CONNECTIONS

Peikko guides you towards a faster, safer, and more efficient way to design and build.

2*2020

DELTABEAM® GREEN AND HYBRID CONSTRUCTION

COMBINE DIFFERENT MATERIALS AND ECOLOGICAL THINKING

OPTIMIZING THE FOUNDATIONS

TO GIVE YOU THE BEST POSSIBLE OUTCOME

PEIKKO **WHITE PAPER**

- DELTABEAM® TO LIGHTEN BUILDINGS' ENVIRONMENTAL FOOTPRINT
- DELTABEAM® AND HOLLOW-CORE SLABS IN FIRE CASE
- TALL BUILDING SOLUTIONS

peikko®

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CONNECTIONS

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First Finnish DELTABEAM® Green project in Pudasjärvi, Finland.

NO MATTER THE WEATHER, PEIKKO KEEPS MOVING FORWARD

For most of us the way we work has dramatically changed during 2020. But the goals and targets of Peikko have not changed: we need to provide long-term value to our customers by making the construction industry faster, safer, and more efficient.

During this year, we published 7 White Papers, to explain in writing the technical studies and the laboratory experiments we made. We want to be as transparent as we can on our research activities, as only with transparency we can provide real value to our customers. We also arranged more than 30 webinars of our own, to explain acute technical topics. In addition, Peikko personnel presented in a number of webinars organized by other organizations.

Since the start of this year, we also launched the new DELTABEAM® Green, a product that reduces CO_2 emissions by 50%, and the ATLANT® solid-core column system enabling very slim composite columns – liked particularly by architects. We also brought several new and revised connections, such as STRIFF® Shear Dowel and our EBEA® Balcony Connector into new markets. We also acquired new assessment documents, such as ETA for our TERAJOINT® Free Movement Joints, enabling us to CE mark our flooring products.

With regard to the software, during this year, we did several updates, such as ensuring the compliance of all our Peikko Designer® software modules with the new standard of EN 1992-4. Moreover, a new and modern selection tool, EBEA SELECT, was introduced during the summer as part of our marketing theme 2020 Peikko for designers.

All our factories on four continents have been busy serving our customers. The ongoing investments have continued, and the new ones are going to continue in 2021. Our intention for the next year is to be even more flexible when serving our customers, as an increasing proportion of our products are manufactured in several Peikko factories, in order to to guarantee deliveries also in the ever-changing lockdown situations.

There is more to come, and the speed is accelerating. Keep up following us on what is yet to come!

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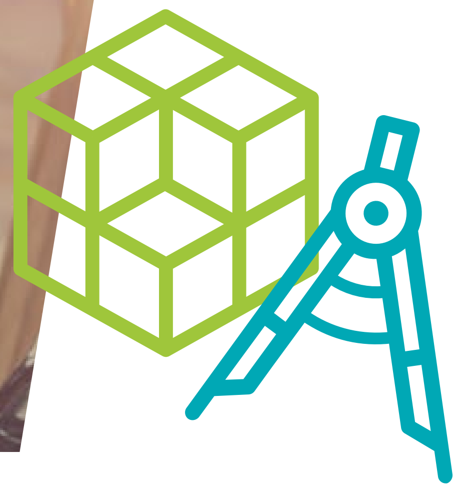


BEHIND THE SCENES: DELTABEAM SELECT HAS A NEW ROLE IN DESIGN AUTOMATION

Peikko Designer® DELTABEAM SELECT is the product where the structural engineer, along with other stakeholders, chooses the frame and floor structure type. It is important for the engineer to find a suitable solution for the floor beams, all relevant boundary conditions considered.

The use of the service has been built to provide cloud selection application in a browser and serves the user DELTABEAM® with profiles that sufficiently and accurately meet the design criteria. So far, this has been an application without straight integration into structural engineers' workflow. This cloud service has been available now for two years and its use has been steadily expanding.

Now, as Peikko's DELTABEAM® is gaining more popularity and at the same time, solutions to enhance structural engineers' workflow are emerging, we have decided to open the service to all structural engineers and engineering applications.

DELTABEAM® SELECTION SERVICE INTEGRATES WITH STRUCTURAL ENGINEER'S WORKFLOW

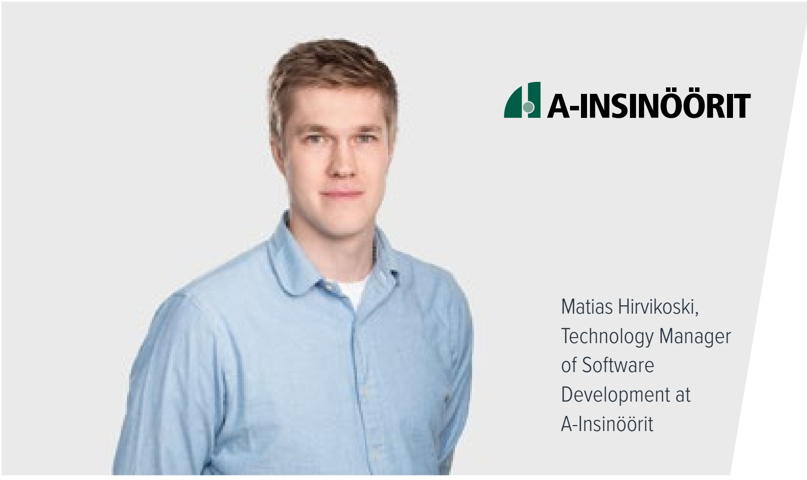
Firstly, if an engineering company has any automation in their floor design procedure, we can give them access to our online DELTABEAM SELECT service. Hence, we decided to automate the floor beam selection in engineers' native design application and to feed these three beam options right in their workflow.

Secondly, we now also offer a reversed process. If an engineer already has a beam selected and in place, they can run the sanity check of their DELTABEAM® profile selections against our service.

That is, the engineer can easily find out the design ratio of already selected beams and get a simple go / no go information on their preselected set of beams. This feature works on the full selection or a list of beams. The beam options are automatically checked one by one and verified instantly. Not ever leaving the native design application at hand.

"The opportunity for such an approach is excellent and pushes the whole industry forward: by opening the service API* to users, tool can be implemented in modern workflows. This way, the designer can take the driver's seat and concentrate on decision making while the computers provide valuable information on the possible choices," describes **Matias Hirvikoski**, Technology Manager of Software Development at A-Insinöörit.

This service's first implementation has been crafted with A-Insinöörit in Finland and the service integrates with Tekla Structures in the beginning.

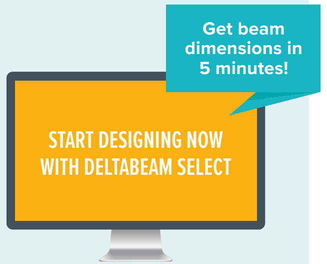


Matias Hirvikoski, Technology Manager of Software Development at A-Insinöörit

*API, Application Programming Interface, services are, by definition, interfaces that provide a program with a description of how to interact with a system in order to retrieve and/or change the data within it.

Use DELTABEAM SELECT at www.peikkodesigner.com/deltabeamselect/

Would you like to automate your DELTABEAM® selection for the entire floor? Please contact us. We can help you deliver your DELTABEAM® projects in a faster and more efficient way.



PEIKKO WEBINARS SHARE USEFUL INFORMATION AND BEST PRACTICES

We arrange webinars to help you and all our stakeholders to stay up to date on the products, tools, and opportunities that we provide to you.

Peikko webinars have been created by our own teams that have been involved in the development and creation of these products and tools, so the webinars provide you with important and useful details on the best practices.

We record all our webinars, so you can watch them based on your own schedule! For access to the library of all recorded webinars, please visit **www.peikko.com/webinars**

INTERESTED IN ATTENDING UPCOMING WEBINARS?

Follow Peikko news at **www.peikko.com** and at LinkedIn: **Peikko Group Corporation**.

PEIKKO DESIGNER® CALCULATES ACCORDING TO EUROCODE 2 PART 4

EN 1992-4 uses cylindrical strength of concrete instead of cubical one.

Since spring 2019, the design of fastenings in concrete is regulated by Eurocode 2 Part 4 (EN 1992-4). This was an important step, as the design of fasteners in the concrete in the past was distributed over numerous individual documents – like CEN/TS 1992-4 technical specification, to which Peikko is referring to in anchorage design of WELDA® and short Anchor Bolts.

"When the new standard came out, it automatically overwrote the guidelines of those individual documents", says **Anna Stirane**, Customer Engineering Manager, Peikko Designer® Connections.

Though the theory of the design has not changed, many formulas have differences in how they are formed and in the results they will produce.

"One of the main reasons why formulas differ is that EN 1992-4 uses cylindrical strength of concrete instead of cubical one. Also, the factors accounting for the condition of the concrete are different", Stirane points out.

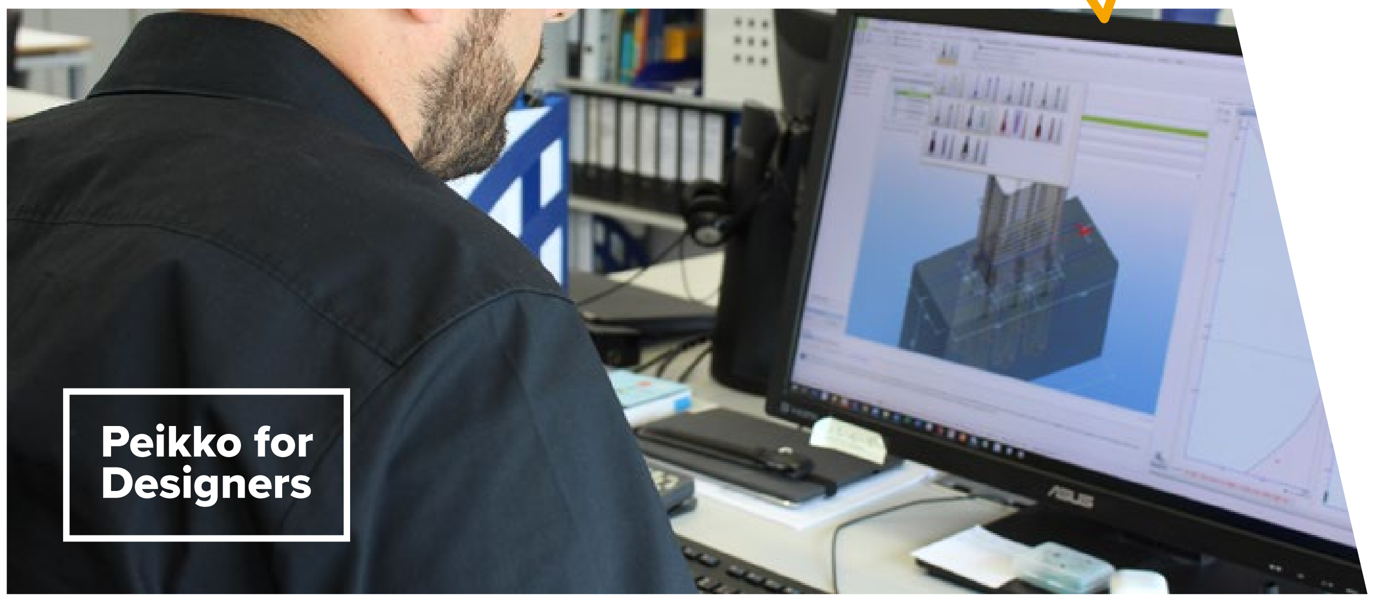
In order to comply with the latest standard requirements, Peikko addressed the changes in the Peikko Designer® software.

2.2.0 version was mainly dedicated to the EN 1992-4 standard implementation for Anchor Plate and Column Connection modules.

"This includes the anchorage design of headed anchors and covers concrete failure modes' verifications, combined resistance check, and supplementary reinforcement calculations."

Design according to CEN/TS 1992-4 is still available for the selection, since the current European Technical Assessments (ETA) of the products are still valid. Updates of approvals with the reference to EN 1992-4 will be coming later.

"Meanwhile, the Peikko Designer® software is already compliant with the new standard. Users have freedom to choose between CEN/TS 1992-4 and EN 1992-4 to run the selected standard anchorage to concrete verifications", Anna Stirane concludes.



Peikko for Designers

STRUSOFT FEM-DESIGN

MAKES THE DELTABEAM® DESIGN PROCESS LEAN

Peikko's products are aimed to provide solutions to make building processes faster, safer, and more efficient. Often that means that each building needs a tailor-made solution to maximize the benefits.

We recognize that most of our products can't be simply selected from a catalogue, but rather the customers need good tools and support during the design process. Presented here is a typical design process for DELTABEAM®, which can be now improved with FEM-Design software from Strusoft.

Basic design process in construction business starts from the architect's building scheme. After that Structural engineer can start to work with structural system (Step 1). When a model is selected, DELTABEAM® profiles can be predefined either by customer or in co-operation with Peikko's local engineering team (Step 2). For preselection, Peikko provides DELTABEAM SELECT tool, which can be found via Peikko's website.

After defining the suitable DELTABEAM® profiles, the detailing can begin (Step 3). For the most common BIM software there are good detailing tools available, and if Peikko's connection products are included, there is a good set of tools and technical manuals for all our products.

When the structural model and geometry are fixed, Peikko's engineering team can start the work (Step 4). Each DELTABEAM® is analyzed and optimized accurately with internal tools and detailing is made with Tekla Structures software. Design system is integrated into Peikko's production and ERP systems, but production does not start before the structural engineer has accepted the design (Step 5).

Peikko has been able to provide tools for customers among the whole process. But it has been noted that customers have often asked questions on how DELTABEAM® profiles can be defined when the initial structural model is analyzed with a global FEM-tool (Step 1).

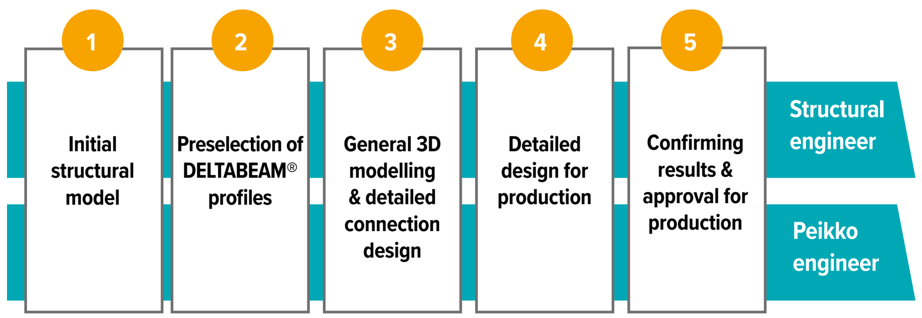
Now Peikko has taken a nice development step with Strusoft company. As a result of the co-operation, Strusoft have released a new version of their FEM-Design tool, where DELTABEAM® profiles are included. With FEM-Design, it is possible to get a good understanding about global behavior of the structural system with cross sections that are most common in typical DELTABEAM® profile sizes. In addition to this, the software is able to check the maximum capacity for bending resistance of a composite DELTABEAM® profile.

These features make the structural engineer's design process lean and effective and also the preselection can be made with the FEM-tool during the initial stage.

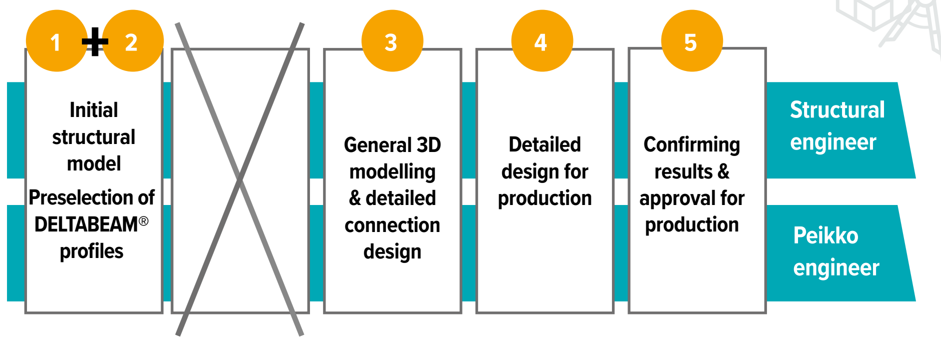
This has definitely been an interesting development step for Peikko and the aim is to continue on the same path. Peikko wants to provide new tools and services integrated into the tools that the structural engineers are using in their daily work. This can make the design process faster, more efficient, and hopefully also more FUN.

StruSoft

BASIC DESIGN PROCESS



NEW DESIGN PROCESS



OPTIMIZING THE FOUNDATIONS

TO GIVE YOU THE BEST POSSIBLE OUTCOME

A pioneer of the faster, safer, and more efficient way to build wind turbine foundations, Peikko has optimized the whole process.

> With a variety of base designs, Peikko can cater for all scenarios that you might have in your wind park.

It's easy to see that optimizing the towers, turbines, and blades have a great impact on the wind park efficiency. But the hidden foundations need to be optimized as well.

EFFICIENCY IN THE DESIGN

With a variety of base designs, Peikko can cater for all scenarios that you might have in your wind park. The Viinamäki wind park in Finland is a prime example of ingenuity.

"The hub height is 175 meters (574 ft) – the highest in the history of the turbine manufacturer Vestas. The tower was stayed by three cables with anchoring points 100 meters (328 ft) away. There was only about 2 meters (7 ft) of tolerance on where the anchoring foundation could be placed," explains Sales Director **Antti Rousku**.

Typically, the customer supplies the soil information, turbine loads and the connection details, and Peikko makes a preliminary suggestion on the foundation design. Peikko's four base designs form a solid starting point for optimization.

"In the initial stages of the project, we act as foundation consultants. The customers might have their own ideas, and we bring ours to the table, based on the foundations we have supplied to date," explains Antti Rousku.

Peikko can meet the needs of any scenario.

"You can either optimize every single foundation by using our designs, or you can optimize the overall project," says Rousku.

Sometimes it can be tempting to over optimize.

"But in a wind park of 10 turbines, it is often better to use one or two foundation designs than to create, let's say, four separate designs. The total price tag will be lower as the design itself also costs something. We always take a helicopter view to determine what's best for the project. The numbers always guide our recommendations."

The on site efficiency also needs to be taken into account.

"Of course, the installation crews are top class professionals, but having too many designs can make the work slower and perhaps costlier too. It's expensive to transport drills to the site for a rock foundation – if it's only one or two foundations that need to be drilled," Rousku points out.

HIGHLIGHTS

EFFICIENCY IN THE PRODUCTION AND LOGISTICS

Being a high volume supplier, Peikko's design and production machine is constantly running.

"This translates into economy of scale. We can optimize raw materials as well as the production and delivery windows. Having several plants capable of producing foundation components means that there is always capacity available – an important consideration during these difficult times."

EFFICIENCY IN THE ON-GOING PROJECT

A successful project requires close cooperation between all the parties.

"If the on-site crew is not familiar with the design, we train them to ensure a smooth installation. For every project we also appoint a dedicated manager, who maintains a daily contact and visits the site regularly to see that the work is progressing according to the plan."

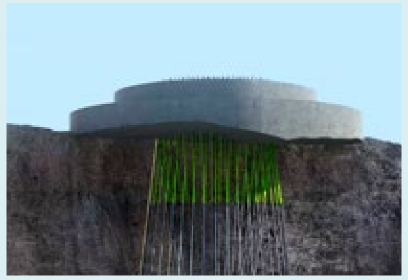
Having a familiar face makes communication easier. Even the structural designer visits the site a couple of times to see how the designs work in real life. And if there are questions or problems, they can be solved right away.

"We are in the project together with our customers and we have a common goal – to ensure a solid foundation for your wind energy business. Sometimes it means that you need to change plans on the fly. And it's perfectly achievable as we control the whole value chain from the design to deliveries," Antti Rousku concludes.

A FOUNDATION FOR EVERY SOIL TYPE

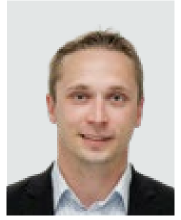
Gravity foundation is a proven performer – we have constantly fine tuned the design to use less concrete and reinforcement.

Pile foundation allows you to build on weak soil.



Rock foundation is the go-to design in areas with exposed bedrock. Based on Peikko's rock anchors, it has an extremely low carbon footprint.

Cage rock foundation is used when there is rock, but it is not on the surface or hard enough for rock foundation.



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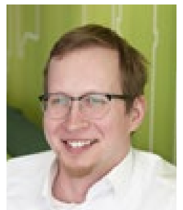

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1. INTRODUCTION

The building industry is responsible for more than 30% of global CO_2 emissions. Development, design, and construction phases are estimated to account for 30% of a building's emissions. Furthermore, over its entire life cycle, the building's emissions have a huge impact on the environment, and they are estimated to account for more than 70% (Fig. 1).

