
CRH
Leviat
A CRH COMPANY

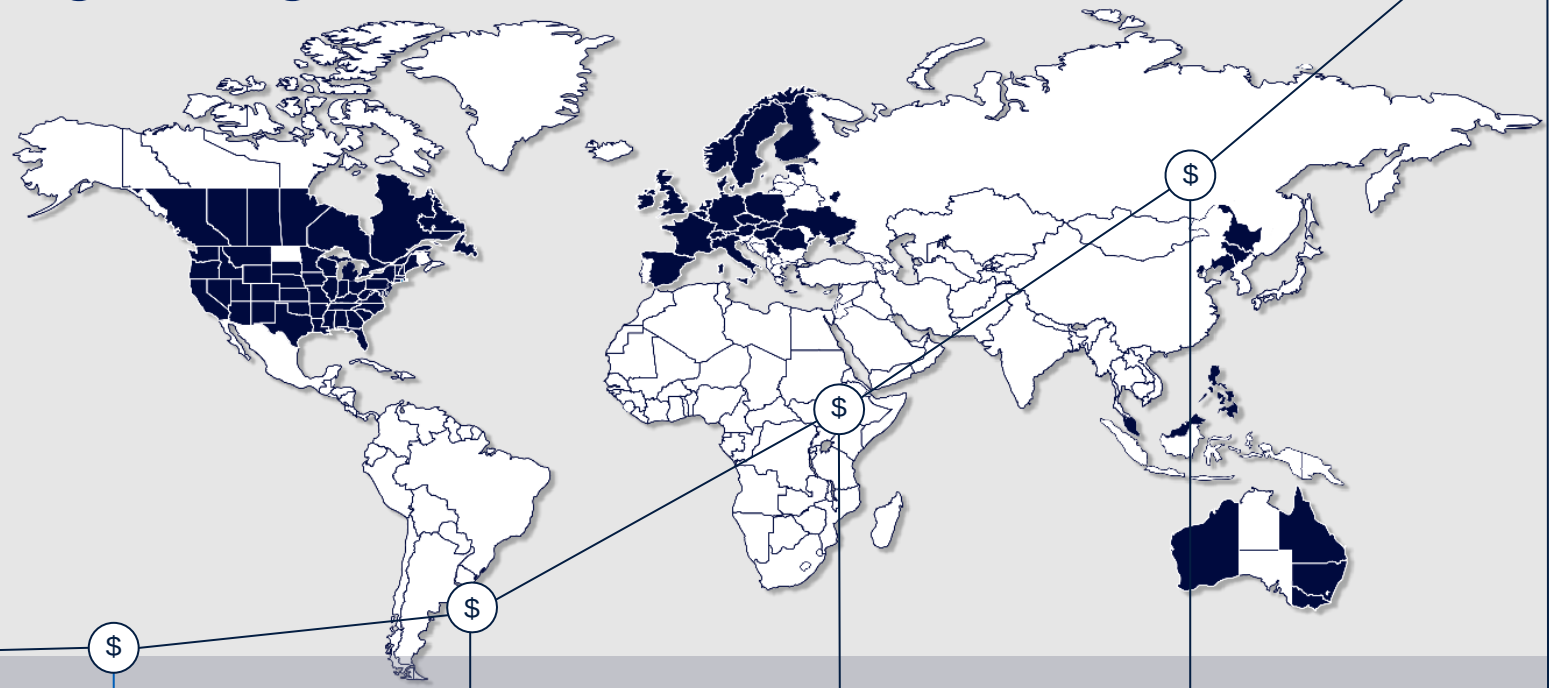
From small beginnings …

Leviat
A CRH COMPANY

95%
Ireland

$51m
Sales

5,350
People



1970	1980	1990	2000	2010	2022
Foundation of **CRH**	Sales: $0.8bn	Sales: $2.8bn	Sales: $9.6bn	Sales: $22.8bn	Sales: $30.0bn
Entry into the Netherlands	Entry into the Americas	Entry into Eastern Europe	Entry into China		US Cement Expansion

CRH at a glance

Leviat
A CRH COMPANY

Materials

- Aggregates
- Cement
- Lime
- Asphalt
- Readymixed Concrete
- Infrastructural Concrete

Products

- Construction Accessories — Leviat A CRH COMPANY
- Architectural Products
- Building Envelope
- Building Solutions
- Infrastructure Products

Leviat Product Overview

Leviat
A CRH COMPANY

Reinforcement systems & mechanical splicing

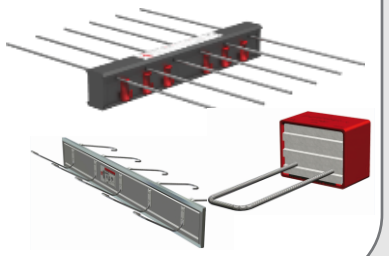
Concrete anchoring & fixing systems

Lifting, hoisting & lashing

Precast connection systems

Façade support

Structural thermal breaks & acoustics



Tension & Compression rod systems

Industrial technology

Floor joint solutions

Other products

Leviat
A CRH COMPANY

Lesson 1

General Volumetric Construction

Volumetric Construction (MiC)

Leviat
A CRH COMPANY

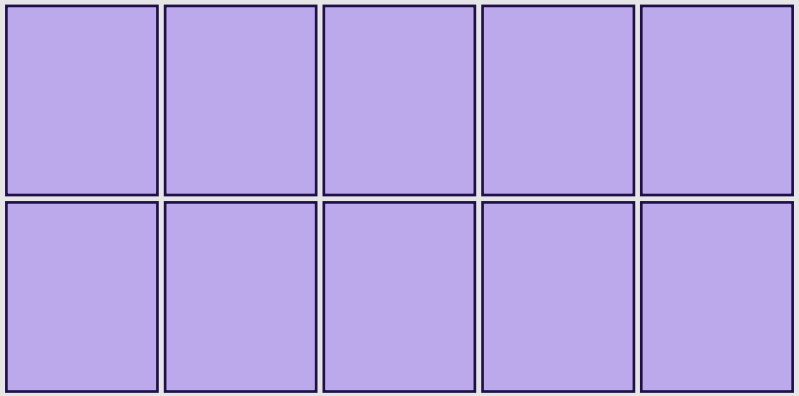
Improved Productivity
MiC can potentially achieve a productivity improvement of up to 40% in terms of manpower and time savings, depending on the complexity of the projects.

Better Construction Environment
As the bulk of the installation activities and manpower are moved off-site to a factory-controlled environment, it can minimise dust and noise pollution and improve site safety.

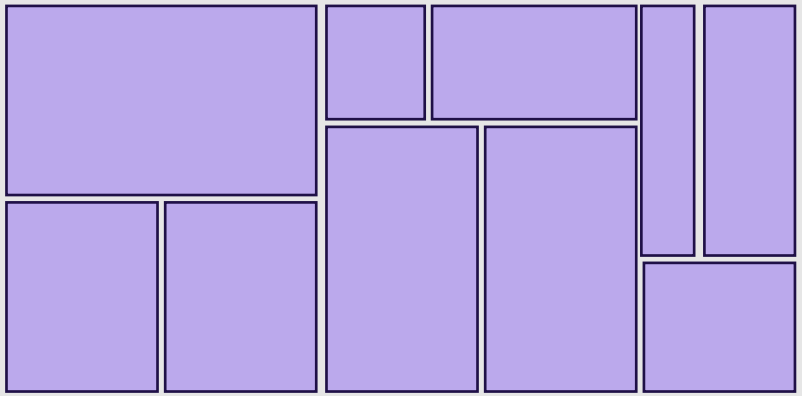
Improved Quality Control
Off-site fabrication can result in higher-quality end products through quality control in a factory-like environment.

Challenges of Volumetric Construction

IDEAL



REALITY

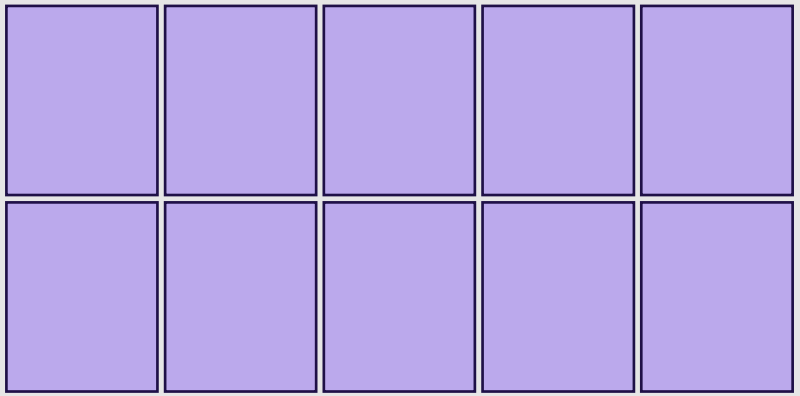


Standardisation of moulds

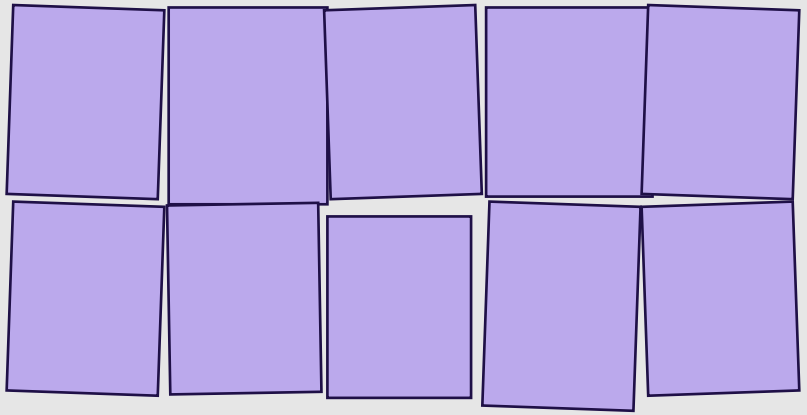
The overall economic viability of volumetric construction relies on repetition and standardisation. But most occupants will not want to live in such apartments where all the rooms are the same size.

Challenges of Volumetric Construction

IDEAL



REALITY



Construction Tolerances

Although tolerances are inevitable and necessary to use volumetric construction, larger tolerances mean that loads at the joints increase, and the connectors need to work harder. This increases the overall size of the connectors and makes congestion worse.

PRECAST vs OFF-SITE CAST

- If the precast industry rises to the challenge, then **TOLERANCES** and **FINISHES** can both be improved
- This will reduce **LABOUR** and significantly improve **CONSTRUCTION SPEED**
- Tolerances of ± 5mm are achievable, but there would need to be increased **QUALITY CONTROLS** at the precast factories
- **MAIN CONTRACTORS** also have to play a part with more attention paid to the interface between **INSITU** and **PRECAST** elements

Leviat
A CRH COMPANY

Lesson 2

Fit for purpose connections

What is a Product Conformity Certificate (PCC)?

