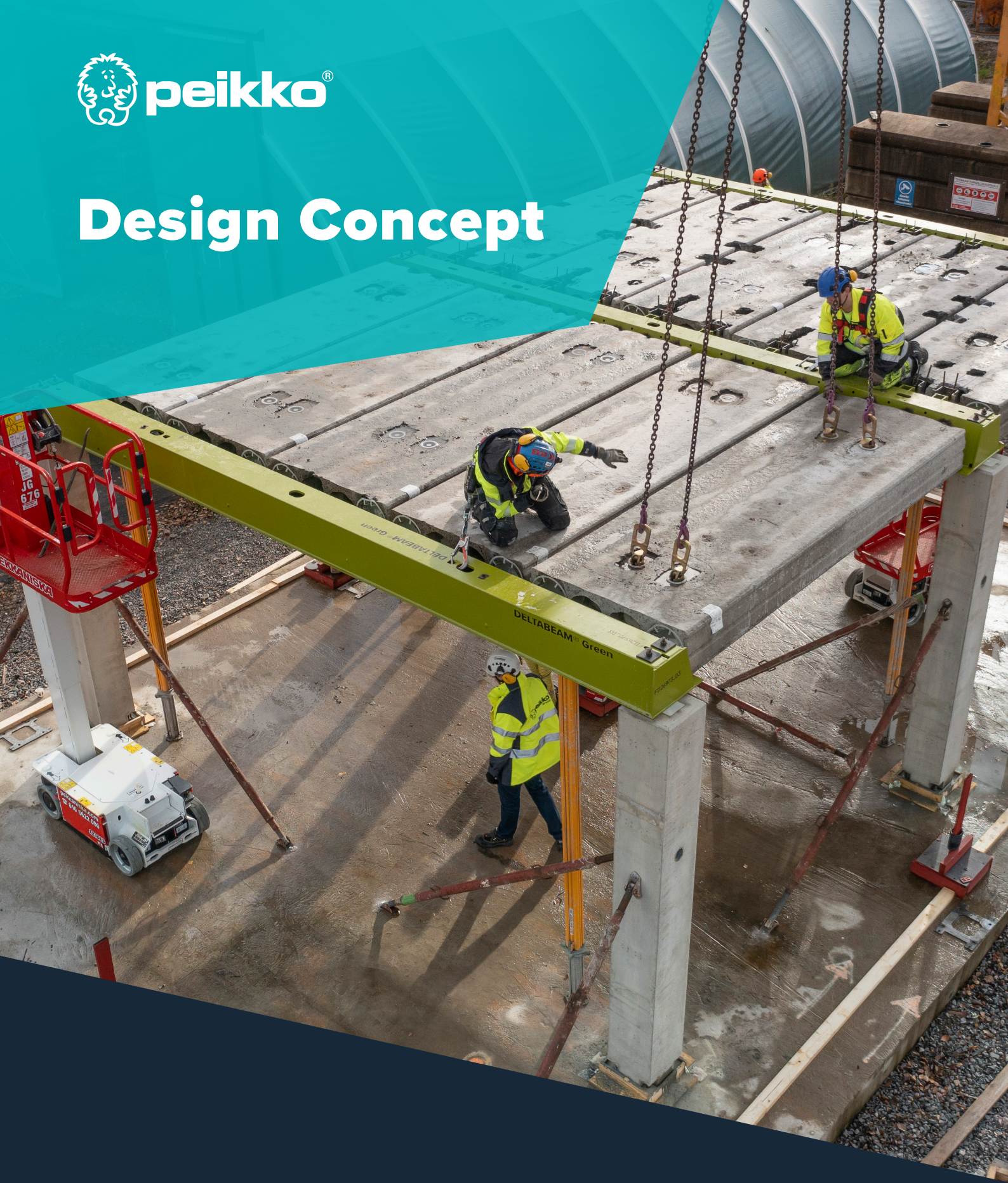
peikko®

Design Concept



An Account of Peikko's Demountable Connections

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Markus Junes
M.Sc. Civ. Eng.
R&D Manager
Peikko Group Corporation

Introduction

The green building industry is continuously evolving in the wake of steady increase in constructions. Presently, more efforts are directed to resource efficiency, with realization that everything is a resource for something else. Resource efficiency goes beyond reliance on seeking products with recycled content to leaning towards designing buildings and products with the intention of material recovery, value retention and meaningful next use. One of the key objectives of EU and national construction guidance in promoting circular economy is the utilisation of demolition materials of buildings and promotion of reusing building components, (Zhu, 2022). Achieving this means designing in a way that the building and its parts or pieces are reused at the end of its first useful life, and thereby intentionally eliminating waste, referred to as circular design.

Peikko is continuously researching and developing circular solutions through its bolted connections. Bolted connections promote the Design for Disassembly (DfD) concept. The fundamental principle of DfD is creating buildings that can easily be deconstructed so that materials, products, and components can easily be recovered, and their value retained so that they can be reused. Peikko achieves this by designing accessible connections and choosing the appropriate joinery that will ease dismantlement and avoid use of heavy equipment or too many tools. Bolted connections have been proved to be reversible and even recommended, (ISO 20887:2020(E), 2020). They are advantageous in that not only can the material be reused but the connectors (such as screws, bolts etc), can also be reused.