Future urbanization rapidly requires solutions to meet this challenge. For this reason, we in the building industry need to be innovative in creating solutions that are economical yet ecological. DELTABEAM® Slim Floor Structures greatly improve the sustainability of buildings in both the construction and the operational phases. Building height is decreased, total material consumption can be reduced, and recyclable materials and processes can be used. Bu choosing products that are manufactured by using recycled raw materials with lower CO_2 emissions in the process, even challenging environmental targets can be achieved sooner than expected.

Peikko promises to change the building industry to be faster, safer, and more efficient and to lighten its environmental footprint. By using DELTABEAM® Slim Floor Structures, the environmental impact of buildings can be decreased in many ways. In this White Paper, three ways of achieving this goal are presented along with recent case studies and a new, recently launched and innovative product called DELTABEAM® Green. This product is made from recycled steel using renewable energy and delivered with low-emission logistics. And eventually sustainable promises have to be proofed with certified Environmental Product Declarations, EPDs, enabling reliable, comprehensive building life cycle assessments, LCAs.

2. REDUCTION IN BUILDING HEIGHT

By reducing building height while retaining the same number of floors, significant environmental and economical savings can be made. In a six-storey building, for example (Fig. 2), has a height of 27.8 meters, and the surface area of one floor with a conventional structure is 20,000 m^2 (550,000 m^3).

The same building designed with a Slim Floor Structure has a height of 25.4 meters, a reduction in hight of 2.4 meters and reduction in volume of approximately 50,000 m^3 which is 10% less. Less cladding and lower columns, walls, elevator and stair shafts, pipes and ducts all lead to savings and a more sustainable structure. As the building envelope is smaller, energy consumption for heating and cooling is lower throughout the lifespan of the building. A slim floor structure can also save significantly on person-hours during construction, and HVAC installation is also easier in a ceiling with no obstructions.

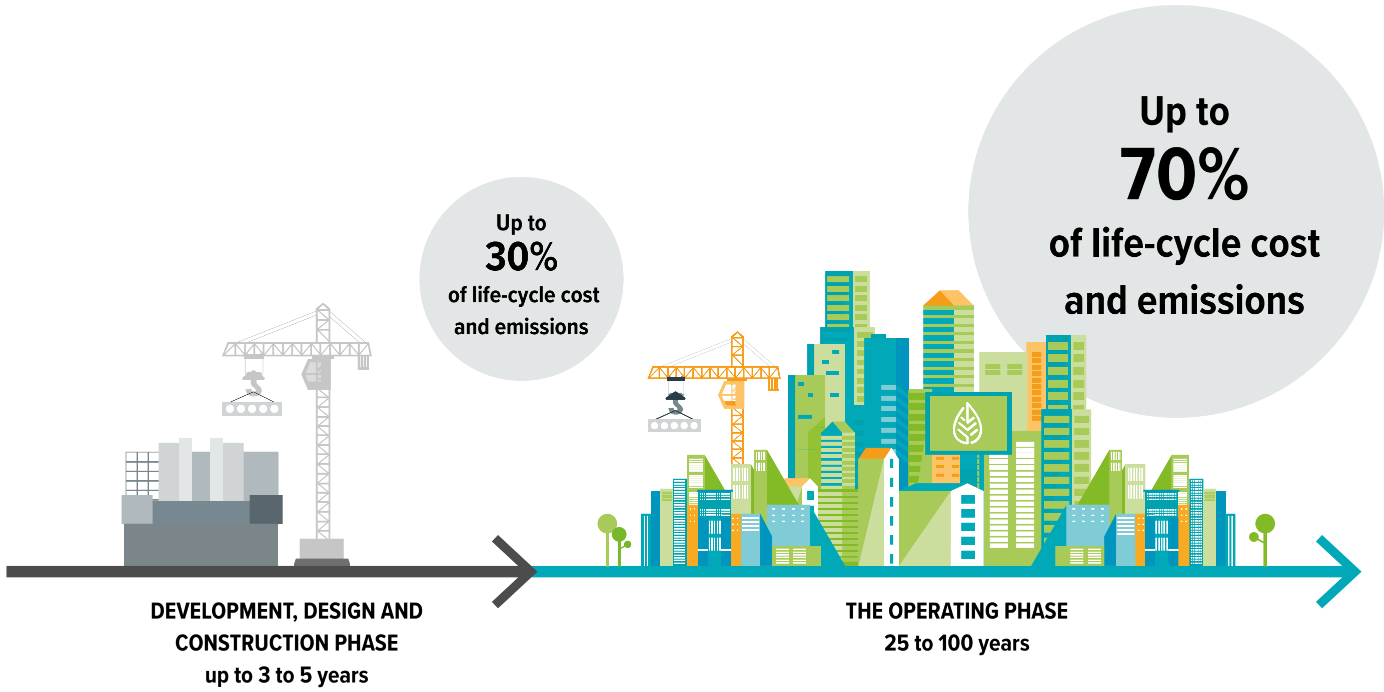


FIG. 1 A BUILDING'S ECONOMIC AND ECOLOGICAL FOOTPRINTS OVER ITS ENTIRE LIFE CYCLE

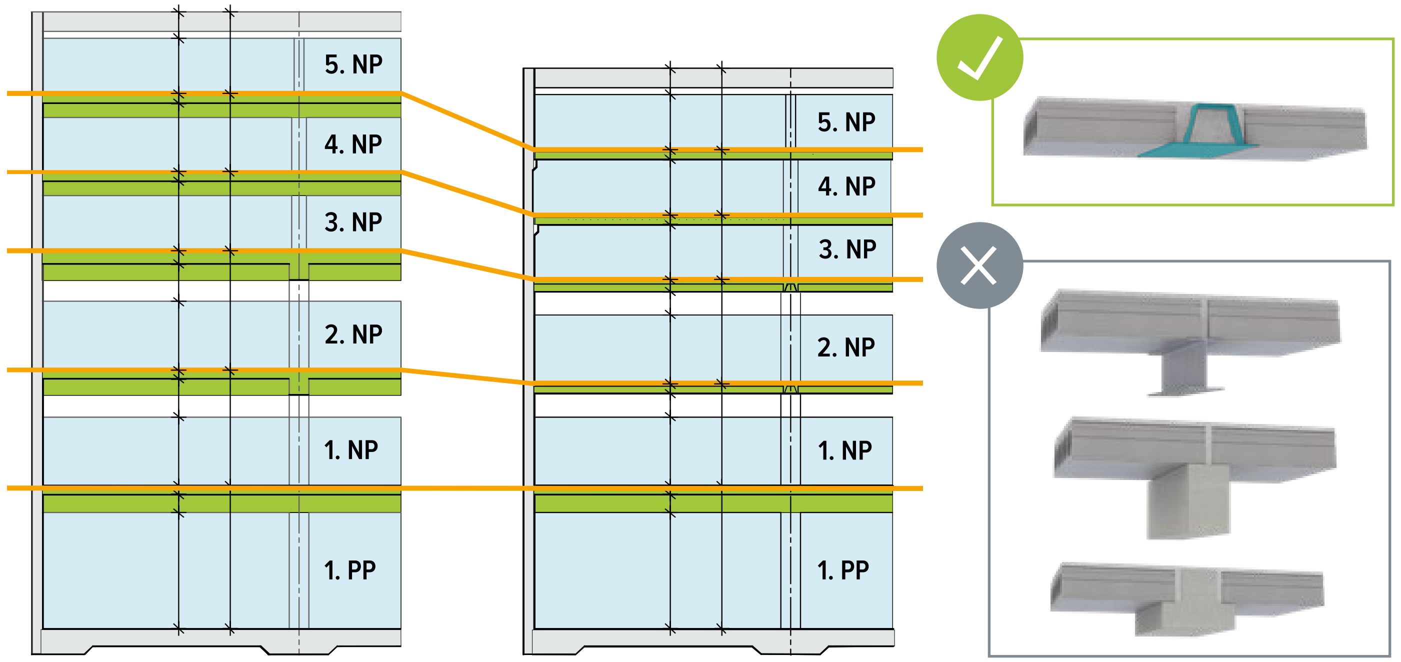


FIG. 2 DIFFERENCE IN HEIGHT AND BUILDING ENVELOPE BETWEEN A SLIM FLOOR STRUCTURE AND CONVENTIONAL STRUCTURE

3. REDUCTION IN SITE LOGISTICS AND USE OF BUILDING MATERIALS

In another building example, the initial design resulted in an overall floor depth of 700 mm using a traditional solution. However, it was quickly realized that a traditional fully cast-in-situ solution presented significant difficulties due to a shortage of local ready-mixed concrete supply, the number of construction workers required, and the lack of construction site area required. The large number of vehicle deliveries would have resulted in serious disruption and emissions in the already congested construction site area. A solution was needed that would result in a faster construction schedule and reduced on-site activities, create less need for in-situ concrete works, and be more eco-friendly in particular.

Initial calculations were carried out with various combinations of DELTABEAM® composite beams, hollow-core slabs, and topping depths. The calculations indicated that it was possible to find a structural solution that meets the stringent specification requirements with the required construction advantages. Finally, a detailed FEM analysis revealed that the required low response factors would be achieved with D32-500 DELTABEAM® beams, 300 mm-deep hollow-core slabs, and 200 mm of structural concrete topping. The designed result was a hybrid frame combining the benefits of both precast and cast-in-situ techniques. The use of DELTABEAM® facilitated a 200 mm-slimmer floor compared to an in-situ-casted floor (Fig. 3). According to the main contractor's estimation, the engineered hybrid solution reduced the number of truck deliveries to the site by over 500 and the dead weight of the building by more than 3,000 tons compared to the original in-situ frame solution. The onsite construction program was 20 weeks faster and saved over 2,500 person-weeks in comparison to the envisaged in-situ solution. Moreover, the overall carbon footprint was significantly reduced, with fewer truck deliveries and high-quality offsite production of the DELTABEAM® and precast concrete units.

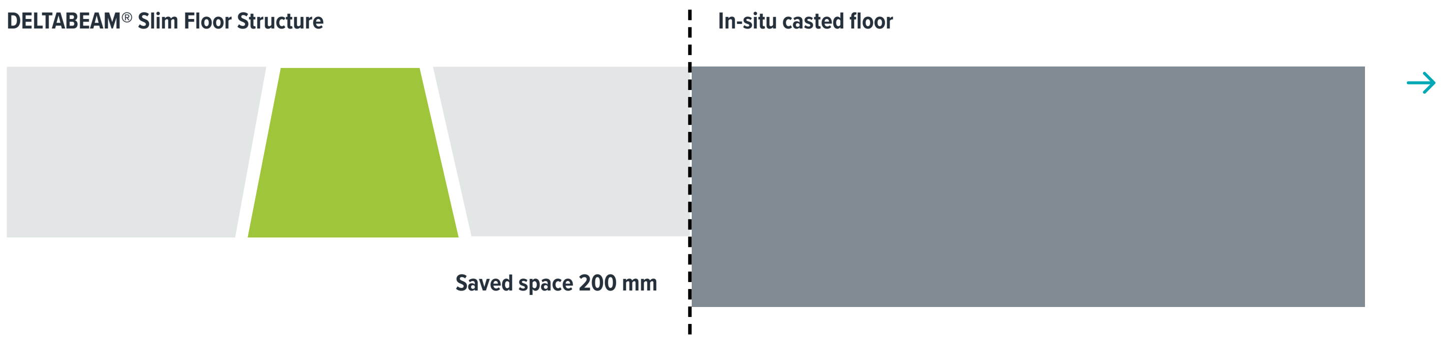
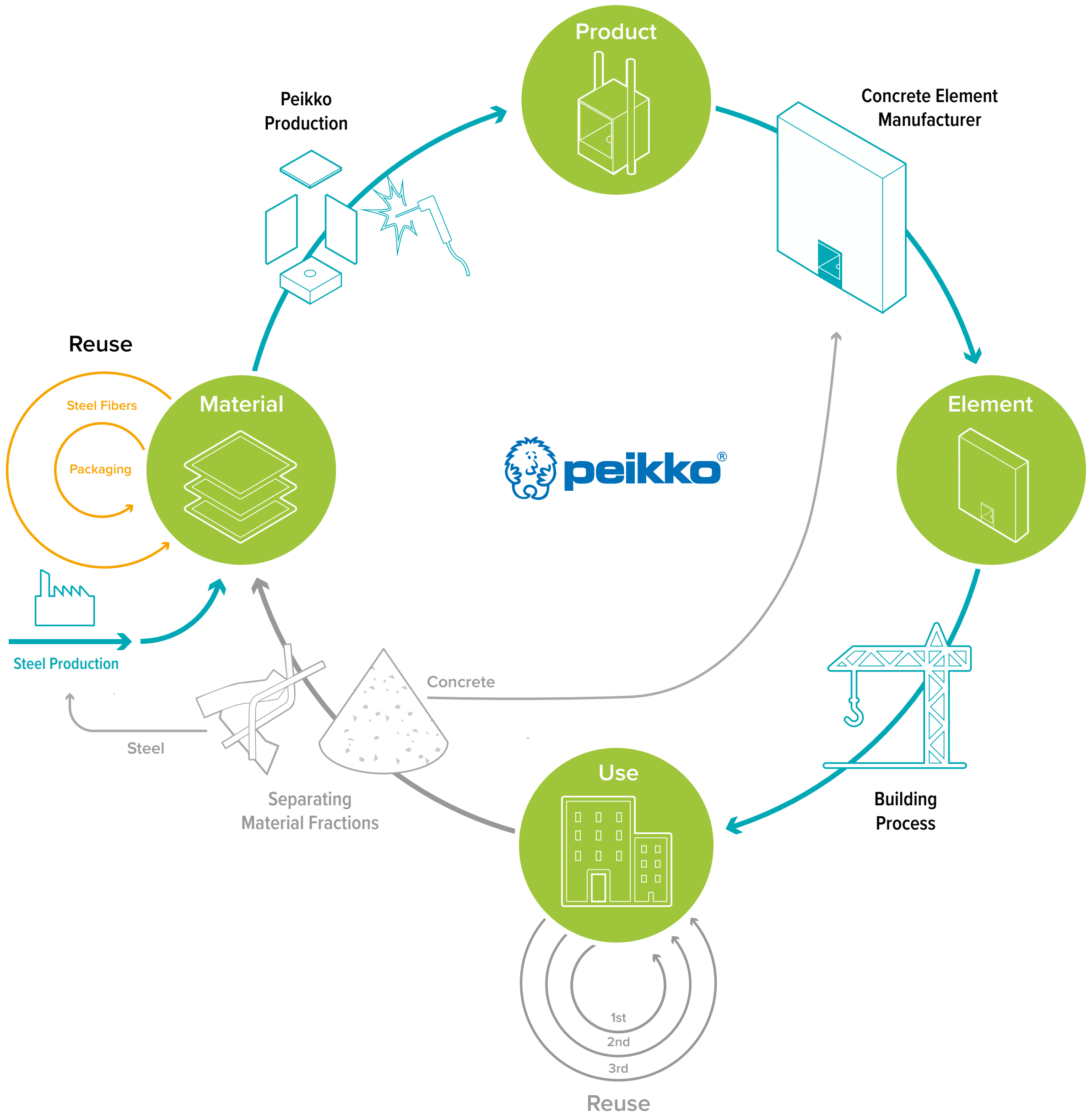


FIG. 3 THE OVERALL SLAB THICKNESS WAS REDUCED BY 200 MM AND THE DEAD WEIGHT OF THE BUILDING WAS MORE THAN 3,000 TONS LOWER COMPARED TO THE ORIGINAL IN-SITU FRAME SOLUTION.



4. LIGHTENING A BUILDING'S ENVIRONMENTAL FOOTPRINT WITH DELTABEAM® GREEN

Optimizing material usage is a step towards closed-loop economy. In frame manufacturing, it entails reducing the amount of virgin material and resources used. This can be achieved by analyzing the entire production chain presented in Fig. 4. The aim of reducing and re-using materials and components offers significant potential for cutting CO_2 emissions. The best-case scenario, in which all materials would be separated and reinserted into the circular process as raw materials at the end of their life cycle, is the goal that the entire industry needs to further develop.

To lighten the environmental footprint, Peikko has made significant progress by increasing the use of recycled steel in the DELTABEAM® Slim Floor Structure (Fig. 5). The result is DELTABEAM® Green, produced from 90% of recycled steel and using green energy. This new, environmentally friendly version of Peikko's Slim Floor Structure solution offers the same benefits as the standard DELTABEAM® but with a significantly reduced environmental impact compared to traditional steel structures.

DELTABEAM® Green composite beams cut CO_2 emissions by up to 50%. Their eco-friendly design encompasses everything from materials and production to certifications and transport. The environmental impacts are confirmed by the third-party verified Environmental Product Declaration, EPD, and project-specific Life Cycle Assessment calculations of CO_2 emission can be based on this certificate. For those seeking to achieve high BREEAM or LEED standards, DELTABEAM® Green is an easy, efficient solution. Peikko's DELTABEAM® Green goes all out on sustainability, and the extra mile, too.

In the following chapter, a comparative calculation explains how much DELTABEAM® Green can reduce the CO_2 emissions of an office building in practice.

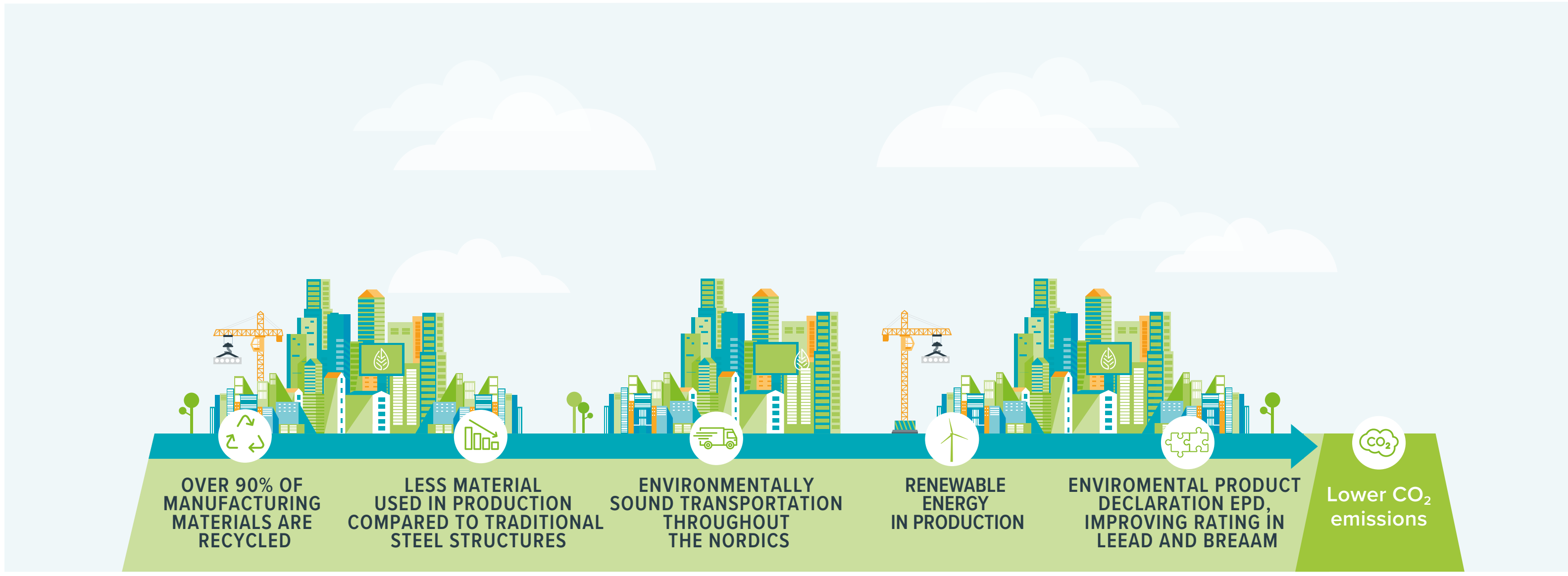


FIG. 5 DELTABEAM® GREEN LIGHTENS THE ENVIRONMENTAL FOOTPRINT OF BUILDINGS IN MULTIPLE WAYS

4.1 COMPARISON OF THE ENVIRONMENTAL FOOTPRINTS OF DIFFERENT BEAM TYPES IN A TYPICAL OFFICE BUILDING

Based on available official EPD data, Peikko has made sample calculations for a real office building that has been built. The project involves 10 floors, a floor space of roughly 20,000 m^2, and over 500 beams delivered. In this comparison, one floor with 41 beams was used to calculate the amount of CO_2 emissions. The building frame is of beam-column type with precast staircases and sandwich walls. The compared beams are steel box beam (WQ), pre-stressed concrete beam, standard DELTABEAM® and DELTABEAM® Green. Examples of cross-sections of the different beams are shown in Fig. 6.