- **Type Testing** - Establish acceptable performance criteria that a product can achieve by conducting a rigorous testing regime. Same testing for all to show a like for like comparison

- **Factory Production Control Testing** – Verify production quality so that the performance of the product is repeatable and consistent

- **Management System Audit** - Ensure high quality in production management so that the specification and tolerances are accurately followed

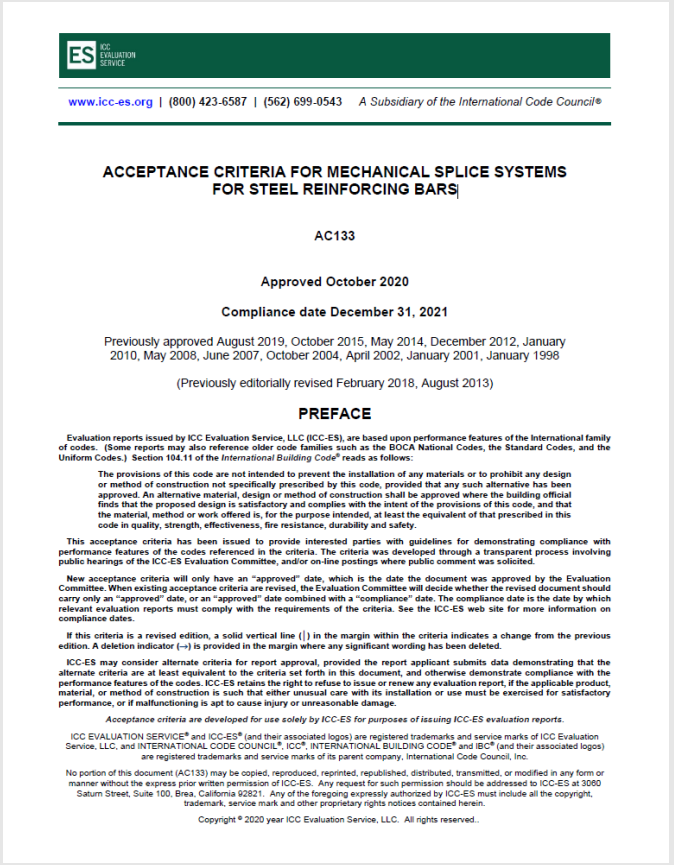
What type of PCC should you accept? ISO?

- ISO 9001
  - Quality Management Certification
- ISO 14001
  - Environmental Management Certification
- ISO 22301
  - Business Continuity Management System Certification
- ISO 45001
  - Occupational Health and Safety Certification
- ISO 15835
  - Couplers for Reinforcing Bars Certification

PCC to fully comply with ISO 15835 is now possible via CARES

USA

- **ACI Standards - Design**
  - ACI 318 - Building Code Requirements for Structural Concrete
  - ACI 349 - Code Requirements for Nuclear Safety Related Concrete Structures
- **ASTM Standards - Materials**
  - ASTM a615 - Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement
  - ASTM a370 - Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- **AC Assessment Criteria - Products**
  - AC 232 - Anchor Channels in Concrete Elements
  - AC 133 - Mechanical Splice Systems for Steel Reinforcing Bars



ES ICC EVALUATION SERVICE

www.icc-es.org | (800) 423-6587 | (562) 699-0543 *A Subsidiary of the International Code Council®*

ACCEPTANCE CRITERIA FOR MECHANICAL SPLICE SYSTEMS FOR STEEL REINFORCING BARS

AC133

Approved October 2020

Compliance date December 31, 2021

Previously approved August 2019, October 2015, May 2014, December 2012, January 2010, May 2008, June 2007, October 2004, April 2002, January 2001, January 1998

(Previously editorially revised February 2018, August 2013)

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes. (Some reports may also reference older code families such as the BOCA National Codes, the Standard Codes, and the Uniform Codes.) Section 104.11 of the *International Building Code*® reads as follows:

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.

New acceptance criteria will only have an "approved" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approved" date, or an "approved" date combined with a "compliance" date. The compliance date is the date by which relevant evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.

If this criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a change from the previous edition. A deletion indicator (↔) is provided in the margin where any significant wording has been deleted.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.

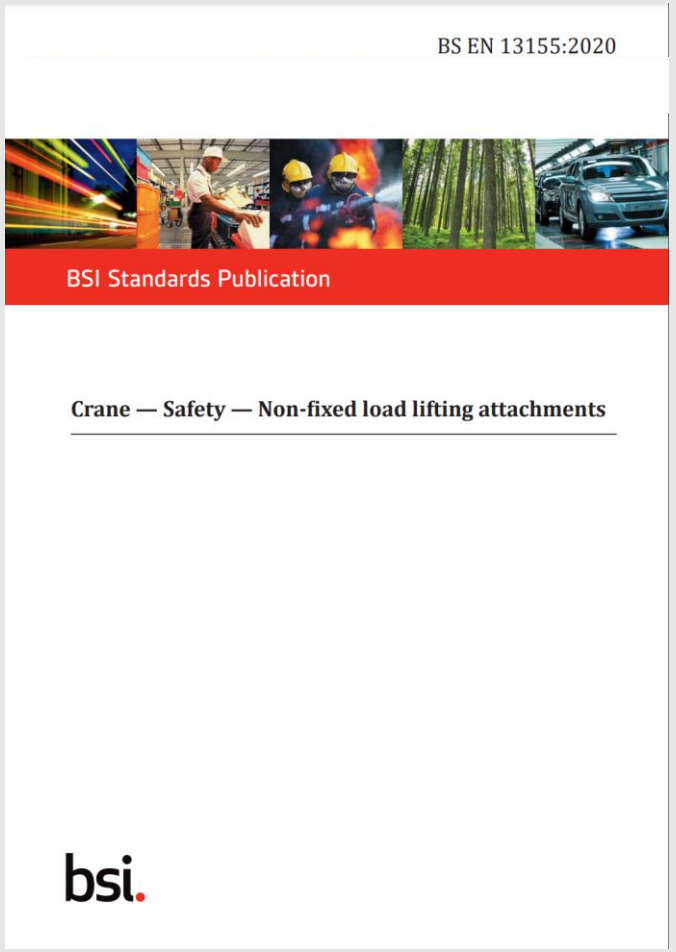
IAPMO or ICC Certifications are possible, if US materials are used

EN

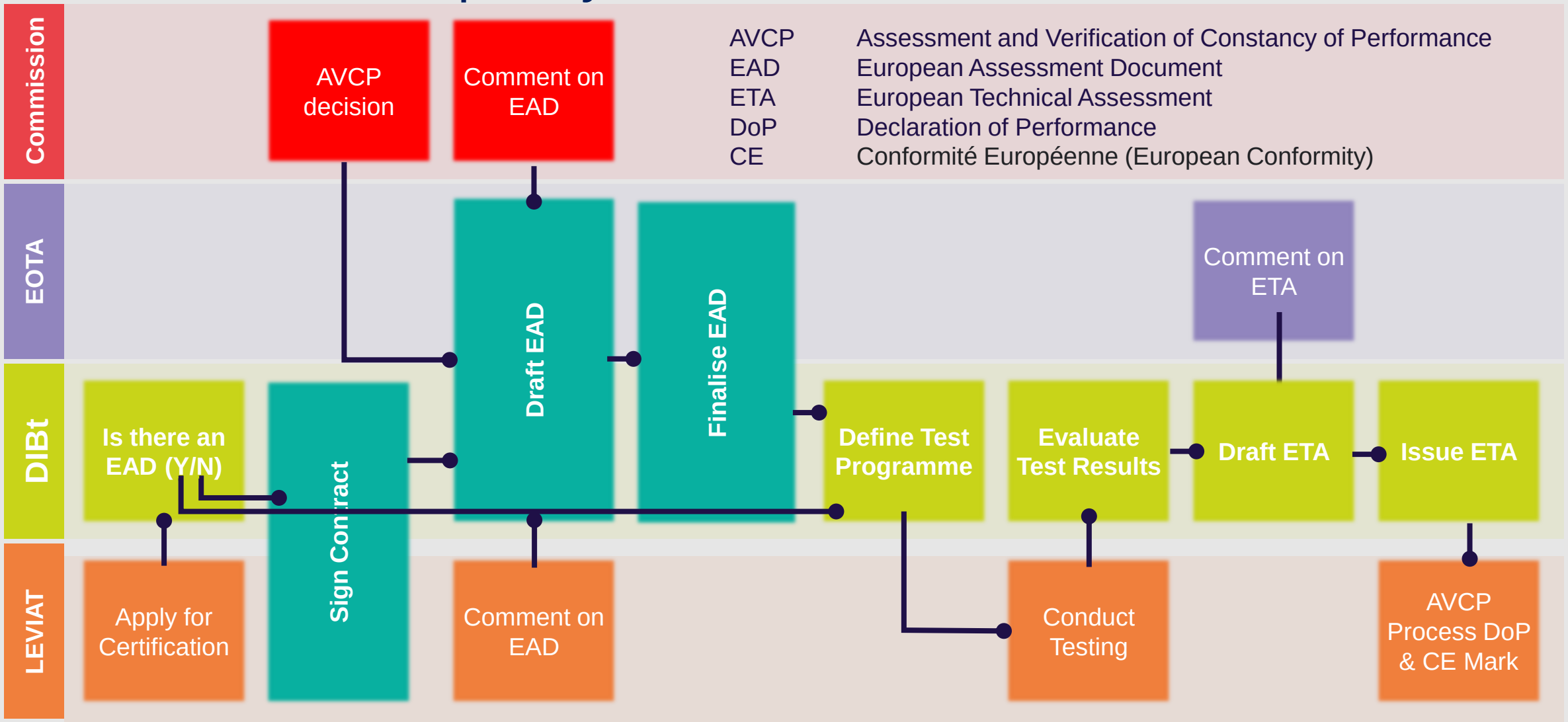
- **EN Standards**
  - SS EN 1992-1
  - SS EN 1992-4
  - SS EN 1998
  - EN 13155

- Compliance with a Harmonised standard can allow CE marking to happen
- CE marking for products without an ETA is a self-certification process
- ETA has a conformity assessment (audit) component
- CE marking alone does not require and audit and is not a PCC

You need to have an ETA for CE marking to be a PCC



ETA Process Complexity



AVCP	Assessment and Verification of Constancy of Performance
EAD	European Assessment Document
ETA	European Technical Assessment
DoP	Declaration of Performance
CE	Conformité Européenne (European Conformity)