In a recent pilot study on dismount and reuse of precast concrete frame, (Yrjölä & Wanjala, 2022), it was established that Peikko's designs allow for ease of accessibility of the joints, making dismount of connections easier, faster and with little to no damage of the structural members. Findings also proved that reusing structural members is not only possible but also cuts on overall costs and CO_2e emissions as compared to traditional construction. It is with this conviction that this guide is written. This write-up gives a brief and clear guide on using Peikko's bolted connections in a way that permits disassembly, recovery, and reuse of structures. The joints illustrated are column to base, column to beam, beam to slab and wall to wall joints. It also gives a summary of applicable European Regulations specifically dealing with reuse of construction products.

In Practice

Before designing any structural component, it is important to know and assess any available options for DfD connections and the impact the demountable connections will have on the structural component design. This helps avoid redesigning.

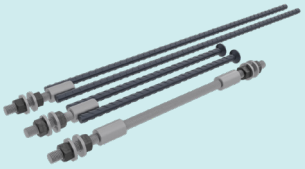
1. Column to base connections

Two set ups were done to study the possibility of dismounting columns from their bases in 2019, (https://peikko.group/demount). The successful study guided this section.

Main Requirements: Anchor bolts and Column shoes.

Table 1 illustrates the options available for the main requirements in Peikko's portfolio.

Table 1. List of anchor bolts and Column shoes options.

Options for Foundation /Concrete base support structures. These create a bolted connection of concrete base structure with precast concrete or steel structure			
HPM® Rebar Anchor Bolt	For moderate loading conditions		
COPRA® Anchoring Coupler	The easiest to connect and disconnect because of the non-protruding threaded part		
PPM® High-Strength Anchor Bolt	For stronger bases		
Options for Precast Column connections. Generally, they are casted in precast column's end. Free space inside shoe allows manipulation and tightening of anchor bolt during erection, but connection is not visible in final structure. After precast column is well positioned and bolts are tightened, surface treatment is done in the recess boxes before grouting			
HPKM® Column Shoe			
BOLDA® Column Shoe	Designed to withstand tensile and compressive forces corresponding to the design values of resistances of PPM® High-Strength Anchor Bolts and COPRA® Anchoring Couplers.		

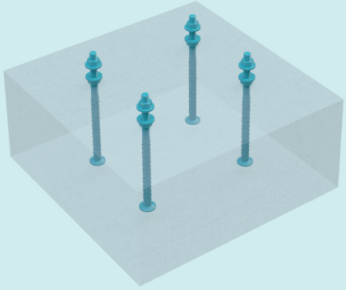
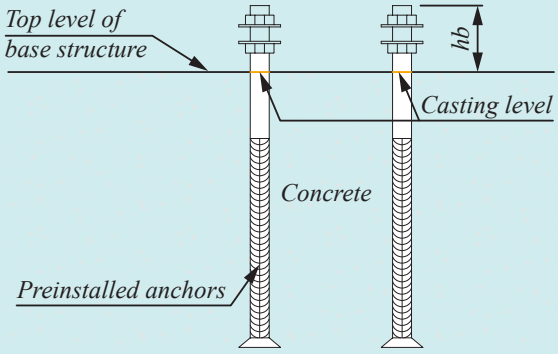
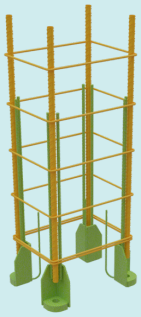
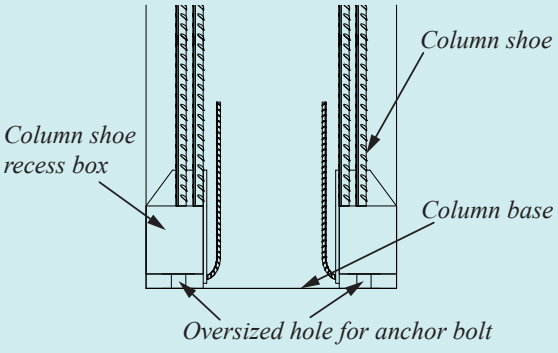
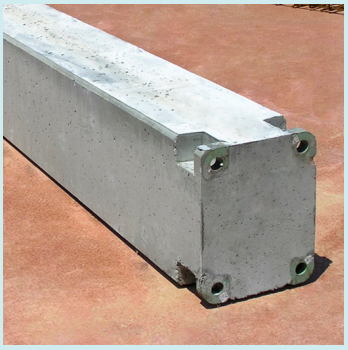
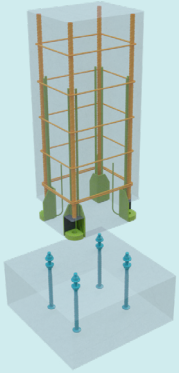
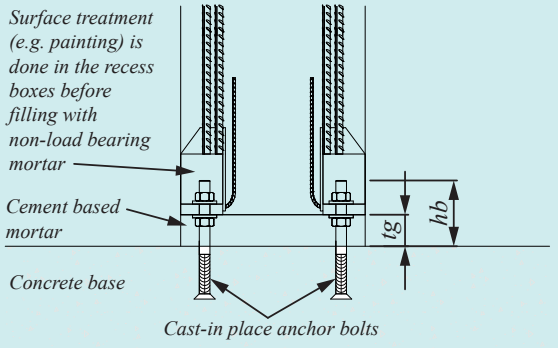
1.1. Connection Details

The foundation or column base is cast with anchor bolts preinstalled. When the base is set, cranes are used in setting up the column. The Column is installed directly on the pre-levelled washers and nuts (at the foundation base level) and checked for verticality using long builder's spirit level, optical level or two theodolites from different directions. Upper nuts and washers are screwed on the bolts and the nuts tightened using slog ring spanner or open-ended slogging spanner and sledgehammer. The surfaces of the recess boxes are treated (e.g., by painting). This is to make removal of grout from recess boxes easier during deconstruction.