Based on these beam types, Fig. 7 shows the equivalent amount of CO_2 emissions in kg per square meter of floor in the building. Total CO_2 emissions are divided into CO_2 emissions caused by raw material used in the production of the beam ($kgCO_2/m^2$), emissions caused by fire protection paint in the WQ beam and infill concrete used in DELTABEAM®, and emissions caused by higher walls needed because of the height of the bottom flanges of beams. Wall areas are calculated from the actual project.

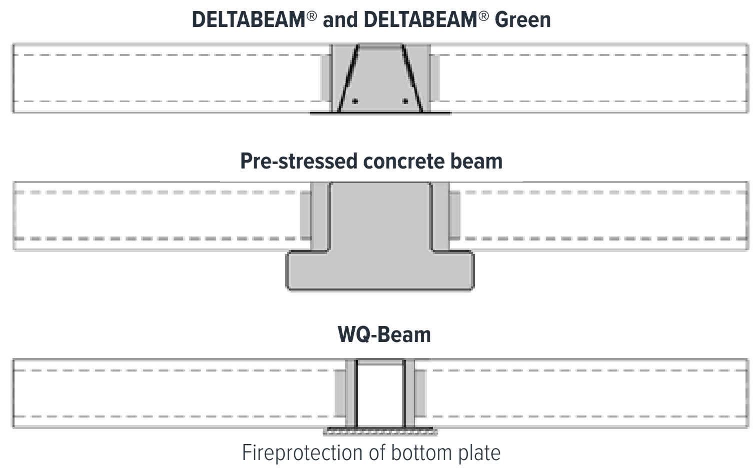
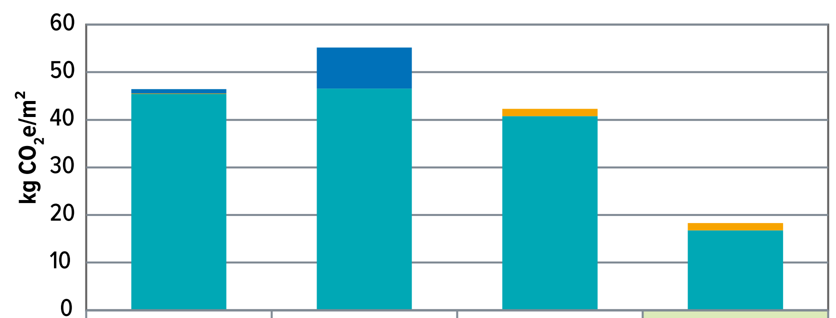


FIG. 6 BEAM TYPES USED IN THE COMPARISON



	WQ	Pre-stressed concrete beam	DELTABEAM®	DELTABEAM® Green
% of max value	98%	100%	88%	**36%**
■ CO_2 kg from higher walls	0,9	8,6	0,0	0,0
■ Fire protection paint or infill concrete	0,1	0,0	1,5	1,5
■ kg CO_2/m^2	45,4	46,6	40,8	**16,8**

FIG 7. COMPARISON OF CO_2 EMISSIONS IN OFFICE BUILDING

4.2 STRUCTURAL COMPARISONS AND CO_2 CALCULATION METHOD

WQ beam steel kilograms are optimized by manual calculations in the structure while also making the WQ beams as effective as possible. This led to multiple different cross-sections for the beams, but the result can be considered conservative in a comparison of CO_2 emission. It can be assumed that in reality the project would have had a bit more steel kilograms in WQ beams, as the profiles would have been combined into a lower number of different beam profiles. Beam weights per meter vary from 51 kg/m to 213 kg/m. Some of the beams require downstands and the highest beam used was 400 mm high, with several 370 mm high beams also needed. In the CO_2 emission calculation, it is assumed that 50 mm-higher walls are needed because of the use of downstands in the beam. The global warming potential of steel in WQ beams in the CO_2 emission calculation is 2.72 $kgCO_2e/kg$.

Pre-stressed concrete beams are dimensioned by means of table dimensioning used in pre-design to determine the required profile. Using the profile, the total mass of concrete is calculated. The highest beams used are 800 mm high, and it is assumed that 470 mm-higher walls are needed because of the height of the ledge. The global warming potential of concrete in pre-stressed beams in the CO_2 emission calculation is 0.265 $kgCO_2e/kg$. For higher walls the figure is 0.196 $kgCO_2e/kg$. Pre-stressed beams have a higher impact because of the use of high-strength concrete.

DELTABEAM® profiles for the project had already been designed by a structural engineer, and the final design for the beams had already been prepared by Peikko. The DELTABEAM® weight from the Peikko design is used in the CO_2 emission calculation. DELTABEAM® weights per meter vary from 61 kg/m to 169 kg/m, so it appears that, especially in longer beams, DELTABEAM® beams are significantly lighter than steel box beams. The global warming potential of DELTABEAM® used in the CO_2 emission calculation according to DELTABEAM® EPD is 2.94 $kgCO_2e/kg$. For DELTABEAM® Green, the EPD figure is 1.21 kgCOe/kg. For infill concrete, the figure used is 0.146 kgCOe/kg, which is lower than the figure used for concrete walls as no reinforcement is needed.

4.3 RESULTS OF THE OFFICE BUILDING COMPARATIVE CALCULATIONS

As a conclusion from this study based on one office building considering only CO_2 emissions from building materials, it appears that all three basic solutions are equal when compared. Significantly lower CO_2 emissions can be achieved by choosing recycled material for beams such as DELTABEAM® Green. In this comparison, DELTABEAM® Green causes 64% lower emissions in the comparison from pre-stressed concrete beams. Compared to traditional DELTABEAM®, the green version generates 59% lower CO_2 emissions.

4.4 DELTABEAM® AND GREEN ENVIRONMENTAL FOOTPRINT CALCULATOR

Peikko has developed a calculation tool that can estimate the CO_2 emissions of beams at the preliminary stage of a project, as shown in the example in Fig. 8. Only the building type, floor type, floor thickness and grid need to be defined in order to obtain estimated CO_2 emissions for DELTABEAM® and DELTABEAM® Green for two different profiles. More information on this tool is available from local Peikko sales offices (www.peikko.com).

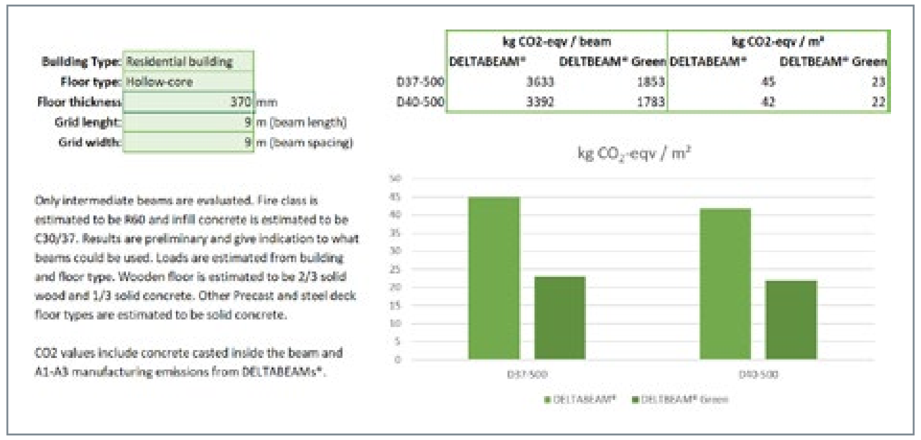


FIG. 8 CALCULATION EXCEL TOOL FOR ESTIMATING THE CO_2 EMISSIONS OF DELTABEAM® BEAMS AND DELTABEAM® GREEN AT THE PRELIMINARY STAGE OF A PROJECT.

5. CONCLUSIONS

The main conclusions of this White Paper are as follows:

1. Using Slim Floor Structures can significantly reduce both the constructional and the operational environmental impacts of buildings
2. Commercially available solutions can be used for both economically and ecologically sound construction
3. Tried and true building methods are already available for use in combination with low-emission materials and processes
4. Using circular economy in structural components is an effective way to lower building CO_2 emissions further using DELTABEAM® Green, for example

HYBRID CONSTRUCTION COMBINES DIFFERENT MATERIALS AND ECOLOGICAL THINKING

A small town of Pudasjärvi in the far North will soon host the highest log, steel and concrete composite apartment buildings constructed in Finland to date.

The construction of Hirsihovi – The Log Court – began in the spring of 2020, and the buildings are scheduled for completion in the fall of 2021. The two houses will include a total of 53 rental apartments with five commercial premises at street level.

The open-minded method of construction combines different materials to ecological thinking.

The composite frames will consist of concrete columns and Peikko's new DELTABEAM® Green composite beams. The intermediate floors will be made from hollow-core slabs, while precast elements are to be installed as interior walls. The exterior walls are to be built using non-settling logs.

> We are working together with our customers and suppliers to bring better and greener products into the market.

IN-DEPTH UNDERSTANDING OF THE MATERIALS NEEDED

"It calls for a deep understanding of the materials and their special characteristics. Only then you can identify challenging points and resolve emerging issues. Different materials behave differently depending for example on the weather. The designer must be familiar with their physical and chemical properties as well as the conditions on site," Sweco's Structural Engineering Designer **Tuomas Jaakkola** describes the requirements of the design process.

Jaakkola finds the Pudasjärvi project interesting because you can use the best properties of materials both in terms of structural engineering and esthetics.

DELTABEAM® GREEN LOWERS THE CO_2 FOOTPRINT

As construction generates roughly 30% to 40% of the world's waste, there is a great pressure in the construction industry for sustainability.

"We take sustainability very seriously," says Peikko's Business Director **Simo Hakkarainen**. "Peikko wants to set new standards for the whole construction industry and we are working together with our customers and suppliers to bring better and greener products into the market. The new DELTABEAM® Green is a prime example of that."

Manufactured with over 90% of recycled materials, DELTABEAM® Green is well in line with the ecological principles of the Hirsihovi project and cuts the CO_2 emissions of the beam up to 50%. In addition, it offers the benefits of a slim floor structure.

NON-SETTLING LOGS TO BE USED IN CLADDING

"This is our first apartment building project in Finland that involved logs, but I'm sure it will not be the last one," says **Hanna Haipus**, B2B Business Director of Kontio.

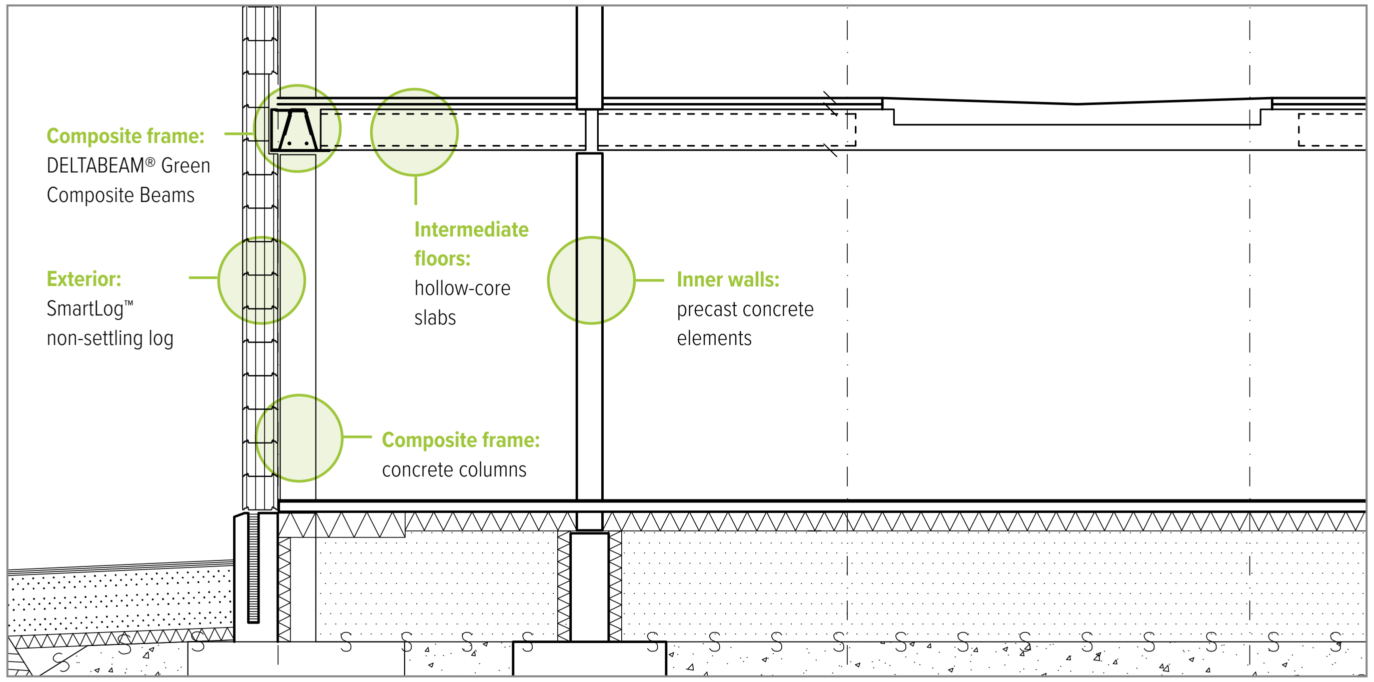
The new concept has also inspired experienced construction professionals.

"It's great to be a part of a team that's developing something new, as the choices we make today affect the future," says **Mikko Lohi**, Regional Director, Northern Finland of Rakennusliike Lapti Oy.

> **Manufactured with over 90% of recycled materials, DELTABEAM® Green is well in line with the ecological principles of the Hirsihovi project and cuts the CO_2 emissions of the beam up to 50%. In addition, it offers the benefits of a slim floor structure.**

DELTABEAM® Green

Lightening environmental footprint.



The composite frames will consist of concrete columns and Peikko's new DELTABEAM® Green composite beams. The intermediate floors will be made from hollow-core slabs, while precast elements are to be installed as interior walls. The exterior walls are to be built using non-settling logs.

PROJECT FACTS

- DEVELOPER: PUDASJÄRVEN VUOKRATALOT OY
- ARCHITECT: LINJA ARKKITEHDIT OY
- STRUCTURAL DESIGNER: SWECO
- MAIN CONTRACTOR: RAKENNUSLIIKE LAPTI OY
- LOG SUPPLIER: KONTIOTUOTE OY

Linja Arkkitehdit Oy

AMAZON BUILDS A HUGE WAREHOUSE IN SPAIN USING BOLTED CONNECTIONS WAS A LOGICAL CHOICE

Booming online business requires investments in the logistics infrastructure. Amazon meets the growing demand with a 100,000 m^2 (120,000 sq yd) warehouse.

A soon-to-be logistics hub to serve in the Madrid area, the Amazon warehouse rises three-storey high above the ground floor. The entire frame was designed with precast columns, beams and hollow-core slabs.

Thanks to previous successes, the precaster Tecnyconta-Consolis chose Peikko.

"With more than 400 columns with a length of 22 meters (72 ft) each, using bolted connections was a logical choice. Peikko´s solution increases work safety and reduces the risk of accidents," says **Óscar López de Sola**, Technical Office Manager of Tecnyconta-Consolis.

Having such a quantity of columns to erect, speed and safety are crucial for making good progress on site. A bolted connection can be installed in any weather conditions. And when the bolts have been precisely installed to the foundation, it's easy to keep the rest of the structure within tolerances.

NO PROPPING, INCREASED SAFETY, AND LESS CRANE TIME

"By using conventional column connection methods, propping would have been needed to allow the grout to cure – a work phase that not only makes the construction slower, but also is a safety hazard with the unnecessary obstructions created by the propping. Also, the risk of failing bracing was totally avoided with the column shoes," says **Adrián Liste** Sales Director of Peikko Spain.

> **More than 2,000 column shoes were delivered from Peikko to the precasters', on time.**

> **The whole frame is built in a lego-like manner – erect the columns, install the beams, and hoist the hollow-cores in place.**

The ability to easily level the column with nuts helped to keep the pace of installation high.

"As soon as the nuts are tightened, the connection is moment bearing, and the erection crew can move on to the next column. This translates into lower crane time and cost savings. The whole frame is built in a lego-like manner – erect the columns, install the beams, and hoist the hollow-cores in place," Liste explains.

MAKING HOLES TO THE HOLLOW-CORE

There are more than 100 openings in the hollow-core, so the ability to easily create them with PETRA® Slab Hangers did benefit both the design and construction phases.

"The structural designer was able to skip the time-consuming static analyses and tailor-made structural solutions. In the construction phase, the installation of slab hangers and hollow-core was straightforward," says Liste.

EFFICIENT DELIVERIES

More than 2,000 column shoes were delivered from Peikko to the precasters', on time. The anchor bolts from size M20 to M45, and around 200 customized PETRA® Slab Hangers were delivered directly to the site.

"We always aim to do the deliveries as efficiently as possible. In this case, four full truck loads were needed to transport the hardware."

The project will be completed by the end of 2021.

PROJECT FACTS

- INVESTOR: AMAZON
- CONTRACTORS: UTE FERROVIAL-INTERCON
- STRUCTURAL DESIGNER: LKS GROUP
- PRECASTER: TECNYCONTA-CONSOLIS

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PEIKKO
WHITE PAPER

Video on Youtube: Fire Tests on DELTABEAM® with Hollow-Core Slabs

DELTABEAM® IN COMBINATION WITH HOLLOW-CORE SLABS IN FIRE CASE – FIRE TEST PROGRAM 2020

AUTHOR:
Oliver Beckmann
Dipl.-Ing. (FH)
R&D Engineer
Peikko Group Corporation

Peikko's ambition to start this research project:
Assess the fire safety of DELTABEAM® in combination with prestressed hollow-core slabs to optimize the design concepts and to provide a safe and reliable solution for our customers.

INTRODUCTION

Fire safety in modern buildings has become one of the major concerns in the global construction business. With its DELTABEAM®, Peikko has not only aimed to provide a fast and efficient building solution for today's construction needs, but also focused on the demanding requirements for fire situations in multi story buildings. DELTABEAM® is a slim floor composite beam that is integrated into the height of the slab (see Figure 1). Its steel flanges support precast slab elements during assembly and the integrated fire reinforcement allows for an application without any additional fire protection. The national technical approvals have been obtained in various countries, fulfilling the local needs for fire resistance rating of 90 minutes or higher.

Prestressed hollow-core slab elements (HCS) are produced and designed according to the European harmonized standard EN 1168 within Europe and fulfill the requirements for at least 90 minutes fire resistance. Local additional design specifications may apply for the application of HCS in ambient temperature design and fire design.

Fire safety of slim floor structures consisting of DELTABEAM® composite beams and prestressed hollow-core slabs (HCS) has been investigated by Peikko in several previous fire tests.

Peikko's ambition to provide **a faster, safer and more efficient way to design and build** has been the basis for the sophisticated research project described in this paper to ensure safe and reliable solutions and guarantee reliability without surprises in the planning and execution phase to our customers.

With this research project, Peikko aimed at finding facts for optimizing design strategies about the following two specific design issues when combining DELTABEAM® with hollow-core slabs.

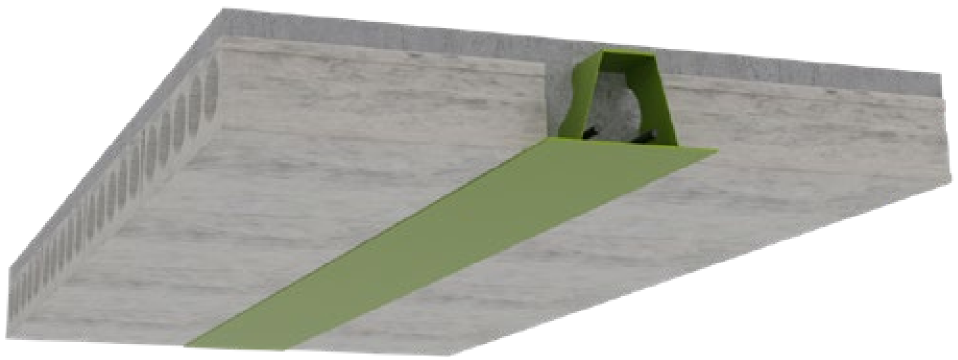


FIGURE 1 DELTABEAM® CROSS SECTION WITH HOLLOW-CORE SLABS

INDIRECT SUPPORT IN FIRE CASE

The HCS are indirectly supported when the steel bottom flange of steel or composite beams (e.g. DELTABEAM®) is exposed to fire and therefore heated up to around 1000°C after 90 minutes of ISO fire exposure. At this high temperature, the unprotected steel material loses most of its strength and stiffness. Therefore, the direct support underneath the ends of the slab elements may not be maintained during a fire.