Leviat
A CRH COMPANY

Lesson 3

Grouted vs Bolted connections

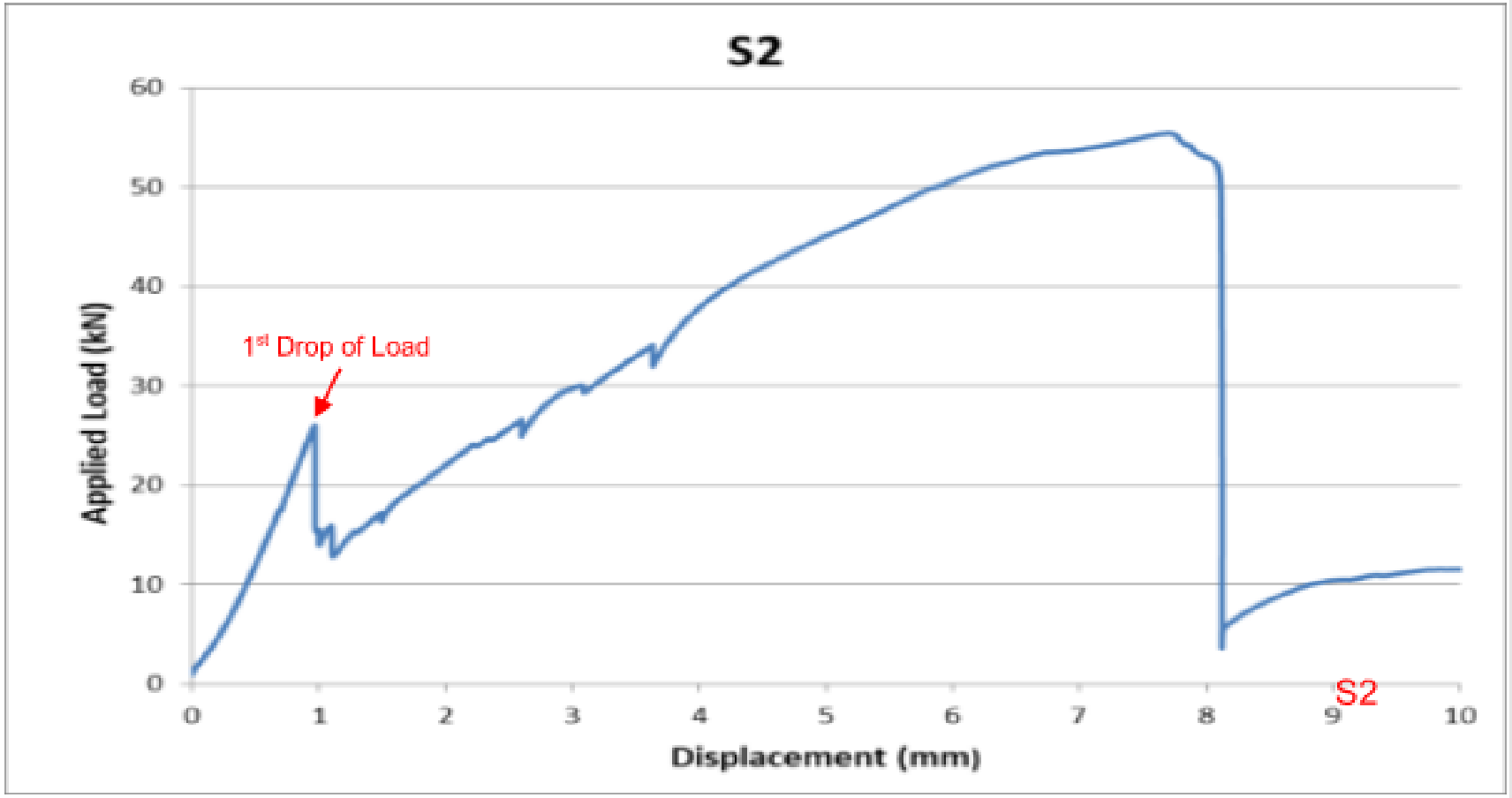
TYPES OF CONNECTIONS

Leviat
A CRH COMPANY

- **GROUTED**
  - **SLOW -** the grout needs to cure before construction can continue
  - **PROPPED -** external props or braces will be required to resist the construction loads until the grout has cured
  - **PASSIVE -** often there will be visible hairline cracks as there is no prestress across the joint

- **BOLTED**
  - **FAST -** the tightening of a bolt is all that is required to make the connection load bearing
  - **UN-PROPPED -** the bolted connection eliminates the need for props or braces
  - **ACTIVE -** the bolt provides additional compressive force across the joint to mitigate the risk of cracking

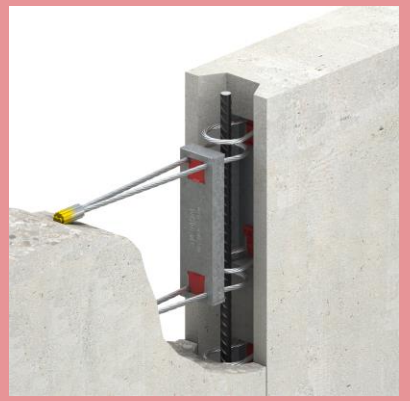
Passive Grouted Connections



APPLICATIONS

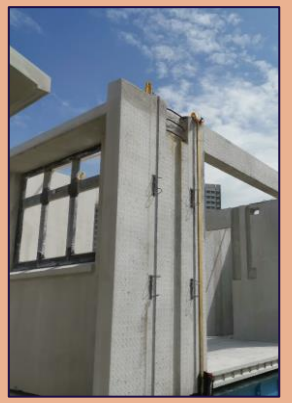
Leviat
A CRH COMPANY

WALL to WALL



COLUMN to COLUMN

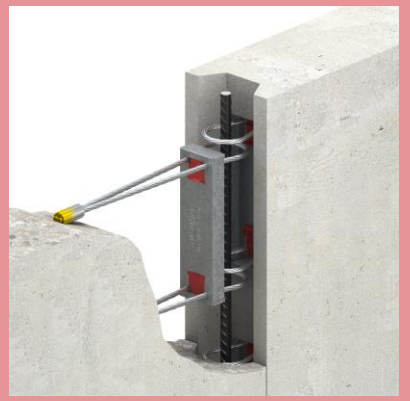
VOLUMETRIC to VOLUMETRIC



WALL to WALL

Leviat
A CRH COMPANY

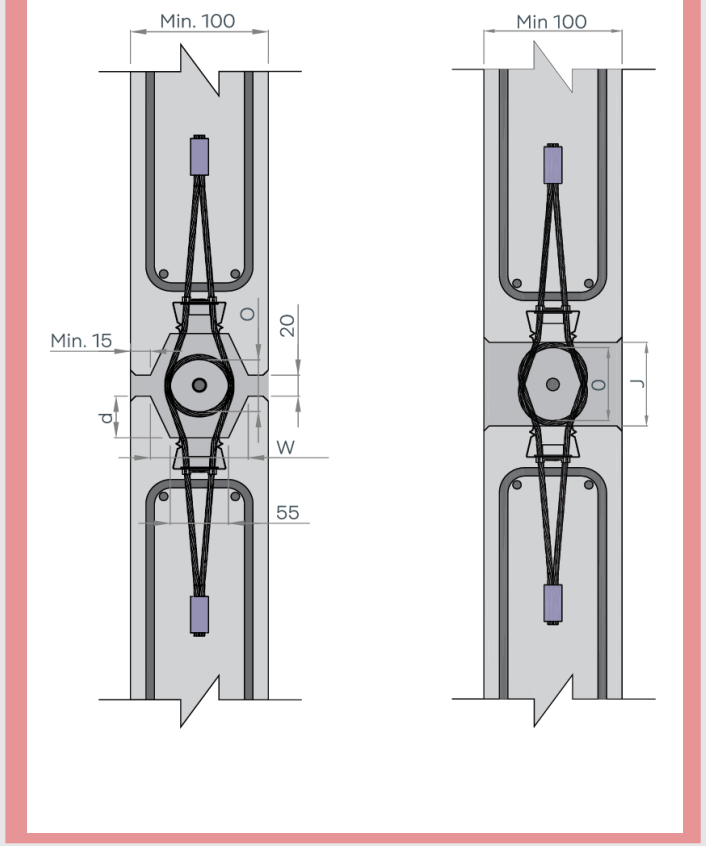
WALL to WALL



- **Loopbox Lessons**

WALL to WALL

WALL to WALL



- **Loopbox Lessons**
  - Specified wire length needs to be sufficient

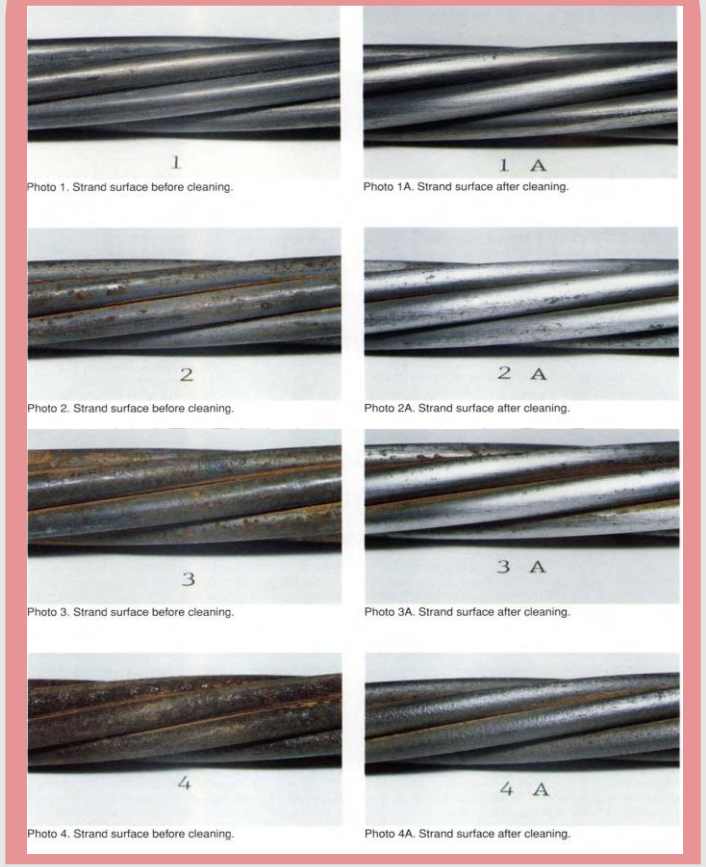
WALL to WALL

WALL to WALL

- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained

WALL to WALL

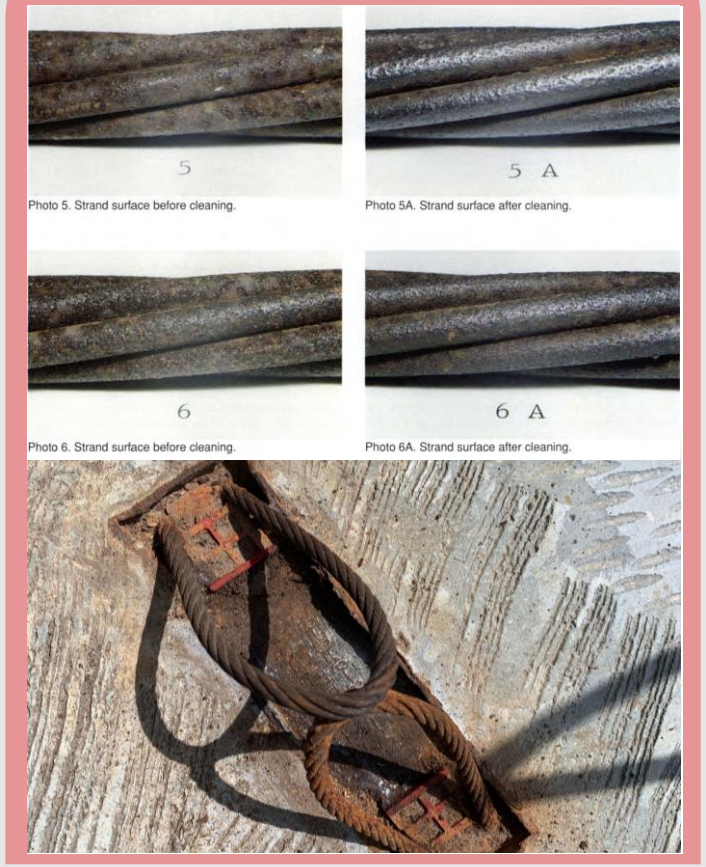
WALL to WALL



- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained
  - Awareness of corrosion conditions needs to be understood