Table 2 below illustrates the anchor bolts in the column or foundation base, column shoe in the column and finally the connection details between the column base and the column.

Figure 1. Slog ring spanner.

Table 2. Connection details.

Anchor bolts in column base 	 *hb* – casting depth of the anchor bolt	
Casting Column shoe in column 		
Column to base (or floor) connection 	 *tg* – thickness of grout *hb* – casting depth of anchor bolt	

When the column is firmly in position the open joint underneath the column and recesses are grouted. The grout must harden and reach its designed strength before loading the attachment with any other structures. The recess boxes are grouted with non-cement mortar that can easily be removed to readily access the bolts. *Figure 2* below illustrates the formwork setup for grouting and installed column.

Figure 2. Formwork in readiness for grouting (left), finalized connection after grouting has hardened (right).

1.2. Disassembly of column from the base

Disassembling involves removal of grout from the recesses using appropriate and applicable simple tools. Experiments proved that a simple handheld drill can be used to remove the mortar, (*Figure 3*).

Figure 3. Removing of mortar off the recess boxes.

The next step is opening and removing the nuts attached to the anchor bolts, (*Figure 4*).

Figure 4. Opening and Removing of nuts.

The column is then lifted off the grout pad using a crane. The hardened grout pad (that was between the column and the base) can be removed with ease using a demolition hammer in cases where the base is to be reused. The initially installed anchor bolts may be reused after simple cleaning of the threads to remove any residual particles. Thread cleaning can be done by wire brush.

Figure 5. Removing of hardened grout pad.

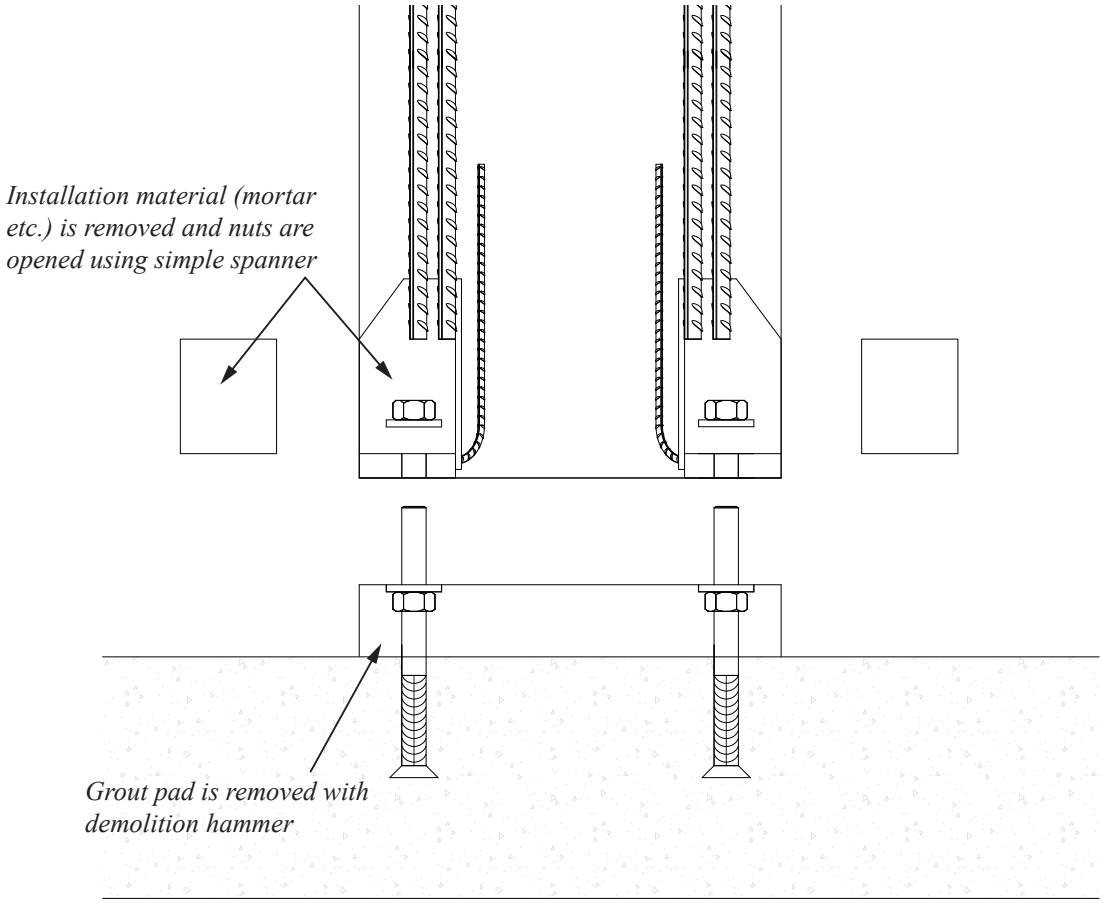


Figure 6. Deconstruction details.

