CONNECTIONS

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

1*2017

Bolted connection

A STROKE OF GENIUS

PAGE 10

Nordic wind power

MORE THAN 1,200 TURBINES ON PEIKKO FOUNDATIONS

PAGE 14

ENERGY DISSIPATIVE CONNECTIONS IN SEISMIC AREAS

PAGE 22

peikko®

ISSUE 1 | 2017

CONTENT

REFERENCES

HIGHLIGHTS

TECHNICAL

CONNECTIONS

PUBLISHER:

Peikko Group Corporation
Voimakatu 3
FI-15101 LAHTI, FINLAND
peikko@peikko.com

EDITOR-IN-CHIEF

Molli Nyman
molli.nyman@peikko.com

OFFSET:

Grano Oy
ISSN-L 2489-4516
ISSN 2489-4516 (Print)
ISSN 2489-4524 (Online)

DESIGN:

Recommended Finland Oy

ON THE COVER:

With Peikko's bolted column connections the erection of heavy and large columns was fast, easy, and safe on the construction site of the IKEA store in Malacky, Slovakia.

WE HAD NO IDEA HOW IMPORTANT PEIKKO DESIGNER® COULD BECOME

Life is full of surprises. Some are good and, of course, some are bad. This also applies to business: it's difficult to predict the outcome some of our actions will have. In many cases, the only way is to see them through, via testing and corrections along the way.

Between 2009 to 2010, Peikko experienced the worst times in its history, and our net profit was clearly negative. But, luckily enough, we had an idea and decided to take a bold step towards creating a new kind of software. The first module of Peikko Designer® was launched in 2010.

Now, seven years later, it would be easy to say that this was a product of "great strategic thinking to help our customers". However, in those days it was much less clear.

Nevertheless, it was a decision to totally rethink how customized calculation software could look – how it could be updated, how it could work, how it could make designing easier.

The current modules for column connections, punching shear reinforcement, and fastening plates are helping designers around the globe. New functionalities, such as the ability to export calculation results from the column connection module directly into Tekla, have been well received by our customers.

I am very proud that we reached the milestone of 20,000 registered users for Peikko Designer® in December 2016.

We are still at the beginning of our journey. That's why we have decided to invest further in software development in 2017 and add a new team of talented software engineers to speed up the development work.

Onwards and upwards, with clear improvements every single year.

TOPI PAANANEN
CEO, Peikko Group Corp.

ECCENTRIC COLUMNS

REPLICATE NATURE, BUT HAVE A CONSIDERABLE BENDING MOMENT

Halle Architekten of Bern created Arborea Köniz, which beautifully combines urban city lifestyle to nature with concrete and wood. However, an expert was needed to connect the columns to a foundation.

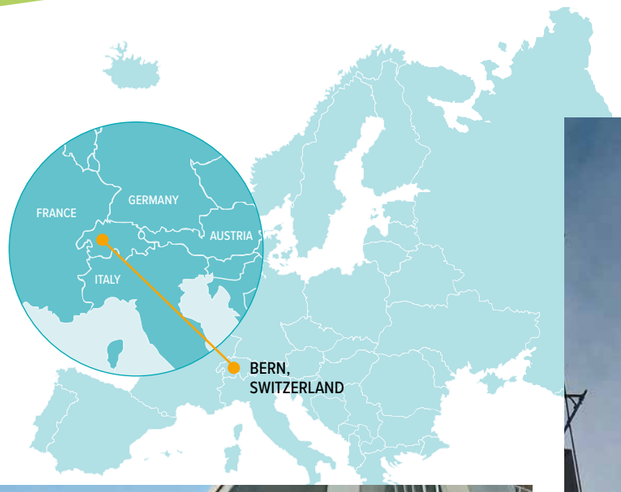
Among the 23 columns weighing between 10 and 15 tons, there were three different types shaped like Y, V and lambda. While giving the new Bernese residential building a nature inspired appearance, they were practically impossible to cast in situ.

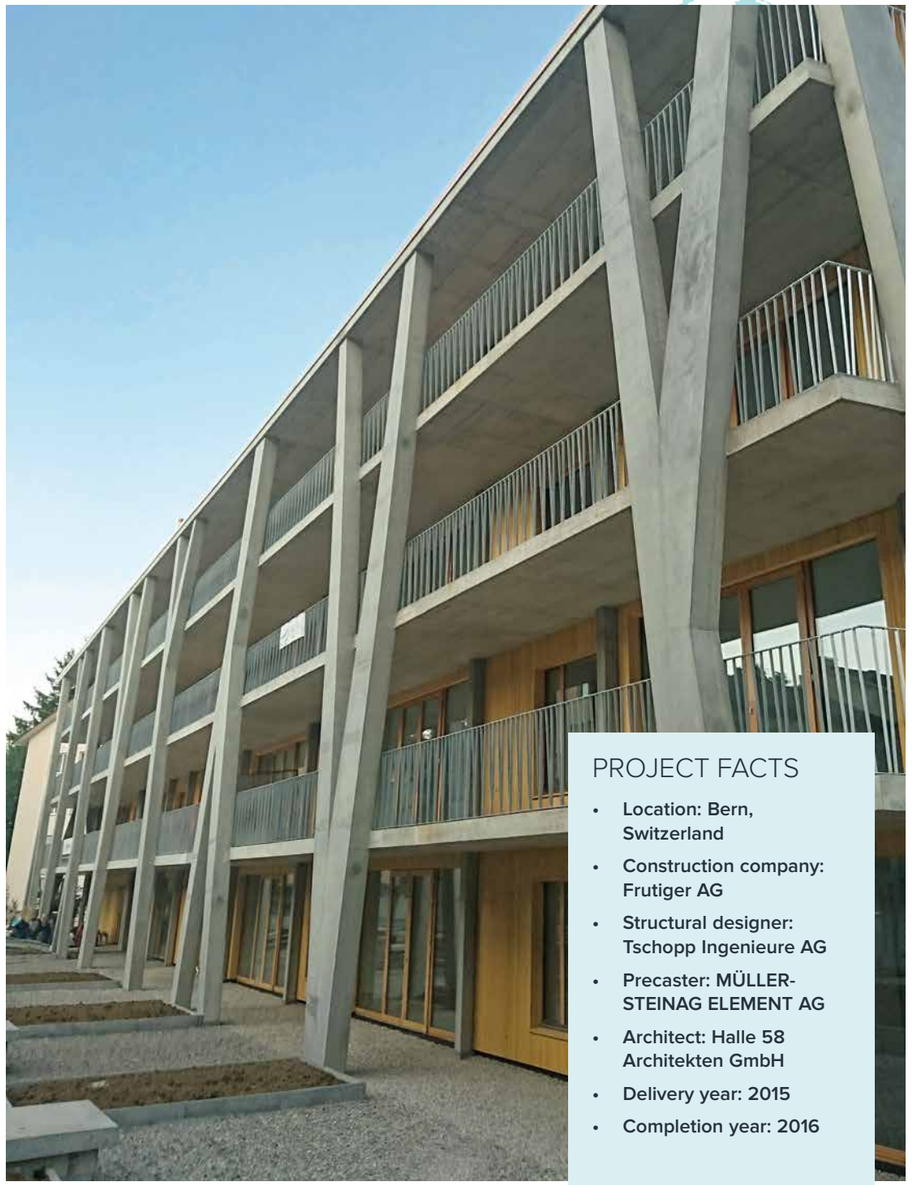
When the precaster **Müller-Steinag Element AG** got the order, it immediately recognized that one of the main challenges was to come up with a way to fix the columns to a foundation, as the bending moments and shear forces were considerable. Having worked with Peikko before, Müller-Steinag recommended that Tschopp Ingenieure AG take a closer look at bolted column connections.

