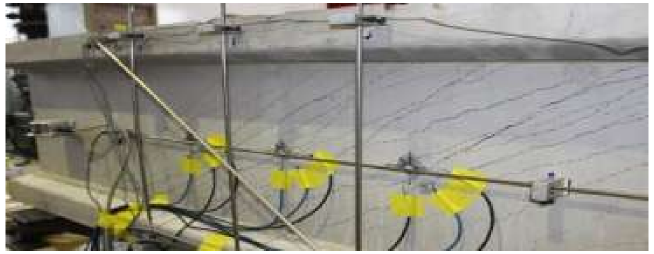
Q3 – Mikrobewehrter Beton

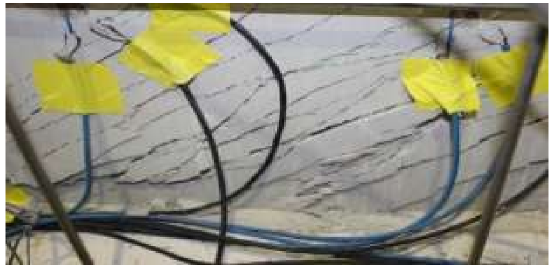
- Mikrobewehrung Ø1/20 – ρ_w = 1,5 %
- feines Rissbild
- Sekundäres Betonversagen











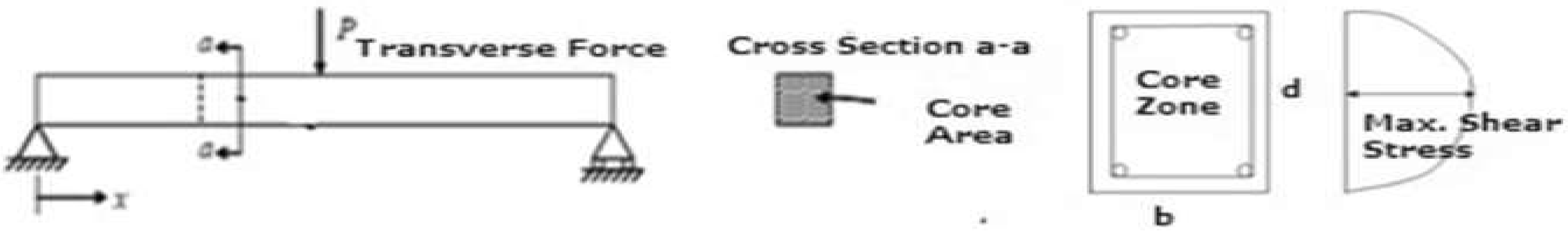
Date : 25 Nov Year 2020

Concrete Beam Web Using Welded Metal Mesh

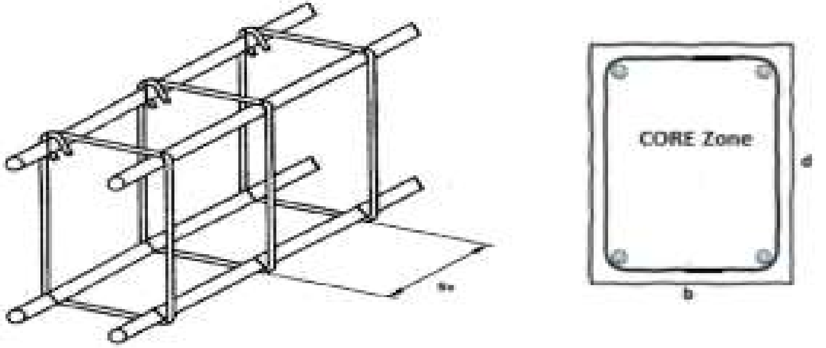
A novel means of improving the performance of reinforced concrete beams using the welded wire mesh as core zone reinforcement

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.