1.3. Reassembly

Reuse process is similar to the initial installation process. Only minor cleaning is done to remove residual concrete or grouting from the joints. Cleaning is done with use of simple hand tools like wire brushes (*Figure 7*).

Figure 7. An example of wire brush.

2. Precast Column to beam connections

These details are based on a successful pilot study carried out to assess the dismount and reuse of precast concrete frame in November 2021 (https://peikko.group/reuse).

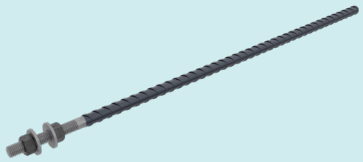
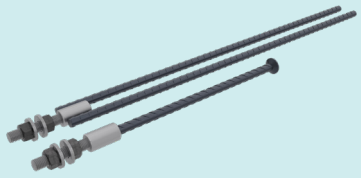
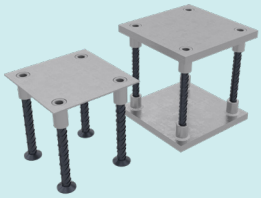
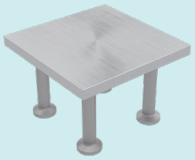
Main Requirements: DELTABEAM®, anchor bolts and anchor plate (cast in the column). Available options in Peikko's portfolio are shown in *Table 3*.

Table 3. Main Requirements (available options) in setting up beam and column connections.

DELTABEAM® Options. This is a superior composite beam enabling slim-floors for multi-story buildings of any type, whether low-rise or high-rise			
DELTABEAM® Composite Beams			
DELTABEAM® Green	Has 50% lower CO_2 emissions as compared to DELTABEAM® Composite Beams because of the higher recycled content of steel		

Continued on next page...

Table 3. Continued. Main Requirements (available options) in setting up beam and column connections.

Options for connecting column to beam. *a) Anchor Bolts* These are preinstalled during column casting to create bolted connection with DELTABEAM®			
HPM® Rebar Anchor Bolt	HPM® P is recommended in structures with sufficient depth		
Anchoring Coupler	COPRA® P and COPRA® L are recommended		
b) Anchor plates Are also cast in place during casting of column. Are used to transfer horizontal loads into column. THRELDA® Anchor Plates is a bolted connection hence connected with the beam through bolts. WELDA® Anchor Plate is connected by welding the beam onto them.			
THRELDA® Anchor Plates	The bolted connection transfers axial and shear forces from connected steel member and anchors them into concrete		
WELDA® Anchor Plate	Used in shallow structures to transfer standard loads		
WELDA® Strong Anchor Plate	Used in deeper structures to transfer heavier loads		
KL Anchor Plates	Transfer loads to concrete through rebar anchors		

2.1. Connection Details

Anchor bolts and anchor plate are preinstalled in column during pre-casting. Details and picture shown on *Figure 8*.

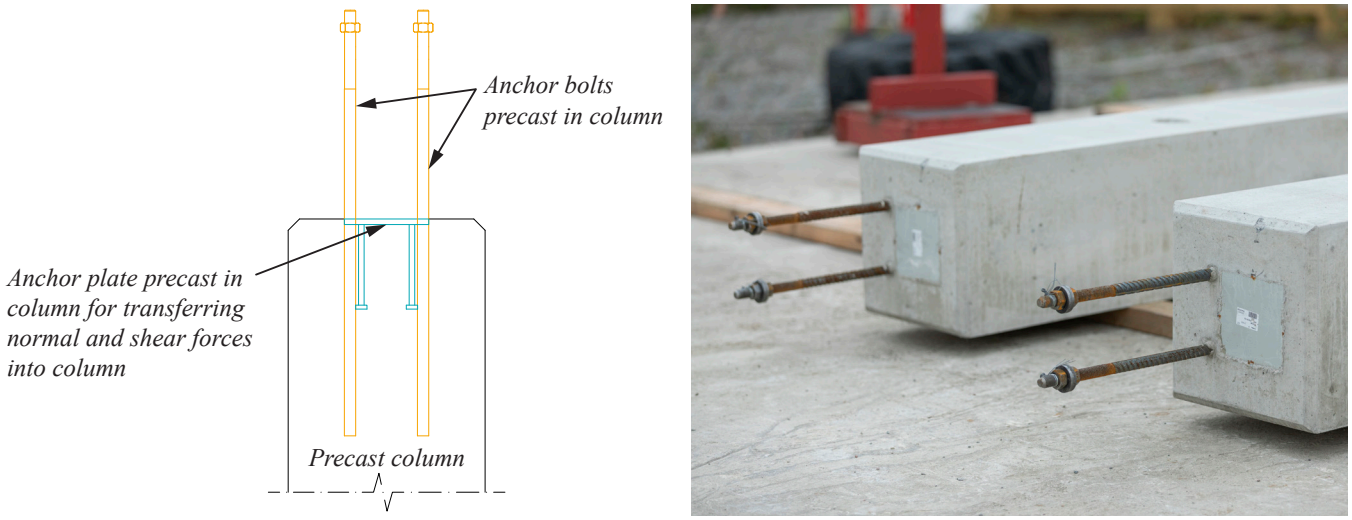


Figure 8. Section details of anchor bolts and plate cast in column (left), anchor bolts and plate in column (right).

