CONNECTIONS

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

1*2020

OMNITURM, FRANKFURT

SCRAPING THE SKY WITH PRECAST

PAGE 24

PEIKKO EXPANDED PRODUCT RANGE WITH

ATLANT® STEEL CORE COLUMNS

PAGE 20

CO_2

Cuts CO_2 emissions by up to 50%

DELTABEAM® GREEN

LIGHTENING ENVIRONMENTAL FOOTPRINT

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peikko®

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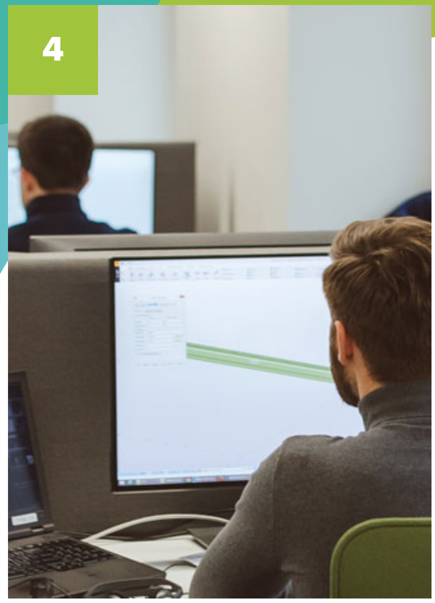

HIGHLIGHTS

REFERENCES

TECHNICAL

CONNECTIONS

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ON THE COVER:
OMNITURM, Frankfurt. Structurally, the OMNITURM was designed as a high-rise building with main and secondary precast reinforced concrete beams, cast in-situ slabs and a reinforced concrete core.

THE WORLD NEEDS REAL-WORLD TESTING WITH RESULTS

I'm a great admirer of the latest technologies such as artificial intelligence (AI), and the capabilities of Finite Element Method (FEM) software. But despite all the 'bells and whistles' of these virtual test options, the world also needs products tested in real life as opposed to solely simulated in a remote cloud.

Peikko's business is creating modern, safe building structures, and it cannot solve every issue with a computer. We have a real-world need to press, pull and burn steel and concrete. For this, we need state-of-the-art expertise from multiple universities and institutions around the world. Software is good, but is only one means of supporting our development.

This CONNECTIONS magazine features two technical articles on our DELTABEAM®. We have tested the behavior of our DELTABEAM® in high-load cases, where the beam might be as much as 700 mm (28 in) in height. Typical applications might be car parks or heavy shopping mall structures. We have also tested our DELTABEAM® in terms of its ductility in cases of sagging and hogging. This behavior is important to understand, particularly for beams used in seismic areas.

Peikko is the first company in our industry to go to such lengths in presenting real evidence of its product solution: DELTABEAM®. We need proof of our promise to you our clients.

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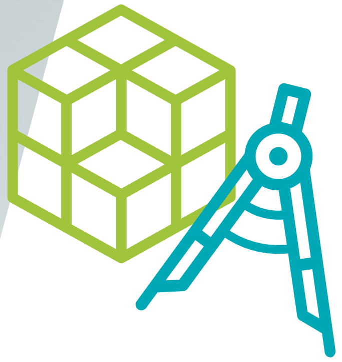


DESIGNER IS IN THE CORE OF THE BUILDING INDUSTRY

No foundations are cast, no frames are erected, and no topping out ceremonies are held without a structural designer.

Designers have a significant impact on what solutions are specified in the plans and what solutions are ultimately used on site. And most importantly, the designer is the one who ensures that structures are designed according to the structural design standards and best practices.

This is why we have dedicated the year 2020 to the designers. Our aim is to serve you even better.

> **2020 – Year of the Designers.**

UNDERSTANDING THE CHALLENGES

We think that we have a pretty good understanding of designers' challenges, as at Peikko we have our own customer engineering function designing for our customers – every day.

But to get a real sense of what the designers' opinions and needs are, we conducted a series of interviews to truly kick off the Year of the Designer. We want to thank all of the professionals who used their valuable time to take part in the interviews – your comments and views are greatly appreciated.

> **More than 30,000 structural designers are working with Peikko Designer®**

We learned that many things are pretty well as they stand. But there is also room for improvement. We got some good suggestions on how we can make our communications and the Peikko Designer® software even better. This is crucial, as more than 30,000 structural designers are working with it.

> **The designer section of the website is now entirely new.**

PEIKKO FOR DESIGNERS WEBSITE SECTION RENEWED

To this end, as part of our Year of the Designer, we reworked our offering. The designer section of the website is now entirely new, and the content structure has been rearranged to better match the designers' workflow. Our aim is to come up with content that will make the designers' job easier and quicker, as well as more reliable and efficient.

Here, you will find everything you need: free Peikko Designer® software download, online tools such as DELTABEAM SELECT, as well as design components for Revit, AutoCAD, and Tekla. And if you need to contact our support team – they are there for you.

Also, take a look at the in depth expert articles that will help you work faster and easier. Don't forget to check the webinars in the News and Events section of the website!

NEW PEIKKO WEBINARS TO SHARE USEFUL INFORMATION AND BEST PRACTICES

Have a look at our recordings.

We arrange new 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.

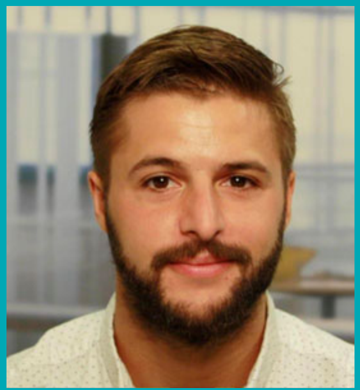
We record all our webinars, so you can watch them based on your own schedule! For access to the library of all recorded webinars, please visit **www.peikko.com/webinars**

Interested in attending upcoming webinars?
Follow Peikko news at peikko.com and at LinkedIn: Peikko Group Corporation.

3 DESIGNERS, 3 CONTINENTS, MUCH IN COMMON

To celebrate the year of the designer, we talked to professionals located in three corners of the world – Denmark, Australia, and the USA.

We wanted to know what makes them tick. How they ended up in structural design and what inspires them? What makes them get out of bed every day? What are their goals? Even though the continents and business environments vary, there were many common denominators. See if you can spot them.



Riccardo Pedroni: ENABLER OF THE ARCHITECT'S VISION

Riccardo Pedroni is a Senior Engineer at Ramboll High Rise, Copenhagen. When not solving structural puzzles or playing football, he travels to admire new architecture and to experience new cuisine.

"For me, inspiration comes from being involved in projects that you are genuinely excited about. This is something that gets you out of bed every day."

"My dad is a quantity surveyor, so I've always been surrounded by drawings and blueprints. In my family, we share a passion for architecture and much of my childhood was spent visiting architectural landmarks in Italy. Growing up, math and physics were my favorite subjects and I remember that in high school I became interested in static analysis. Later, when I had to choose university, I was split between studying mathematics or engineering. Eventually, I decided on structural engineering as I wanted to apply my knowledge in the physical world and see the results of my work.

After graduation, I joined Ramboll, which gave me the opportunity to work in London, Singapore, and now here in Copenhagen. It's a great company to work for, you get a lot of autonomy and responsibility, plus there's a strong focus on sustainability and safety in all projects. Also working in different cultures and markets has really broadened my mind."

SHARING THE RESPONSIBILITY OF SHAPING OUR CITIES

"My main goal is to add value to a project. I try to keep a holistic approach in my projects and involve all stakeholders – clients, architects, and end users – early in the design process and I aim at delivering an integrated design solution. I'm a strong believer in the fusion of engineering knowledge and the architectural vision, which makes it possible to solve some of the challenges connected to the design of complex building structures early in the process, while at the same time generating value for the user and savings for the client.

I see myself as an enabler of the architect's vision. One of the best examples is Tate Modern Gallery Extension in London. It was a fantastic project to be involved in – a small scale high rise with great work on prefabrication, as well as a cool engineered facade with over 3,000 Peikko connections that made the job faster and easier. I'm proud of having been part of the construction and whenever in London, I'm sure to pass by the museum.

I find it inspiring to work with developers, architects, and contractors in shaping the urban environment. Every project should have some element that you are truly proud of – so that you can look back and think what you have learned when working on the project.

Historically, engineering has been defined by a trial and error process and iteration until the most suitable solution was found. I believe you should never say no. Never say that something cannot be done. You need to explore all possible solutions – I'm certain that you will find one iteration that will solve your problem.

I want to push the boundaries of the construction industry in order to deliver magnificent and sustainable buildings. This can only be done in close collaboration with all the stakeholders."

Nerisa Balliu: PURSUER OF LIFELONG KNOWLEDGE

Nerisa Balliu is a Structural Engineer at Calibre Group, Brisbane, Australia. When not reading or going for family walks on the beach, she plays with Legos or builds long train tracks with her 6 and 2 year old children (who keep her on her toes all day).

"If the right people are working together, anything can be achieved. The team I belong to is truly inspiring. This urges me to learn, grow and give the best I can every day."

"I grew up in a family where I was always told there were no limits to be what I wanted to be, as long as I worked hard to achieve my goals. My parents were both teachers and they instilled in me the desire to learn and do well at school.

First, I wanted to be an architect, but to enter the University of Architecture in Albania you had to do a test where you'd literally sit outside with other students and draw buildings. If you were good at drawing it would actually be fun, but I quickly realized I would never pass that test – even though I took a few drawing lessons beforehand. But I was good at math in high school and loved technical drawing, so the civil engineering profession seemed the best bet."

WITH THE RIGHT PEOPLE, YOU CAN ACHIEVE ANYTHING

"After my undergraduate studies, I had the choice to specialize in structural engineering. I thought why not – I wanted to be the one to design and bring to life the work of an architect. I had always thought that it must be quite fulfilling to stand in front of a building structure that you have designed together with the team and be proud of your achievements.