WALL to WALL

WALL to WALL

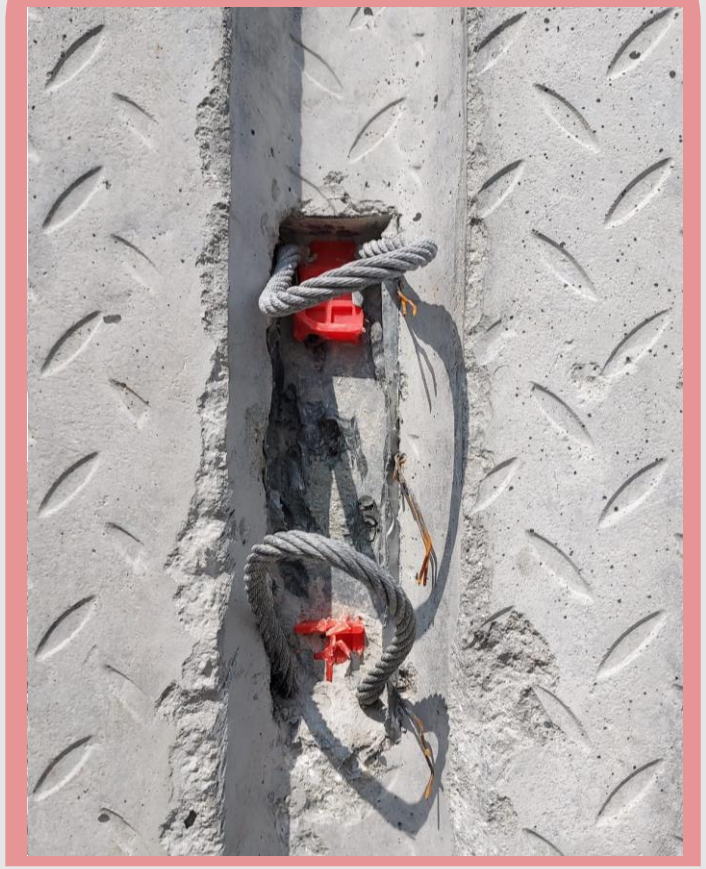


- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained
  - Awareness of corrosion conditions needs to be understood

WALL to WALL

Leviat
A CRH COMPANY

WALL to WALL



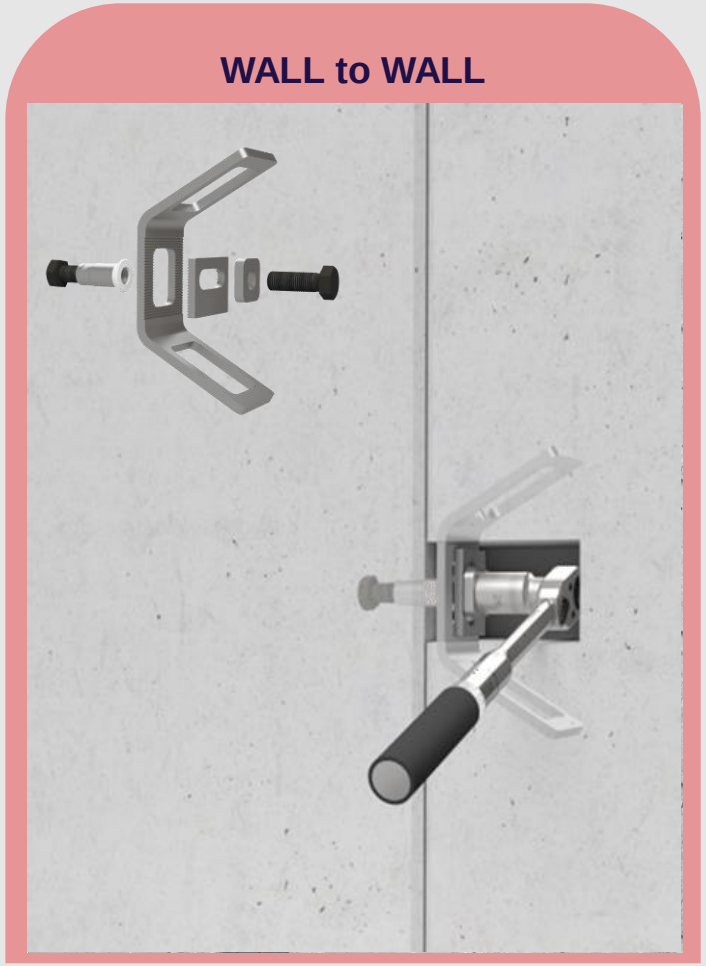
- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained
  - Awareness of corrosion conditions needs to be understood
  - No EAD currently exists for loopboxes
  - Poor lid connection can result in concrete ingress

WALL to WALL

Leviat
A CRH COMPANY

- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained
  - Awareness of corrosion conditions needs to be understood
  - No EAD currently exists for loopboxes
  - Poor lid connection can result in concrete ingress
  - Alignment of loop needs to be maintained

WALL to WALL

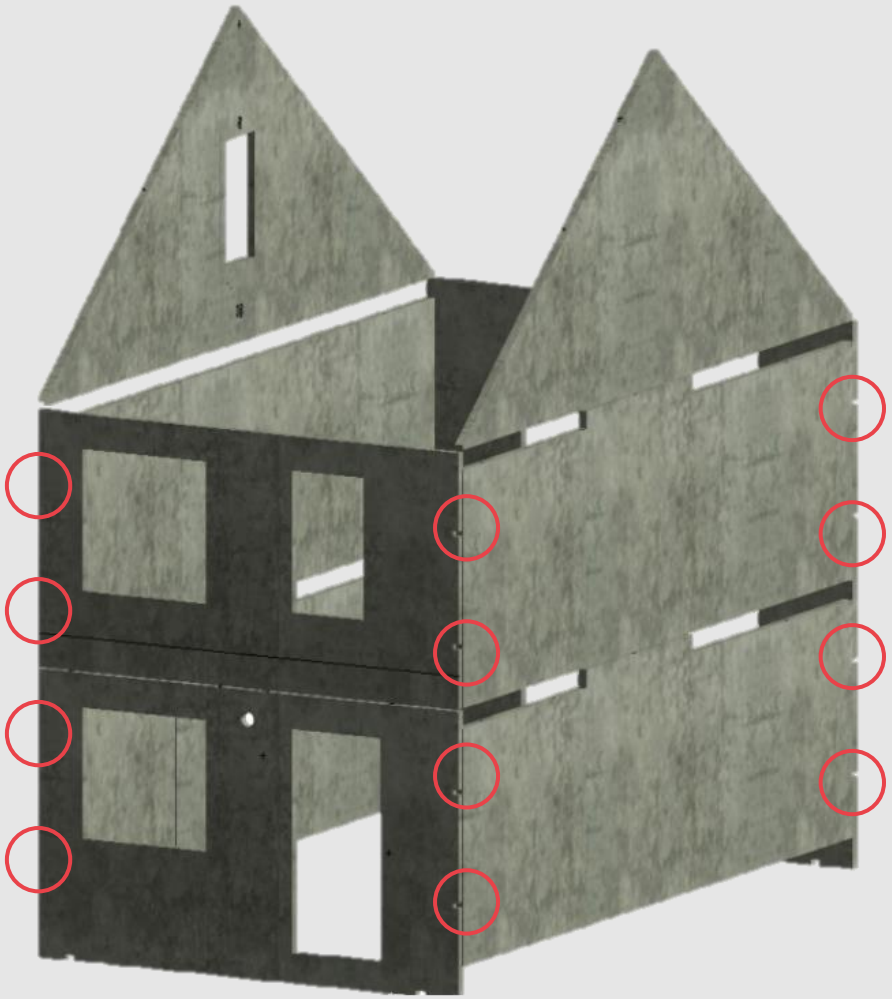


- **Loopbox Lessons**
  - Specified wire length needs to be sufficient
  - Loop length inside box needs to be maintained
  - Awareness of corrosion conditions needs to be understood
  - No EAD currently exists for loopboxes
  - Poor lid connection can result in concrete ingress
  - Alignment of loop needs to be maintained
  - Bolted solutions do exist that solve all these issues