"They asked how the eccentric columns could be attached to a foundation using bolts. The solution was to use standard Peikko technology, which of course had to be adapted to the special requirements of this project. We did a quick calculation with the Peikko Designer® to come up with the necessary information for the quotation," noted **Gregor Schabrun** of Peikko Switzerland.

The anchor bolts were carefully cast into position using specially designed and manufactured templates to ensure the right bolt inclination. Some of the anchor bolts were totally upright whereas some had an inclination of up to 7 degrees.

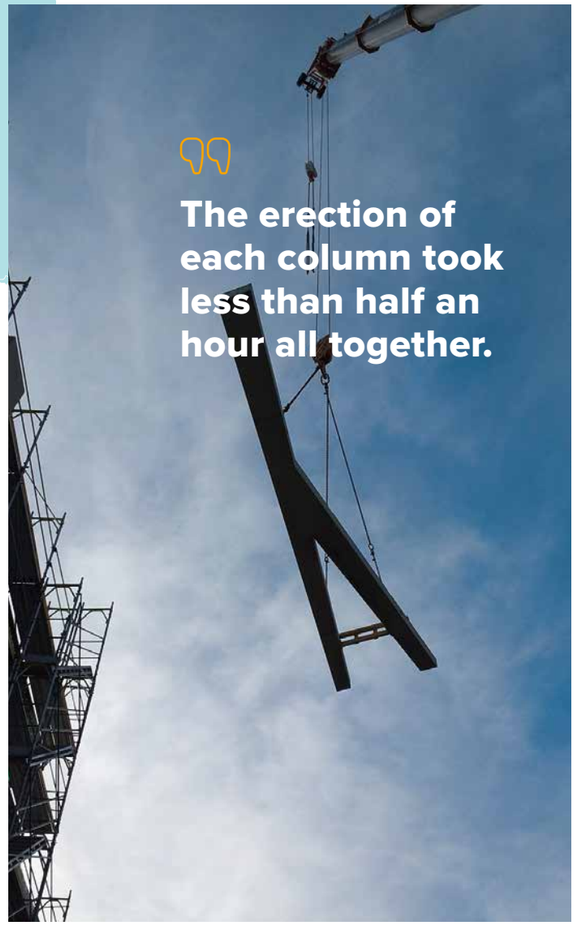
"Peikko Designer® is great for calculating tricky things, such as the bending and shear moments in the installation phase," Gregor Schabrun added. "Bolted connections are also quick on site. The erection of each column took less than half an hour all together and needed only a crane operator and two men on the ground."





PROJECT FACTS

- **Location: Bern, Switzerland**
- **Construction company: Frutiger AG**
- **Structural designer: Tschopp Ingenieure AG**
- **Precaster: MÜLLER-STEINAG ELEMENT AG**
- **Architect: Halle 58 Architekten GmbH**
- **Delivery year: 2015**
- **Completion year: 2016**



The erection of each column took less than half an hour all together.

ONE OF THE MAIN CHALLENGES WAS TO COME UP WITH A WAY OF FIXING COLUMNS IN THE FOUNDATION, AS THE BENDING MOMENTS AND SHEAR FORCES WERE CONSIDERABLE.

EXCEPTIONAL HEIGHT MADE FOR A CHALLENGING PROJECT

When building the 22-storey high Copenhagen Towers in Denmark, angled columns would have been difficult to handle with traditional support.

We did not even consider using the products of other manufacturers.

The Copenhagen Towers is the seventh highest building in Copenhagen. “The height of the office block – 22 floors and 85 meters (279 ft) – made it a more challenging project than average. The building was also special because of its curved facades,” noted **Aksel Rasmussen**, Project Leader at CRH Concrete A/S.

Peikko’s Column Shoes and Anchor Bolts enabled columns to be placed on top of each other without bracing. Per Aarsleff A/S, contractor of the project, has used Peikko’s products in several earlier projects.

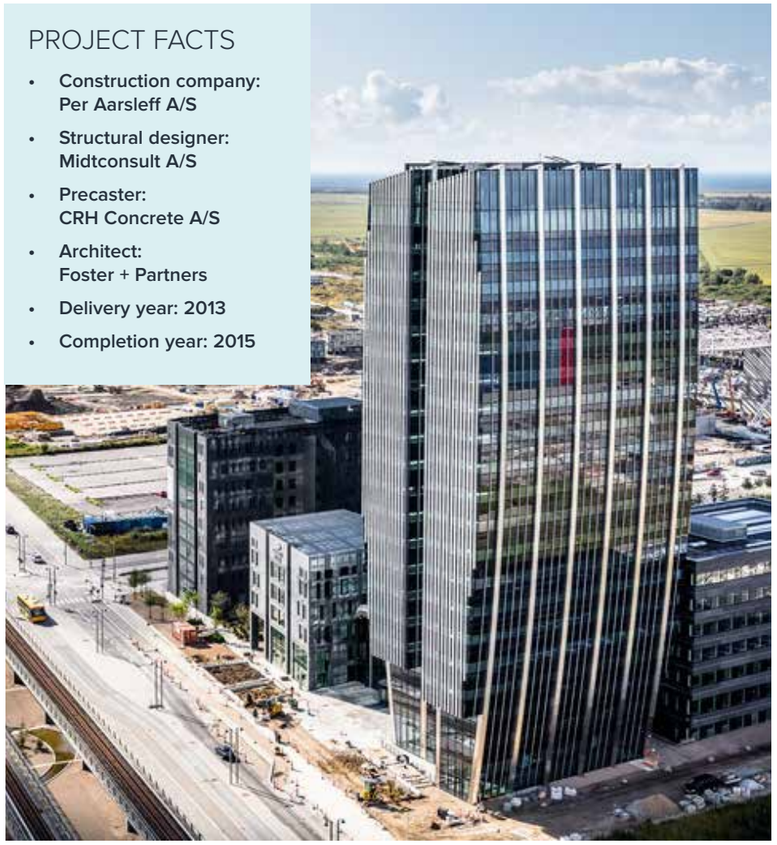
“We did not even consider using the products of other manufacturers because Peikko’s Column Connections fulfilled our requirements,” **Karsten H Mathiesen** of the constructor Per Aarsleff A/S, said. “They facilitated the placement of columns in a safe way, and allowed us to avoid handling heavy traditional supports.”