I have been lucky enough to be part of the team which have achieved some great results. I'm particularly proud of The Drapery, a 21-storey residential tower in Brisbane with 4 levels of car park and a commercial space at the ground level. It has 2,000 m² (2,400 sq yd) post-tensioned floor plates, reinforced concrete cores, and a piled substructure. The structural design allowed us to build over an existing heritage brick drain and the overland flow path. It was a challenge, but the end result is amazing. I also was involved in the Flagstone Shopping Centre project where I used the DELTABEAM® and Peikko's bolted connections for the first time. These solutions significantly sped up the construction – also the design was very straightforward."

PASSION FOR LIFELONG LEARNING

"The work requires critical thinking skills and a strong grasp of engineering fundamentals. The objective – I believe for every engineer – is to produce safe and efficient solutions that withstand different load combinations, while taking into consideration social, economic, and environmental factors.

Currently I'm working towards becoming a Chartered Member of Engineers Australia. Obtaining this credential is important as it means getting recognized for all the hard work. And as a structural engineer, you need to embrace a passion for lifelong learning.

In the future, I'd like to see more women in engineering. It is perceived as a male-dominated industry, but things have changed and continue to change. Most of the companies already have or are adopting strategies to attract, retain, and support women.

So, follow your dreams and never give up. You hear this almost everywhere, but I can't express it enough how true this is. As a structural engineer, you could encounter a number of challenges, but with the right mindset, knowledge, tools, and collaboration you can achieve great outcomes."

Shawn A. Graham: LEADING THE WAY IN DESIGN INNOVATION

Shawn A. Graham works as Vice President of the Building Structures Division at Whitney Bailey Cox & Magnani, LLC in Pittsburgh, Pennsylvania. At work, he enjoys variety and problem-solving with his team. In his free time, team play takes on different forms: Shawn is an ice hockey player, along with being a hockey and softball coach for his 6 and 4 year old daughters.

"I loved building with Legos and Lincoln Logs as a kid and always liked math at school. One day my Dad showed me an old blueprint book of his from high school and it prompted me to take a Computer-Aided Drafting Class in high school. From there, I went to Pennsylvania State University and majored in Architectural Engineering with an emphasis in Structures."

Shawn adds, "I spent the first 12 years of my engineering career working for an engineering company in Maryland, near Washington, DC. Over the years I have gained experience in structural design and project management. I have also been the Engineer-of-Record for numerous projects from office, retail, parking, mixed-use, educational, and residential projects from renovations to adaptive reuse of buildings."

DESIGNING ECONOMIC STRUCTURES THROUGH INNOVATION AND TECHNOLOGY

"Today my work consists of overseeing an engineering team, quality control, strategic planning, and business development. For us, no project is too small or too large – the variety of projects keeps things interesting and helps us in taking a fresh look at any challenge. We strive to design economic structures through innovation and technology. Our relationship with Peikko and DELTABEAM® is a good example of this."

Shawn loves a good challenge: "I really like problem-solving. Seeing a conceptual design on paper come to life in the form of a real structure is exciting every time. It is really inspiring to contribute to society by creating safe structures for people to live, work, and enjoy life in", says Shawn.

"A structural engineer is the link between architectural creativity and a safe, economic structure. A quality structural engineering firm brings value to a project team, through communication, coordination, and attention to detail."

"I'm proud of all my projects from small to large projects and new to renovation projects. If I had to pick one, I'd say the recently completed Bridge on Forbes Apartment project in Pittsburgh. It was a DELTABEAM® project with an irregular floor plan that required us to think outside the box with how we meshed the advantages of the DELTABEAM® system with concrete/masonry shear walls and steel braced frames. This project is a great example of the benefit of spending the necessary time required to bring creativity to life in an economical, detailed, and innovative way", says Mr. Graham.

My future plans are clear: To continue to grow the Pittsburgh WBCM office that my boss, Mike Wuerthele, has built over the last 20 years with the support of our home office in Baltimore, MD. He understands the importance of adapting to change and innovation in the industry. He has put a lot of hard work and dedication into developing and nurturing many client relationships over the years. My goal is to continue providing the excellent service that our clients have come to expect. My four cornerstones of success are: Work hard and play hard. Give credit where credit is due. Be honest. Keep innovating and learning new things."

PEIKKO WHITE PAPER

DUCTILITY PROJECT
DELTABEAM® SLIM FLOOR SYSTEM

INTRODUCTION

The global construction market is facing an increasing need to go for solutions that are faster, safer, and more efficient. This means possibilities to build houses with less time and effort on site and lower building life cycle costs without endangering safety. For these needs, Peikko has invented a steel-concrete composite beam known as DELTABEAM® to enable slim floor in multistory buildings.

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The benefits of this system are long spans, flexible open spaces, additional room height, easy and space-saving HVAC installations, lower heating and cooling costs, and integrated fireproofing. DELTABEAM® Composite Beam's market position is strong in Northern Europe, mainly in non-seismic areas where hollow-core floors are common. Due to the increased popularity of the shallow floor solution in general and requests by customers, Peikko decided to start a development program to be able to offer a solution for requirements in seismic design. In addition, Eurocodes have requirements concerning robustness and progressive collapse. By combining requirements in these two related design scenarios, Peikko started a program which has been called in short 'Ductility'. This paper summarizes the first step of the program and presents what has been done and the results.

PEIKKO'S DELTABEAM® COMPOSITE BEAM

In the last decades, there has been an increased interest in slim floor constructions in many countries worldwide. Reduced construction costs combined with the need of new and more efficient ways of designing and building led to this advanced composite system. It was in 1989 when Peikko launched DELTABEAM® to the market, and since then thousands of buildings have been designed and built by using DELTABEAM® Composite Beams.

DELTABEAM® is a steel beam which is integrated into the floor enabling slim-floors. The beam is completely filled with concrete on site and forms a composite structure after the concrete has hardened. Its composite action between steel and concrete allows for open spaces with long spans even for architecturally demanding shapes. Additionally, it can be used with all common floor types: hollow-core slabs, filigree slabs, composite steel decking, trapezoidal steel decking slabs, and cast-in-situ concrete slabs (figure 1) [1].

DELTABEAM® COMPOSITE BEAM IS PREFERRED OVER OTHER SOLUTIONS THANKS TO THE FOLLOWING BENEFITS:

- Quick and easy installation
- Standardized connections
- Saves construction height
- Easy HVAC installation
- Cost-efficient
- Flexible DELTABEAM® types and details
- Flexible layouts through the whole life cycle
- Fire rating as high as R180 without additional protection
- CE marked
- Enables getting LEED and BREEAM certification points
- Local technical support

There are two types of DELTABEAM®: the D-type and the DR-type. The D-type has ledges on both sides allowing the placement of floor units on both sides of the beam, while the DR-type has a vertical web and ledge only on one side and is mainly used as an edge beam.

DELTABEAMs® can be used as single-span beams or in multi-span beam construction. In multi-span beam construction, Gerber connections, the locations of which are designed by Peikko, provide continuity to the lines of DELTABEAMs®. DELTABEAM® can be combined with all common column types. In cases of concrete columns, the beams are connected to the columns with Peikko's PCs® Corbel [2], a modular hidden column corbel designed especially for DELTABEAM®, or through the columns as shown in figure 2. In cases of steel or composite columns, the beams are mainly fixed to the top of the columns with bolts or welds.