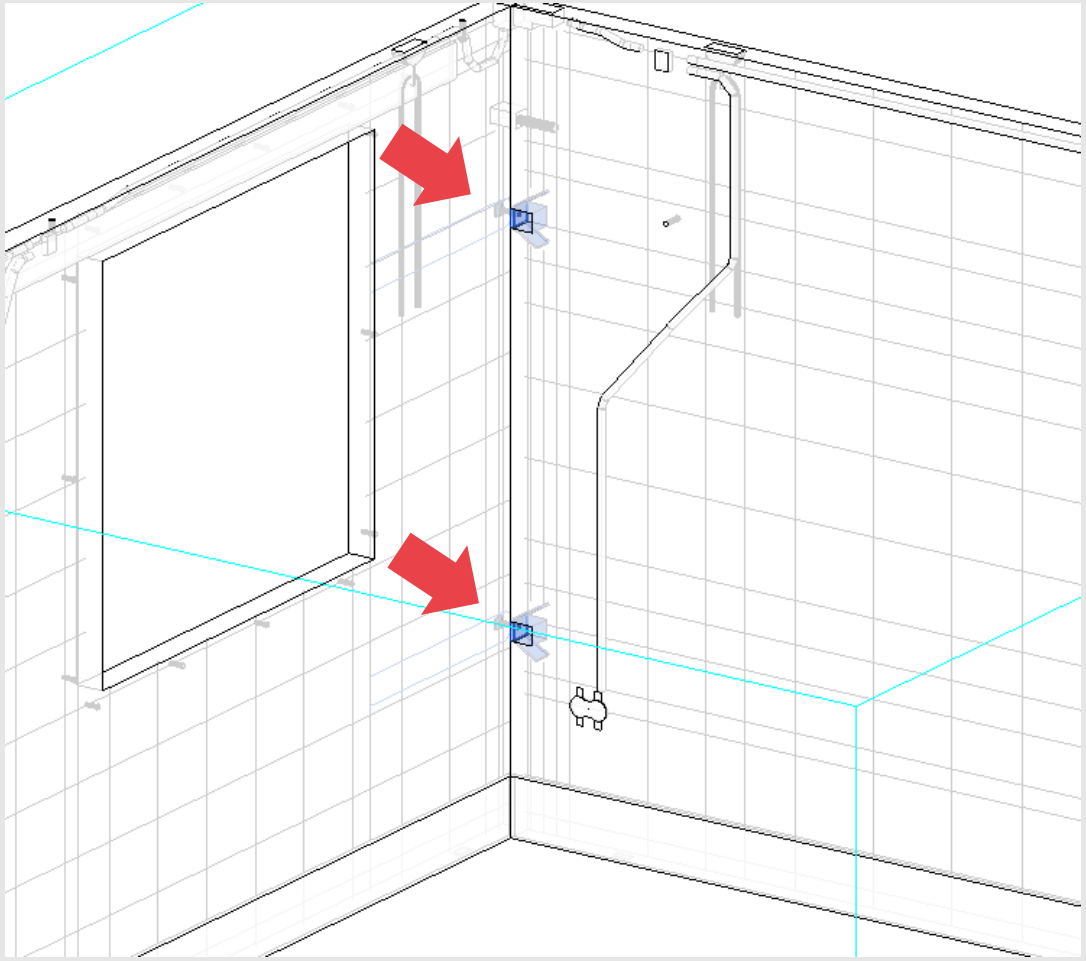
Reference project NL

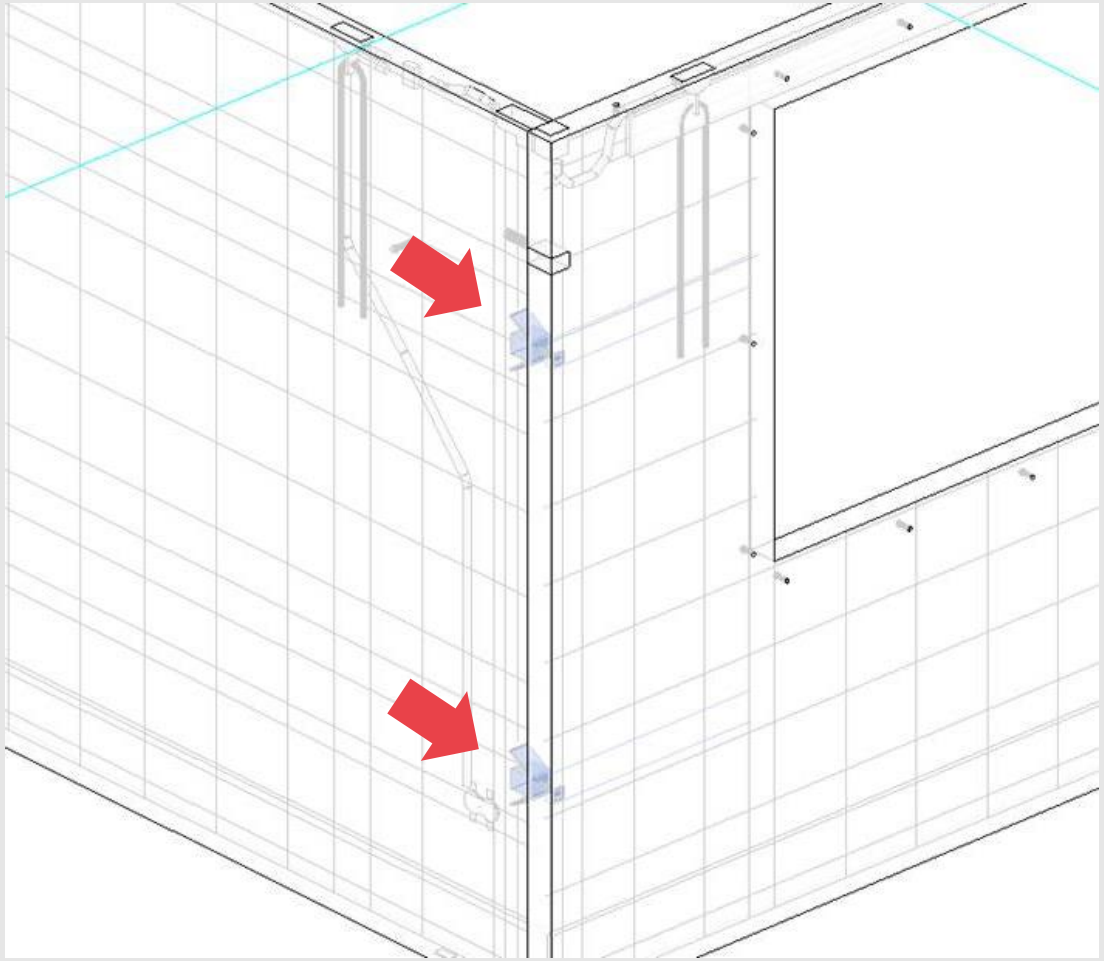
Facts of process and production:

- Full BIM 3D process from design until production in factory
- Custom made structural design, for different contractors
- Automatic carousel production with time cycle of 8 working hours
- Capacity with 80 mould tables for maximum 1.500 house per year (1 shift)
- In 9 years >60% of all houses are designed and installed with HEK dry connection



Reference project NL





Reference project NL

Reference project NL

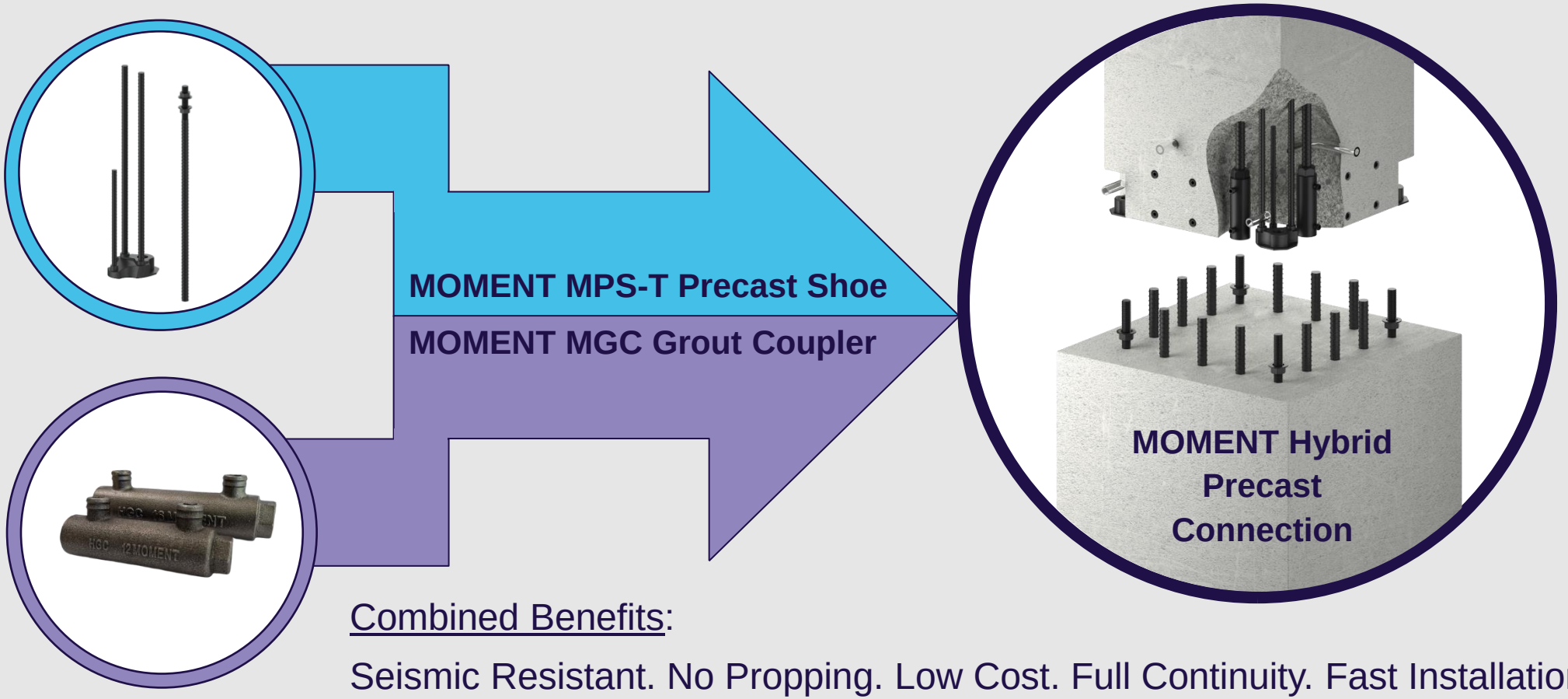
COLUMN to COLUMN

COLUMN to COLUMN

- **Grout Coupler Lessons**
  - Can the coupler resist seismic loads?
  - Is the tolerance big enough?
  - Are there any air pockets in the grout?
  - There is also a bolted solution that solves most of these issues, but the price point is higher

Technical Information

- **Hybrid Connection**



Combined Benefits:

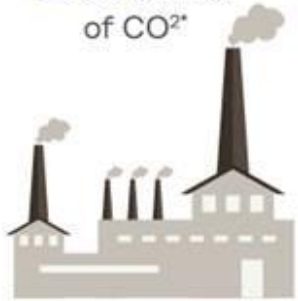
Seismic Resistant. No Propping. Low Cost. Full Continuity. Fast Installation.