The DELTABEAM® has a slight modification where steel tubes with diameters larger than the anchor bolts are welded inside over positions where the anchor bolts from columns would pass through, (*Figures 9 a) and b)*). The tubes prevent in-situ concrete injected into the beam from adhering onto the anchor bolts in the precast concrete columns to ease deconstruction process.

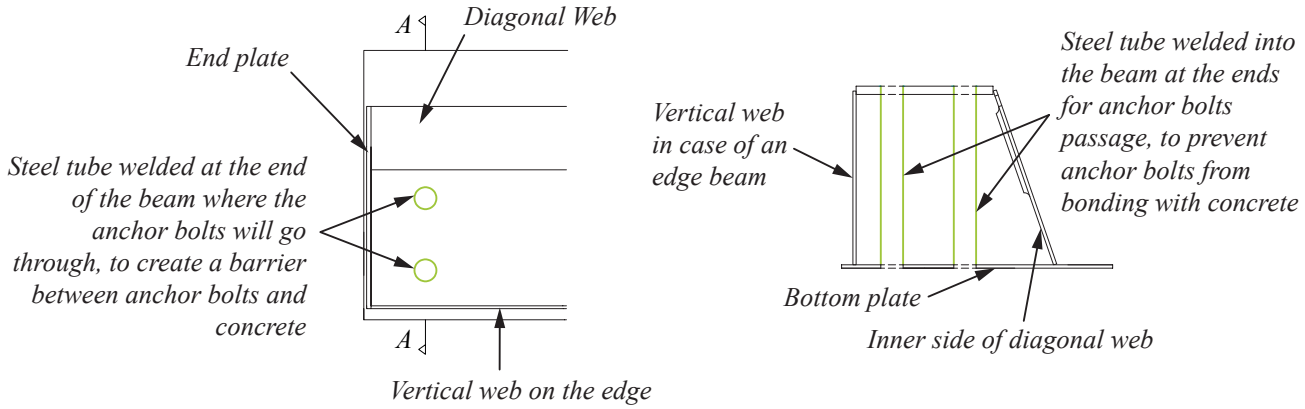


Figure 9. Steel tube in beam detail (plan, left). Steel tube in beam detail, (section, right).

With the help of the cranes beam is installed and connected to column by following project's erection method statement, installation plans and the connection details. The connection details are specified in the construction plan for each project.

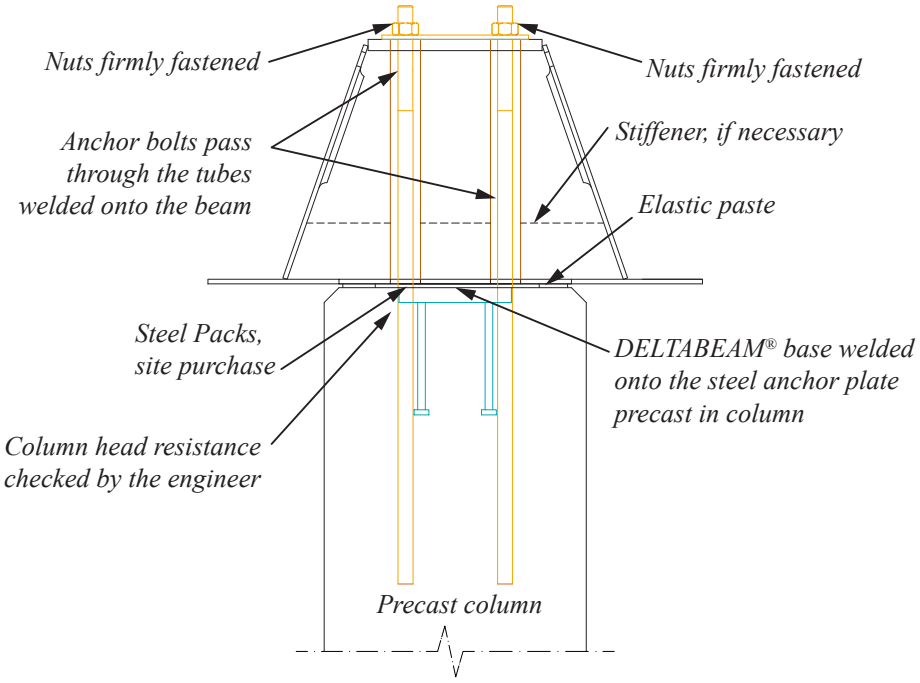


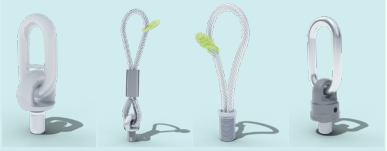
Figure 10. Column-beam connection details (left), Column-beam connection (right).

In this method, tubes are left empty while casting the beam, however, this needs to be taken into account when designing the connection details for all design situations and forces.

2.2. Dismounting beam from column

Dismount process is carefully planned with detailed process and drawings by professionals and followed carefully at the building site. Essentially dismounting requires mainly lifting. Available lifting options in Peikko's portfolio are shown on table 4 below.

Table 4. Available lifting anchors in Peikko's portfolio.

JENKA Lifting Keys	Enables a crane hook or lifting accessories such as lifting slings or spreader beams to be connected to the beam for lifting and handling.		
JENKA lifting inserts	These are installed during manufacturing of the DELTABEAM®. JENKA Long Inserts are used in elements with sufficiently large enough anchoring depth. JENKA TF is used in DELTABEAM®		

Clear temporary support details are given by professionals and followed on site. The connection is disconnected by opening the nuts from the anchor then cutting of the weld joint between the beam and column. Cutting of the weld joint between beam and anchor plate is done using a simple angle grinder. The beam is then lifted off the column using a crane (Lifting anchors are necessary as the beam in this stage is full of concrete). The beam is carefully and safely stored as by plan stipulated by project professionals for reuse.