Note: The word "indirect" used in this paper does not represent a slab hanging on its top flange. The steel bottom plate of the beam and the lower section of the inclined web provide a combined direct support underneath the slab, shifted towards the slab end, together with a compressive force supported against the end surface and the shear keys provided by the concrete grout. The simplification of the model shown in Figure 2 is based on the fact that the exact distribution and support of the compressive strut is not explained in detail.

For assessment of the indirect support, an existing design approach based on a strut-and-tie model has been applied (Figure 2). A straight horizontal reinforcement is placed through DELTABEAM® web holes and anchored in the joints and in opened voids of the HCS. This so-called transverse reinforcement ties the slab to the DELTABEAM® and ensures a proper support for the inclined concrete strut.

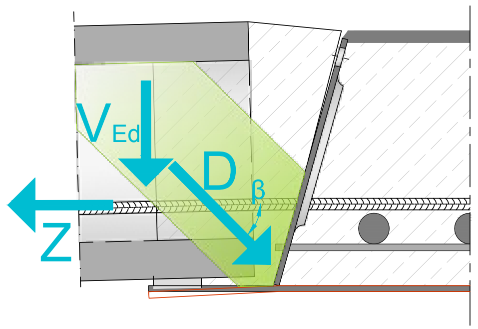


FIGURE 2 SIMPLIFIED LOAD TRANSFER MODEL FOR INDIRECT SUPPORT

FLEXIBLE SUPPORT IN FIRE CASE

When HCS are supported on flexible supports (beams bending due to vertical loads from the slab), their vertical shear resistance at ambient temperature is reduced due to additional stress in the HCS webs (cf. Roggendorf [1], Borgogno [2] et. al.).

Will this effect called **flexible support** persist in fire situation?

In current approaches for verification of flexible support at ambient temperature (see Figure 3), the deflection of the beam supporting HCS is supposed to cause additional stress in the webs of HCS elements close to the beam support (edge slabs) caused by a forced displacement c2 of the top flange of the HCS element. This additional concrete stress reduces the uncracked vertical shear resistance of HCS.

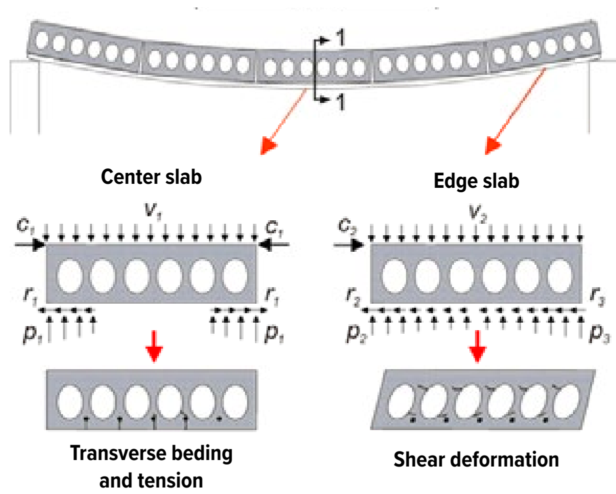


FIGURE 3 IMPOSED DEFORMATIONS AND CONSTRAINING STRESS (FROM ROGGENDORF) [1]

When exposed to fire, longitudinal cracks due to thermal expansion of the heated bottom flange will eventually develop in the slab elements, as could be observed in earlier fire tests (e.g. Borgogno [2]). This longitudinal cracking reduces the interaction between slab and beam and is assumed to release torsional stress arising from flexible support.

FIRE TESTS FOR ASSESSMENT OF BEAM-SLAB INTERACTION

A research project was started by Peikko in order to:

- Assess the indirect support in fire case of HCS on DELTABEAM®;
- Analyze the relevance of flexible support in fire case for HCS on DELTABEAM®;
- Find out if a vertical shear utilization ratio of HCS of 100% of $v_{Rd,c,fi}$ is possible (with $v_{Rd,c,fi}$= vertical shear resistance in fire case acc. EN 1168, Annex G)

For this purpose, an extensive fire testing program with

- Single HCS unit loaded shear tests at elevated temperatures, and
- Full scale system fire tests with HCS supported on DELTABEAM®

was carried out. The tests were accompanied by associated theoretical analysis including FEA calculations.

SINGLE SLAB ELEMENT SHEAR TESTS

Based on the preliminary evaluation of the existing material, single slab loaded shear tests were planned and carried out in order to back up the assumptions listed in the preceding sections of this document (cf. [3]). The focus of these tests was to:

- Calibrate FE models for analyzing other cross sections of HCS;
- Check the maximum horizontal displacement under vertical loading in fire case;
- Assess the ductility of HCS units after initial thermal and horizontal displacement induced cracking.

A set of five different slab cross sections was tested to compare the behavior of different slab geometries (amount and shape of voids, thickness of webs, thickness of top and bottom flange, prestress level, etc.). A combined loading with vertical shear forces and a horizontal forced displacement at elevated temperatures was applied.

Electrical heating mats on an upside down installation of the specimen were used to heat the HCS during an initial heating phase.

The slab elements were loaded in several steps and finally, **150% of their vertical shear resistance in fire case** ($V_{Rd,c,fi}$ acc. EN 1168) was applied without a failure at that stage. **This load level is 50% more than required for fire design proof.**

Slabs loaded with 150% of their fire design vertical shear resistance

Figure 6 shows the measured reaction forces in vertical and horizontal direction during the four loading phases of one of the slab tests. When the first major longitudinal cracking with a significant drop of the horizontal reaction force occurred (end of phase II), the horizontal displacement reached a level around 4 to 8 mm in all 5 tests. This result points out that even a single slab element without additional reinforcement, concrete grout or constraint shows a **high distortion capacity** and **sufficient ductility** for flexible shear when thermal loading and vertical shear load are present.

The single unit slab tests were successfully carried out and the results exceeded our expectations:

- All slab types performed well and comparable under combined loading with vertical shear force, elevated temperatures, and forced horizontal displacement;
- High distortion capacity and ductility of tested HCS under combined loading;
- Horizontal displacement of top flange before failure was more than 5 mm for all slabs;
- All slabs resisted a vertical shear force of 150% of $V_{Rd,c,fi}$ acc. Annex G of EN1168 even with the imposed horizontal distortion;
- Test results provide a good basis for the intended design approach and for extending this approach to all relevant slab cross sections in the market.

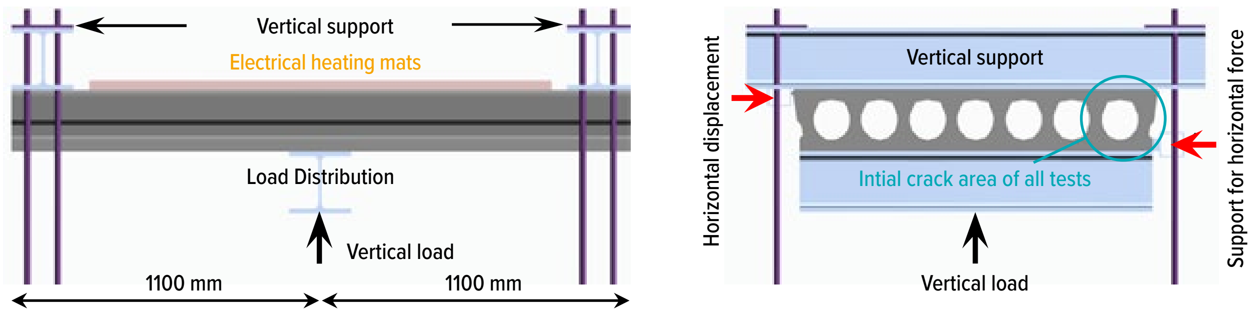


FIGURE 4 SETUP OF SINGLE UNIT SHEAR TESTS (FROM [4])

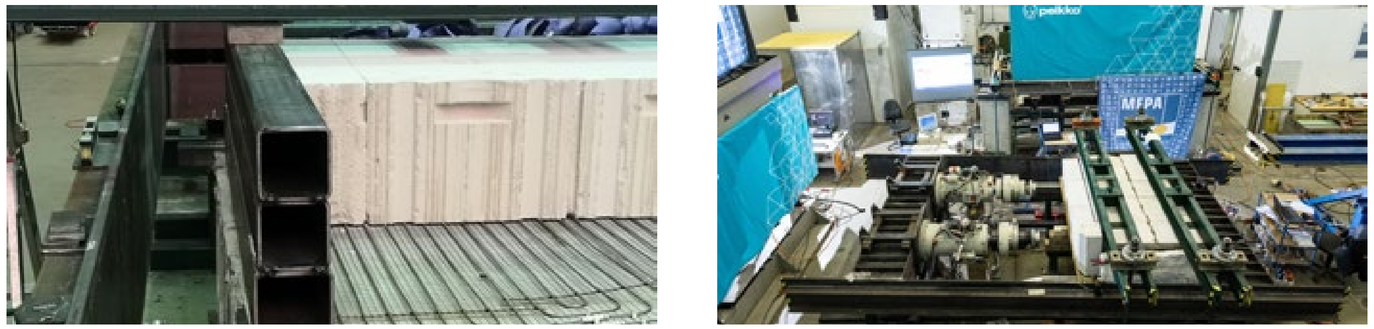
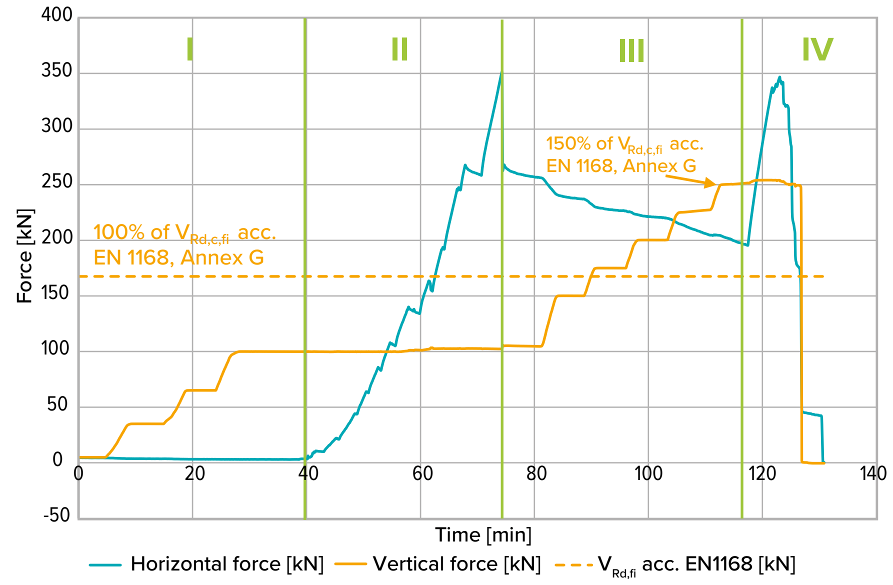


FIGURE 5 SETUP OF SMALL SCALE TESTS; A) HEATING MATS, INSULATION, AND SUPPORT STRUCTURE DURING ASSEMBLY; B) GLOBAL VIEW OF TEST SETUP



(Note: The time axis represents the load and displacement application over time, not a fire exposure time)

FIGURE 6 LOADING PHASES AND MEASURED REACTION FORCES OF SINGLE UNIT SHEAR TEST (A32V)

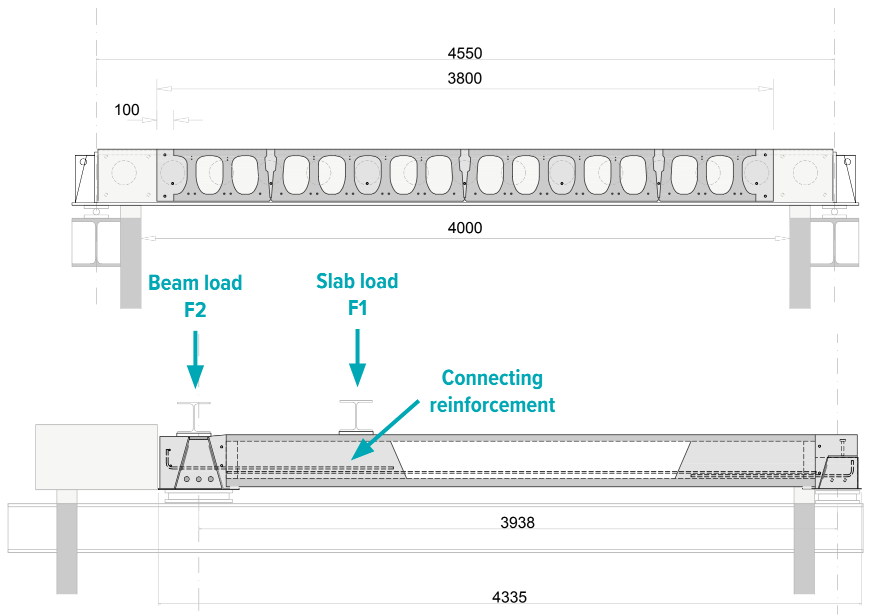


FIGURE 7 SECTIONS OF SYSTEM TEST SETUP (D32-300 WITH A32V)

FIGURE 8 – FIRE TEST SETUP DURING FIRE EXPOSURE

SLAB SYSTEM TESTS

A set of system fire tests (cf. [5], [6]) with a slab system consisting of two DELTABEAM® slim floor beams and HCS between them (see Figure 7) have been carried out.

Two different geometries of slab systems were prepared with slab and beam heights of 320mm and 200mm. The 320mm high specimen consisted of a D32-300 main beam and DW Systembau A32V 5-void HCS elements. The 200mm high specimen was assembled with a D20-400 main beam and DW Systembau A20B 7-void slabs. The DELTABEAM® at the opposite end provided limited flexibility in the slab support to limit initial torsional stress in the slab elements similar to real-life geometries. The DELTABEAM® span was 4,55 m and the slabs had a length of around 3,7 m. The slabs were connected to the DELTABEAM® with straight horizontal reinforcement.

A vertical line load was applied both on HCS and on DELTABEAM® before starting the fire exposure (Figure 7). The line load on the slabs reflected the vertical shear resistance $V_{Rd,c,fi}$ of the applied HCS elements according to Annex G of EN 1168 and was kept constant throughout the whole test procedure. The line load on the main DELTABEAM® could be varied during the fire exposure time to follow a predefined estimated deflection.

In both tests, the utilization ratio for vertical shear resistance of the applied HCS was clearly above 100% of $V_{Rd,fi}$ (see Table 1).

The fire exposure applied in the system fire tests followed the standard ISO 834 fire curve and was maintained for 100 minutes (200mm test) and >120 minutes (320mm test).

		Ambient temperature (design values)		Fire situation (R90)
Height	Slab type	$V_{Rd,ct,I}$ (uncracked) [kN/m]	$V_{Rd,ct,II}$ (cracked) [kN/m]	$V_{Rd,c,fi}$ (Annex G, EN1168) [kN/m]
200mm	DW Systembau A20B	Imposed forces: V_{Ed} = 52.4 kN/m		
	Resistance	72.9	43.4	49.2
	Utilization ratio	72%	121%	107%
320mm	DW Systembau A32V	Imposed forces: V_{Ed} = 73.7 kN/m		
	Resistance	127.9	86.3	72.5
	Utilization ratio [-]	58%	85%	102%

TABLE 1 DESIGN BENDING AND VERTICAL SHEAR RESISTANCES OF HCS (INCLUDING ADDITIONAL REINFORCEMENT)

Figure 9 shows the load and deflection of the 320mm high loaded fire test. The load level was maintained above 100% of the vertical shear resistance of the HCS units for 90 minutes fire rating and was reduced after reaching 90 minutes. The deflection of the DELTABEAM® is given with the curve "WS10" and the measured values showed excellent compliance with the estimated deflection of the beam obtained by finite element analysis (FEA).

The total measured DELTABEAM® deflection after 90 minutes reached 110 mm in this test which corresponds to a relative displacement of L/41 (142mm corresponding to L/32 was measured after 90 minutes and 150 mm respectively L/30 after 100 minutes in the 200mm test). The calculated deflection considering only the imposed mechanical loads, without thermal deflection, was as high as 65mm, corresponding to L/70.

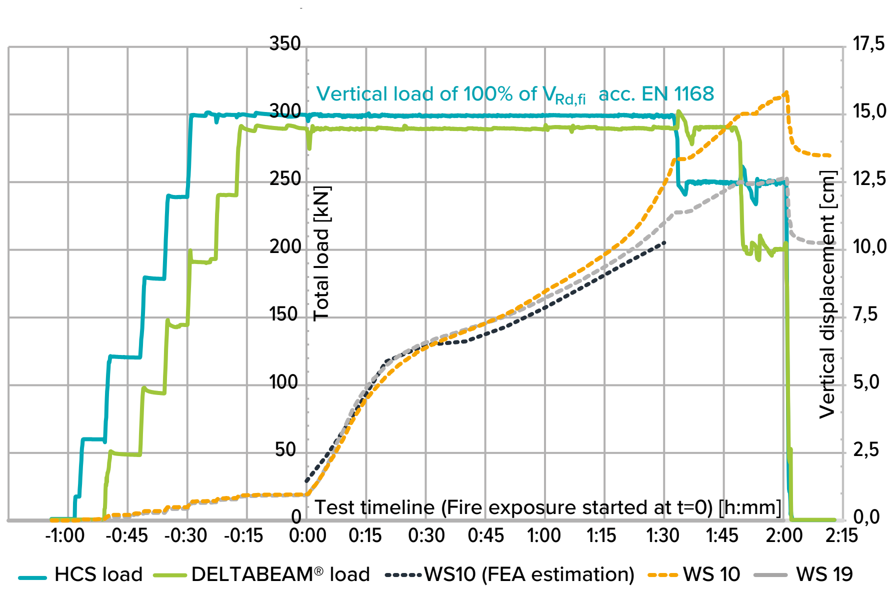


FIGURE 9 – LOAD AND DISPLACEMENT HISTORY OF 320 MM HIGH SLAB SYSTEM TEST – D32-300 WITH A32V; WS10: CENTER DELTABEAM® DEFLECTION; WS19: CENTER DEFLECTION IN LOAD AXIS ON HCS

The system fire tests were carried out successfully in proving that the **indirect and flexible support of HCS on DELTABEAM® in fire case with different heights of slabs is safely maintained.**

- ISO 834 fire exposure of 100 and 120 minutes
- Vertical shear force applied on HCS at 100% of $V_{Rd,c,fi}$ acc. to EN 1168, Annex G
- Tests were stopped after the given fire exposure time without a failure in load-bearing resistance (criterion "R"), insulation (criterion "I") or integrity (criterion "E")
- Imposed vertical shear force on the slab was resisted by the HCS units and transferred safely to the DELTABEAM®
- The suggested design approach for indirect support of HCS on DELTABEAM® steel flanges in fire case can be safely applied

Slabs loaded with 100% of their fire design vertical shear resistance

SUMMARY

The test series carried out by Peikko was a full success and exceeded the expectations with respect to ductility of the slab behavior, load transfer from slab to DELTABEAM® and vertical shear resistance of the tested HCS in flexible support situation in fire case.

It could be shown that the suggested design approach applying straight horizontal tie reinforcement for indirect support of HCS on DELTABEAM® steel flanges and inclined webs in fire case can be safely applied.

For flexible support of HCS on DELTABEAM® in fire case, it could be shown that the vertical shear resistance of the tested HCS can be safely designed according to Annex G, EN 1168. No reduction of the design resistance due to flexible support is required.

The measured beam deflections in the system fire tests, including thermal deflection, were as high as L/30 and L/41. The test results and parallel FEA calculations support that the design approaches can be adopted for other HCS sections and heights available in the market.

Overall, the test series has confirmed that the combination of Peikko's DELTABEAM® and prestressed hollow-core slabs provides a safe and reliable solution also in the event of fire.

With the results obtained from this test program, Peikko underlines its ambition to be a forerunner in the construction market.

It is noted that the test results and the design models are clearly depending on the geometry of the supporting DELTABEAM® cross section and its specific details like the inclined steel webs and round web holes with straight reinforcement for shear connection, designed according to the applied design models. The behavior of other types of beams, even with similar geometry, cannot be derived from the tests and the underlying research papers.

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[4] M. Cyllok, S. Pessel, S. Hothan und D. Häßler, „Gutachtliche Stellungnahme "Zur biegeweichen und indirekten Auflagerung von Spannbetonhohlplatten auf Slim-Floor-Trägern "DELTABEAM®" im Brandfall - Abstimmung Validierungsversuche"," 2018.