Sustainability

Environmental Benefits of Rebar Couplers

With 1,000 pieces of 40mm Moment JoinTec Coupler we are able to save

35 tonnes of CO^{2*}



*approximately 18 tonnes of steel saved

=

212,100 km by car (Citroen Picasso type)

Source: Worldsteel.org 2020

Leviat.com

VOLUMETRIC to VOLUMETRIC

VOLUMETRIC to VOLUMETRIC

- **GROUTED - MLB**
  - Same issues as Wall to Wall

VOLUMETRIC to VOLUMETRIC

VOLUMETRIC to VOLUMETRIC

- **GROUTED - MLB**
  - Same issues as Wall to Wall
  - Careful installation is required to ensure correct loop lengths

VOLUMETRIC to VOLUMETRIC

VOLUMETRIC to VOLUMETRIC

- **GROUTED - MLB**
  - Same issues as Wall to Wall
  - Careful installation is required to ensure correct loop lengths

- **GROUTED - CORRUGATED DUCT**
  - Lots of wasted grout
  - Limited space inside wall elements leads to congestion
  - Hybrid system is better, providing there are no internal finishes

Reference project KSA

Leviat
A CRH COMPANY

The customer

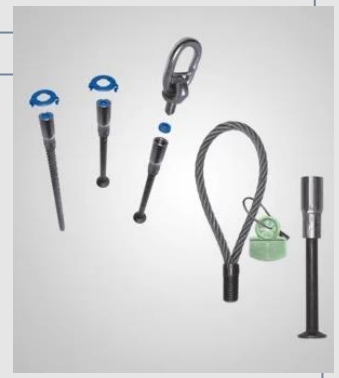
AYAN precast – Jeddah (KSA):

- Production plant in Jeddah, part of a wider group (megastores)
- Plant Manager is an Italian who had experience with Leviat from Italy
- Started operations 2 years ago

The Project

Bathroom units for pilgrims in Mecca (KSA):

- 110 buildings, 3D precast units to be assembled on side: first 3D elements produced
- Two level high precast buildings – 3.500 precast elements



Leviat Team

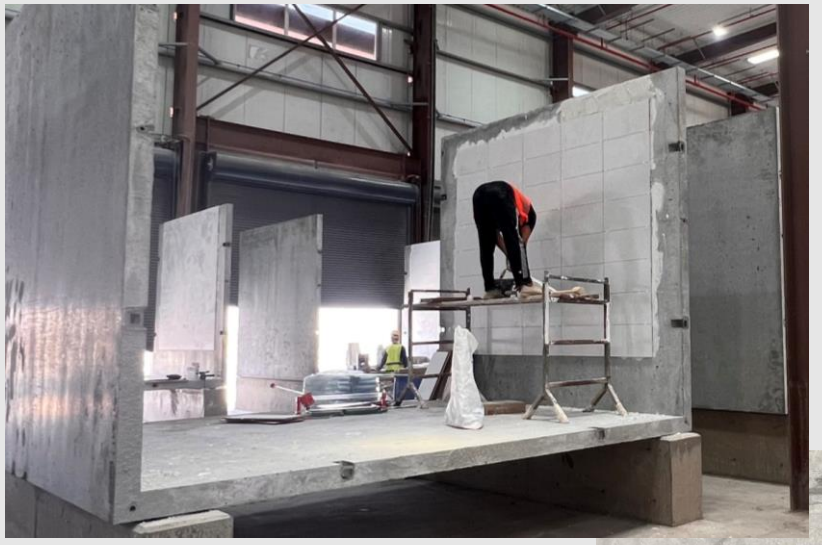
Actions:

- Design of setup model anchoring, fixing and lifting
- Support on model of FEM calculation to extract to loads in the joint for connecting
- Detailing of all connections
- Calculation of all connections
- Define and calculate total lifting model of all elements
- Overview of all additional stirrups for HEK3 connections, DEMU bolt anchors and HD transport anchors
- Support and training in the factory during installation on the mould

Reference project KSA

The moulds with hydraulic set-up

HEK3 recess in wall after de-moulding, ready to install



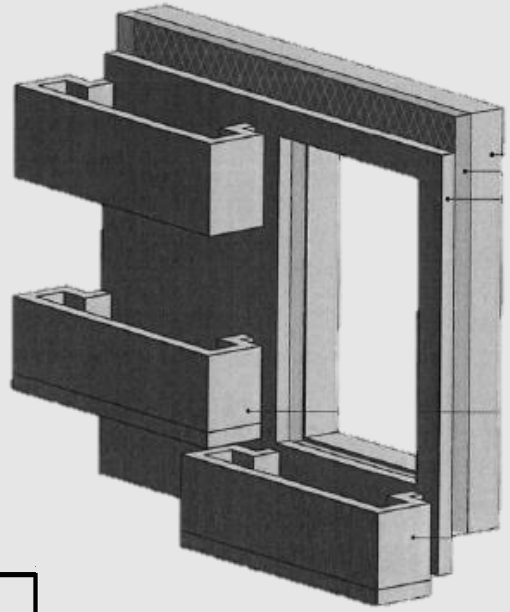
Reference project KSA

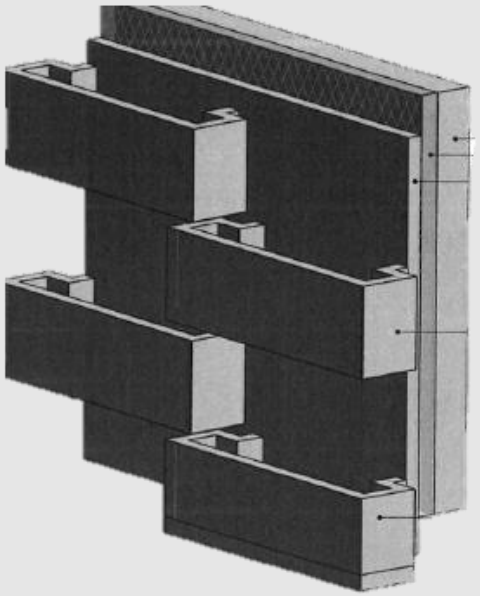
Installation on site (in situ foundations)

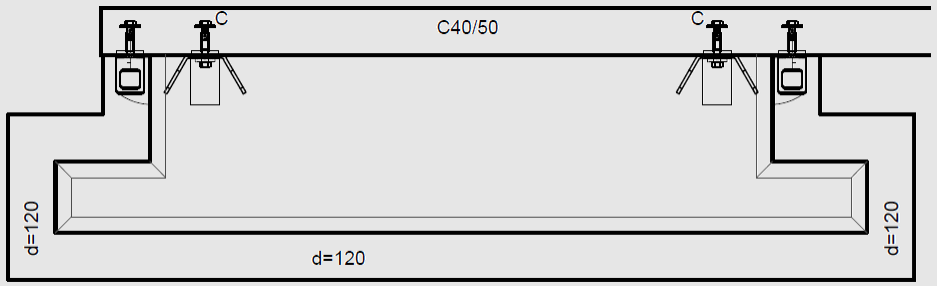
Other volumetric applications

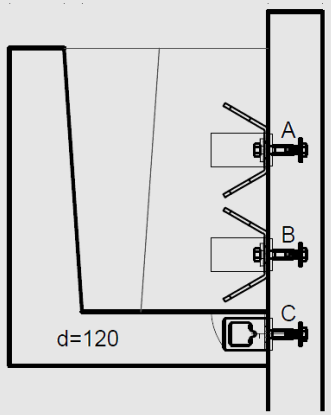
Complicated sandwich precast:

- Sandwich element with integrated flower box on facing layer
- Simple production by HEK2 precast coupler, install precast box after finishing both parts









Leviat
A CRH COMPANY

Lesson 4

More research is required to optimize the designs

Intellectual Property (IP)

- Protection of foreground IP can limit the speed of adoption of background IP, that would otherwise be ideal for such applications