Figure 11. Supporting of beam using props, before dismounting.

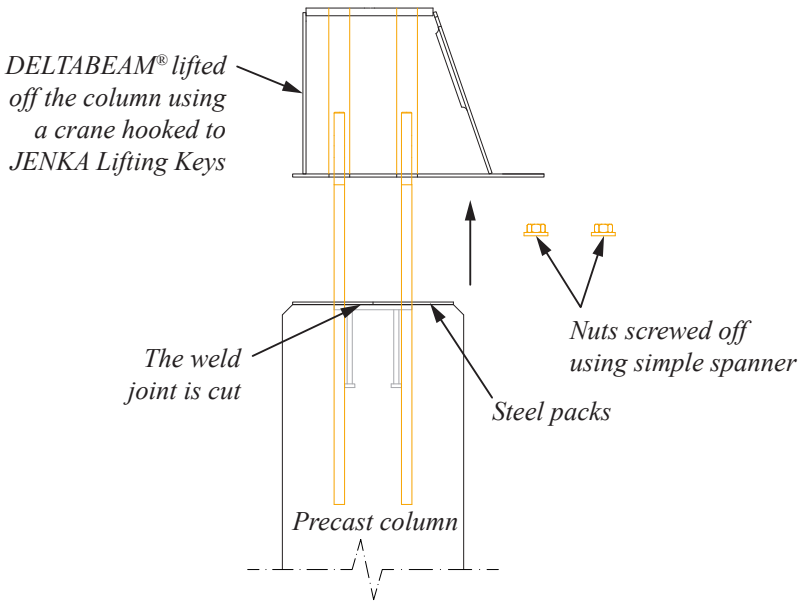


Figure 12. Dismounting details.

Figure 13. Nuts screwed off the bolts.

Figure 14. JENKA Lifting Key screwed into the DELTABEAM® Green, ready for lifting.

Figure 15. DELTABEAM® lifted off the column.

2.3. Reassembly

Reuse of building components is subject to legislative and validation-related framework conditions. At the same time, its development is promoted and accelerated by developing methods, procedures and guidelines for substantiating and verifying the characteristics of materials and for validating them. At the moment such guidelines are not yet well stipulated, and as such this Reuse process therefore only follows the pilot project findings and was conducted without checks and approval of components by the experts. The process was similar to the initial installation process. Only minor cleaning to remove residual concrete from the joints and bolts is done with use of simple hand tools such as wire brushes.

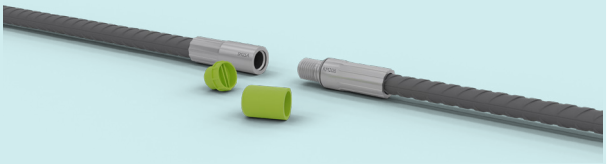
3. Beam to slab connections

Main Requirements: DELTABEAM®, Hollow Core Slab (HCS), MODIX® rebar coupler bar.

Two slight modifications are done on DELTABEAM® where:

1. MODIX® rebar coupler bars are welded into DELTABEAM®, to be used for reassembly phase.
2. Webholes are covered by welding circular dowels on them. This is to limit the simultaneous casting of the beam with HCS. The aim is to ease dismounting.

Table 5. MODIX® rebar coupler male and female parts.

For creation of transverse reinforcement in the second assembly		

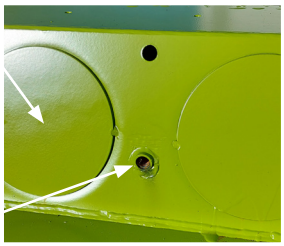


Figure 16. Circular dowels welded onto beam to cover the web holes and MODIX® Coupler part A.

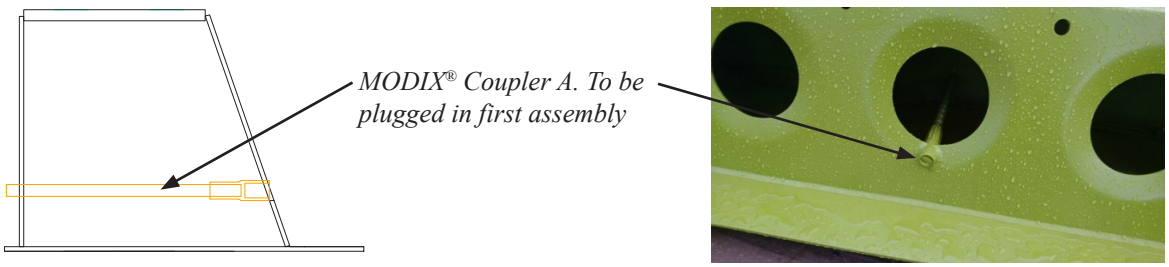


Figure 17. MODIX® Coupler position.

The DELTABEAM® connections and the props must be securely installed, tightened, or welded before assembling the floor units by following project's erection method statement, installation plans and the connection details. The connection details are specified in the construction plan for each project. The floor units are carefully lifted up and laid on the beam ledge using a crane.