[5] MFPA Leipzig GmbH, „Prüfbericht Nr. PB 3.2/19-251-2 - Belasteter Brandversuch," Leipzig, 2020.

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VISTAS OF VILNIUS – BEST ENJOYED FROM THE BALCONIES

To appreciate the city buzz and the splendid view of the Gediminas' Tower on the south side of the river Neris, Raitininkų Sodas Apartment Complex called for large and airy balconies.

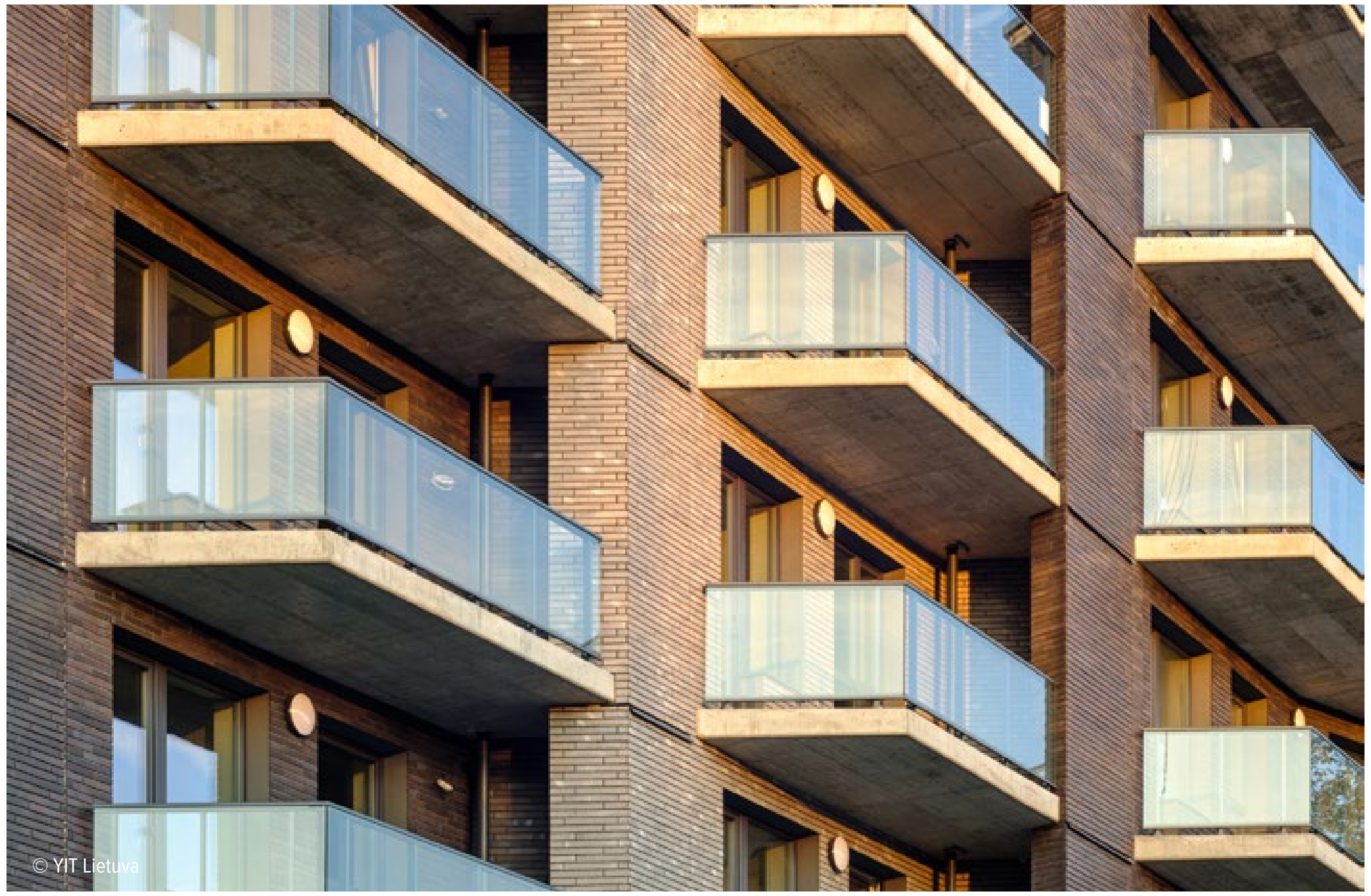
The Lithuanian architect Karolis Radiūnas has created a high quality, seven-storey residential block in downtown Vilnius, Lithuania.

"Designed and built in Scandinavian high quality standards, the balconies really are the architectural highlights of the project," says Peikko's Sales engineer **Arnoldas Tumėnas**.

However, to meet the strict Class A energy efficiency requirements, the balcony connections needed effective thermal insulation.

"Without the thermal breaks, there would have been substantial energy loss through the connections," Tumėnas notes.

The solution was the load-bearing and insulated EBEA® Balcony Connector developed especially for use with cast-in-situ balconies.



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"Peikko delved into the project and helped to adapt a non-standard balcony connection. We discussed the project with engineers from Lithuania and Hungary – they answered all the questions as well as submitted the necessary reports and plans. Peikko helped to save time in installation and reduced the possibility of mistakes on site. Together we achieved a great result," describes **Raimondas Druskinis**, Structural engineer of Vilniaus Architektūros Studija.

A DAY OF LABOR SAVED PER FLOOR

Peikko supplied the project with 568 pieces of EBEA® Balcony Connectors and 4.6 tons of PSB® Punching Reinforcement.

"Using customized EBEA® connectors with longer reinforcement rebars saved a day of assembly time per floor," says **Mantas Grigalis**, Construction manager of YIT Lietuva.

With the PSB® Punching Reinforcement, floors are slim, column capitals are not needed, and there are no obstructions in the ceiling.

> **Using customized EBEA® connectors with longer reinforcement rebars saved a day of assembly time per floor**

"Peikko provided optimal solutions and precise element layout plans that were double-checked by the main designer. The project went smoothly, with a convenient delivery schedule according to the construction stages, which allowed us to use the narrow space of the construction site efficiently," points out Grigalis.

Carried out in two stages, the Raitininkų Sodas apartment complex will comprise of a total of 210 apartments and 21 commercial premises. YIT Lietuva invested 34.6 million euros in the apartment complex and 17.2 million euros in the development of the commercial premises.

PROJECT FACTS

- ARCHITECT: KAROLIS RADIŪNAS
- STRUCTURAL DESIGNER: VILNIAUS ARCHITEKTŪROS STUDIJA
- CONTRACTOR: YIT LIETUVA

WOOD WITH LONGER SPANS, OPEN SPACES AND SLIM FLOORS?

YES, WITH THE DELTABEAM® HYBRID FRAME AND MASSIVE TIMBER

Hopealaakso kindergarten is currently being built in Helsinki, Finland. The frame is made of solid wood elements and DELTABEAM® Composite Beams.

The developer of the kindergarten, the City of Helsinki, organized a "design and build" competition. The frame solution was not specified in the call for tenders, so each participant suggested a frame of their choice. The winner was decided on price, architecture and environmental issues.

"It became clear that we were the only one of the four finalists to offer a timber-structured option. We assume that a timber-framed option was not more expensive to build than concrete, even though weather protection was included in the tender," recalls Project manager **Janne Manninen**.

ENTER THE DELTABEAM®

As the aim of the frame solution was to achieve long spans, open spaces, and slim floors, the DELTABEAM® was a conscious choice.

"We used DELTABEAM® to make full-height cross-laminated timber elements work as floor-height walls. This kept the number of elements and joints much smaller," says Manninen.

According to Puurakentajat Rakennus Oy – the sub-contractor for the frame – the hybrid frame solution works well, as it does not present any special needs for the construction.

"When erecting the frame, the composite beams were mounted on the walls and screwed on. Using wood beams would have left much less room for technical installations," explains **Jyrki Huttunen**, CEO of Puurakentajat Rakennus Oy.

Another bonus, the wood-concrete intermediate floor provides sound insulation especially suitable for kindergartens.

THE FIRST IS BOUND TO GET SEQUELS

Puurakentajat used DELTABEAM® for the first time at the Hopealaakso site. The designs had been done so well that there were no problems during the installation.

"They are certainly easy to install at the site, since the requirements of building technology have been taken into consideration as regards perforations, for example," says Jyrki Huttunen.

According to Manninen, there are weighty reasons – interior air quality and CO_2 emissions – why the choice of the building material is increasingly directed at wood in Finland.

It is possible that reducing carbon footprint will gain in importance in future. This would favor the choice of DELTABEAM® Green, an even more environmentally friendly composite beam.

Huttunen and Manninen's future construction sites in Helsinki are Pakilanpuisto school and Verkkosaari kindergarten. Both buildings will be constructed with the same concept, a wood frame with DELTABEAM® composite beams.

PROJECT FACTS

- ARCHITECT: AFKS ARCHITECT
- DEVELOPER: CITY OF HELSINKI KYMP/RYA
- MAIN CONTRACTOR: OY RAKENNUSPARTIO
- WOOD FRAME CONTRACTOR: PUURAKENTAJAT RAKENNUS OY
- GROSS AREA: 2,150 GROSS m^2 (2,570 sq yd)

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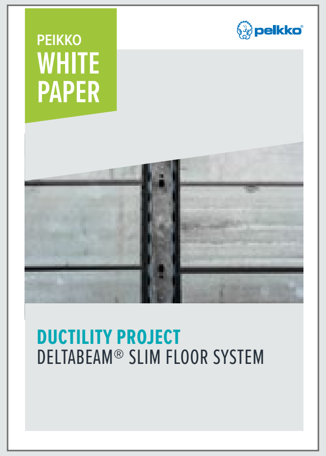
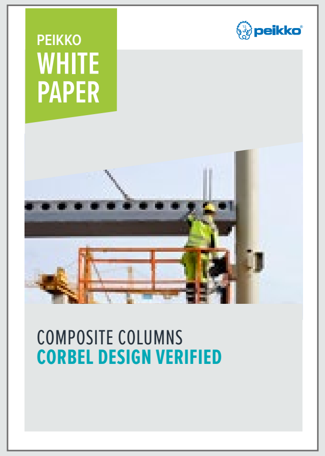
White Papers, authored by our Product and Development professionals, provide you a broader insight into the technical features and latest developments of our products and solutions. White Papers go deeper into technical issues, cases and trends, and explain their causes, implications, and benefits.

Have a look at the White Papers that have been published earlier this year.





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PEIKKO
WHITE
PAPER

TALL BUILDING SOLUTIONS

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INTRODUCTION

Tall Buildings are a product of our time and a globally accepted solution to densification, lack of land, growing population and reducing commute time.

Although Tall Buildings play an important role in modern society, this type of construction presents unique challenges for all parties involved in their design and construction. With over 50 years of experience in building design of all heights, Peikko can help stakeholders to make their next Tall Building more efficient to build and operate.

This document will explain best practices of Peikko's products and solutions in Tall Buildings from all over the world.

1 DEFINITION OF TALL BUILDING

High-Rise Building, Tall Building and Multi-story Building – are different terms having one meaning.

The Council on Tall Buildings and Urban Habitat mention height relative to context, proportions and tall buildings' embracing technologies as criteria which can determine whether the building can be classified as a "Tall Building" [1].

> "If a building can be considered as subjectively relevant to one or more of the above categories, then it can be considered a tall building. Although number of floors is a poor indicator of defining a tall building due to the changing floor-to-floor height between differing buildings and functions (e.g. office versus residential usage), a building of 14 or more floors – or more than 50 meters (165 feet) in height – could typically be used as a threshold for a "tall building."
>
> (The Council on Tall Buildings and Urban Habitat)

FIGURE 1 CTBUH HEIGHT CRITERIA THAT CAN HELP IN CLASSIFICATION OF THE BUILDING [1]

2 DRIVING ASPECTS IN TALL BUILDING DESIGN

As a building grows taller, the vertical loads increase with the height of the building. At the same time, horizontal loads start to increase rapidly and significantly affect the Tall Building. Under lateral loading, the building behavior can be compared to a cantilever beam with its base fixed in the ground. When wind loads are acting on the top level of the building, a significant moment is generated at the base of the structure (Figure 2). The columns on the side where the wind load is applied are subject to tension forces, while the columns on the opposite side of the building are subject to compression forces. Therefore, Tall Buildings must have adequate shear and bending resistance and must not lose vertical load-bearing capability.

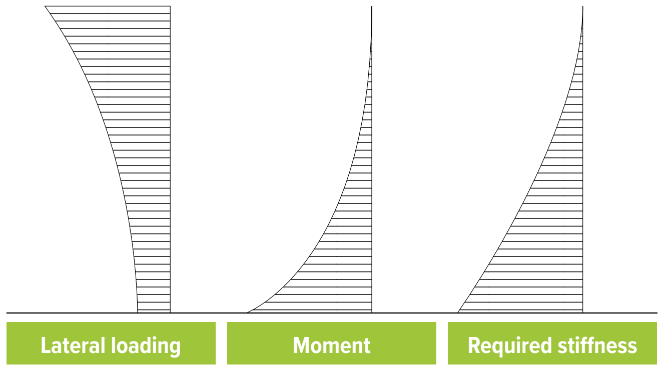


FIGURE 2 WIND LOAD, MOMENT, AND STIFFNESS DIAGRAM FOR A TALL BUILDING

Worldwide Tall Building design practices are different and might be governed by a combination of gravitational, wind and seismic loads, depending on the local building code. The design for a Tall Building in Tokyo will likely be governed by seismic loads, while the design for a building in Copenhagen – by wind loads. Lateral loads of seismic forces increase in direct proportion to acceleration of ground motion and the mass of the building. If the ground motion acceleration or the building mass is doubled, the horizontal force will be doubled as well.

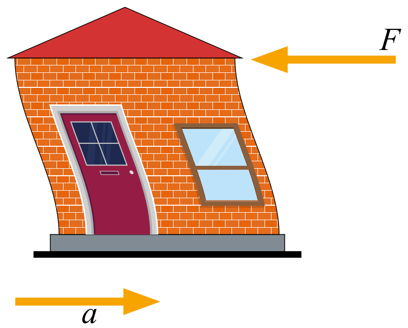


FIGURE 3 NEWTON'S SECOND LAW OF MOTION, WHERE "F" IS INERTIA FORCE AND "A" IS ACCELERATION

Unfortunately, the structural design of a Tall Building is not as simple as described in Newton's Law, and it contains many additional variables and considerations to be solved. But no doubt the main design objective is adequate lateral stiffness of the building. In principle it would require a structural engineer to satisfy two serviceability criteria – lateral deformation (deflection, drift) and motion perception (acceleration, vibration).

Satisfying the first means limiting the maximum lateral displacement at the top of the building and inter-story drifts separately. For a total drift of the building, there is a commonly used drift index that is expressed as ratio of the maximum deflection at the top floor of the building to the total height of the building. Even though many international design codes do not apply limits on total lateral deflection of the building, the rule of thumb for the limit is between h/400 and h/600. The main purpose of controlling deflection is enabling non-structural elements of the building to function properly. Practical ways of limiting drift can be to increase the bending stiffness of the horizontal members, adding stiffeners like shear walls or core, or even designing stiffer connections.

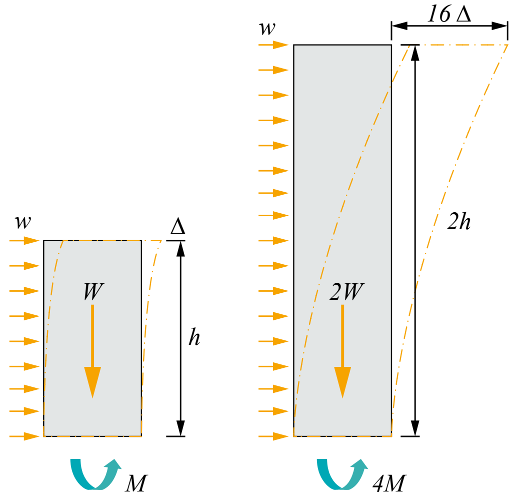


FIGURE 4 LATERAL DEFLECTION DIAGRAM OF SHORTER AND TALLER BUILDINGS

The second criteria is ensuring the occupant's comfort level, which is dictated by the amount of wind induced movement. Tall Buildings can be allowed to sway considerably, but the acceleration (the rate at which its movement increases) must be damped within acceptable limits. Those limits are based on the sensitivity of our inner ear to motion. Since humans are more sensitive to motion when lying down, residential buildings typically allow less acceleration than commercial office buildings. Acceleration can be damped in different ways, including stiffer structure or sometimes with the use of supplementary damping such as Tuned Mass Dampers. A Tuned Mass Damper limits the horizontal acceleration by mechanically shifting a large mass in the opposite direction of the applied lateral forces.

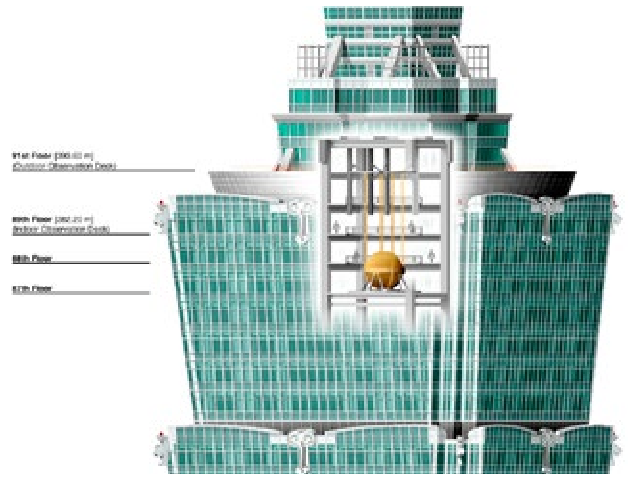


FIGURE 5 THE TUNED MASS DAMPER IN TAIPEI 101 [2]

3 STRUCTURAL SYSTEMS OF TALL BUILDINGS

Strength, lateral stability and rigidity are the main requirements for the structural design of Tall Buildings.

For decades, structural engineers all around the world have been improving the performance and efficiency of lateral stability systems through countless iterations and with the ever-increasing help of structural design softwares.

Moving major resisting structure from perimeter towards the interior of the building, wrapping the building into a diagrid web, splitting the building into several tubes standing next to each other – these are just some examples of structural systems' evolution, which are still valid nowadays, but used in more comprehensive ways. The most common classification to describe Tall Building structural systems is shown in Figure 6.

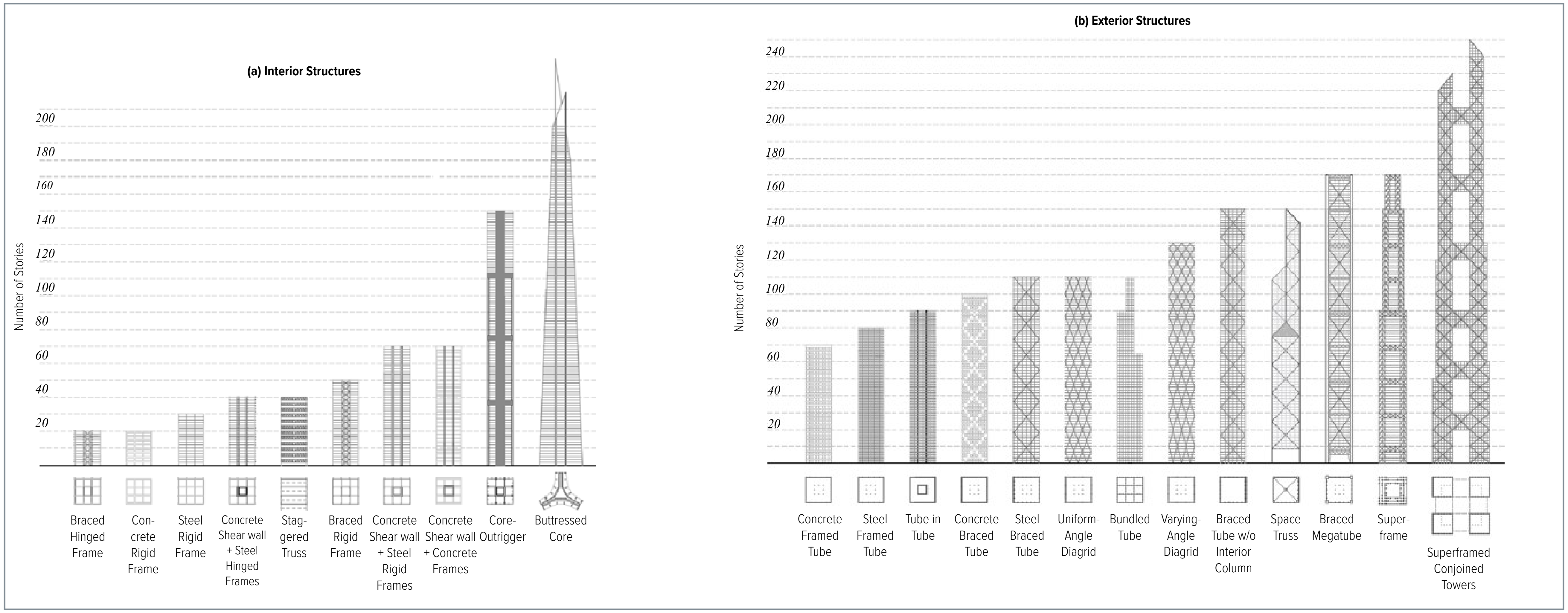


FIGURE 6 CLASSIFICATION OF TALL BUILDING STRUCTURAL SYSTEMS BY MIR M. ALI AND KYOUNG SUN MOON [3]

One of the first structural systems from which other systems started to evolve was a rigidly jointed structural frame. The core idea was to place as much vertical load-carrying elements as possible on the periphery of the building to maximize its ability to resist angular acceleration. The angular acceleration resistance of a building can be explained by Newton's 2nd Law - $\alpha=\frac{\sum\tau}{I}$, where α is an angular acceleration, $\sum\tau$ – a net torque and I – a moment of inertia. A structural system that has large moment of inertia will resist acceleration more easily. An effective way to increase the moment of inertia is to move the mass away from the center of the building ($I=mr^2$, where m is a point mass and r^2 is a radius from the axis squared).