COLUMN SHOES’ ADVANTAGES ARE VISIBLE

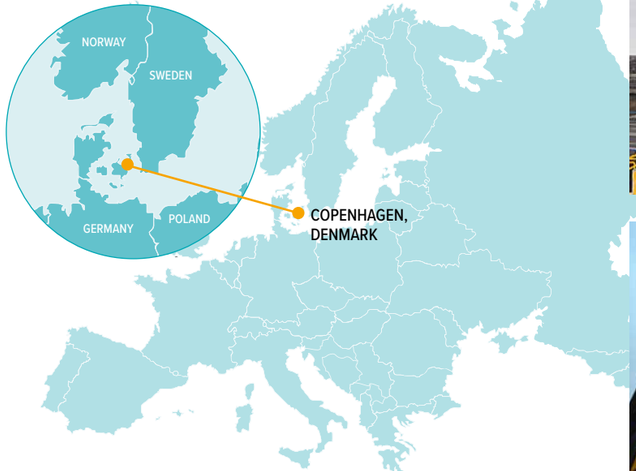
Peikko Denmark received lots of positive comments from engineers and erection companies who have seen the building site from the nearby highway.

PROJECT FACTS

- Construction company: Per Aarsleff A/S
- Structural designer: Midtconsult A/S
- Precaster: CRH Concrete A/S
- Architect: Foster + Partners
- Delivery year: 2013
- Completion year: 2015



“We have used Peikko’s products in several projects earlier – mostly column shoes, hidden corbels and fastening products. We chose to use Peikko’s Column Connections in this project because we have always been satisfied cooperating with Peikko. There were no hurdles in the processes and deliveries arrived as planned. I would work with Peikko in the future, too,” said Rasmussen of CRH Concrete A/S.



TAKE A LOOK AT THE AERIAL FOOTAGE OF THE CONSTRUCTION PHASE.

CONSTRUCTION SITE PHOTOS: WILLY NAESSENS, NETHERLANDS

HUGE DISTRIBUTION CENTER

BUILT FOR BOL.COM

Increase in online business has turned Netherlands into a booming logistics hub.

Responding to market demand, bol.com has built a distribution center in Waalwijk. Spanning over 50,000 m² (59,800 sq yd) or five football fields, the new warehouse has a total floor area of 130,000 m² (155,500 sq yd). The frame of the warehouse consists of 188 precast columns, which were erected with 1,248 column shoes and 1,248 anchor bolts.

Thanks to the bolted column connections, a heavy and labor-intensive phase such as propping left out of the building process. As speed and safety were the main criteria for choosing Peikko column connections, the frame was built in just 42 days.

Willy Naessens Nederland took care of both structural engineering and construction.

"Mounting without temporary bracing is a major advantage, and furthermore, the Peikko system can be used very quickly. There is less work at the construction site," **Tijn Valk**, the structural designer of Willy Naessens Nederland says.

The project will be completed in fall 2017. Bol.com has already reserved a plot for the expansion of the warehouse.

PROJECT FACTS

- Architect: FKG architecten aan de zaan
- Structural designer: Willy Naessens Nederland
- Contractor: Willy Naessens Nederland

Connecting columns:

WHAT IF YOU USED A BOLT INSTEAD?

In the early 1980ies, erecting precast columns was slow and inefficient – until Peikko's R&D had a stroke of genius.

At that time, the predominant way to connect precast columns into foundations was using a socket.

"That method was as old as Adam. Even the ancient Romans used it to erect their columns. While the socket worked, it was neither very fast nor quite safe," explained **Raimo Lehtinen**, who joined Peikko in 1989 as Research & Development Engineer.

Another widely adapted method was welding. From the designers' point of view, it was difficult to dimension properly. And on-site, welding was clumsy and took a lot of time.

There clearly was room for improvement. At Peikko's R&D department, someone started to think of bolts – what if they could be used for the job?

INSTALLATION TOLERANCE A KEY TALKING POINT

The first iterations of bolted column connections were made in 1983 and contractors soon identified the main benefit for them: frames were extremely fast to erect and the connection was adjustable.

"Some of them even offered discounts for customers who were using our column connections," Lehtinen reminisced.

Structural designers quickly realised that a bolted column connection was easier to dimension, but it was also seen as a safer way to erect columns.

"In every sales meeting there was one standard question – the installation tolerance. Contractors, in particular, were concerned about that. If you were specialised in concrete, you were used to ± 20 mm (0.79 in) tolerances. Our solution called for ± 15 mm (0.59 in). At first this 5 mm difference felt like a lot. But when we pointed out that tolerances were ±5 mm (0.20 in) when erecting steel columns, the opposition usually waned," explained Raimo Lehtinen, who is currently stationed in Peikko Sweden. "The accurate positioning of columns also allowed for more sophisticated connection methods, such as hidden consoles, to be used higher up in the frame."

On site, bolted column connections also radically reduced the excavation depth and eliminated the need for bracing.

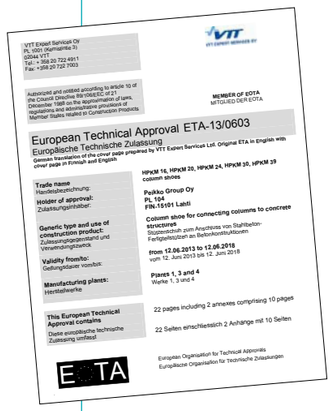
To ensure that the new working method was understood within all user groups, a Peikko representative was always present when a precaster made its first columns.