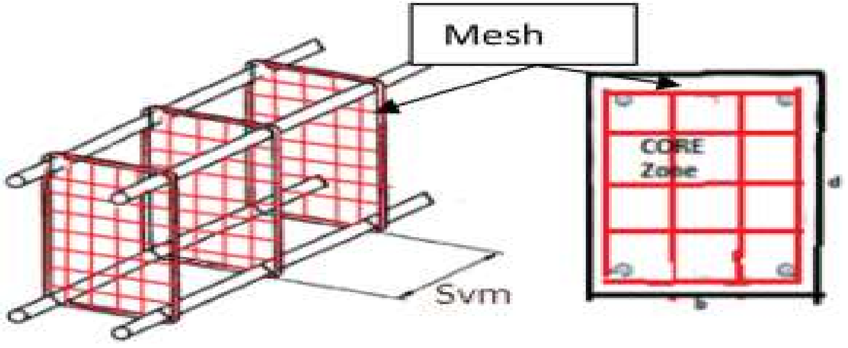


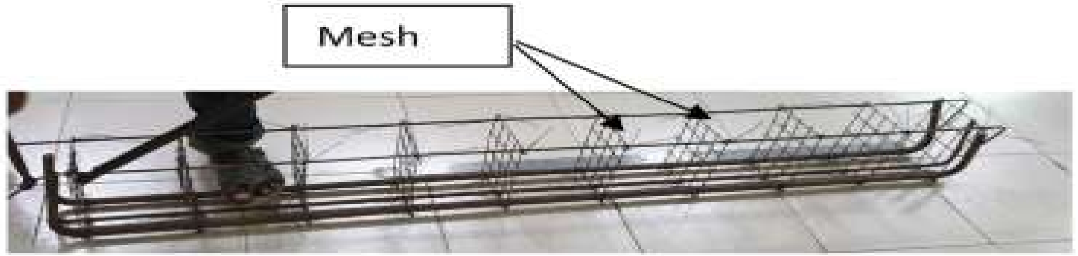
Concrete Beam Web Using Welded Metal Mesh



R-160

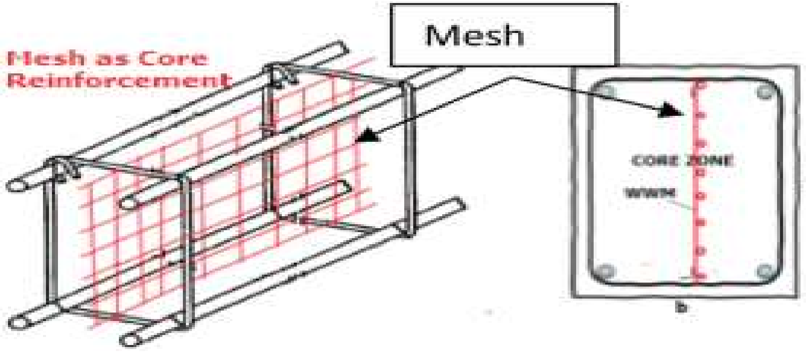
Stirrup Rebar As Transverse Reinforcement