Rigid frames, also called moment resisting frames, typically consist of beams and columns connected by rigid joints that minimize relative rotation between the two structural components. In this system, both gravity and lateral loads are resisted by the bending action of the main frame elements i.e. beams and columns. Lateral stiffness of the entire frame is dependent on the bending stiffness of its elements.

As seen in Figure 8, rigid or moment-resisting frames have bigger deflection and drift than the shear walls. Each of the above-mentioned structures have strengths and weaknesses. To overcome shortcomings of a single structural system, a natural idea is integrating strengths of different systems to obtain desired behavior of the Tall Building. Rigid frames are economical for buildings roughly up to 25-30 floors, above which their drift resistance is costly to control. If, however, a rigid frame is combined with shear wall system, the resulting structure becomes much stiffer, enabling the building to rise roughly up to 60-70 floors. To reach Super Tall Building's reference mark, the resulting structure generally has to be more complex than just the combination of two above-mentioned systems.

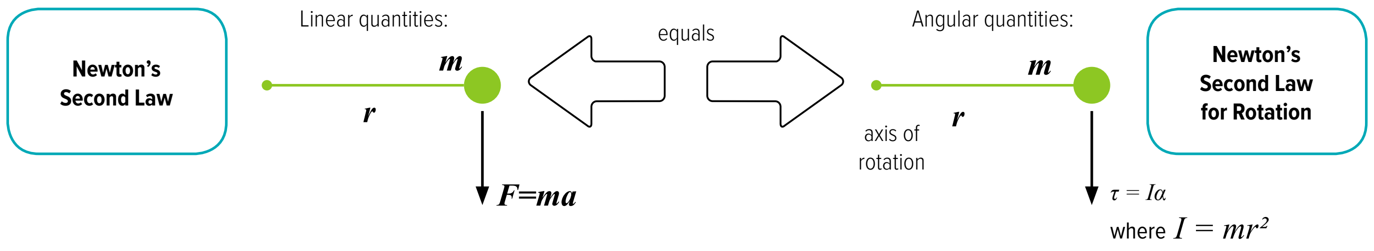


FIGURE 7 VISUALIZATION OF NEWTON'S SECOND LAW FOR ROTATION

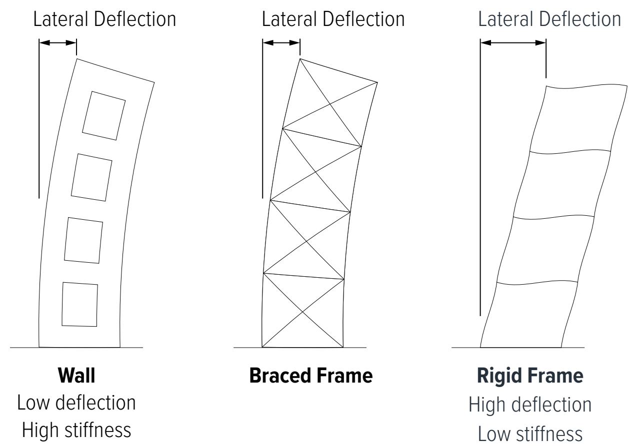


FIGURE 8 CHARACTERISTICS OF RIGID, BRACES FRAMES AND WALL SYSTEM

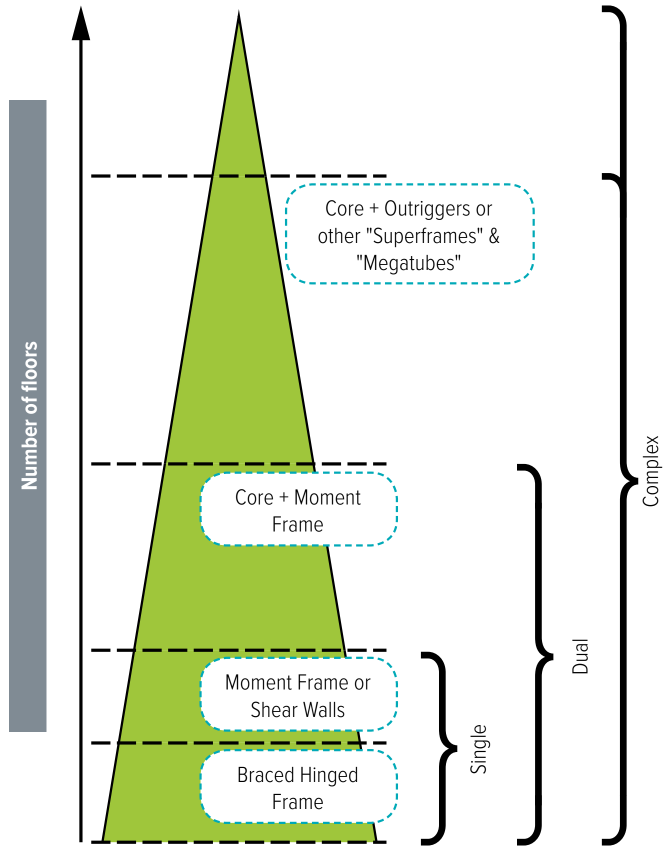
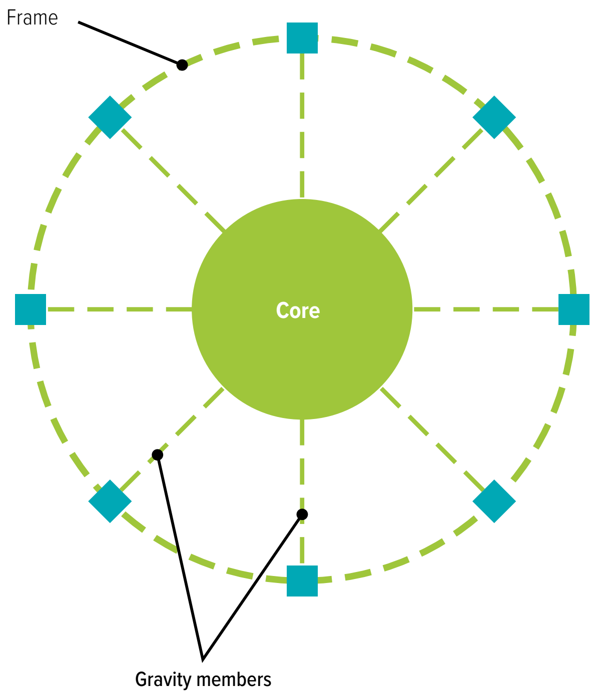


FIGURE 9 SCHEMATIC DIAGRAM OF SYSTEM TYPES FOR VARIOUS BUILDING'S HEIGHTS

4 PEIKKO'S PRESENCE IN TALL BUILDINGS

Regardless the structural system chosen by the structural engineer, the connections between elements are vital in every Tall Building. One of the most important aspects of lateral force design is the connections between the structural elements of the building. Over the years, Peikko has developed multiple solutions to simplify the design and installation of connections for securing structural elements together.



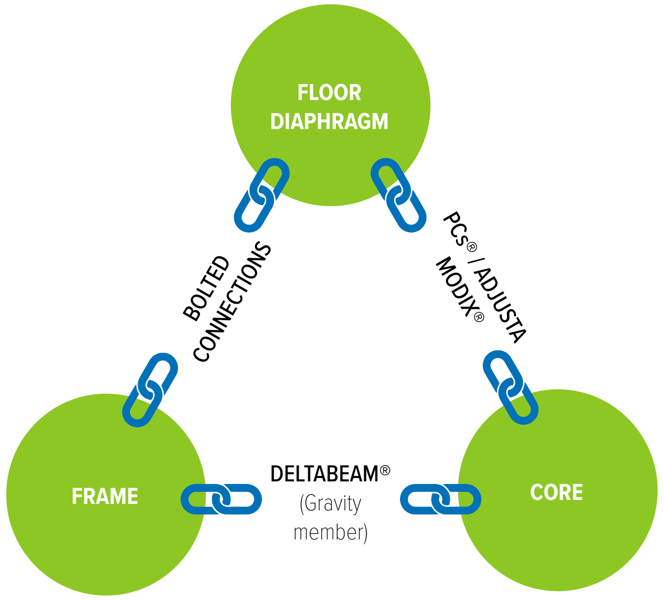
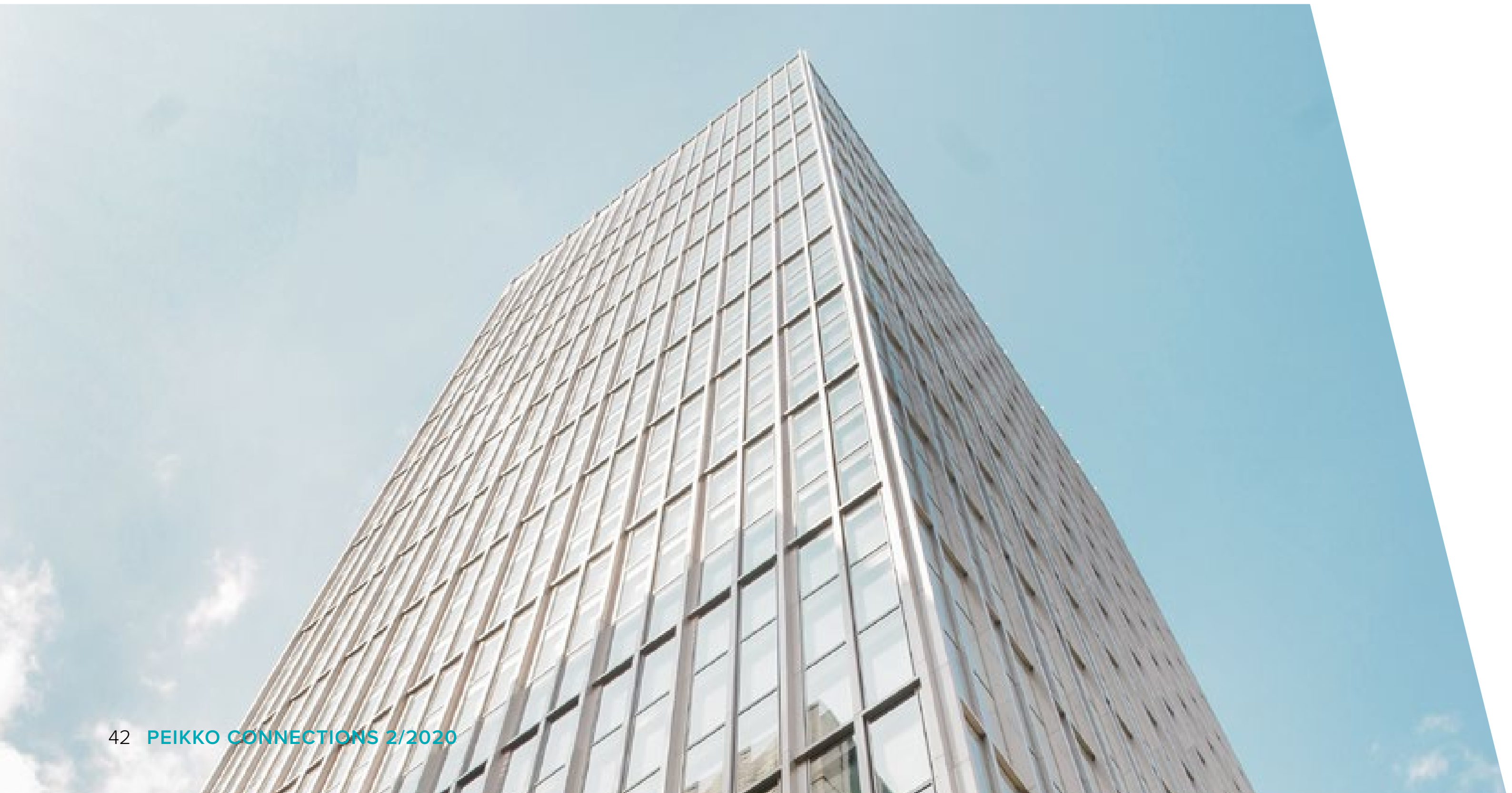


FIGURE 10 SCHEMATIC REPRESENTATION OF SOME PEIKKO'S SOLUTIONS IN TALL BUILDINGS



4.1 OPTIMIZING THE SIZE OF FOUNDATION (EFFICIENT FOOTINGS AND FOUNDATIONS)

MONDE CONDOMINIUMS IN TORONTO, CANADA

Project data:
30 floors
Building type – Residential
Developer – Great Gulf
Construction Company – Tucker Hirise
Structural Designer – RJC (Read Jones Christoffersen)
Architect – Quadrangle Architects
More info – Peikko Canada Inc.

In this project, Peikko's double-headed shear rail system is not tying structural elements together, but contributing to their elements in geometry and construction process. Depending on the market requirements (compliance with local design standards and material standards) you will find PSB® Punching Reinforcement and ARMATA® Punching Reinforcement in Peikko's portfolio. The purpose of such shear rail systems is to prevent punching shear failure in flat slabs. The same solution works for foundations, beams and even walls. Monde, a high-rise project in Toronto, in particular is using a shear rail system in the foundation walls of five-level underground parking. Kumbo Mwanang'onze from RJC Consulting Engineers is the head structural engineer for Monde. "The underground parking proved to be a challenge due to the earth pressure applying high shear forces on foundation walls" he explains. ''Earth density is usually 2000 kg per cubic meter. In the presence of ground water, the pressure on foundation walls rises considerably, increasing the shear force on walls at either side of the slabs'' points out Mwanang'onze. Because this site is located directly adjacent to Lake Ontario, the walls are designed on the assumption of the water-table being at ground surface. For a 5-story underground structure, this pressure creates high shear forces on both sides of each suspended slab. Easy to install stud rails were specifically designed to resist these shear forces. Traditionally, rebar stirrups are used to strengthen foundation walls against shear forces, but they are labor-intensive. Compared to working with rebar stirrups, shear rails greatly reduce onsite manual labor. Installation is simply done with two workers: one hanging stud rails on the wall rebar, another tying the stud rails to the rebar. This solution is not only enabling cost effective construction process, but also improves the design itself. Compared to working with a thickened foundation wall, shear rails make your walls thinner and therefore increase your interior space for parking.

FIGURE 11 MONDE CONDOMINIUMS IN TORONTO

PSB® Punching Reinforcement

ARMATA® Punching Reinforcement

FIGURE 12 MONDE'S UNDERGROUND FOUNDATION WALLS DONE WITH ARMATA® PUNCHING REINFORCEMENT (LEFT). CROSS-SECTION OF THE WALL WITH PEIKKO'S PUNCHING REINFORCEMENT (RIGHT).

FIGURE 13 SIDE VIEW OF THE MONDE'S FOUNDATION WALL

Installation pace was 80 rails per hour with only 2 workers. If we take an average of 10 studs per rail, this is the equivalent of placing and fixing 800 stirrups in one hour with 2 workers.

4.2 REDUCING FLOOR-TO-FLOOR HEIGHT WITH SLIM STRUCTURES

300 MAIN IN WINNIPEG, CANADA

Project data:
142 meters
42 floors
Building type – Commercial and residential
Construction Company – Marwest
Structural Designer – Crosier Kilgour & Partners Ltd.
Architect – Raymond SC Wan Architects
More info – Peikko Canada Inc.

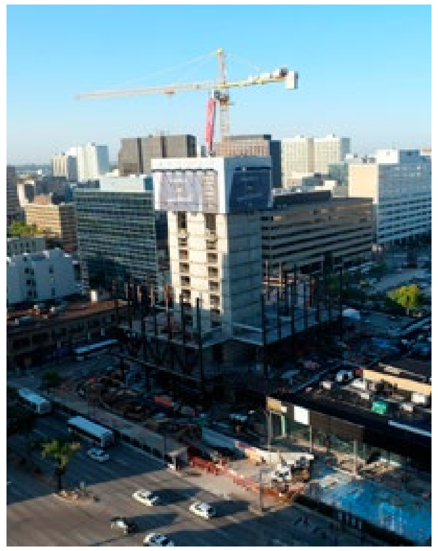
DELTABEAM® Composite Beam

It's no secret that developers want to maximize the number of floors in order to get more rentable space within a certain height allowance. Slim Floor Structures help to address this need very successfully. By reducing the floor plate thickness, floor-to-floor height becomes lower. Which in turn yields more floors for a given building height. 300 Main, a 42-story building on the corner of Main Street and Graham Avenue in Winnipeg, uses the Slim Floor concept as well. A typical floor in 300 Main is a combination of DELTABEAM® Composite Beams and hollow-core slabs. Grout fill is used to tie the beams and slabs together and create composite action on-site. The other option of using hollow-core slabs with wide flange steel beams was also considered for the new tower but this solution would have resulted in a building at least 15m (50 ft) taller, which would have increased the total price of the project significantly. DELTABEAM® Composite Beams instead have saved overall height of the building to add additional floors and maximize the building total square footage.

Another powerful argument in favour of Slim Floors is reduced weight of the overall structure, which in turn makes foundation less expensive. In this case, 300 Main's new tower is using the same foundation pad as 360 Main, an adjacent 30-story tower built in 1979. Since the combination of DELTABEAM®, hollow-core slabs and steel columns is much lighter than 360 Main's cast-in-place structure, the developer was able to increase the number of floors from 30 to 42 using the same foundation pad as the 30 story building.

The added advantage of DELTABEAM® Composite Beams 2-hour fire rating without additional fireproofing also provided substantial savings. The underside of these floors is commonly used as a finished ceiling that is smooth and regular.

FIGURE 14 300 MAIN IN WINNIPEG © RAYMOND SC WAN ARCHITECTS AND SAFDIE ARCHITECTS



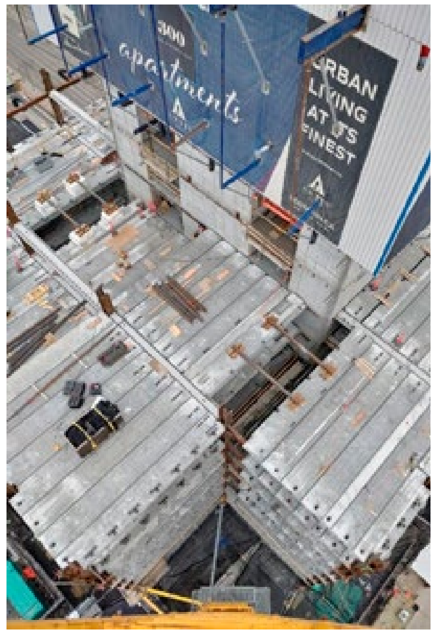


FIGURE 15 LEVEL 21 OF 300 MAIN TOWER. DELTABEAM® AND HOLLOW-CORE SLAB LAYOUT.

GLASSHOUSE IN WINNIPEG, MB, CANADA

Project data:
21 floors
Building type – Residential
Developer – Urban Capital
Construction Company – Bockstael Construction Ltd.
Structural Designer – Crosier, Kilgour & Partners
Architect – Stantec Architecture Winnipeg
Precaster – Haywood
More info – Peikko Canada Inc.