"Everyone quickly got a grasp of it from

→

ON SITE, BOLTED COLUMN CONNECTIONS ALSO RADICALLY REDUCE THE EXCAVATION DEPTH AND ELIMINATE THE NEED FOR BRACING.

HPKM®/HPM® BOLTED COLUMN CONNECTION SYSTEM



VTT Expert Services Oy
PL 1001 (Tekniikantie 21)
02044 VTT
Tel. +358 20 722 4911
Fax. +358 20 722 7003

Authorized and notified according to article 10 of the Council Directive 89/106/EC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to Construction Products

MEMBER OF EOTA
MITGLIED DER EOTA

European Technical Approval ETA-13/0603
Europäische Technische Zulassung
German Translation of the cover page prepared by VTT Expert Services Ltd. Original ETA in English with cover page in Finnish and English
ersetzt

Trade name / Handelsbezeichnung: HPKM 16, HPKM 20, HPKM 24, HPKM 30, HPKM 39 column shoes
Holder of approval: / Zulassungsinhaber: Peikko Group Oy, PL 104, FIN-15101 Lahti
Generic type and use of construction product: / Zulassungsgegenstand und Verwendungszweck: Column shoe for connecting columns to concrete structures / Stützenschuh zum Anschluss von Stahlbeton-Fertigteilstützen an Betonkonstruktionen
Validity from/to: / Geltungsdauer vom/bis: from 12.06.2013 to 12.06.2018 / vom 12. Juni 2013 bis 12. Juni 2018
Manufacturing plants: / Herstellwerke: Plants 1, 3 and 4 / Werke 1, 3 und 4
This European Technical Approval contains / Diese europäische technische Zulassung umfasst: 22 pages including 2 annexes comprising 10 pages / 22 Seiten einschließlich 2 Anhänge mit 10 Seiten

EOTA
European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen

- Meets the latest European requirements
- European Technical Approval ETA-13/0603 valid in almost 30 European countries
- Tested and CE-marked
- Rigidity of the connection corresponds to a cast-in-situ column connection
- Eurocode 3 conformant greater shear capacity approved for use in a HPKM® Column Shoe Connection on the basis of tests
- Can be designed for fire resistances R60, R90 and R120
- Design made easy with Peikko Designer®

The basic column connection concept has evolved through the years to meet the needs of designers and contractors.

the installation point of view. It's not that complicated. Once you saw how the connections were placed into the mould, it was plain sailing from there," Lehtinen recalled.

NEXT STEP GERMANY

With the new way of connecting columns, construction process became four times faster than with other solutions in the market. By the end of eighties, a breakthrough was really underway in Finland and it was time to set sights toward European market.

In 1992, Peikko entered Germany. There were no competitors in the field – but also very little awareness of the product.

"Existing market players would even make suspicious, sarcastic comments regarding column connections at the first industrial fairs in which we participated. The building business in Germany was and still is conservative. But when our success increased and we became more known in Germany with a track record of success, that mindset changed," explained engineer **Christian Gerke**, Managing Director of Peikko Germany.

DEVELOPMENT NEVER STOPS

Jorma Kinnunen joined Peikko in 1996. As a Senior Manager in R&D, he has had a great vantage point to see the evolution of Peikko column connections.

"The basic concept has evolved through the years to meet the needs of designers and contractors," Kinnunen added.

In the early nineties, a lighter version of the column shoe was developed.

"Ideal for applications with lighter loads, the new versions were lighter and easier to handle in precast plant. This is a benefit that still applies," Kinnunen described. The improved version was an international success.

"We started selling the product country by country and the sales volume just kept increasing and still does so today. Nowadays, our factories manufacture more than 300,000 column shoes per year, and column connections are being sold all over the world," Kinnunen noted.

THIRD PARTY TECHNICAL APPROVAL ALWAYS A PRIORITY

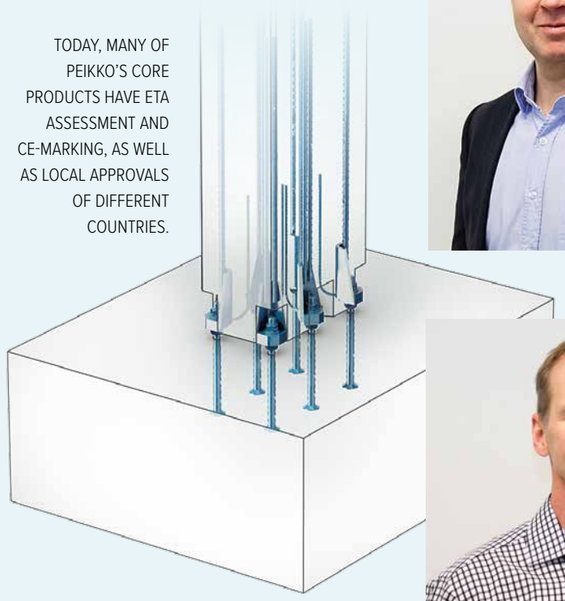
Today, many of Peikko's core products have ETA assessment and a CE-marking, as well as local approvals of different countries. "International approvals have always been important to Peikko as the technical approvals are the best way to declare the performance of our products," explained Kinnunen, who oversaw the process and currently focuses on international standardization at Peikko.

The national regulations were especially strict in Germany.

"We could not have even operated in Germany without first getting national technical approvals for our products. Potential customers would always first ask if we had already done our paperwork. It was such an innovative product that the German authorities had to come up with a new set of rules in order to accommodate it."

Earlier there were national standards in every market, now we have the Eurocodes in Europe.

"We follow the development of building and design standards very closely, and, as such, is a demanding task. We operate in many countries, but want to match local demands wherever we go. Our products meet the valid standards and regulations, which is an advantage for our customers and for Peikko, as well," Kinnunen explained.



TODAY, MANY OF PEIKKO'S CORE PRODUCTS HAVE ETA ASSESSMENT AND CE-MARKING, AS WELL AS LOCAL APPROVALS OF DIFFERENT COUNTRIES.

RAIMO LEHTINEN

JORMA KINNUNEN

PEIKKO LEADS THE NORDIC WIND TURBINE FOUNDATION MARKET

Even though the foundation may seem like a minor detail in a wind power development project with a EUR 50–200 million price tag, slow progress in foundation design, production and assembly will postpone the day when the investment starts to generate profits. With that in mind, Peikko has created a holistic solution consisting of the design, manufacturing and installation of both gravity and rock foundations.