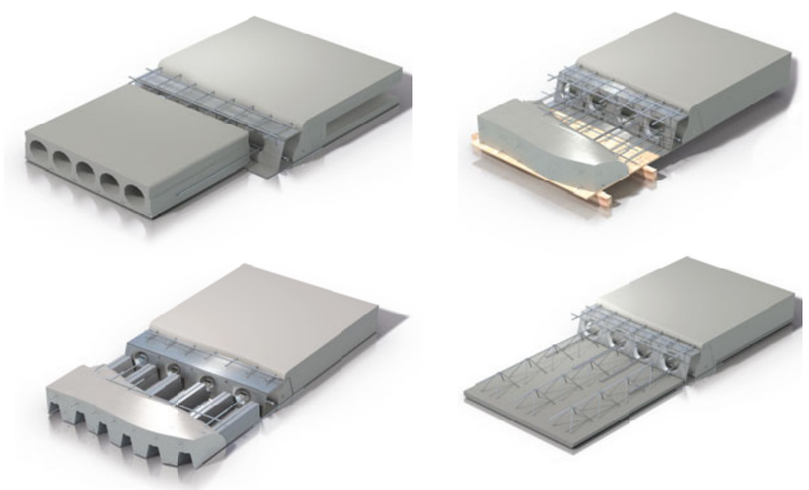


FIG. 1. COMBINATION OF DELTABEAM® WITH VARIOUS SLAB TYPES

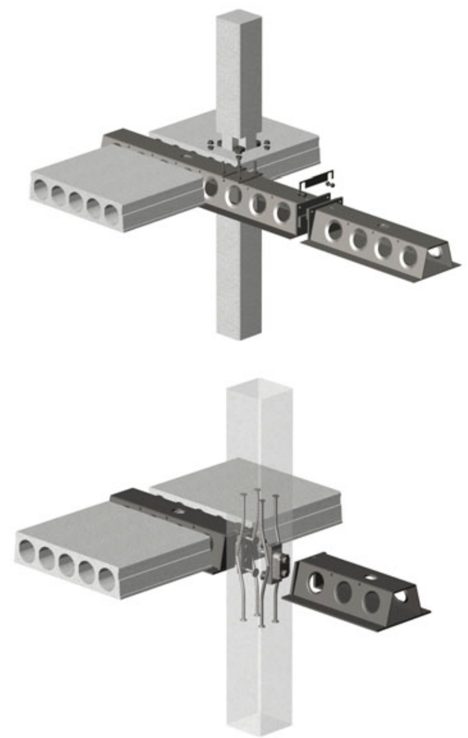


FIG. 2. CONNECTION OF DELTABEAM® WITH CONCRETE COLUMNS

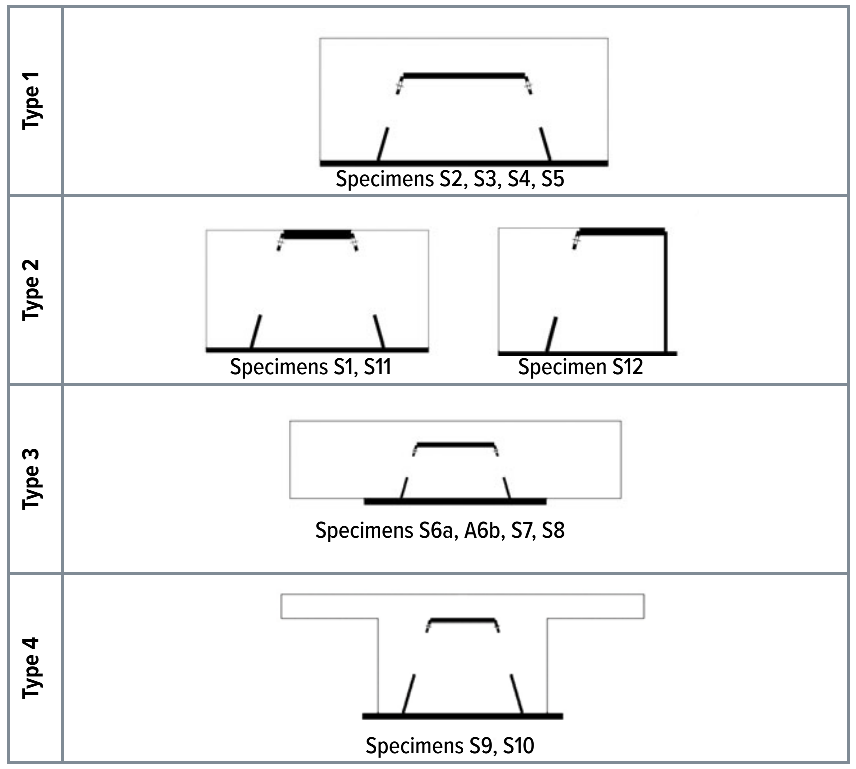


FIG. 3. CROSS-SECTION DETAILS OF TEST SPECIMENS

SCOPE OF THE PROJECT

Devoted to our brand promise of “a faster, safer and more efficient way to design and build”, we do not only supply the market with our products, but we are aiming to lead the constantly evolving construction industry in a manner that fulfills the evolving needs of customers. Lack of any guidance in codes related to shallow (slim) floor constructions combined with a very limited number of tests in technical literature sparked us to start our own experimental project related to DELTABEAM® Composite Beams against extreme situations, like earthquakes or column loss scenarios, in order to provide our customers with a safe, ductile, robust and economical solution.

EXPERIMENTAL INVESTIGATION

Design against extreme load cases demands ductile and flexible structural elements that must have adequate rotational capacity and be able to sustain huge deformations without losing their strength. In order to assess the flexural behavior of DELTABEAM®, 13 full-sized beams with various geometry and reinforcing details have been tested at the Institute of Steel Structures of National Technical University of Athens (NTUA) [3].

The cross-section types of the specimens tested are presented in figure 3. The experimental setup consisted of a steel frame used to support a computer controlled hydraulic actuator and two supports specifically designed for the tests (figure 4). The distance between the central axes of the supports was 7.2 meters. Deflection at middle-span, strains at bottom and top flanges, slips between steel and concrete, and rotations of the specimens were monitored throughout the tests.

The loading protocol was divided in three parts. The first part included three serviceability cycles at displacements approximately equal to L/260. The remaining parts included monotonical loading up to the end of the tests with two different speeds.

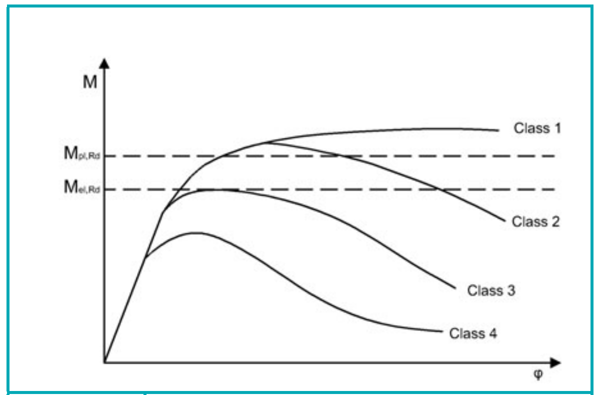
FIG. 4. EXPERIMENTAL SETUP

RESULTS

When a structural element or a part of it is subjected to compressive axial loads, some of the plates that contain the element, if they are too slender, may buckle before the element reaches its full strength. This phenomenon, which is called local buckling, is one of the major concerns in the design of steel and composite structures because it essentially defines the strength limit of the elements. Thus, the codes have a classification of steel sections according their ability to resist local buckling and subsequently their ability to reach their plastic moment and rotational capacity (figure 5):

- **Class 1:** The section can form a plastic hinge and has sufficient rotational capacity to maintain this moment over a considerable range of in-plane rotation
- **Class 2:** The section can develop plastic resistance but has limited rotational capacity to act as a hinge
- **Class 3:** The section can develop elastic resistance of the full cross-section
- **Class 4:** Local buckling of slender elements reduces the elastic resistance; the section can develop elastic resistance of an effective cross-section, smaller than the full section.

This phenomenon does not affect only the plates made of structural steel but also the reinforcement rebars that are under compression leading to unexpected and unwanted cracking of concrete.



Class	Bending resistance
1 and 2	Plastic
3	Elastic
4	Elastic taking into account local buckling

FIG. 5. DEFINITION OF CLASSES OF COMPOSITE SECTIONS

Type 1 sections

Type 1 sections were the least reinforced specimens and represent the current configuration of the beams and reinforcement in the slab. After the maximum load, which was higher than the plastic design resistance of the beam, the concrete under compression at the top of the beam was crushed. As a result of that, the lateral protection provided by the external concrete to the web and top plates was lost leading to the buckling of these plates (figure 7). This behavior resulted in the reduction of the beams' resistance as can be observed in the load deflection curves (figure 6).

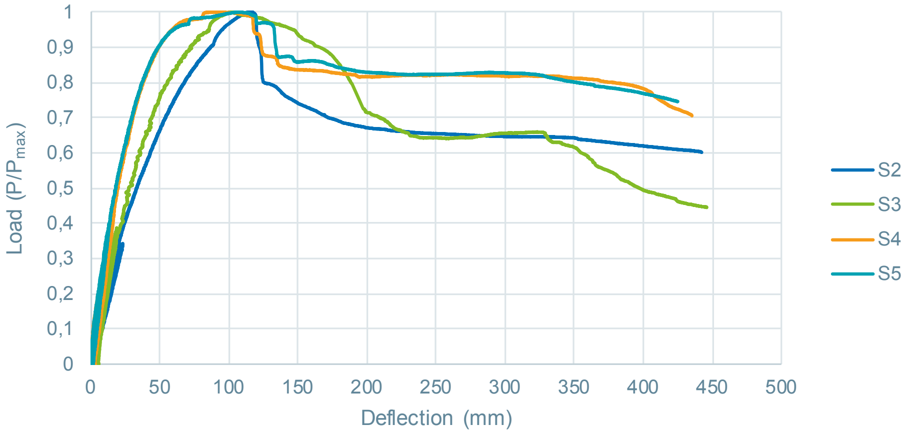


FIG. 6. LOAD- DEFLECTION CURVES OF TYPE 1 SPECIMENS

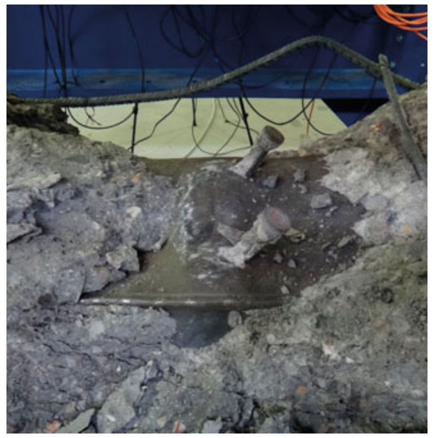


FIG. 7. LOCAL BUCKLING AT THE END OF THE TEST

Type 2, 3 and 4 sections

The major difference between Type 1 specimens and the others is the usage of reinforcement in the outer concrete surrounding DELTABEAM®. All specimens exhibited hardening behavior after the yielding point on the load-deflection curve (figures 8, 10 and 12). The beams at the end of the tests were in good condition, despite the large permanent deflection, because the reinforcement and the confinement provided by the stirrups prevented the spalling of concrete and hence the lateral movement and buckling of the web plates (figures 9, 11 and 13). The small strength reductions of type 4 specimens represent the failure of the concrete ledges on both sides of the beams. However, the main central body of the beams was protected by the open stirrups and maintained its integrity. It should be noted that all these tests stopped at a deflection approximately equal to 450 mm with no strength softening because the maximum stroke of the actuator was reached. This means that even higher deflection values could be reached before failure.