DELTABEAM® Composite Beam

Just as in the previous project, DELTABEAM® Composite Beams have played an important role in meeting the needs of the architect, structural designer and contractor. The architects of the Glasshouse project in Winnipeg were looking for a solution that would incorporate a slab thickness of 9 to 10 inches (roughly 229 to 254 millimeters). DELTABEAM® Slim Floor Structure was the perfect solution, allowing the top and bottom planes to include both the structural floor and the structural beams in a 9-inch-deep system, without the beams projecting below the slab. DELTABEAM® reduced the structural depth of each floor by 16 inches, which translated into 2 extra floors compared to conventional structural technology.

DELTABEAM® Slim Floor Structure allows for a rapid speed of erection due to the prefabrication of slabs and steel frame. DELTABEAM® Composite Beams were connected to the columns using Peikko's modular PCs® Corbels, which were factory-welded to the steel columns to provide lego-like ease of installation. Flat ceilings also meant straightforward HVAC installations that further reduce building time.

An additional bonus at the Glasshouse building site was that DELTABEAM® Composite Beams did not require intumescent coating. Intumescent paint is the standard industry procedure if the steel is exposed, but this has to be done on site. It can also take some time, as you need a primer, base coat and decorative topcoat. None of this was needed with DELTABEAM®, as the beam is cast in concrete. To prove the point, DELTABEAM® was UL-tested to achieve 2-hour, 3-hour and 4-hour ratings with no additional fire protection on the beam.

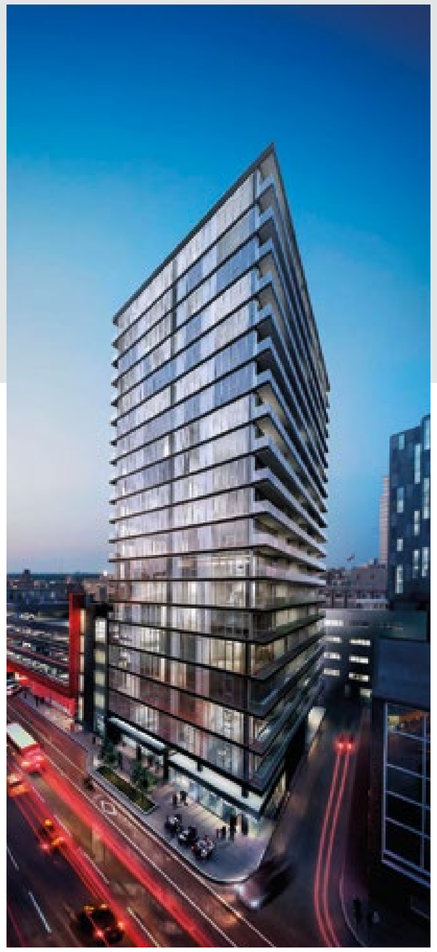


FIGURE 16 GLASSHOUSE

FIGURE 17 SIDE VIEW TO CONSTRUCTION SITE OF GLASSHOUSE (LEFT). DELTABEAM®– STEEL COLUMN CONNECTION (RIGHT).

ÖBB CORPORATE HEADQUARTERS IN VIENNA, AUSTRIA

Project data:
88 meters
23 floors
Building type – Commercial
Developer – ÖBB, Wien
Construction Company - ARGE Habau – ÖSTU-Stettin
Structural Designer – Thomas Lorenz ZT, Graz
Architect – Zechner & Zechner ZT, Wien
Precaster – MABA Fertigteilindustrie, Micheldorf
More info – Peikko Austria GmbH

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Reinforced concrete slabs have been used in ÖBB Headquarters, supported by high-strength precast concrete columns and shear wall cores. Generally, in-situ flat slabs are characterized by the absence of the beams. Whatever loads are exerted onto the slab are transferred directly to the columns, so the columns tend to punch upwards through the slab. To avoid drop panels over column positions in the slab, and to accommodate high shear stresses, Peikko's PSB® Punching Reinforcement was applied in combination with CUBO Column Caps. The thickness of the slab was kept at a relatively low level with the help of PSB® and CUBO. Part of the concrete columns were produced in a precast element factory and delivered with the CUBOs installed. This solution was chosen due to high quality demands defined under Execution Class 3. Peikko also delivered special Fastening Plates to connect inclined precast concrete columns to the slabs.

FIGURE 18 PSB® PUNCHING REINFORCEMENT AND CUBO COLUMN CAP (LEFT). PRECAST CONCRETE COLUMNS WITH SPECIAL FASTENING PLATES (RIGHT).

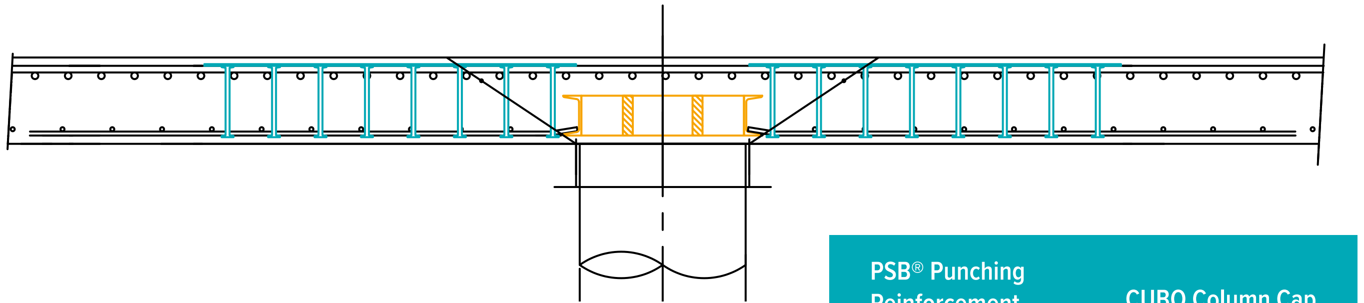


FIGURE 19 FLAT SLAB CROSS-SECTION THROUGH THE COLUMN AT ÖBB HEADQUARTERS.

PSB® Punching Reinforcement

CUBO Column Cap

LIGHTHOUSE IN AARHUS, DENMARK

Project data:
142 meters
43 floors
Building type – Residential
Construction Company – Per Aarsleff A/S
Structural Designer – Rambøll A/S
Architect – 3XN A/S
More info – Peikko Danmark ApS

PSB® Punching Reinforcement

Post-tensioned flat slabs are used for almost every floor of the Lighthouse Tower in Aarhus, Denmark. Post-tensioning helped to achieve the formation of 200 mm thin slabs with up to 8.2m long spans devoid of any column-free spaces. The flat slabs are supported by the central core and the blade columns on the perimeter of the building. In addition, the outrigger action, where the slab is rotationally fixed to the columns and the core, was employed to increase the stiffness of the building against wind loads and vibrations. These requirements made the column-slab connection design very critical, and the high loads on the connections required the use of punching reinforcement for all floors. Peikko's PSB® Punching Reinforcement was selected because the ETA (European Technical Assessment) allows for a higher upper limit of punching capacity than the one provided in the generic Eurocode. Lighthouse Tower is scheduled to be completed in 2022.

FIGURE 20 VISUALIZATION OF LIGHTHOUSE TOWER, ©RUNE KILDEN [4]

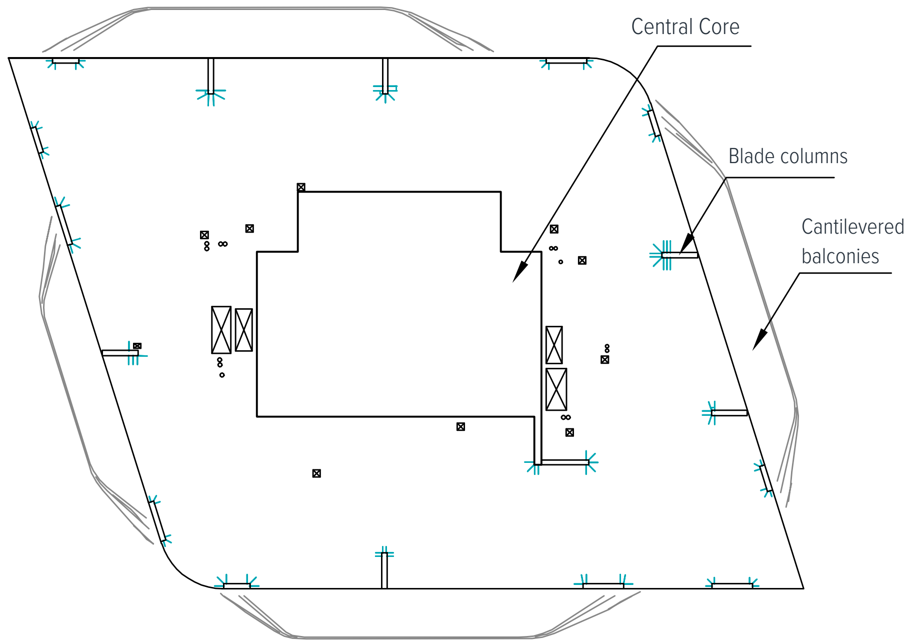


FIGURE 21 STRUCTURAL LAYOUT OF A TYPICAL FLOOR AT LIGHTHOUSE, ©RAMBOLL.

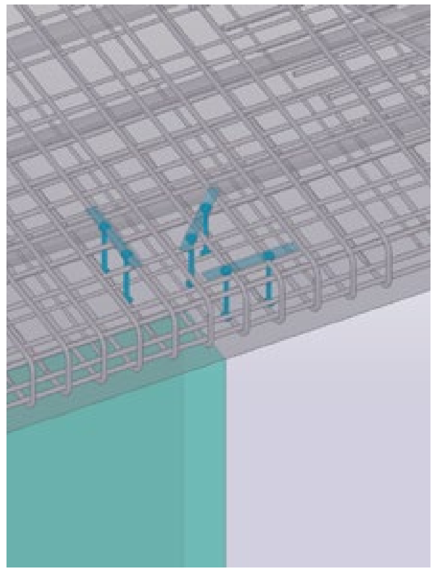


FIGURE 22 PUNCHING SHEAR DESIGN OF A SLAB WITH PSB® PUNCHING REINFORCEMENT AT BLADE COLUMN ENDS, ©RAMBOLL

4.3 ENABLING CLIMBING FORMWORK FOR SHEAR WALL CORES

TAUNUS TURM IN FRANKFURT, GERMANY

Project data:
170 meters
40 floors
Building type – Commercial
Developer – Tischman Speyer, Commerz Real AG
Construction Company – Ed. Züblin AG
Architect – Gruber + Kleine-Kraneburg
More info – Peikko Deutschland GmbH

FIGURE 23 TAUNUS TURM

PCs® Corbels

PC® Beam Shoes

Taunus Turm was designed with closely spaced precast concrete columns along with cast-in-situ shear wall core in the center. The space between the core and perimeter was bridged by prefabricated concrete beams with filigree planks grouted with in-situ concrete. These composite floors act as diaphragms, resisting horizontal forces and transferring them from columns on the perimeter to the central core, which then takes the forces to the ground.

FIGURE 24 STRUCTURAL LAYOUT OF A TYPICAL FLOOR AT TAUNUSTURM, ©ED. ZÜBLIN AG (LEFT). BEAM-TO-WALL CONNECTION WITH PCS® HIDDEN CORBEL (RIGHT).

Cast-in-situ reinforced concrete shear walls and cores are widely spread in Tall Buildings. In-situ concrete technology is favored by engineers due to the structural continuity it provides to the elements. On the other hand, nowadays we can see a clear increase in use of precast concrete technology in Tall Buildings. What makes precast a worthy choice now? Main advantages are its high speed of construction, reduced shoring requirements and an easier quality assurance process to implement. A major challenge in the TaunusTurm was the limited space available on the building site, thus the storage capacity in the upper floors of this tall building was very limited. Prefabricated concrete columns, beams and slabs were selected for the project to eliminate the need for space consuming formwork. To simplify construction, Peikko's PCs® Corbels were implemented to support precast concrete beams while having slipform construction technique for the core. Peikko's PCs® Corbels allowed for the erection of straight mold walls, and at the same time it allowed for the support of beams without having projecting concrete corbels out of the shear walls.

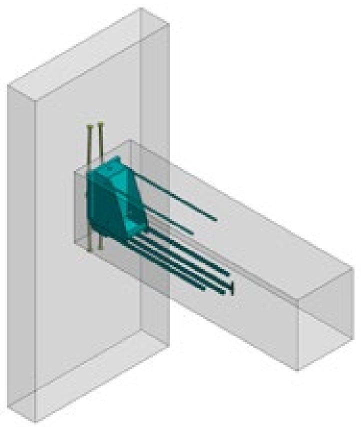


FIGURE 25 ASSEMBLY OF PCS® CORBEL COLUMN PARTS ONTO WALL MOLDS

PCs® Corbels were cast in the shear walls, while matching PC® Beam Shoes were embedded in the precast concrete beams' ends. The corbel plates supporting the beams were bolted after the formwork was removed, thus accelerating and simplifying the formwork turnaround time.

FIGURE 26 ERECTION OF THE BEAM ON PCS® CORBEL PLATE (LEFT). BOLTED PCS® CORBEL PLATE (RIGHT).

NORDBRO IN NORREBRO DISTRICT, IN COPENHAGEN, DENMARK

Project data:
96 meters
29 floors
Building type – Residential
Construction Company – KPC & Per Aarsleff A/S
Structural Designer – ÅF Buildings Denmark
Architect – Arkitema
Precaster – MT Højgaard
More info – Peikko Danmark ApS

PCs® Corbels

MODIX® Rebar Couplers

Same as in the previous project, the contractor was committed to an efficient erection of elements and a rapid progress of the in-situ concrete core. The in-situ concrete core was constructed using climbing formwork. To avoid protruding corbels in the core, which would get in the way of the shape of the climbing formwork, the hidden PCs® Corbel solution was used to support both concrete and steel beams. This resulted in an efficient propulsion of the climbing formwork. In addition to the PCs® Corbels, MODIX® Rebar Couplers were used to handle the horizontal loads between the core and the top concrete of the hollow core slabs.

FIGURE 27 SIDE VIEW OF CONSTRUCTION SITE AT NORDBRO (LEFT). PCS® CORBEL COLUMN PART INSIDE REINFORCEMENT CAGE (RIGHT).

ROCHE TURM BAU 2 IN BASEL, SWITZERLAND

Project data:
205 meters
50 floors
Building type – Commercial
Developer – F. Hoffmann-La Roche AG
Construction Company – ARGE Marti Roche Bau 2
(Marti AG Basel and Marti AG Bauunternehmung Zürich)
Structural Designer – wh-p Ingenieure
Architect – Herzog & de Meuron
More info – Peikko Deutschland GmbH

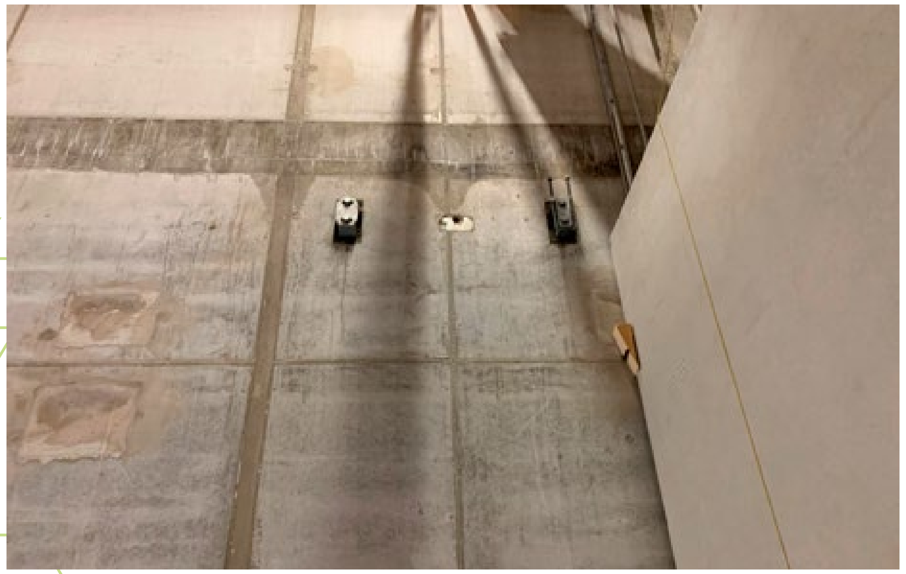
PCs® Corbels

PC® Beam Shoes

EINDAO / CC BY-SA [5]

The building footprint starts with 32 m x 59 m in floor area, and ends up with 32 m x 16 m area for the upper floor. Similarly to Roche Turm Bau 1 (Tower 1), the floor area of Bau 2 (Tower 2) decreases as the building gets taller. This results in having pre-stressed cantilevered slabs up to 3,6 meters with large openings in the stairway zone. The main stability structure consists of two reinforced concrete cores, fixed in the three-level basement structure.

In this building, to simplify the installation, Peikko provided PCs® Corbels used in staircase walls and PC® Beam Shoes used in precast concrete landing plates. Standard PCs® Corbels were used at first levels, and modified corbels were required at all other levels. Having precast staircases and post-installed corbels proves to be the right solution to accelerate construction time in comparison to the concept used in Tower 1.



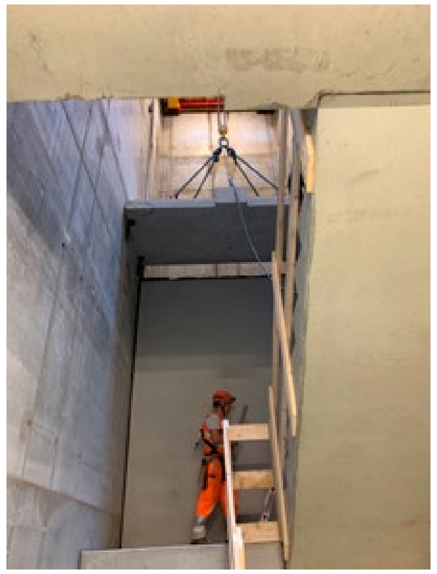


FIGURE 28 PCS® CORBELS CASTED IN THE STAIRCASE WALL (LEFT). ERECTION OF A LANDING PLATE ON THE PCS® CORBELS (RIGHT).

JEWEL TOWERS ON THE GOLD COAST OF AUSTRALIA

Project data:
47, 41 and 34 floors
Building type – Residential
Developer – Yuhu Group
Construction Company – Multiplex
Structural Designer – Arcadis
Architect – DBI Design
More info – Peikko Australia Pty Ltd

ADJUSTA Joint reinforcement

FIGURE 29 AERIAL VIEW AT CONSTRUCTION SITE OF JEWEL TOWERS, ©MULTIPLEX.

The Jewel consists of three towers.The highest, central tower has 47 floors – that's 170 meters tall. The other two are of 41 and 34 floors respectively. The towers' development includes three levels of basement parking.

The lateral system of each building consists of primary reinforced concrete shear wall core with additional shear walls. To maintain the load-path and redistribute gravity and lateral loads from the discontinued columns and walls of the residential part to the basement level, the transfer slab was introduced. This two meter thick slab is a reinforced concrete slab which carries the load of all the floors situated above it and transfers it to the ground through columns.

ADJUSTA Joint Reinforcement was installed in the slab-to-core connections via climbing formwork to enable continuity of reinforcement between the concrete members. The majority of the ADJUSTA connections on the project were 16mm-diameter threaded anchors at 200mm spaced increments between the connections. The deep transfer slabs on 3rd Level carried ADJUSTA 25mm connections at 100mm spaced increments (and in some instances 3 rows) around the core's perimeter. You can see the typical slab-to-core connection with ADJUSTA Joint Reinforcement used on this project in Figure 30. Initially, the ferrule anchors, inserted into the Rebate Former Boards, are cast into the walls. When the concrete has cured, the Rebate Former Board is removed for the second stage installation of the threaded rebars into the anchors. These rebars overlap with the main reinforcement of the in-situ poured concrete slab.

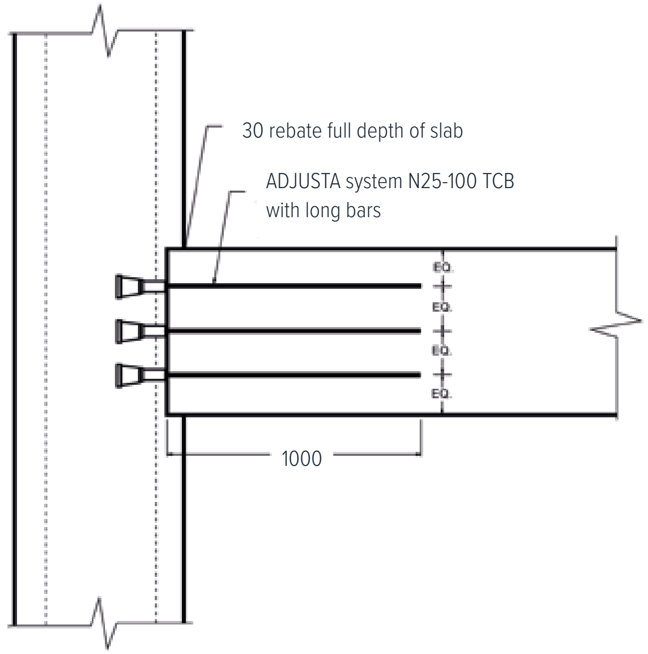


FIGURE 30 CLOSEUP OF ADJUSTA CONNECTIONS FOR THE TRANSFER SLAB INSTALLATION, ©MULTIPLEX (LEFT).
SECTION DRAWING OF WALL-TO-TRANSFER SLAB CONNECTION (RIGHT).