3.1. Connection Details

Floor units are assembled on the beam ledge, leaving a gap of maximum 30 mm between slab and beam. Slab Reinforcement, and other necessary works are then carried out. DELTABEAM® is filled with concrete simultaneously with slab or joints of the Hollow-core slabs.

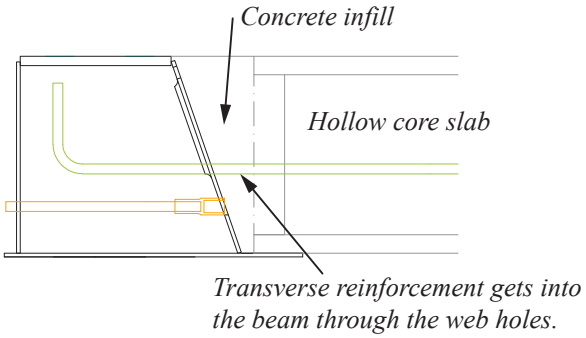


Figure 18. Beam – Hollow core slab connection detail.

Use of MODIX® Coupler instead of Ordinary Transverse reinforcement bar

Alternatively, the use of ordinary transverse reinforcement can be eliminated altogether. In this case, only MODIX® rebar coupler is used. Plugging the coupler is not necessary as Part B is connected to part A before concreting, however, the exposed muffs should be protected, (e.g., by tape) before concreting to limit concrete bonding with the muffs, (*Figure 19*).

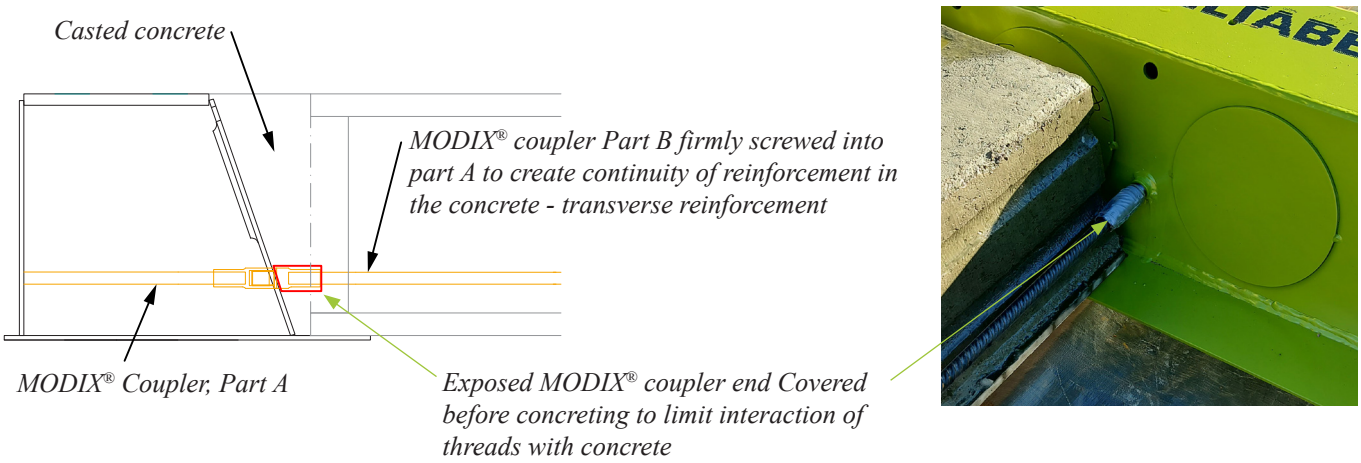


Figure 19. Using MODIX® Rebar coupler for transverse reinforcement.

3.2. Dismounting slab from beam

Dismount should always follow a set out plan. This illustrates the method that was followed in the pilot project. The concrete joint between beam and slab is cut using a diamond saw. The cutting line is set by careful measurements from drawings to ensure it doesn't extend to the MODIX® sleeve and DELTABEAM® bottom ledge. The transverse reinforcement (*T*) if it was used is also cut during this process (*Figure 20*). Also, the diamond saw is used to cut longitudinal joints between the HCS (*Figure 21*).

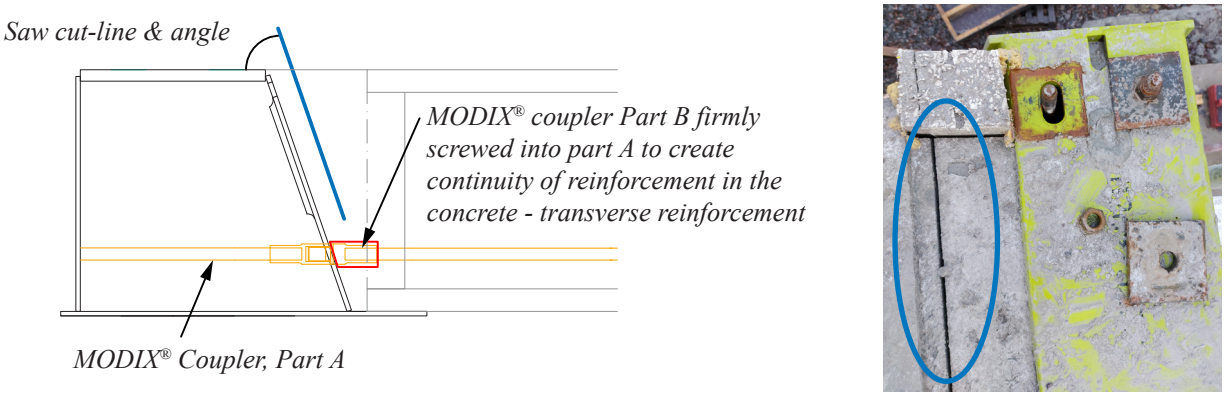


Figure 20. Saw cutting details.