Since 2014, Peikko has been the technology distributor for more than 1,200 foundations in Nordic wind power projects. Success has come with a simple insight that is easy to relate to, whether you are an investor or a contractor.

"Any delay in the building process will postpone the day when the investment starts to generate profit," **Kari Tuominen**, Business Director of Peikko's wind turbine foundation business, noted. "It's not a small detail we are talking about, as the overall price tag of these projects may well reach 1 billion euros."

In 2012, Peikko started the quest for faster wind power projects by fine-tuning its design, manufacturing and installation process with gravity foundations. The result was quickly noticed, and the market share rose quickly. Currently, around 600 wind turbines are built annually in the Nordic countries. One third of these will have Peikko foundations.

"We have fine-tuned our processes and organization to be able the meet the needs of demanding large-scale wind park projects. Peikko foundations have been used by many leading manufacturers, such as Vestas, Siemens and Senvion," Tuominen added.

→

To date, Peikko has delivered technology for more than 1,000 gravity foundations and for almost 200 rock foundations.

FOUNDATIONS CURRENTLY UNDER CONSTRUCTION

- 41 gravity foundations in Lehtirova, Sweden
- 71 rock foundations in Roan, Norway

FOUNDATIONS JUST COMPLETED

- 50 rock foundations in Tellenes, Norway
- 33 rock foundations in Egersund, Norway
- 7 rock foundations in Svåheia, Norway

Peikko has a designated design team solely for wind turbine foundations.

© SKANSKA – JOHN INGE MATHIENSEN

Any delay in the building process will postpone the day when the investment starts to generate profit.

ROCKY NORWAY: A PERFECT SETTING FOR WIND POWER

The Feed-in Tariff created a wind energy boom in Finland. Now the same is happening also in windy Norway. However, foundations pose a challenge for foundation designers as Norwegian wind parks are often planned on rock. A gravity foundation could be used – but you would need to blast away a huge amount of rock.

Having supplied technology for more than 1,000 gravity foundations, Peikko is now excited to bring its expertise to wind parks located in rocky areas.

"We are geared toward serving developers who are keen on taking advantage of the Norwegian subsidies. Our rock foundation technology will save both their time and money as the price of concrete and transportation is very high. A rock foundation with just 10-20 m^3 (353 - 706 sq yd) of concrete is very competitive in rocky places," Tuominen promised.

Soil inconsistencies can also cause additional headaches for the foundation design team and the investors alike.

"Our approach works particularly well in areas with heterogeneous soil – you can have both gravity and rock foundations in the same wind park. And thanks to our swift design and manufacturing process, every foundation will be optimized to the exact location," said Tuominen.

STREAMLINED DESIGN PROCESS A PRIORITY

"One of the main hurdles in developing large wind parks is timetable. Typically, it takes four to eight weeks to get a foundation design from an engineering company or a structural designer. And if there are different soil types in the area chosen for your wind park, more weeks are lost doing additional designs," noted **Andris Berzins**, the Product Manager of Peikko's wind turbine foundation technology.

Thanks to Peikko's experience on designing connection details on an industrial scale, a preliminary foundation design can be done within a day.

"Compared to other design offices, Peikko has a designated design team that is focused solely on wind turbine foundations. A lot of the repetitive work is automated and we are constantly looking for ways to make our process even more efficient. The aim is to free the designers' time for what's most important – thinking – and to avoid time-consuming tasks that generate only little or no value," Berzins explained.

"Our industrial operating model means that the wind turbine foundation design is seamlessly integrated with production. We can have the components – anchor cage and reinforcement – ready for shipping starting from 3 weeks. Global warehousing of standard components further adds delivery flexibility," added Tuominen.

THIRD PARTY VERIFICATION A MUST

With the huge amount of money invested in wind energy projects, investors often require third party, such as DNV-GL, verifications. After the preliminary design, a calculation report is made for authorities and third party approvals.

"We like to think our design service as a conveyor belt. You put the correct data in and get the high quality design from the other end of the belt," Berzins described.

OPTIMIZED USE OF MATERIALS

Peikko's design team will optimize the amount of concrete and steel used – and come up with a pretty close figure for what the foundation will cost in the end.

"This gives especially the contractors a clear understanding on the foundation costs and helps them to make winning bids. And if you need to change perhaps to another turbine manufacturer, the new calculations are quickly available," Andris Berzins noted.

QUICK TO INSTALL

"By carefully scheduling the delivery of materials, we can simplify site planning and resource allocation," Tuominen says.

An anchor cage can be installed in a day, while a gravity foundation is completed within a week. The installion of a Peikko rock foundation will take two weeks spread over a longer period of time. Even though the delivery always includes step-by-step instructions for assembly, a Peikko expert will be available to offer on-site advice.

"If needed, we can also do the installation and casting as a part of the overall delivery," Kari Tuominen added.

OPTIMIZING TIME-TO-MARKET WITH DECENTRALIZED MANUFACTURING

Getting what you need exactly when you need it is of utmost importance for the schedule of your project.

THE MAIN MANUFACTURING LOCATIONS FOR PEIKKO'S PRECAST CONNECTIONS

- **Zhangjiagang, China**
- **Lahti, Finland**
- **Waldeck, Germany**
- **Kaunas, Lithuania**
- **St. Petersburg, Russia**
- **Kralova nad Vahom, Slovakia**
- **Ras Al Khaimah, United Arab Emirates**

In addition, we have some manufacturing activities in workshops in United Kingdom, United States and Saudi Arabia.

PEIKKO STRICTLY ADHERES TO QUALITY REQUIREMENTS

Quality, Environmental and Safety Management Systems	ISO 9001, ISO 14001 and OHSAS 18001
Production in the main production units	ISO 3834-2 and EN 1090-1, 2

98% of our precast connections are manufactured in Peikko facilities

PEIKKO GROUP IN A NUTSHELL

Peikko Group Corporation is a leading global supplier of connection technology for concrete constructions, and slim floor structures. Peikko's innovative solutions make its customers' building processes faster, easier and more reliable. Peikko has subsidiaries in 30 countries in Asia-Pacific, Europe, the Middle East, and North America, with manufacturing operations in 9 countries. Peikko's revenue in 2016 was EUR 173 million. Peikko is a family-owned and run company that employs over 1,500 professionals. Peikko was founded in 1965 and is headquartered in Lahti, Finland. Further information: www.peikko.com

ALL OUR FACTORIES OPERATE UNDER SAME QUALITY STANDARDS INSPECTED BY DNV-GL.