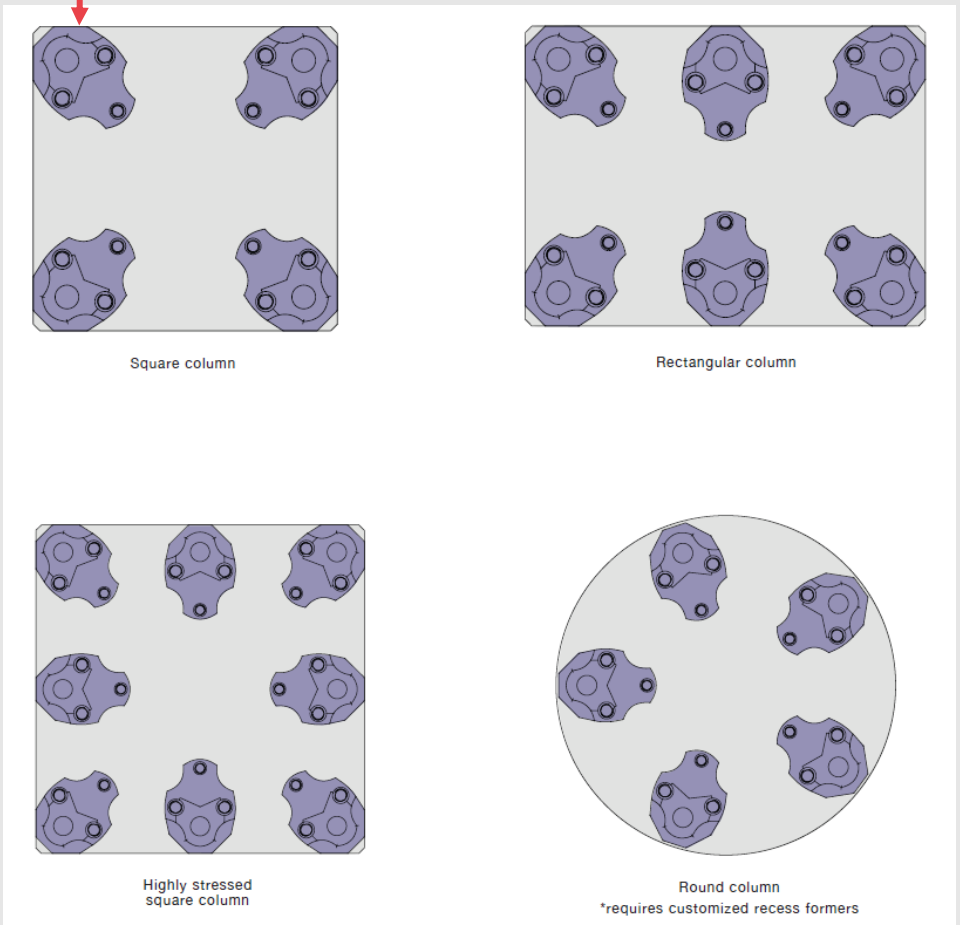



Product Application

- **Column Connections**

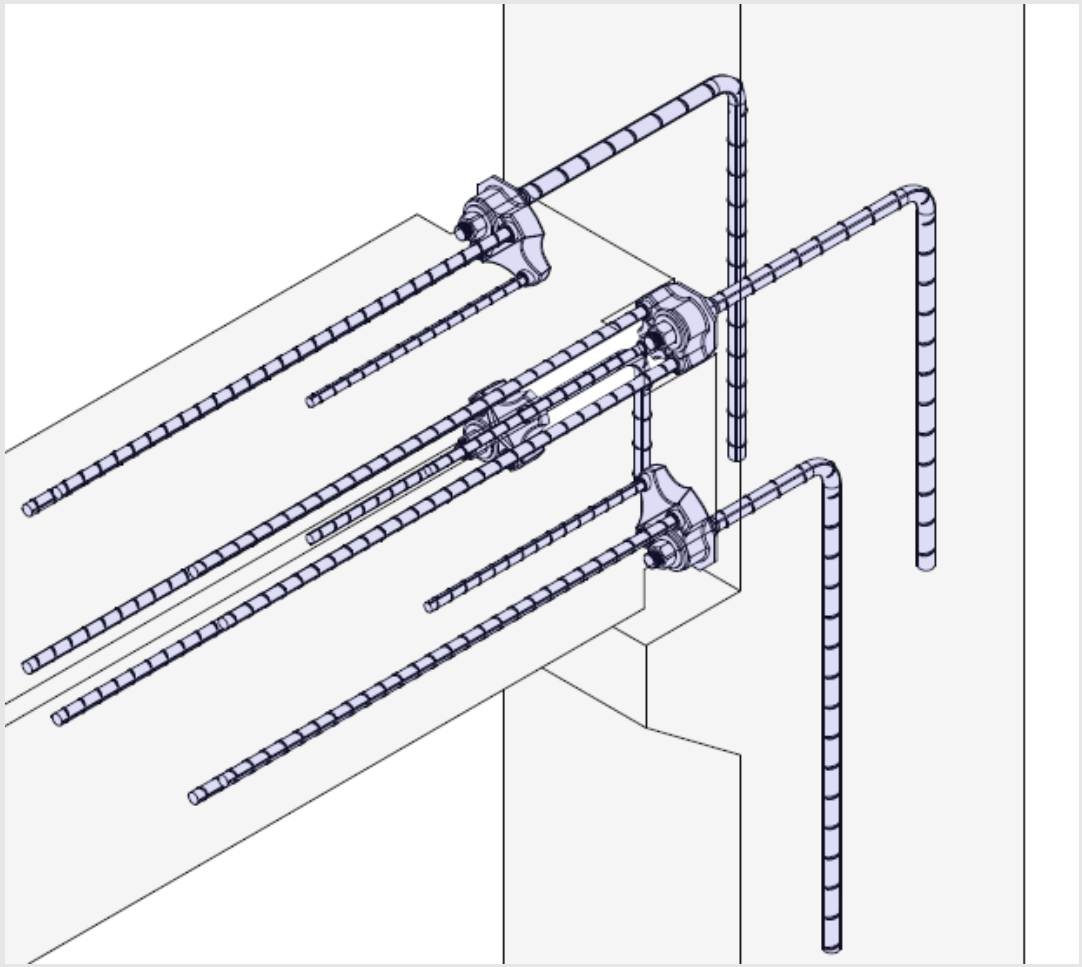
Column – Foundation

Column – Column



Product Application

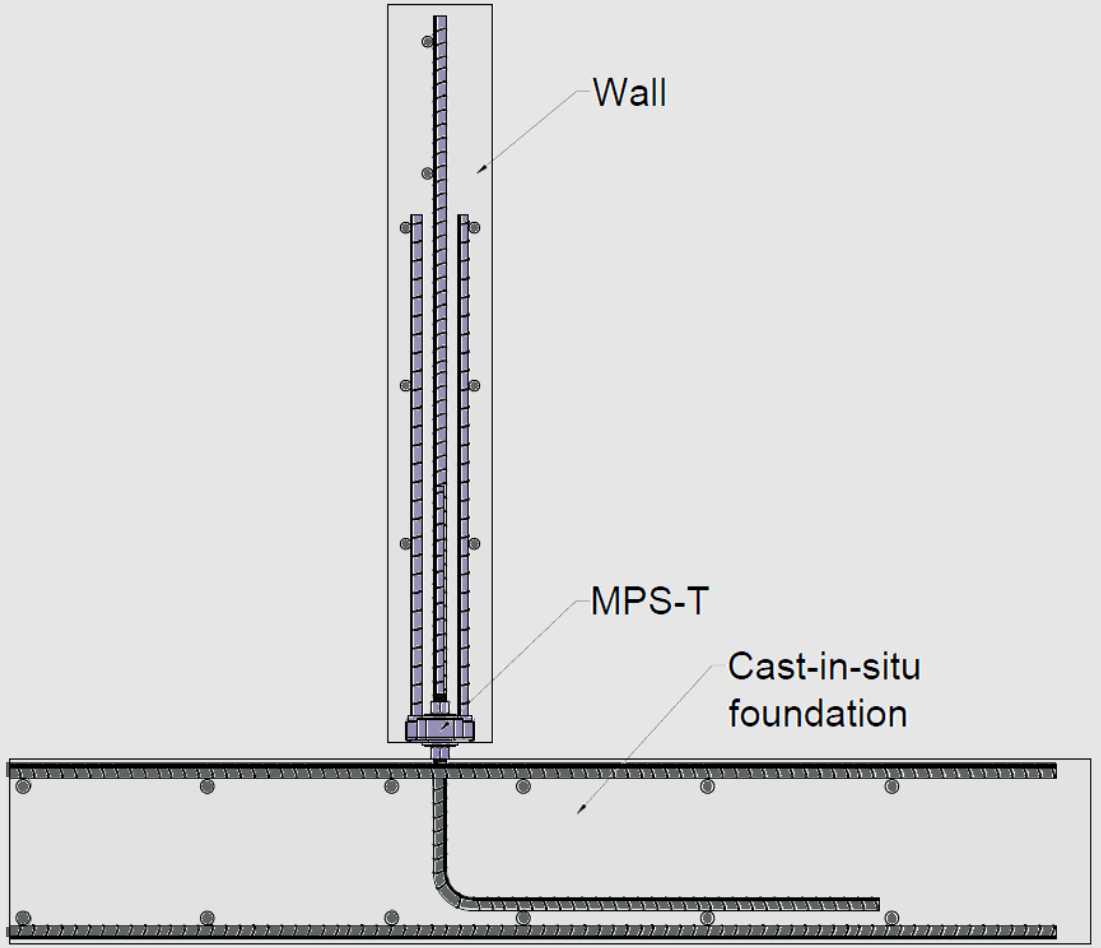
- **Beam Connections**



Beam – Column Connection

Product Applications

- **Wall Connections**



Wall – Foundation Connection

SAFECAST: Column to foundation connections

- **Leviat** Column to foundation - Standard Shoe

The hysteretic cycles are shown in fig. 61 in terms of force-displacement and in fig. 62 in terms of moment-drift. The cyclic behaviour is stable and ductile until failure, since the yielding phase is clear and well developed. The shear force is decreasing at large drifts, but this is due to the second order effect, since the bending moment at the bottom section is increasing until failure. The failure corresponds to the progressive rupture of the threaded bars that make the connection between shoes and foundation (see fig. 67), started at 4.5 % of drift.

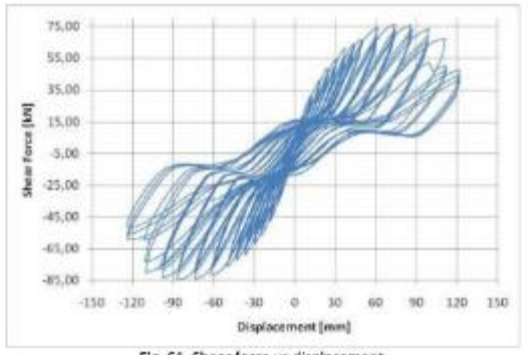


Fig. 61. Shear force vs displacement

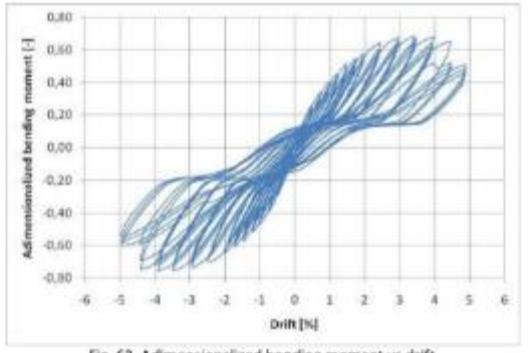


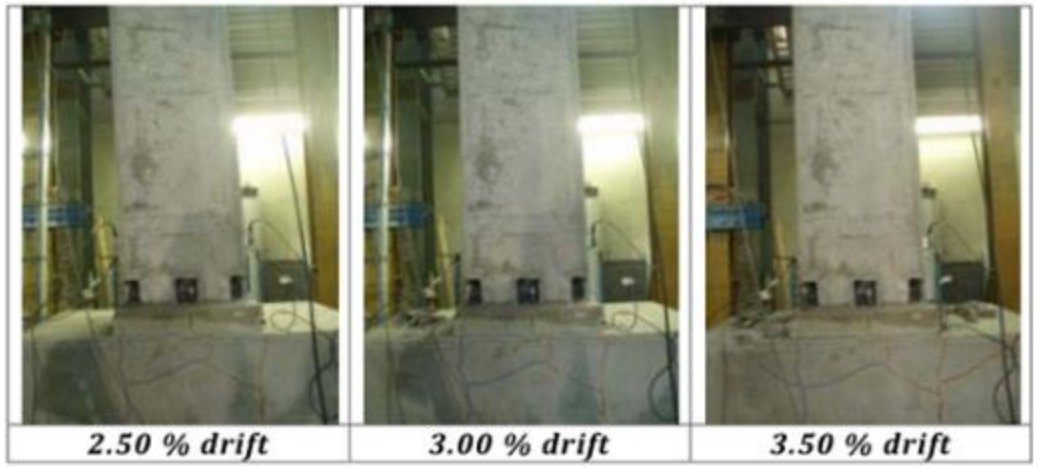
Fig. 62. Adimensionalized bending moment vs drift

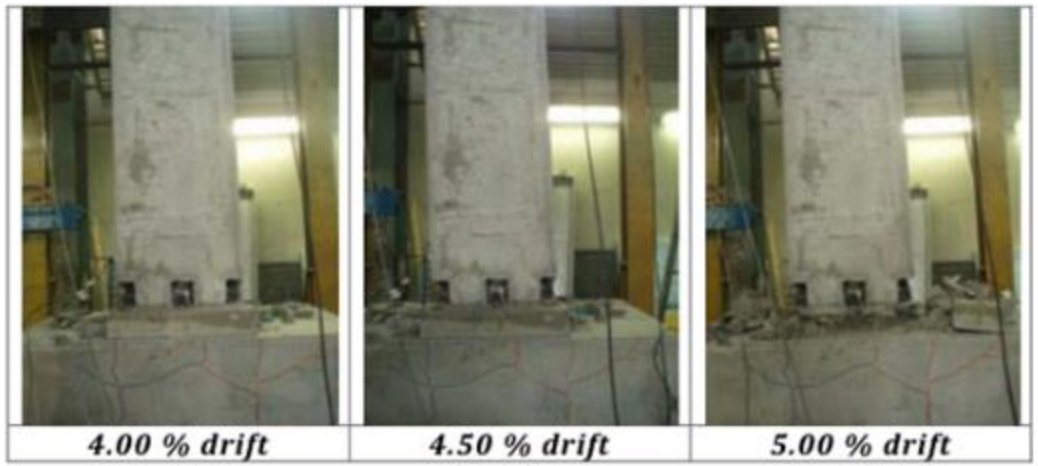
The behaviour of the connection appears to be ductile and stable until failure, the yielding is clear and well developed.