Figure 21. Diamond saw cutting through HCS longitudinal joints.

When the concrete joints are fully cut, the slabs are lifted off the beam ledges using a crane. Any residual concrete, e.g., inside the voids, is cleaned off using simple tools like hand operated demolition hammer. The slabs are carefully stored for reuse as per given plan.

The DELTABEAM® is also carefully lifted off the column using a crane and stored aside according to given plan. Cleaning of the DELTABEAM® is done to remove any residual concrete from its sides using simple handheld demolition hammer.

Figure 22. Cleaning of the elements (slab above and beam below) in preparation for reuse.

Figure 23. Removing of plug from MODIX® coupler A.

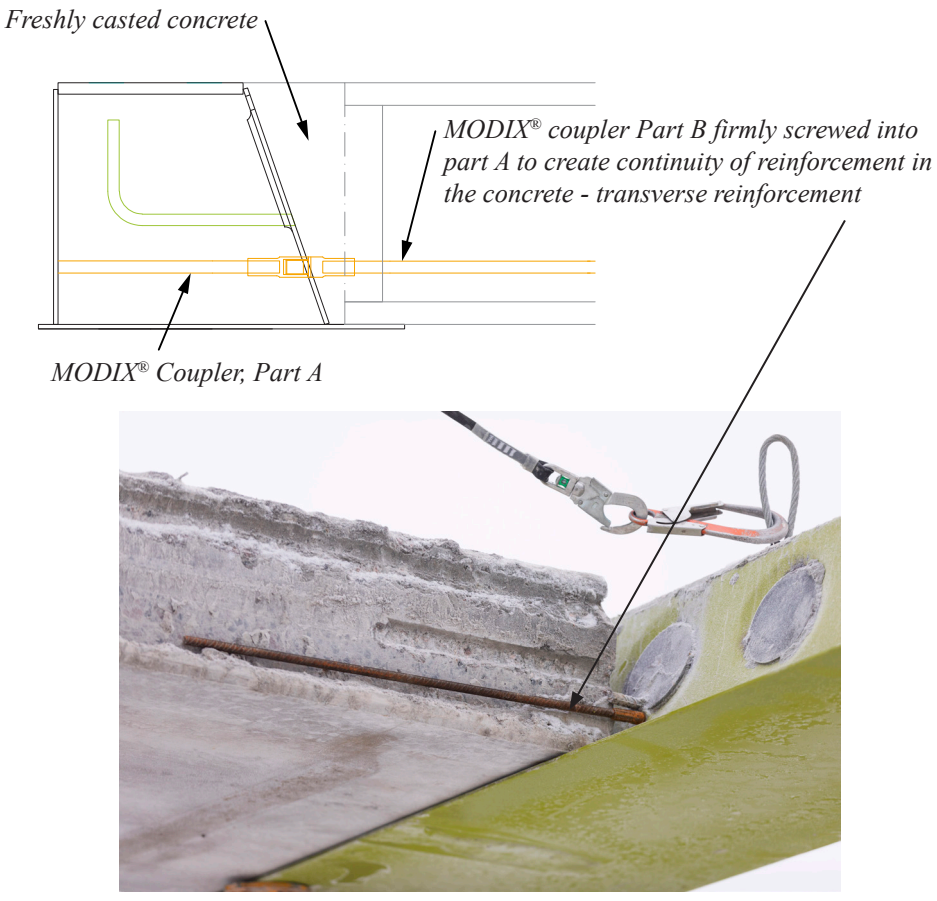


Figure 24. Part B of the MODIX® rebar coupler firmly screwed into Part A.

4. Carbon regulations Related to Reuse in Europe

(Note that these may change as the regulations are reviewed from time to time)

Table 6. Reused material impact approaches.

Policy	Description
Fraction	Modules calculated with this approach are considering a fraction of the impacts of a new material.
As normal	Modules are calculated in the same way as with a new material. A typical example is the transportation impacts to allow for these to be considered when a reused material is brought from outside the construction site.
No impacts	Here the reused material is considered to have no environmental impacts. Typical example in this case is the A1-A3 impacts.
Not defined	This characterization means that the methodology does not define how these impacts should be calculated.

Table 7. Reused material impact by module.

Country	Methodology	In force	A1-A3	B4	C1-C2	C3-C4	D
Denmark	Bygningsreglement	2023	No impacts	As normal	N/A	As normal	As normal
Finland	Finnish method / RakL	2024	No impacts	As normal	As normal	As normal	As normal
France	RE2020	2022	No impacts	No impacts	No impacts	No impacts	No impacts
Netherlands	MPG	2013	Fraction	As normal	As normal	Fraction	Fraction
Norway	NS 3720 / TEK 17	2022	Not defined	Not defined	N/A	N/A	N/A
Sweden	Klimatdeklaration av byggnader	2022	No impacts	N/A	N/A	N/A	N/A
UK	London Plan / Part Z 30	Proposed	Not defined	Not defined	Not defined	Not defined	Not defined

Conditions for reuse of building components in Finland, POLICYBRIEF 2022:20

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