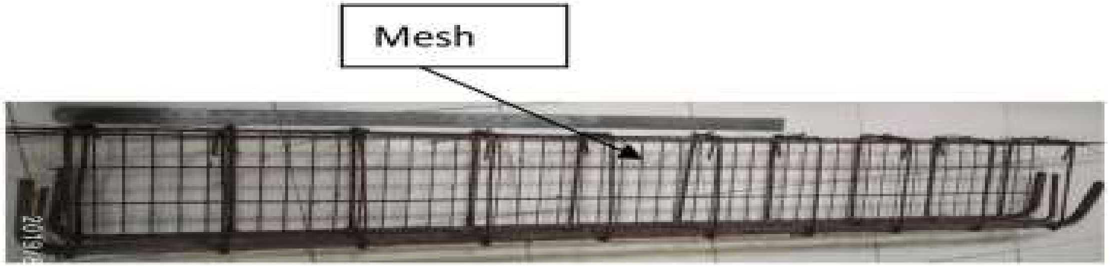




M-160

Prefabricated Mesh As Transverse Reinforcement





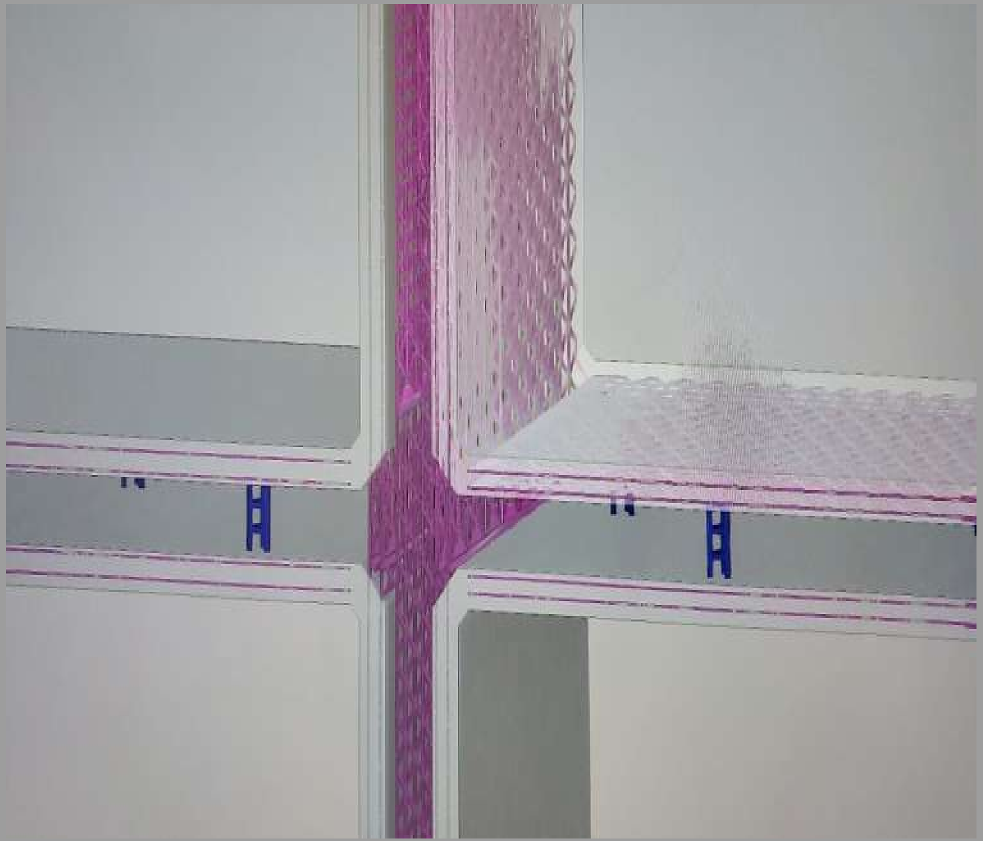
L-160

Prefabricated Mesh As Longitudinal Reinforcement

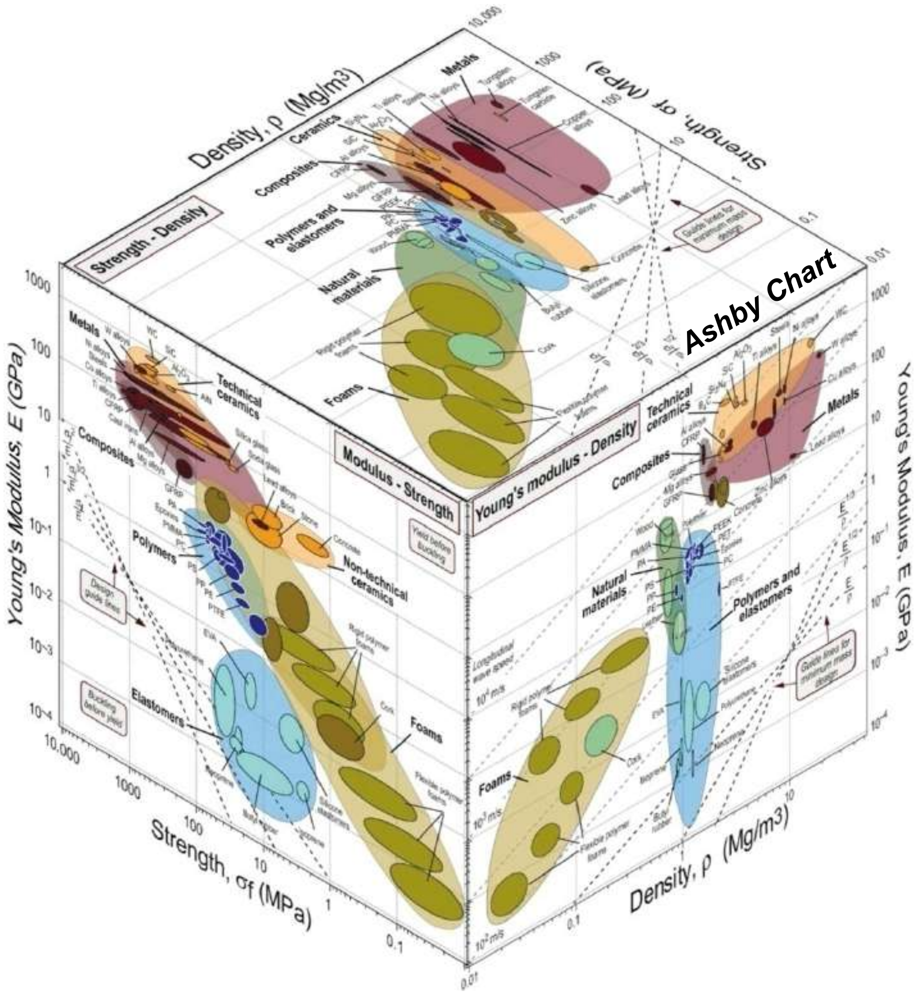
Date : 25 Nov Year 2020

Structural . MiC

Material . Architecture



Q & A



Lightness . Visibility . Consistency . Multiplicity

Thank you very much for your interest !

END OF PRESENTATION

Date : 25 Nov Year 2020