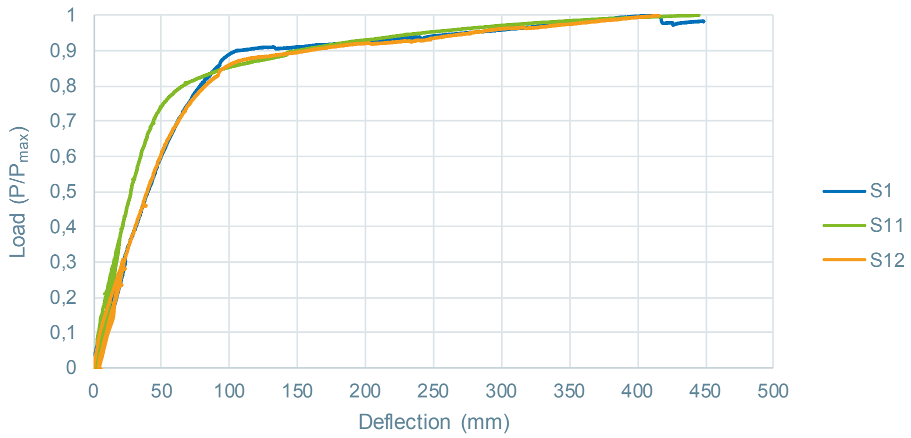


FIG.8. LOAD- DEFLECTION CURVES OF TYPE 2 SPECIMENS

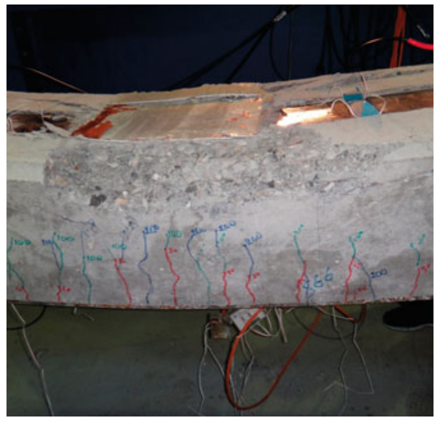


FIG. 9. TYPE 2 SPECIMEN AT THE END OF THE TEST

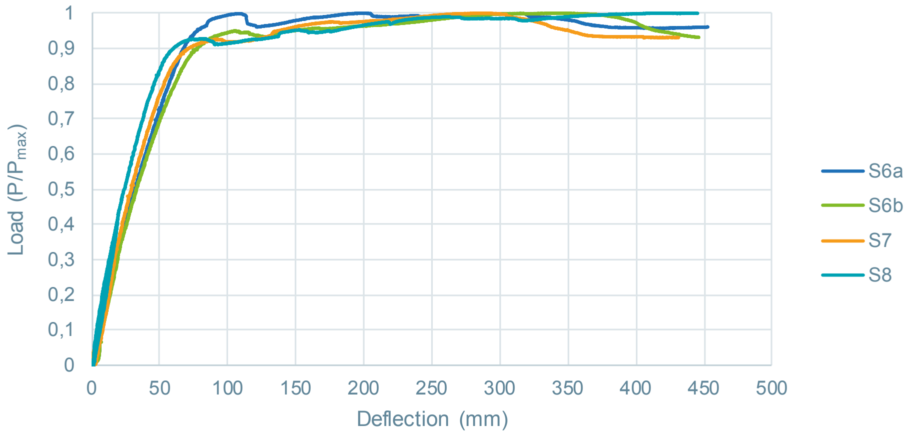


FIG. 10. LOAD- DEFLECTION CURVES OF TYPE 3 SPECIMENS

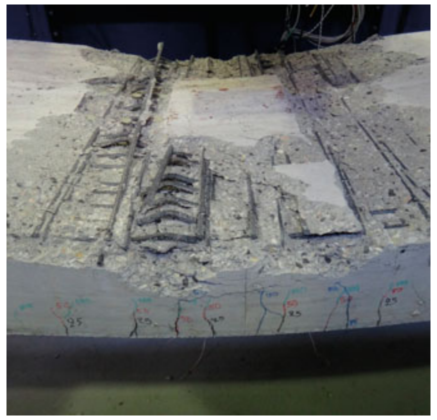


FIG. 11. TYPE 3 SPECIMEN AT THE END OF THE TEST

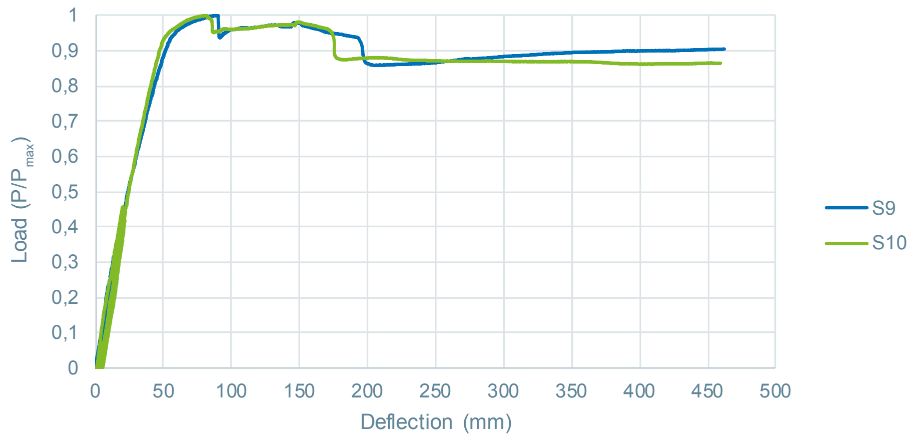


FIG. 12. LOAD- DEFLECTION CURVES OF TYPE 4 SPECIMENS

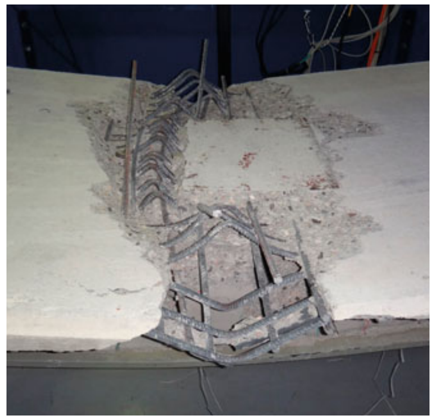


FIG. 13. TYPE 4 SPECIMEN AT THE END OF THE TEST

When we design a structure to sustain static loads, the primary structural elements must have sufficient resistance against the applied loads. In cases of extreme dynamic loads, the procedure is different. Earthquakes and generally extreme accidental situations are dynamic phenomena that occur rarely and last for only few seconds. Based on that, it can be easily understood that it would be uneconomical to design a structure to behave elastically in an extreme scenario and not take advantage of its ability to acquire a plastic behavior and deform plastically without losing its strength and its stiffness. In other words, it is more economical to allow the structure suffer minor damage rather than having an initially strong structure to be able to take all the load without any damage. Of course, appropriate measures must be taken to ensure that the damage is controlled and repairable. [4-7]

The factor that defines the deformation capacity of a structure and its structural elements and the size of the damage is called the ductility factor and indicates how much higher the maximum inelastic deformation d_m is in relation to the yielding deformation d_y:

$$\mu = \frac{d_m}{d_y}$$

The maximum value of factor μ depends on two basic factors:

- **The material of the structure.** Systems using ductile materials (structural steel) are allowed to develop larger values of factor μ than systems built with brittle materials (masonry, concrete).
- **The static system.** The more restrained degrees of freedom one structure has, the better its behavior is. This is because a local failure, generally, will not pose a collapse risk for the whole structure due to the redistribution of the loads and the remaining strength of the elements that are not severely damaged. On the contrary, isostatic constructions do not have “safety valves” and a failure of one element can lead to a collapse. Consequently, the ductility factor is highly related to the nature of the project and the use of the structure, and it is a matter of the collaboration and connection between all the structural elements assembling the structure and not of the beam’s behavior alone.

The desired ductility is finally defined by the designer according to the instructions and the limitations provided by the Eurocodes. The ductility factor can be described in terms of displacement or rotation (curvature). Higher ductility values mean bigger inelastic deformations and thereby a more economical design.

More specifically, the seismic design rules for dissipative composite structures aim at the development of reliable local plastic mechanisms (dissipative zones) in the structure and of a reliable global plastic mechanism dissipating as much energy as possible under the design earthquake action.

Earthquake resistant composite buildings shall be designed in accordance with one of the following design concepts:

- Concept a) Low-dissipative structural behavior.
- Concept b) Dissipative structural behavior with composite dissipative zones;
- Concept c) Dissipative structural behavior with steel dissipative zones.

Design concept of a structure	Structural ductility class	Required cross-section class
Concept a) Low-dissipative structural behavior	DCL (Low)	1, 2 or 3
Concept b) or c) Dissipative structural behavior	DCM (Medium)	1 or 2
	DCH (High)	1

TABLE 1. DESIGN CONCEPTS RELATED TO DUCTILITY CLASS AND CROSS-SECTION CLASS

In order to calculate the ductility of each tested beam the design plastic moment $M_{pl,Rd}$ was calculated. Ductility factor μ is part of the $M_{pl,Rd}$ line between two intersection points with the experimental curve (figure 14).

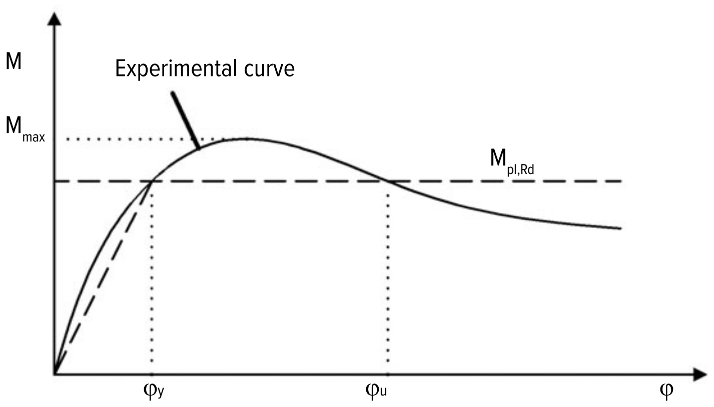


FIG. 14. CALCULATION OF DUCTILITY FACTOR M

The calculated ductility and the cross-section class of each specimen are presented in table 2.

Specimen	Ductility	Cross-section class	Specimen	Ductility	Cross-section class
S1	4.84	Class 1	**S7**	7.80	Class 1
S2	1.81	Class 2	**S8**	9.88	Class 1
S3	2.66	Class 2	**S9**	10.45	Class 1
S4	2.47	Class 2	**S10**	10.68	Class 1
S5	2.62	Class 2	**S11**	9.14	Class 1
S6a	7.63	Class 1	**S12**	4.49	Class 1
S6b	7.39	Class 1			

TABLE 2. DUCTILITY VALUES AND CLASSIFICATION OF SECTIONS

SIMULATION OF THE RESULTS WITH THE USE OF FINITE ELEMENT METHOD (FEM)

To shed more light into factors that could not be physically observed during the experiments and to deeper understand every aspect of the overall behavior of DELTABEAM®, a 3-dimensional model was created for each specimen using the Finite Element Method [8]. This paper presents the results of an example analysis of one beam. As can be observed in figures 17 and 18, high attention was given to the accurate and detailed creation of the models. The high collaboration of load-deflection (figure 15) and load-strain curves (figure 16) between the experimental and the calculated results as well as the realistic deformed shape (figure 19) prove the validity and the accuracy of the FE model. Some indicative images of the stresses and strains of the steel beam are shown in figures 20 - 21.