4.4 SIMPLIFYING CONNECTIONS BETWEEN STRUCTURAL COMPONENTS

OMNITURM IN FRANKFURT, GERMANY

Project data:
190 meters
46 floors
Building type – Office and residential building
Developer – Tishman Speyer
Construction Company – Adolf Lupp GmbH & Co. KG
Structural Designer – Bollinger + Grohmann, PfeiferundPartner Part GmbB
Architect – Bjarke Ingels Group (BIG)
Precaster – Adolf Lupp GmbH
More info – Peikko Deutschland GmbH

HPKM® Column Shoe

COPRA® Anchoring Coupler

A central feature of the architectural concept is the "hip swing", an alternating cantilevering of the 15th to 22nd floors (residential floors) by up to five meters in different directions. At that level, the building forms a spiral by shifting the stories along its vertical axis. Above the 22nd floor, the tower returns to rationally optimized floor areas and thus completes its rotation to realign with the structure outline beneath. This architectural feature presented several challenges to the structural designers. Inclined columns were giving extreme horizontal forces, which were transferred with the help of steel ties through the slabs into the stiffening core.

Additionally, the first three base levels, designed as public space, are also offset along the vertical axis, which meant that the geometry of the support sections had to be optimized in order to minimize inclinations and deflections of the columns.

The office floors from level 3 to level 15 and level 23 to the roof of the building have the same regular floor plates. For these typical floors, the diaphragm consists of main and secondary precast concrete beams with cast-in-situ slab on top.

The main beams run between the exterior columns and support secondary beams between the stiffening core and the perimeter frame. With this configuration, the secondary beams create an eccentric load and tend to twist main beams laterally. To avoid torsional moments in the beams, Peikko's HPKM® Column Shoes and COPRA® Anchoring Couplers were specified on all levels above the second floor.

This solution transfers tension forces through the joints of a cast-in-situ structure in a quasi-monolithic behavior, and allows for fast assembly of the precast construction. In addition, the column shoes meet all requirements, including R120 fire resistance for the load-bearing structure.

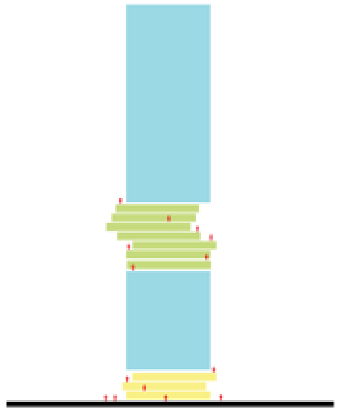


FIGURE 31 ARCHITECTURAL CONCEPT OF OMNITURM, ©BIG

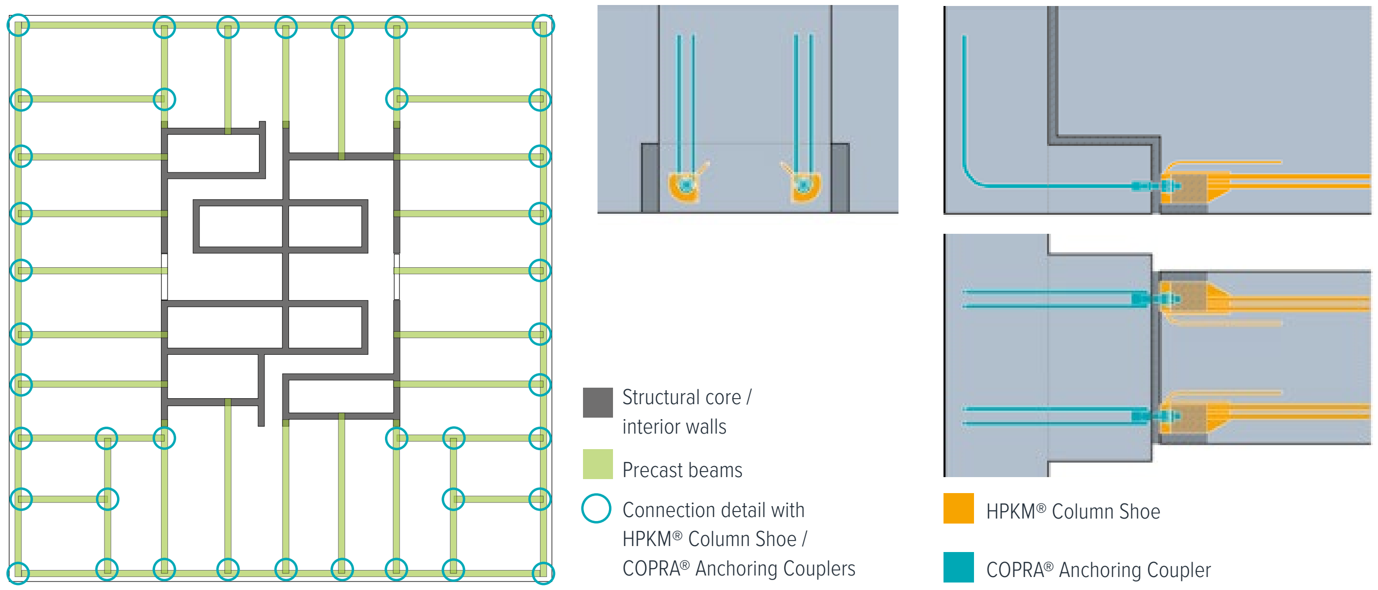


FIGURE 32 SCHEMATIC STRUCTURAL LAYOUT OF L03-L13 IN OMNITURM (LEFT). ILLUSTRATION OF MOMENT RESISTING CONNECTION BETWEEN MAIN AND SECONDARY BEAMS DESIGNED FOR OMNITURM (RIGHT).

COPENHAGEN TOWERS IN DENMARK

Project data:
85 meters
22 floors
Building type – Commercial
Developer – Sjælsø
Construction Company – Per Aarsleff A/S
Structural Designer – ÅF Buildings Denmark
Architect – Foster + Partners
Precaster – CRH Concrete A/S.
More info – Peikko Danmark ApS

HPKM® Column Shoe

COLIFT Mounting System

© H.L.NE MOGENSEN DE MONL.ON

The building complex consists of 2 towers and 3 smaller wings, which are situated around a central atrium space. The 22-story high North Tower is special for its curved facade columns. Since crane time was decisive when building this tower, it was decided to use two-story precast concrete columns in the facade. The two-story façade columns, as well as all other precast concrete columns (140 in total), were done with Peikko's HPKM® Bolted Column Connections. This solution helped to reduce the number of operational cranes from three to two during one of the construction phases of the building. The beauty of a bolted, mechanical connection is that columns can be installed with a small crew on site, and no temporary bracing is required. As soon as the nuts are tightened, the connection is moment-resistant, and the crane can move on to the next column. Furthermore, Peikko's Bolted Connections are full-scale tested and ETA approved, which ensures that the stiffness of Peikko's column connection is at least as rigid as a continuously reinforced cast-in-situ column connection.

Often the construction process becomes very costly due to non-operational delays of cranes caused by strong winds. These are the common conditions in Nordic countries during autumn and winter periods. With the use of COLIFT Mounting System, the erection of the precast concrete columns is less wind-sensitive. COLIFT Mounting System allows the column to be released remotely from the ground, without lifting up a man to release the mounting device at the top of the column. Peikko's Bolted Connections and COLIFT Mounting System ensure safe erection operations with wind speeds up to 15 m/s (54 km/h), whereas other traditional columns are allowable to erect up to a limit of 10 m/s (36 km/h). The combination of these two solutions allows for an extended construction period in unfavorable weather conditions.

FIGURE 33 SIDE VIEW OF CONSTRUCTION SITE AT COPENHAGEN TOWERS.

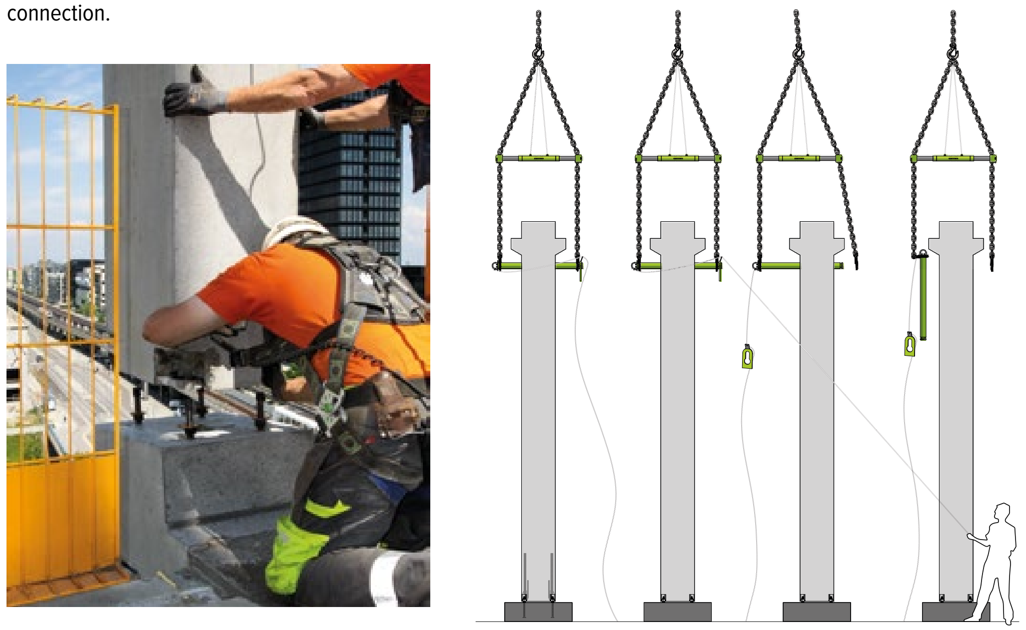


FIGURE 34 ERECTION OF THE PRECAST CONCRETE COLUMN ON ANCHOR BOLTS' PRE-LEVELED NUTS AND WASHERS (LEFT). RELEASING PROCESS OF COLIFT MOUNTING SYSTEM FROM PRECAST COLUMN (RIGHT).

4.5 DESIGN FLEXIBILITY THROUGH PEIKKO SOLUTIONS

ICON IN VÄXJÖ, SWEDEN

Project data:
67 meters
20 floors
37 000m²
Building type – Commercial and Residential
Developer – APP Equity AB
Construction Company – Prefabsystem Entreprenad Syd
Structural Designer – Peikko Lietuva UAB
Architect – Semrén & Månsson
More info – Peikko Lietuva UAB
DELTABEAM® Composite Beams – 5800m
Composite columns and steel structures – 700t

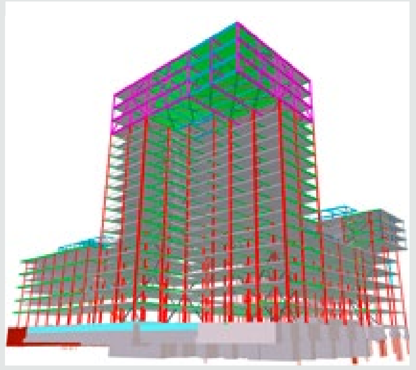



FIGURE 35 A THREE-STOREY CROWN STRUCTURE OF ICON.

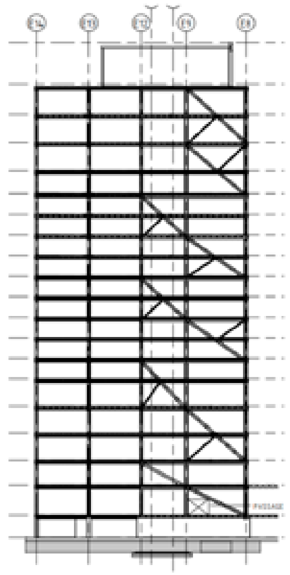
The 20-story-tall ICON, with its boldly cantilevered form, is a new landmark in the Växjö skyline. The full frame stability design of the ICON was done by Peikko. Global stability of the building was achieved with braced DELTABEAM® Frame, a steel and concrete composite structure consisting of composite columns and DELTABEAM® Composite Beams. The composite frame was paired with hollow core slabs and precast elevator shafts.

With DELTABEAM® Frame, you can maximize space utilization, making room for more people within the same available space. Besides slim floors that allow for higher floor-to-ceiling heights (or more floors for a given building height), slender composite columns take up very little space, which translates into more floor area to sell or rent.

In the ICON, the structural system of the DELTABEAM® Frame is based on nominally pinned joints between beams and columns, while the sway stiffness of the frame is arranged by the diagonal braces. In braced structure like this, most of the beams and columns were designed under vertical load only, assuming the braced bays carry all the lateral loads. Lift shaft due to very low axial load was not used as a lateral load-resisting part.

A unique feature of the building is a three-story crown structure that forms the top three floors of the building and extends up to 14 meters beyond the main building's footprint. The primary cantilever structure consists of a system of 4 structural steel bolted cantilever trusses located above the residential levels with floors made from cellular beams and composite deck.

FIGURE 36 SIDE VIEW OF CONSTRUCTION SITE AT ICON.

DELTABEAM® Composite Beam

DELTABEAM® Frame

4.6 OTHER SOLUTIONS FOR TALL BUILDINGS

DC TOWERS COMPLEX IN VIENNA, AUSTRIA
DC TOWER 1

Project data:
220 meters
60 floors
Building type – Commercial and Residential
Developer – WED AG
Construction Company – Max Bögl
Structural Designer – Bollinger-Grohmann-Schneider
Architect – Dominique Perrault
More info – Peikko Austria GmbH

© 2013 MICHAEL NAGL, WIEN II

The Donau City complex consists of Donau City Tower 1, Donau City Tower 2 and Donau City 3. The tallest 220 m high DC Tower 1 was completed in 2013. The second tower will be about 168 meters high. But before that, the much smaller DC Tower 3 will be built, in which a student dormitory will be located. Two towers, DC 1 and DC 2, should represent an uneven, in-the-middle-broken monolith, and at the same time form the gateway to the Donau City.

A reinforced concrete structure was used for DC Tower 1. Flat slabs span between the core and the columns. Lateral stiffness of the building was achieved by two elements – in-situ core with walls of up to 1m thickness and 2m thick outrigger slabs above the MEP plant floors which activate the columns. The mass pendulum system was used to fulfill serviceability requirements regarding maximum acceleration in the upper residential floors.

The connection between the individual reinforced concrete members is established with Peikko's MODIX® Rebar Coupling Systems. The reinforcing couplers of DC Tower 1 were implemented using over 45000 MODIX® Rebar Coupler connections. The columns were connected with SM36 and outrigger slabs to the core mainly with SM40 couplers. SM20, SM26 and SM30 were employed to connect the typical slabs to the core.

More than 40,000 double-headed studs of Peikko's PSB® Punching Shear Reinforcement System enable construction of flat slabs, preventing punching shear failure. In addition to MODIX® Rebar Couplers and PSB® Punching Reinforcement, Peikko provided about 12 tons of special steel components that form part of the supporting structure and the connections between structural components. Custom-made steel components have always been part of Peikko's portfolio. DC Towers is an excellent example which shows the complexity level of the structures that Peikko can manufacture to meet all quality requirements.

PSB® Punching Shear Reinforcement

MODIX® Rebar Couplers

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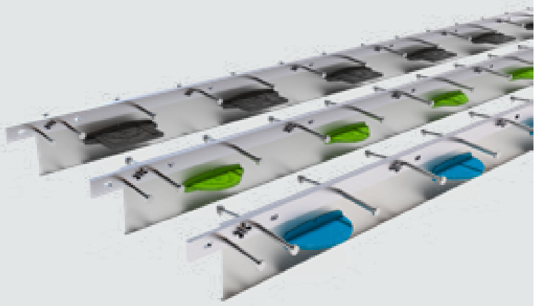
TERAJOINT® AND TERAJOINT® STRONG ARE NOW CE MARKED

A new TERAJOINT® Free Movement Joint product range was launched last spring. We are now happy to announce that both TERAJOINT® and TERAJOINT® Strong have CE marks based on European Technical Assessment ETA 20/0488.

The new product range offers a wider selection of free movement joints – just pick the most suitable one for your project. TERAJOINT® system is designed to build formed free-movement joints, consisting of heavy-duty arris armoring, permanent formwork and a load transfer system. TERAJOINT® Strong is specialized for high loads and wider joint openings.

Despite the fact that movement joints are not a structural part of the building, Peikko has taken into account the high quality requirements during the product life cycle, so that the floor will remain representative and functional even in demanding conditions after several years of usage, cleaning and maintenance.

This is especially important when you have special projects with high visual or technical requirements. To fulfil customers' needs and meet the demand in special projects in energy, chemical and pharmaceutical sectors, Peikko has developed the TERAJOINT® range and introduced TERAJOINT® Strong Stainless and Acid Proof models.



PEIKKO AND CORPORATE RESPONSIBILITY

Do you know how we work with environmental, social, and governance (ESG) matters? Visit our website section **www.peikko.com/esg** to learn more.

COLUMN SHOES FOR HIGH LOADS: BOLDA® REPLACES PEC® IN 2021

Peikko has developed a new Column Shoe for high loads, ideal for industrial, logistics, and chemical industry, as well as tall buildings, also in seismic areas.

Peikko BOLDA® Column Shoe enables over 20% slimmer cross-sections due to more compact design. BOLDA® Column Shoe and PPM® Anchor Bolt will form the only ETA tested and CE marked high resistance Bolted Column Connection in the world.

More compact and efficient design increases sustainability and improves handling in precast factory. Current projects can be converted from PEC® to BOLDA® directly, and deliveries of BOLDA® will begin in January 2021.

ONLINE HELP FOR COLUMN CONNECTION INSTALLERS

Peikko marks all HPKM® and BOLDA® Column Shoes with a QR code, which launches information app on code reader's mobile device. The GUIDE also allows for anonymous feedback.

Please take a look by scanning this QR CODE:

HPKM®

NEW STRIFF® SHEAR DOWELS ENSURE SILENT BUILDINGS

Reducing crackling noises is a must in high quality cast-in-situ apartment buildings. Even more so in Norway, where the temperature range is large.

Crackling noises due to expansion and shrinking of concrete can be unsettling for the users of the building, especially in apartments.

"To overcome the problem, the building industry has used a variety of cast expansion joints, which have been both difficult and time-consuming to build. The Structural Designers of the Kvernstua project in Norway chose a different approach – Peikko STRIFF® Shear Dowels," says **Stefan Gavura** from Peikko.


© ØIE Eiendomsutvikling

Peikko STRIFF® Shear Dowels are used to make up to 80 mm (3 in) wide high load expansion joints in cast-in-situ concrete. They can also be used as a thermal break.

"Due to the local requirements, we needed to create a seismic joint," explains **Eduardo Freitas**, Project Manager at Eiqon Betongbygg AS. According to him, Peikko STRIFF® was easy to install and the support from Peikko was outstanding.

"Compared to the common circular cross section dowel, the rectangular Peikko STRIFF® has a bigger contact area to reduce contact stresses. This has a positive effect on reducing the crackling noises," Gavura points out.

Manufactured in high quality, 1.4462 stainless steel, Peikko STRIFF® has both longitudinal or longitudinal/transverse displaceable versions

Located in Nitteldal, north of Oslo, Kvernstua comprises 7 buildings with a total of 196 apartments.

PROJECT FACTS

- CLIENT: AF BYGG OSLO
- ARCHITECT: ENERHAUGEN ARKITEKTKONTOR AS
- HEAD OF DESIGN: PRODECON AS
- CONTRACTOR: EIQON BETONGBYGG AS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DELTABEAM® Green composite beam cuts CO_2 emissions by up to 50%

Fast, safe, efficient – and now more sustainable than ever before. DELTABEAM® Green is the new, eco-conscious version of our innovative composite beam. It brings pure value to everyone involved before, during, and after the construction process.

-50 % CO_2

- 90% recycled materials
- Renewable energy used in production
- EPD certifications
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Read more: www.peikko.com

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