98 % of our precast connections are manufactured in our own facilities around the world. The aim of the decentralized manufacturing is to optimize time-to-market and also allow extra flexibility when a customized product is called for.

All our factories operate under the same quality standards inspected by DNV-GL. In most locations the technology and production machinery is similar if not the same. The core manufacturing technologies are steel cutting, mechanical processing and welding. We also use modern thread rolling, forging, plasma cutting and robotized welding technologies. To safeguard quality and efficiency, our central sourcing uses no middlemen – instead, we source directly from steel mills.

"There are a number of new investments ongoing in our connections factories. During 2017 we are going to install several new welding robot stations equipped with top-of-the-class welding technologies and several highly automated thread rolling lines as well as continue investing into forging technology for many of our factories. There will be new equipment coming to all of the facilities listed above – to continuously increase our capacity, productivity and customer satisfaction," states **Andrius Surantas**, Vice President of Operations at Peikko Group.

The manufacturing and quality specifications are the same in all the factories for each product. They are based on product specification drawings and centrally maintained quality assurance instructions.

The products are packed in a standardized way. However, there are some variations due to market-specific factors such as the availability of packing materials or customer demand. ●

→ AUTHOR: **ELENA CAMNASIO**
D.SC. (TECH.), R&D ENGINEER,
PEIKKO GROUP CORPORATION

BOLTED COLUMN CONNECTION FOR SEISMIC APPLICATIONS

A

FIGURE 1. (A) PEIKKO'S BOLTED COLUMN-TO-FOUNDATION CONNECTION (ADAPTED FROM [16], [17])

B

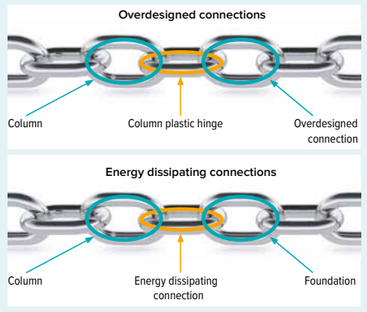


FIGURE 1. (B) CHAIN ANALOGY OF THE DESIGN ALTERNATIVES.

INTRODUCTION

The connections between precast elements play a fundamental role in the overall performance of the structure, especially if seismic applications are considered. In fact, precast connections represent a critical link where structural continuity is needed. Early precast constructions had inadequate detailing and lacked continuity or redundancy in the structure, resulting in poor seismic performance. Furthermore, there were no design guidelines for precast concrete structures used in seismic areas.

For these reasons, precast has seen limited use in earthquake-prone zones. So far, engineers have favoured cast-in-situ solutions or used alternatives such as protruding bars or hybrid connections out of habit. However, there is not always clear evidence of their seismic behaviour, and usage risk evaluations are lacking. In addition, precast structures offer several advantages during both production and installation compared with traditional solutions, such as better material and product quality control, improved erection speed and cost savings.

In the last two decades, numerous studies have been performed regarding the cyclic behaviour of precast joints in order to support the development of modern Codes [5], [8], [9], [14], [15]. The major aim is the mitigation of seismic risk through a performance-based design approach where accepted damage levels are considered as limit states. Specific requirements for both strength and ductility of connections have been imposed so that structures can withstand seismic load reversals without a substantial reduction in global resistance.

With regard to such design needs and considering customers' interests, Peikko initiated a wide-ranging experimental research program in 2008 in cooperation with Politecnico di Milano (the Technical University of Milan) to investigate the performance of bolted column-to-foundation connections made with HPKM® Column Shoes [16] and HPM® Anchor Bolts [17]. The aim of the research was to develop a precast connection that emulates monolithic joints with the same performance in terms of ductility, energy dissipation capacity, stiffness and strength degradation, thus combining compliance with the Codes with the advantages of precast structures.

PEIKKO'S BOLTED COLUMN CONNECTION

Peikko's Bolted Column Connection consists of HPKM® Column Shoes and HPM® Anchor Bolts (Figure 1a). HPKM® Column Shoes [16] are assembled from base and lateral steel plates and anchoring rebars, which are cast at the base of the precast element. Weldings between such components have a nominal strength at least twice that of the anchor bolts. This guarantees the elastic response of the welds.

HPM® Anchor Bolts [17] are ribbed steel bars, which are partly cast into the foundation. The external threaded part allows the base plate to be tightened using two washers and two hexagonal nuts.

The open joint between the column and base structure, including column shoe pockets, is filled with non-shrink, cementitious grout. The grout has a design compressive strength at least one class higher than the highest grade of concrete used in the connected elements, so that brittle concrete failures are avoided in the joint.

The main advantage of using bolted connections is that an immediate connection is made. The column can be installed on the construction site without temporary bracing, simply by levelling and tightening the nuts. Peikko's Column Connection offers sufficient assembly tolerances to adjust the column to the correct level and vertical position. The construction process is fast and safe, and the final look of the connection is very similar – if not identical – to conventional cast-in-situ solutions.

The part of the column above the joint is overdesigned so that plastic hinging is developed exclusively inside the grouted joint. This is due to the column shoes, which are stronger than the bolts, and to the overlapping of column shoe rebars with column reinforcement, which results in a column cross-section flexural resistance much higher than that of the joint.

DESIGN ALTERNATIVES FOR THE CONNECTION SYSTEM

Generally, the Codes allow two different approaches to designing precast column-to-foundation connections (Figure 1b). Firstly, connections can be overdesigned so that the critical region moves to the connected column. The connection remains almost elastic with limited displacements or local deformations, representing a "strong" link in the hierarchy of resistances. This means that the resistance of the column connection is dependent on the resistant moment of the column that it supports. However, the area of the column above the joint is over-strengthened due to the overlapping of column shoe rebars and column reinforcement. As a consequence, overdesigned column connections require relatively large column cross-sections to fit the necessary anchoring bolts. This is not economically efficient and may result in dense reinforcement in the joint.