CONCLUSIONS

Facing the challenges of a safer and more economical design of structures against extreme situations, we at Peikko began an extensive research project in order to prove the advantages of DELTABEAM® as a leading-edge solution in precast constructions. The project consists of three parts: i) Bending behavior under positive moments (Sagging), ii) Bending behavior under negative moments (Hogging), and iii) Design and creation of a moment beam-to-column connection. For the first part, thirteen (13) full-sized DELTABEAMs® were tested under three-point bending loads in order to assess their flexural behavior. The results showed that DELTABEAMs®, in conjunction with proper steel reinforcement, offer an extremely ductile behavior. The slips between concrete and steel beams were very small and the integrity of the specimens was maintained up to the end of the tests despite large deflections. This beneficial structural response indicates that properly reinforced DELTABEAMs® can be implemented by the designers not only for typical ultimate state design but also to protect against extreme cases, such as progressive collapse and earthquakes. Designing tools and technical documents will also be published after the completion of the project.

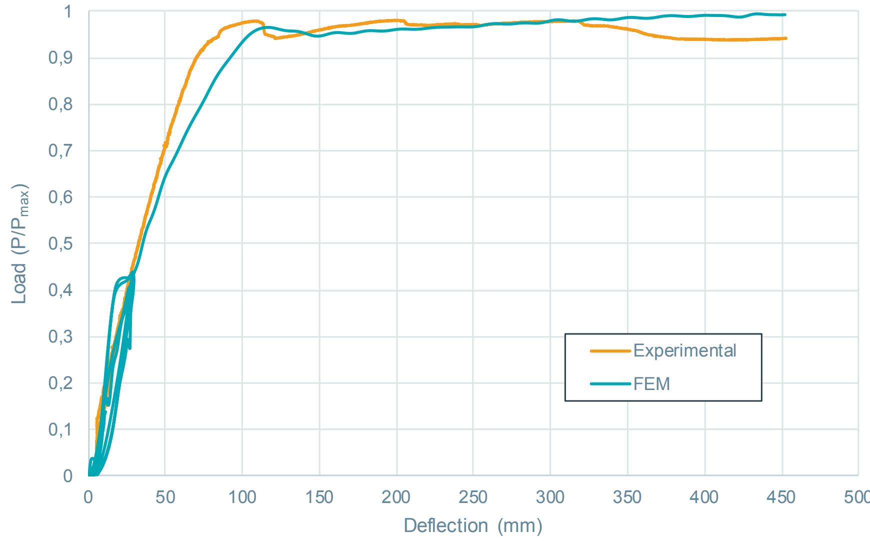


FIG. 15. COMPARISON OF LOAD- DEFLECTION CURVES FOR EXPERIMENTAL AND ANALYTICAL RESULTS

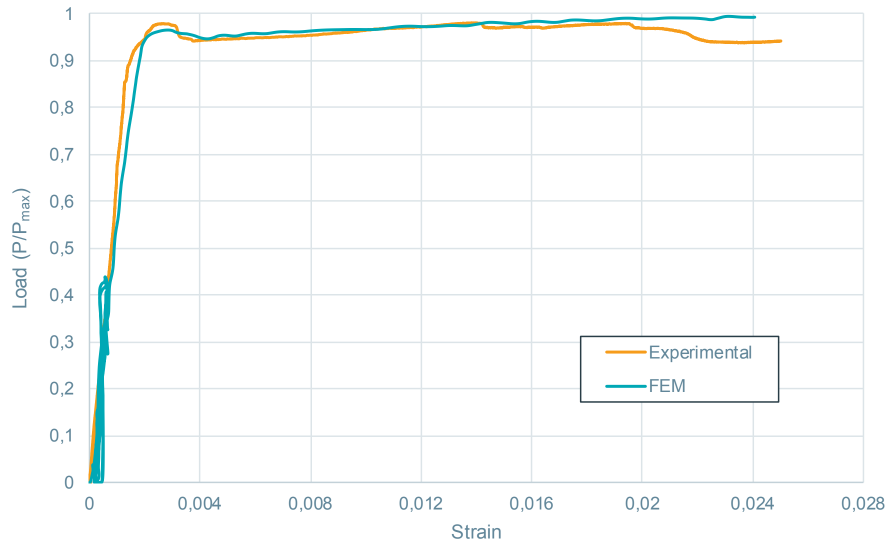


FIG. 16. COMPARISON OF LOAD- STRAIN CURVES FOR EXPERIMENTAL AND ANALYTICAL RESULTS

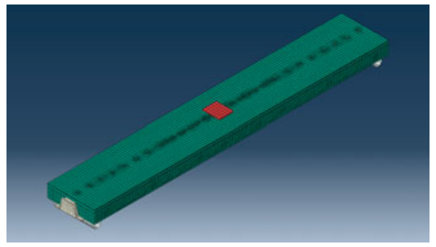


FIG. 17. 3D MODEL OF TYPE 3 SPECIMEN

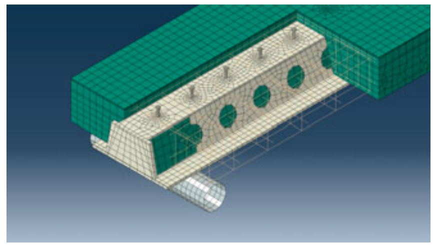


FIG. 18. DETAIL OF THE 3D MODEL

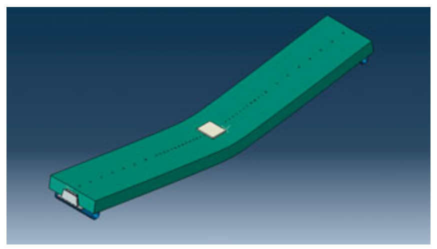


FIG. 19. DEFORMED SHAPE

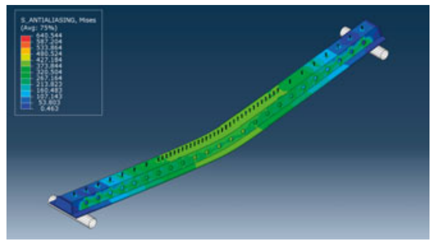


FIG. 20. VON MISES STRESSES OF THE STEEL PART

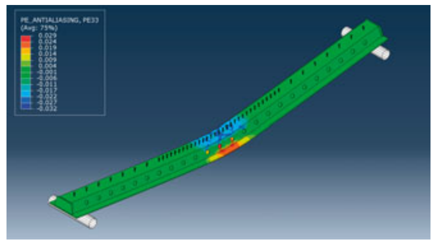


FIG. 21. PLASTIC STRAINS ON THE STEEL PART

[1] Peikko Group Corporation (2014), DELTABEAM® Slim Floor Structure with Integrated Fireproofing - Technical Manual.
[2] Peikko Group Corporation (2019), PCs® Corbel, Hidden Corbel for Supporting Beams - Technical Manual.
[3] Kyriakopoulos P., Peltonen S., Vayas I., Spyrakos C. and Dasiou M., "Enhancement of ductility in shallow floor composite beams". 16th European Conference on Earthquake Engineering, Thessaloniki, 2018
[4] CEN (European Committee for Standardization). (2006). Eurocode 1: Actions on structures - Part 1-7: General actions - Accidental actions, EN 1991-1-7:2006.
[5] CEN (European Committee for Standardization). (2005). Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings, EN 1993-1-1:2005
[6] CEN (European Committee for Standardization). (2004). Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings, EN 1994-1-1:2004
[7] CEN (European Committee for Standardization). (2004). Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings, EN 1998-1:2004.
[8] ABAQUS Theory Manual, "Version 2018," Dassault Systemes, 2017.

PEIKKO
WHITE PAPER

DELTABEAM® SLIM FLOOR STRUCTURE WITH TRANSFER BEAMS

AUTHOR:

→ SIMO PELTONEN
SENIOR R&D MANAGER,
PEIKKO GROUP CORPORATION

DELTABEAM® Composite Beam is known to be a cost effective solution for slim floor construction. Building projects can be small or large, they can be simple box-like two-bay office buildings, or very demanding shopping malls or concert halls.

The requirements vary; in some areas a slim floor solution does the job but then there are places where something else is needed – for instance a transfer beam with long span. DELTABEAM® Composite Beam is selected for this application because of its lower weight compared to concrete beams, making it easier to install and handle, and because it does not require fire protection like steel structures.

A transfer beam is used for instance in cases where a column is discontinuous i.e. it does not extend to the foundation and the load from it must be transferred to the surrounding structures.

This paper shortly describes the load tests made for the deepest DELTABEAM® Composite Beam type – D70-800 (h=700mm).