SAFECAST: Column to foundation connections

3.1.3 Results

Cyclic loading	
"Yield" strength*	≈ 210 kNm*
Maximum strength	+222 kNm; -245 kNm
"Yield" displacement* (d_y)	≈ 37,5 mm (1,5 % of drift)*
Ultimate displacement (d_{max}; breaking of one baranchor)	112,5 mm (4,5 % of drift)
Ultimate displacement ($d_{u,tot}$; maximum displacement attained)	125 mm (5% of drift, reached after some ruptures but not with total failure)
Ductility	≈ 3 (calculated as d_{max}/d_y)*
Total dissipated energy	85,8 kNm
Specific energy	0.10-0.23[1]
Initial stiffness	≈ 3,00 kN/mm[1]





NTC 2018 7.4.5.2.1 - Design Rules

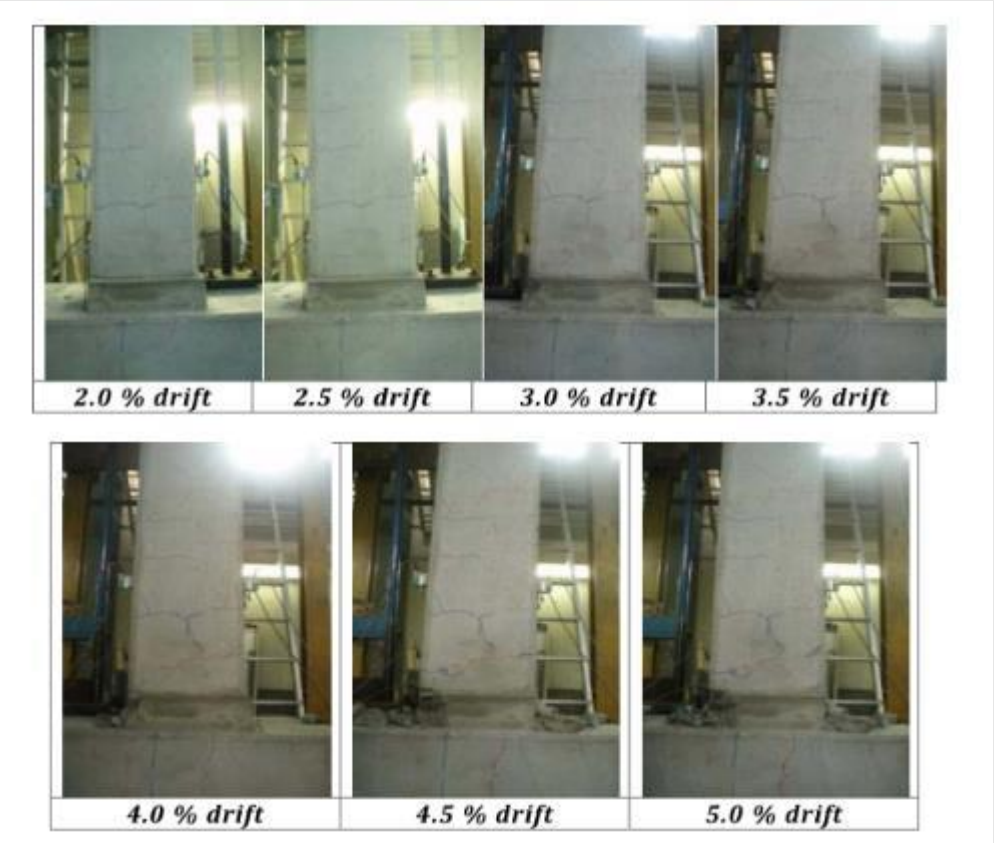
Connections that dissipate energy or of type c)
Subject to analytical demonstration that the operation of the connection is equivalent to that of one entirely built on site and which satisfies the requirements set out in § 7.4.4, the structure can be assimilated to a monolithic type.
The suitability of joints designed to create the plastic mechanism required for frame structures and to satisfy the global local demands of cyclic ductility to the extent corresponding to CD"A" and "B" can be deduced from standards of proven validity or from full-scale experimental tests that include at least three complete cycles of deformation of amplitude at the behavior factor q performed on significant structural sub-assemblies.

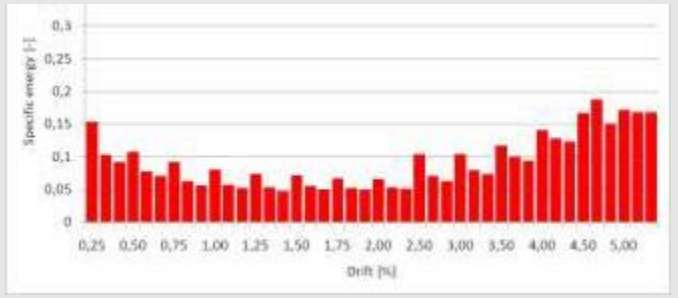
NTC 2018 7.4.1.2 - Ductility checks

$$\mu_\phi = \begin{cases} 1{,}2 \cdot (2q_0 - 1) & \text{per } T_1 \geq T_C \\ 1{,}2 \cdot \left(1 + 2(q_0 - 1)\frac{T_C}{T_1}\right) & \text{per } T_1 < T_C \end{cases} \qquad [7.4.3]$$

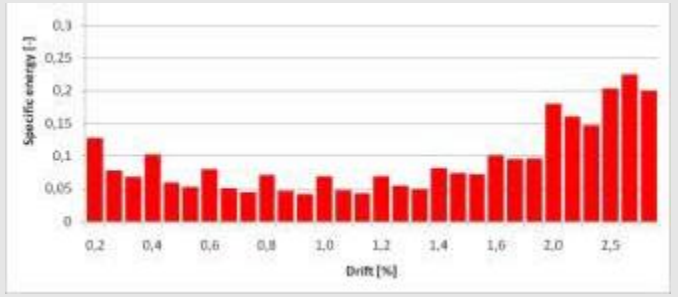
SAFECAST: Column to foundation connections

- **Column to foundation – Show improvements**

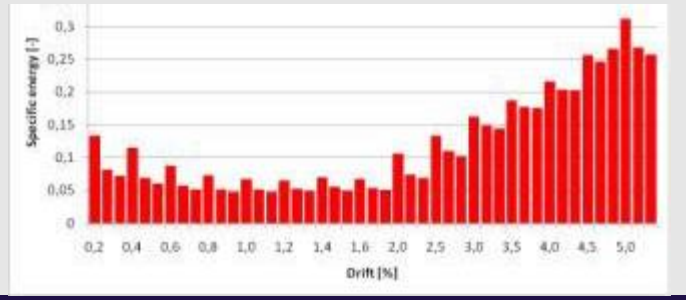




STANDARD SHOE



IMPROVED SHOE 1
With alternative arrangement



IMPROVED SHOE 2
With alternative detailing

Leviat
A CRH COMPANY

SAFECAST: Design Guidelines

ISO 20987:2019
Simplified design for mechanical connections between precast concrete structural elements in buildings

SAFECAST: Design Guidelines

Leviat
A CRH COMPANY

List of content

4.3.2.3 Calculation formulae

For fasteners well spaced among them and from the foundation edges, with reference to the symbols described in Figure 4.3.2 and with γ_R overstrength factor *, the following verifications shall be performed.

a – fastener failure (for non ductile fasteners)
(F_{Rmin} minimum steel ultimate capacity of the fastener declared by the producer)

$F_{Rmin} \geq \gamma_R A_s f_{ym}$ A_s sectional area of the corresponding upper reinforcement

where

$f_{ym} = 1{,}08\, f_{yk}$ mean yielding stress of the steel bars (f_{yk} their characteristic yielding stress)

b – pull-out
($f_{ck,cube}$ characteristic compressive cubic strength of concrete, h effective length of the fastener, F_{Rmin} , A_s and f_{ym} defined before)

$R_d \geq \gamma_R F_u$ $F_u = \min\{ A_s f_{ym} , F_{Rmax} \}$

where

$F_{Rmax} = 1{,}2\, F_{Rmin}$ except differently declared by the producer

$R_k = k \sqrt{(f_{ck,cube}\, h^3)}$ ($R_d = R_k / \gamma_C$)*

and k may be taken from the relevant *ETS* (for current products the safe side value k=7,0 may be assumed).

b – sliding shear
(b width of the section, x depth of its compressed part, f_{cd} design compressive strength of the mortar or of the column concrete if lower, A_d area of the fasteners not yielded by the contemporary flexure and f_{yd} their steel design yielding stress)

$V_{Rd} \geq V$ with $V_{Rd} = V_{cd} + V_{fd}$

($V = V(\gamma_R M_{Rd})$ is the shear corresponding to $\gamma_R M_{Rd}$)

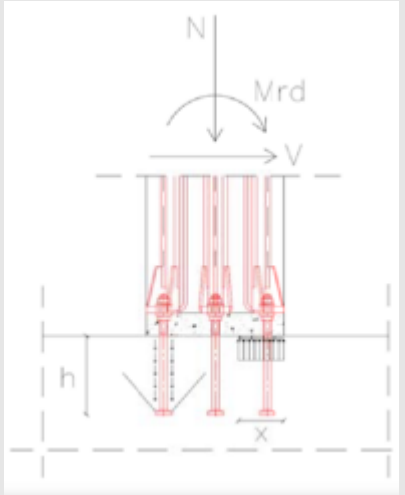
where

$V_{dd} = 1{,}3\, A_d \sqrt{(f_{cd}\, f_{yd})}$ dowel resistance of the resisting fasteners

$V_{fd} = 0{,}5\, b\, x\, f'_{cd}$ sliding resistance of the compressed mortar or concrete

$f'_{cd} = 0{,}5\, f_{cd}$

* The values γ_R=1,2 for DCM and γ_R=1,35 for DCH are recommended by *EC8*.



ISO 20987:2019

Thank you!
Any questions?

Leviat
A CRH COMPANY

For further questions, please send an email to:

gary.connah@leviat.com

Visit our website and follow us on LinkedIn:

Leviat.com

Linkedin.com/company/leviat-in-asia/

We are **One Team**

We are **Leviat**