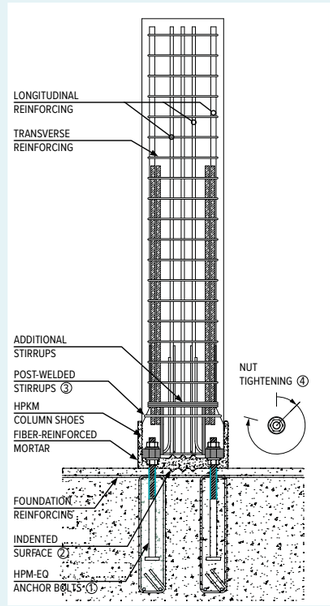
The second alternative is represented by energy dissipating connections, which are located in the critical region but also comply with the prescribed local ductility criteria. In this case, the plastic hinging of the column and/or the buckling of the rebars are avoided while the possible damage is limited to the base of the column at the interface with the foundation, where the anchor bolts represent the "weak" element and act as ductile connectors. In contrast to overdesigned connections, the resistance of energy dissipating connections is dependent on the acting moments as for cast-in-situ joints. Since the joint dissipates energy itself, it can be designed to match the capacity of the column while respecting the capacity design in the overall structure. Under specific conditions, this leads to a smaller and adequately reinforced column cross-section.

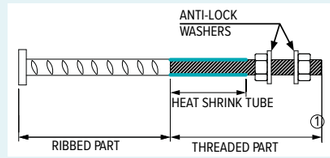
PEIKKO'S COLUMN CONNECTION FOR SEISMIC APPLICATIONS

To be considered "ductile", a connection must show experimentally a stable cyclic behaviour and an energy-dissipative capacity at least equal to that of a monolithic connection that has the same resistance and conforms to the local ductility provisions of the Code. Special detailing shown in Figure 2 was then introduced in Peikko's standard Column Connection for this purpose [11]. The effectiveness of the new features is evaluated basing on the comparison with earlier experimental results, where such improvements were not yet included [3], [12], [13].

HPM®-EQ Anchor Bolts [18] were specifically developed and produced with B500C – the highest ductility steel material. The embedded thread is now debonded by a heat shrink tube so that the anchor bolt is able to deform freely and the deformation capacity of the steel is not reduced. Different debonding materials were tested. The heat shrink tube was the best option for keeping the highest ultimate deformation of the steel during push-pull tests on anchor bolts [13]. Loads are then transferred through the ribs and the headed stud as in standard anchor bolts.

The tightening of the joint under cyclic loading is secured by high strength and anti-lock washers as well as by a type of pre-tensioning of the anchor bolts, which is





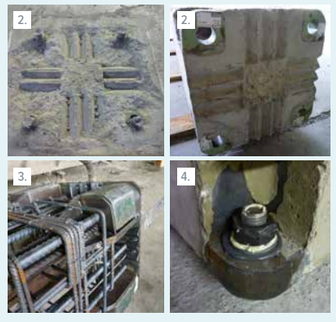


FIGURE 2. PEIKKO'S COLUMN CONNECTION FOR SEISMIC APPLICATIONS.

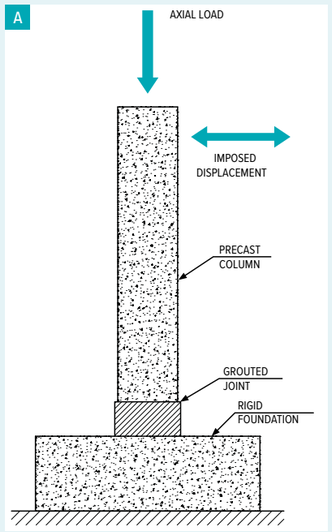


FIGURE 3. **(A)** TEST SETUP AND **(B)** GENERAL VIEW OF THE SPECIMEN IN THE LAB.

induced by an additional rotation of the upper nut after snug tightening. In particular, anti-lock washers are made of two parts with a wedged internal surface where the angle is greater than that of the threads. The possible slippage of the two parts results in an increase in the thickness of the washer that is greater than the pitch of the thread, thus keeping the connection tightened. The additional rotation assures the proper functioning of the connection, which is anyhow guaranteed by a certain tolerance of the pre-tension force value.

An epoxy resin is injected around the anchor bolt inside the over-sized hole of the base plate in order to compensate for the tolerance needed during installation. Any movement of the anchor bolt inside the hole is prevented. This helps to significantly reduce the pinching effect, which is due to mutual displacement of the anchor bolt and column shoe. The beneficial effect results in an increased amplitude of hysteresis cycles as experimentally verified.

A high strength fibre-reinforced mortar is used as joint grouting to avoid the spalling of the unconfined compressed collar of mortar around the column base. This limits damage and hence post-earthquake repair intervention. Moreover, the surfaces at the base of the column and on the top of the foundation are indented so that compressed struts can develop between the upper and lower indentations. This results in avoiding column slippage. The shear resistance of the joint under cyclic loading is increased by relying on both the friction and the mechanical interlocking of the surfaces. Shear is mainly accounted for by this mechanism, while anchor bolts are subjected almost exclusively to tension and compression.

Finally, additional stirrups around the column shoes limit their mutual displacements and rotations, thus reducing the cracking of the joint. The equal displacement of the column shoes under cyclic loading is guaranteed. For example, in a column with four column shoes, two shoes will be compressed and two tensioned alternatively. The presence of stirrups helps to redistribute such forces among the shoes.

EXPERIMENTAL INVESTIGATIONS

In order to assess the performance of such an innovative connection for seismic applications, several full-scale sub-assemblies have been tested at Politecnico di Milano. The specimens consisted of a 2.15 m (7 ft) high column and a rigid foundation element. Different layouts of the connection were investigated by changing the number and size of the anchor bolts and by varying the column's cross-sectional dimensions. Some configurations also underwent three identical tests to assess the replicability of the results.

The main aim of the research activities was to compare the cyclic performance of emulative connections to that of cast-in-situ joints in order to demonstrate that the connection possesses stable cyclic deformation and energy-dissipation capacity according to Eurocode requirements. Two monolithic columns, which complied with reinforcement detailing for high ductility classes as required by [4] and [5] were therefore tested. Such columns were designed to have the same resistance as three of the precast specimens.

TEST SETUP

Quasi-static oligo-cycles imposed-displacement tests were performed. All the specimens were tested by applying the same drift pattern with three cycles of equal displacement for each increasing drift level (0.5%, 1%, 2%...) until failure [2]. The failure criteria were anchor bolt failure or a loss of horizontal resistance greater than 20% from the peak value. Columns were also vertically loaded with a constant axial ratio of about 10% (Figure 3).