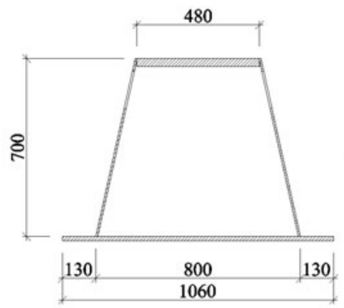


FIG. 1 STEEL BEAM CROSS-SECTION

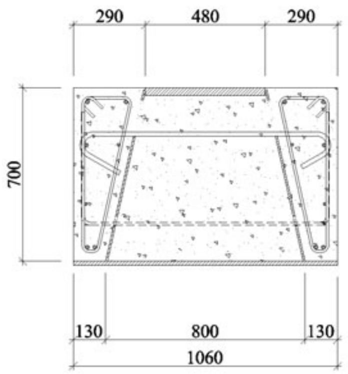


FIG. 2 COMPOSITE BEAM CROSS-SECTION

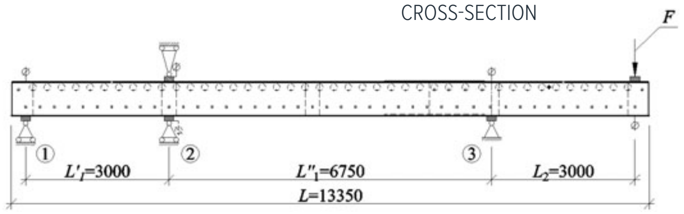


FIG. 3 STATIC SYSTEM OF THE CANTILEVER TESTS

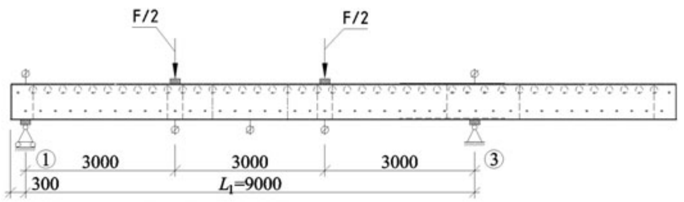


FIG. 4 STATIC SYSTEM OF THE SIMPLE BEAM TESTS

SPECIMENS AND TEST SETUP

DELTABEAM® Composite Beams were tested with two setups: a cantilever setup and a simple beam setup, see figures 3 and 4 below. Specimens were designed so that one specimen could be tested twice, first the cantilever test and, after reorganizing the setup, the simple beam test.

The specimen was quite large with a total length of ~13.4 meters and weight of the steel part approximately 6 tons. The total weight of the composite beam specimen was approximately 30 tons. Because of the size and weight, the setup had to be designed so that both tests for both specimens could be done without moving the specimen.

The loading was arranged so that there were main loading jacks installed with substitute jacks to enable their use without removing the load from the system.

The effects in the cantilever tests were analyzed with the FE method to find out the extent of the local strains and deformations. This in turn helped to define the locations for the support points in the cantilever and simple beam tests to ensure that the results of the tests were not affected by each other.

Both specimens were designed so that local effects at the loading points were prevented. The composite specimen was designed to simulate an intermediate beam with slabs on both sides without compression flanges in the ULS (ultimate limit stage).

FAILURE MODES – EXPERIMENTAL TESTS

First loading test – cantilever of the steel cross-section. The behavior of the specimen was stable. It can be observed from the measured data that the top plate started to yield but eventually the global failure was due to the buckling of the bottom plate just in front of the support.

Second loading test – simple beam test with the steel cross-section. The behavior of the specimen was stable until the failure. Also, in this test tension fields could be observed in the webs. The global failure was the buckling of the top plate. As can be seen in the figure, also the webs buckled locally outwards.

Third loading test – cantilever test with composite cross-section. The behavior of the specimen was stable throughout the test until loading had to be stopped due to technical problems with the loading system. The behavior of the specimen was ductile due to the yielding of the top plate. Externally, it could be seen that cracks, marked with numbers 1 and 2 in the figure on the right, continued to grow in width and length.

Fourth loading test – simple beam test with composite cross-section. The behavior of the specimen was stable throughout the test until loading was stopped due to capacity of the jacks when the deflection grew too large. The behavior of the specimen was ductile, and even the failure of the specimen was due to spalling of the external concrete. Externally, it could be seen that horizontal cracks started to grow and close to the end the concrete started to spall out, which resulted into reduced stiffness.

LOAD DEFLECTION BEHAVIOR – EXPERIMENTAL AND FE SIMULATION RESULTS

Prior steel beam tests were performed with SLS (serviceability limit stage) load cycles. They are not necessary for the steel beam, but they were performed to make sure that the specimen was laying properly on the supports.

Test 1: The result from the FE analysis is well in agreement with the experimental result, see the red and blue curves in the graph. Hand calculation gives a resistance of 91% of the maximum bending in the test.

Test 2: Also the result from the FE analysis of test 2 is well in agreement with the experimental result, see the gray and yellow curves in the graph. Hand calculation gives a resistance of also 91% of the maximum bending in the test.

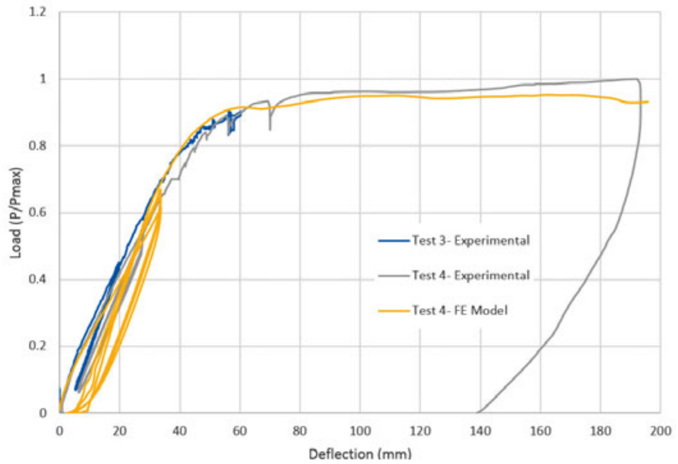
SLS load cycles were performed before the actual ULS loading also in composite DELTABEAM tests. In case of structures including concrete, it is important to run load cycles to release the bond between steel and concrete before the actual loading.

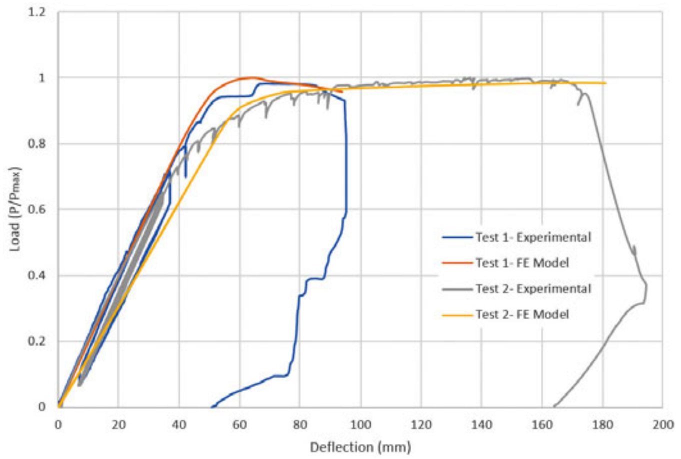
Test 3: The cantilever test had to be stopped prematurely due to technical problems with the loading system.

FE simulation was not done for this case either. However, the bending resistance given by hand calculation is 97% of the maximum bending moment in the test. It is obvious that the load in the test could have been increased.

Test 4: Both FE simulation stiffness and resistance are well in agreement with the experimental result, as can be seen in the graph. Hand calculation gives a resistance of 89% of the maximum bending in the test.

Material tests were performed for all concrete patches, different steel plate thicknesses, and reinforcement diameters which contributed to structural behavior of the specimens.





CONCLUSION

First of all, these tests prove that the behavior of DELTABEAM® Composite Beam is constant and safe apart from the cross-section size. Secondly, with the high load-bearing capacity and stiffness they are an economical solution for heavily loaded applications with long spans.

The behavior of all the specimens was according to the predictions of the current design methods, and the failure modes were as planned. The FE simulations predicted the behavior well, and the created FE modelling techniques are a reliable tool for simulating DELTABEAM® Composite Beam's behavior.

The results from the tests can also be used to further improve and develop the design methods of DELTABEAM® and develop new long span solutions with DELTABEAM®.

The tests were carried out in the FCE SUT testing laboratory in the Slovak University Technology in Bratislava.

PEIKKO EXPANDED PRODUCT RANGE WITH ATLANT® STEEL CORE COLUMNS

In February, Peikko purchased the product rights of the ATLANT® steel core columns, a product developed in Switzerland. These ATLANT® columns are slimmer than traditional, Eurocode-based standard composite columns. This offering first gives Peikko new opportunities in the Austrian and Swiss markets, and will be expanded to other markets in the future.

FAST INSTALLATION, IMMEDIATE LOAD BEARING, INTEGRATED FIRE PROTECTION

ATLANT® prefabricated steel core columns offers fast installation and immediate readiness for the task in hand thanks to their application-specific, engineered design. They are used in underground parking garages and in buildings as facade or interior columns. The steel jacket prevents the integrated concrete covering from breaking off in the event of fire.

THE BENEFITS OF ATLANT® STEEL CORE COLUMNS

- Extreme slimness matched with high load-bearing capacity
- Straightforward static engineering system with a click-in centering system
- Smooth, Impact-proof surface
- Quality assurance and fire certification by VKF, the Association of Swiss Fire Insurance Providers

EFFICIENT INSTALLATION

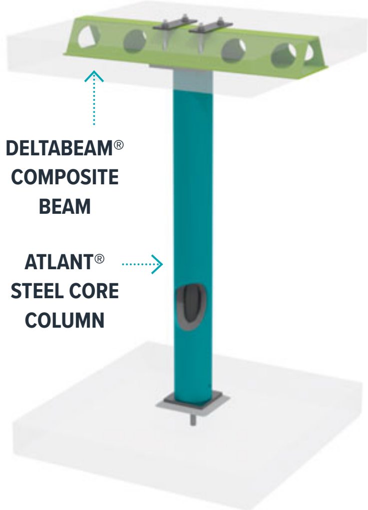
ATLANT® columns are very simple to install. The steel core column is placed on the concrete floor through the opening in the slab shuttering. The centering pin welded onto the base plate is inserted into the hole previously drilled in the concrete floor. A column is lifted in to its place from factory-mounted hook on the top plate. After it has been aligned, the column is secured to the slab shuttering and is immediately load bearing.

AN EFFICIENT COMBINATION WITH INTEGRATED FIREPROOFING: ATLANT® STEEL CORE COLUMNS + DELTABEAM® COMPOSITE BEAMS

Choose a DELTABEAM® Slim Floor construction in combination with ATLANT® steel core columns – for multi-story buildings of all kinds, this gives you a slimmer structure and greater flexibility with a small number of slim columns. Thanks to standardized connections between DELTABEAM® composite beams and ATLANT® steel core columns, installation is fast, safe and easy.

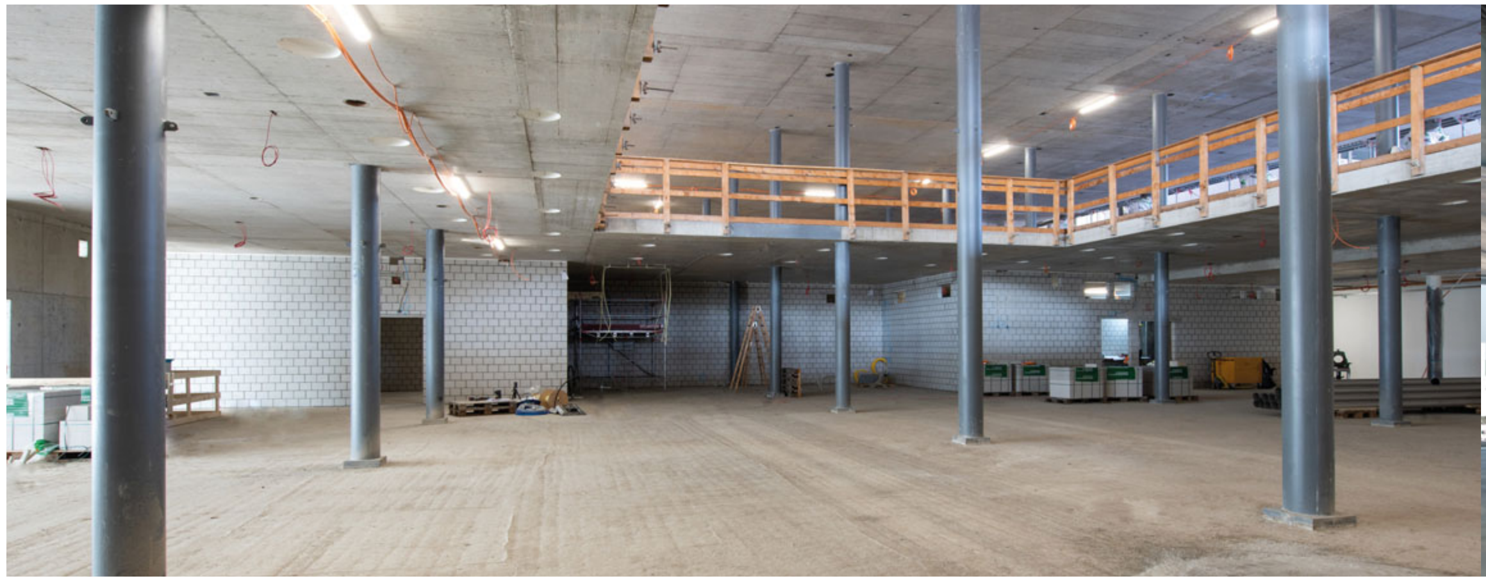
A SYSTEM FOR EVERY BUILDING

Frames made with DELTABEAM® composite beams will reduce the volume of your project design. ATLANT® steel core columns will further enhance this effect, making them a rational addition. Achieve architecturally ambitious designs with new ways to create open spaces.



THE BENEFITS OF USING DELTABEAM® AND ATLANT®

- Integrated fire protection
- Long spans offer greater flexibility in spatial design
- Achieve more usable space
- Create ambitious shapes with ease
- Lightweight components - Easy transport and installation
- Easy, space-saving installation of HVAC
- Optimized CO_2 footprint in both the production and installlation phases
- Excellent technical support



PEIKKO BOLTED CONNECTIONS

STIFFENED INDUSTRIAL CONSTRUCTION

THIS ARTICLE HAS BEEN PUBLISHED PREVIOUSLY BY STAT KON S.R.O.

A new paper mill is under construction in Ruzomberok, Slovakia. Mondi SCP's project ECO Plus was engineered by BHM Ingenieure, and STAT KON s.r.o. designed the precast components. Let the companies tell us more about themselves.

Construction of the buildings for the installation of a new white surface cardboard paper machine for the company Mondi SCP, a. s., has been completed in the plant of Mondi SCP, a. s., in Ružomberok. The complete undertaking is part of the ECO Plus investment project worth € 340 million. As part of the design work, the STAT KON s. r. o. company provided the complete production documentation of the prefabricated concrete structures.

Part of the investment plan is the construction of SO 24.A (PM) and SO 24.B (OCC), which represents the buildings of the paper machine itself. The load bearing construction consists of a prefabricated concrete frame construction, supplemented by a cast in situ concrete frame construction for the paper machine.

Keeping in mind the overall stability, mechanical resistance and overall rigidity of the structure, detailed instructions for the assembly process have been drawn up. The load bearing construction itself is unique in its technical solution, where mostly the embedded BECO®/COPRA® anchoring elements are used, which in terms of statics ensures the continuity of the beams, their optimal use, as well as securing the rigid joints at the ceiling level to increase the complete rigidity and stability of the building.

BEARING STRUCTURE OF THE OBJECT

The object has a ground plan measuring 337.5 × 33.0 m (1110 ft × 110 ft) up to a maximum of 51.0 m (170 ft), and a height of 23.85 m (77 ft). The prefabricated columns are anchored to the basement and the deep foundations consisting of groups of piles. The anchoring of the columns with the foundations was implemented using the Peikko® anchor system. The bracing of the columns is provided by the ceiling constructions at the levels of +7,000 m (+23,000 ft) and +14,000 m (+46,000 ft). For the overall stability, bracing beams were also considered in the A and D axes at the level of +18,000 m (+59,000 ft).

The slab structure consists of a set of primary and secondary beams, topped with the self bearing filigree slabs with the final layer of the concrete.

The main primary prefabricated beams were placed on the column corbels and connected to the columns using BECO® beam shoes and COPRA® anchoring couplers. The joints were then filled with grout to achieve the overall continuity of the beams. Secondary prefabricated beams were placed into recessed holes in primary beams.

The floor structure itself consists of filigree slabs and cast in situ over concrete. Filigree slabs were designed as self bearing from the assembly point of view and were not additionally supported during assembly and concreting, in order to ensure the efficiency of the construction process. The final layer of the over concrete was connected by KBS connecting elements in the places of columns and primary beams before concreting.

The roof structure of the building consists of prestressed, prefabricated saddle and pent girders on several levels, on which the prestressed hollow core slabs were placed. Based on the assembly procedure, the roof girders could only be installed after the installation of the longitudinal bracing beams. At least four frames had to be interconnected while assembling the first girder.

The facade of the building consists of prefabricated reinforced concrete wall elements, on which a thermal insulation system with metallic cladding is implemented. The lower part of the facade is made of prefabricated sandwich panels. The individual wall elements are separately placed on the column corbels to ensure any possible arbitrary spatial modification in the future.

In the central part of the building, a cast-in-situ reinforced concrete frame was created for the paper machine itself. The load bearing structure of the frame consists of cast-in-situ reinforced concrete pillars with prefabricated cantilevered beams and prestressed hollow core slabs.

The supplier of the part of the concrete structures is STRABAG Pozemné a inžinierske staviteľstvo s. r. o. company, which produces its own prefabricated elements in the plant in Sere. This plant is the largest and most experienced in the Slovak Republic in terms of production capacity. Thanks to many years of experience and know how, the production and the team of technicians are able to execute such extensive projects within short deadlines, while delivering high quality. As a long term partner of STRABAG, STAT KON drewn up the production documentation.

BHM INGENIEURE: THE NEW PM19 PAPER MACHINE

The investment of Mondi SCP in Ruzomberok, Slovakia, ECO Plus, consists of several parts, the main one being the new PM19 paper machine. All civil engineering, especially the statics and dynamics for the PM-foundation, as well as the building structure, were performed by BHM Ingenieure, Feldkirch company in a proven and tested manner.

The hall of the PM and OCC buildings are made of prefabricated concrete elements, which are connected to the foundations by Peikko's anchor system, whereas the connections of the columns to the beams were designed by BECO®/COPRA® elements. These elements were used again by BHM, as there has been positive experience in many cases up to now.

Most of the structures were installed in 2019, so the installation of a paper machine and equipment could begin in early 2020.

SCRAPING THE SKY WITH PRECAST

The OMNITURM of Frankfurt proves that a precast concrete structure is ideal for making quick and efficient upwards progress in a high rise.

OMNITURM is one of the five skyscrapers simultaneously under construction in Frankfurt. And with its "hip swing", probably the most spectacular of the five.

Designed as an architectural eye-catcher, the floors between 15 and 22 shift up to 5 meters (16 ft) in different directions and form a spiral by shifting the levels along its vertical axis.

The benefit of the cantilever slabs is the total of 8,200 m^2 (9,800 sq yd) of vegetated terraces in a prime location of Frankfurt's real estate landscape.

CHALLENGE TO THE STRUCTURAL DESIGNERS

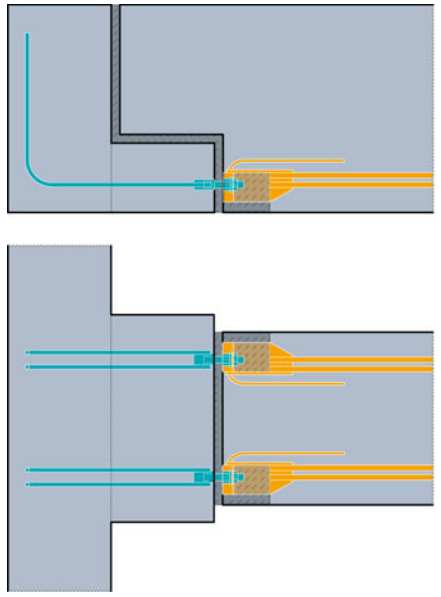
After **Bjarke Ingels** and his BIG architects won the architectural competition, the Bollinger + Grohmann engineers conducted a feasibility study.

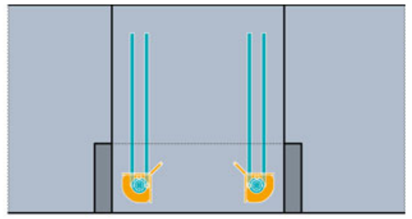
Structurally, the OMNITURM was designed as a high-rise building with main and secondary precast reinforced concrete beams, cast in-situ slabs, and a reinforced concrete core.

“Projects like this are ideal for precast concrete construction, because only a few connection details need to be developed. These details are then repeated over and over again,” explains **Thorsten Heskamp**, who supervised the project in Peikko's Customer Engineering.

DEVELOPING A CUSTOM SUPPORT SYSTEM

The aim was to optimize the geometry of the column strands to minimize inclinations or deflections of the columns.





An example of moment resisting connection between primary and secondary beams designed for OMNITURM.

HPKM® Column Shoe

COPRA® Anchoring Coupler

With precast elements and eccentric supports, the components are subject to torsion. That’s why the load must be centered by a tension connection. To avoid torsional moments on all levels above the second floor, Peikko HPKM® column shoes and COPRA® anchoring couplers were specified, wherever a precast beam is supported by a concrete corbel or a main beam rests on a secondary beam.

A custom design for the OMNITURM, the HPKM® column shoes were dimensioned for horizontal installation. The COPRA® anchoring couplers – another vital component of the connection system – were designed in precisely calculated lengths to match the standard formwork.

This solution transfers tension forces through the joints of a cast in situ structure with quasi monolithic behavior and allows for the fast assembly of the precast construction.

HPKM® Column Shoes were used in this project instead of BECO® Beam Shoes due to the tested R120 fire resistance requirement. This is fulfilled by the verification according to ETA 130603 approval and by indenting the component deeper into the precast element.

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DELTABEAM® GREEN LIGHTENING ENVIRONMENTAL FOOTPRINT

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.

Peikko's new DELTABEAM® Green composite beam cuts CO_2 emissions by up to 50%.

At Peikko we take sustainability seriously. We challenge ourselves constantly and want to set new standards for the whole construction industry. Our R&D department works hard to bring better and greener products into the market. We are proud and excited to begin the new decade by introducing DELTABEAM® Green into our product range.

SETTING STANDARDS FOR 30 YEARS

Since entering the market in 1989, DELTABEAM® Composite Beam has established itself globally as the number one choice for both designers and constructors. It enables flexible open space construction, slim floor structures, and possibilities for easy modifications at any stage of a building's lifecycle. Compared to traditional solutions, our precast technology helps optimize material consumption. Moreover, HVAC installations are simpler and integrated fireproofing reduces work on site.

PUSHING THE BOUNDARIES FOR A GREENER WORLD

Compared to the standard DELTABEAM®, which has already been a sustainable product, DELTABEAM® Green offers even more value for eco-friendly and modern construction work. Over 90% of its manufacturing materials are recycled, and it is produced using renewable energy. Careful and precise engineering means that less material is used in its production compared to traditional steel structures.

Even the logistics of DELTABEAM® Green are organized in an environmentally sound manner throughout the Nordics.

There is an urgent need for solutions that lighten the environmental footprint, and DELTABEAM® Green will cut CO_2 emissions by up to 50% compared to standard steel, composite or concrete beams. As a product, it is also more compatible with various environmental certifications, such as BREAAM and LEED. The environmental impacts are confirmed by the Environmental Product Declaration, EPD, and project-specific calculations of CO_2 emissions are made based on this certificate.

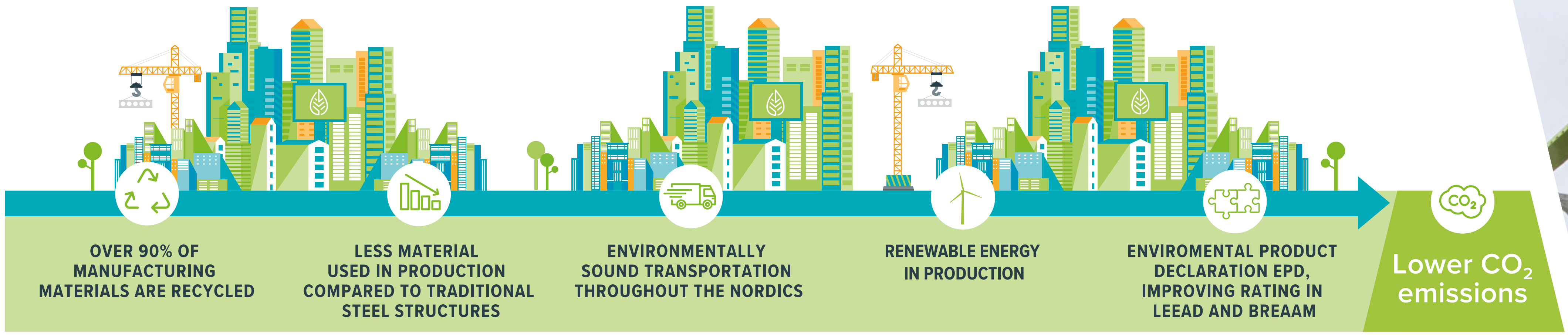
FREEDOM, RELIABILITY, AND ALL-ENCOMPASSING SUSTAINABILITY

The benefits of choosing DELTABEAM® or DELTABEAM® Green are numerous. It is a long-standing, reliable product that is suitable for any kind of multi-story building, and it works with all slab and column types. It gives plenty of architectural freedom for designing spaces with varying functionalities. When it comes to construction time, both DELTABEAM® and DELTABEAM® Green are quick and easy to erect with a small crew and with little or no propping.

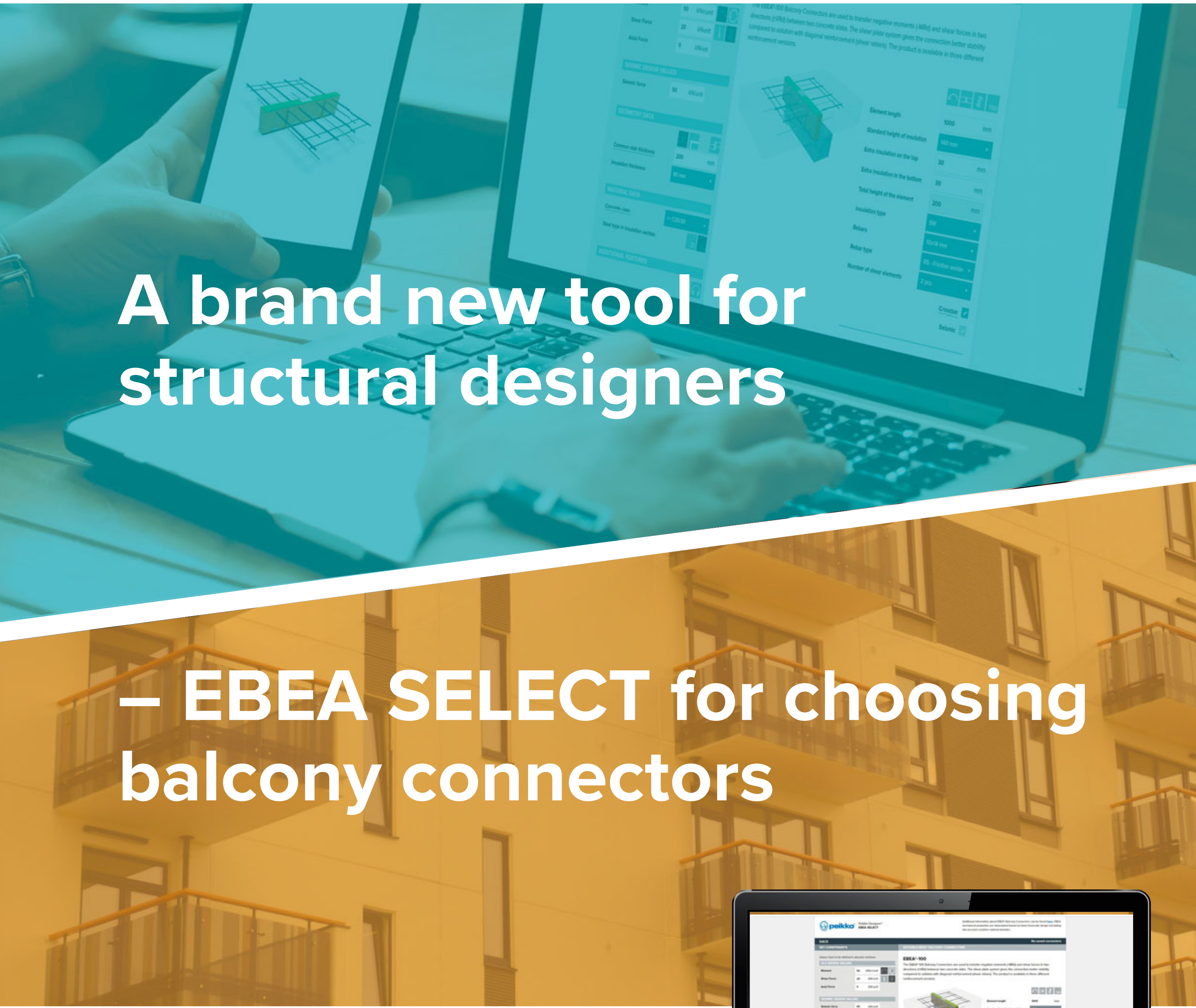
The added value you get when choosing the new and improved DELTABEAM® Green is its all encompassing eco-friendly design that includes everything from materials to production, and from certifications to transport. This is the modern way to build, and with Peikko's DELTABEAM® Green you will not only go the full way, but an extra mile as well.

DELTABEAM® Green

Lightening environmental footprint.



KruseSmith Havneparken in Norway, the first DELTABEAM® Green project.



A brand new tool for structural designers

– EBEA SELECT for choosing balcony connectors

EBEA SELECT is a free web-based tool that has been created for Peikko EBEA® Balcony Connectors. Finding of the perfect balcony connectors for your project is now easier than ever before. No more waiting or digging through extensive documentation. Use EBEA SELECT to make your design process faster, safer and more efficient. It gives you optimized connectors in minutes and creates the RFQ at the same time. Using EBEA SELECT is as easy as riding a bike.

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