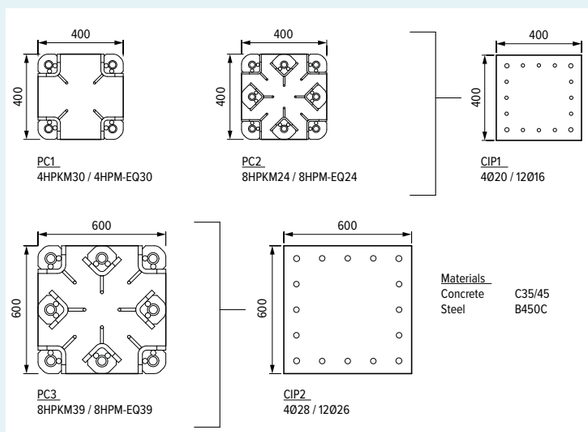


FIGURE 4. COLUMN CROSS-SECTIONS AND MATERIAL DETAILS OF THE SPECIMENS.

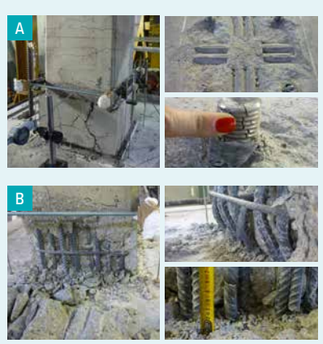


FIGURE 5. (A) PC1 SPECIMEN AND FAILED ANCHOR BOLTS WITH DAMAGED THREAD; **(B)** CIP1 SPECIMEN WITH BUCKLING AND FAILURE OF LONGITUDINAL REBARS.

TEST RESULTS

For the sake of brevity, the presented results refer to the last part of the research program carried out during 2015. The precast connection arrangements and the equivalent cast-in-situ concrete cross-sections considered herein are shown in Figure 4.

The precast specimens all showed localized damage in connection to the grouting, which presented an extensive crack pattern at the end of the test (Figure 5a). Spalling of the mortar was avoided thanks to the steel fibres, which kept the mortar in place around the cracks. It is worth noting that little or no damage was observed for drifts of up to 1%, which is beyond the limit for interstorey drift imposed by the Code [5]. Even after a moderate earthquake, the column remains almost undamaged and any possible repair intervention would affect the grouting only.

In order to investigate the ultimate capacity of the connection, the tests continued until failure, which always occurred for drifts greater than 5%. This highlights the great deformation capacity of the connection, which relies on the anchor bolts. Anchor bolts failed generally below the lower nut or the foundation level. This indicates that the concentration of the stresses is maximum at the interface between column and foundation, as expected. Moreover, the thread of the anchor bolts emerging from the foundation was generally damaged, which is possibly due to tensile and compressive cyclic loading (Figure 5a).

Test		PC1	PC2	PC3	CIP1	CIP2
+Δ	Δ_y	0.8	1.3	1.5	1.0	1.8
	μ_Δ	8.8	6.2	4.0	4.0	>5.0
−Δ	Δ_y	0.8	0.9	1.7	1.2	1.8
	μ_Δ	8.8	6.3	3.5	3.3	>4.4

TABLE 1. DUCTILITY VALUES FOR POSITIVE AND NEGATIVE DISPLACEMENTS.

Conversely, cast-in-situ specimens suffered generalised damage with evident spalling at the base of the column and cracks on the foundation surface (Figure 5b). This would lead to higher repair costs. Furthermore, the longitudinal reinforcement buckled and one of the rebars failed in CIP1 (Figure 5b). This indicates that brittle failure could easily occur, especially in the absence of proper detailing, such as adequate confinement of the critical zone.

DATA ANALYSIS

One of the most important seismic design parameters is the displacement ductility, which is the ratio between the ultimate displacement and the yielding displacement of a structural member. This ratio measures the ability of the connection to undergo large-amplitude cyclic deformations in the elastic range without a substantial reduction in strength [2]. All the precast specimens achieved a displacement ductility of at least 4, showing great post-elastic deformation capacity (Table 1).

In particular, Figure 6a shows the comparison between the force-displacement curves of PC1 and CIP1. It can be noticed that the deformation capacity of the precast specimen is greater than that of the correspondent cast-in-situ one. Moreover, the strength degradation of the precast specimen is extremely limited, fulfilling the threshold (< 20%) recommended by [10], while the cast-in-situ column suffered an abrupt loss of resistance after 4% drift due to rebar buckling and spalling.

The comparison between the backbone curves of all the specimens confirms that the tested precast and cast-in-situ columns are similar in terms of resistance according to the design (Figure 6b). The PC2 specimen also shows a greater deformation capacity than PC1 thanks to the presence of more anchor bolts of a smaller diameter. The CIP2 specimen was the only one that did not reach failure, even at drifts of more than 9%, and it showed better performance than the equivalent precast PC3 specimen. This is possibly due to the continuous reinforcement between the column and foundation in CIP2, which was designed according to the requirements for special moment resisting frames [1].

Another parameter to be taken into account when comparing precast and cast-in-situ specimens is the energy dissipation capacity. The equivalent damping factor has been evaluated by summing the elastic (2%) and the hysteretic components. Both typologies resulted in similar equivalent damping factor values, the precast specimens showing even more stable hysteresis cycles. The result was in general greater than 37.5%, thus fulfilling the requirements in [10] for ductile connectors (Figure 7a). Finally, Figure 7b shows that bolted connections are also as stiff [2] as monolithic joints. It can also be noted that the decay of initial stiffness is gradual, without any sudden and undesirable stiffness loss.

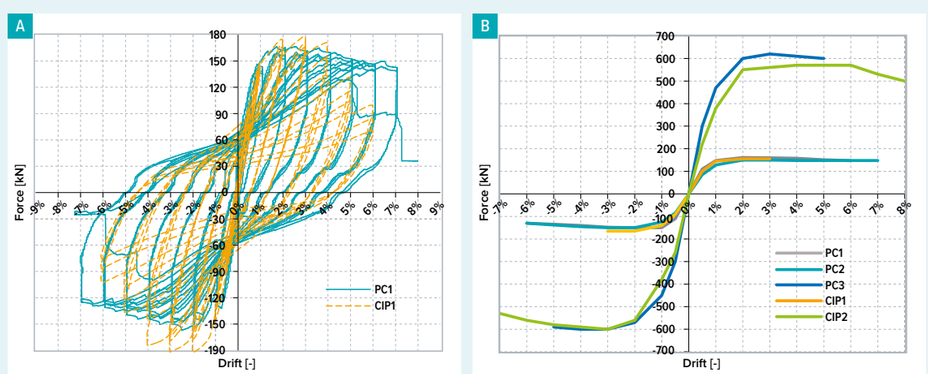
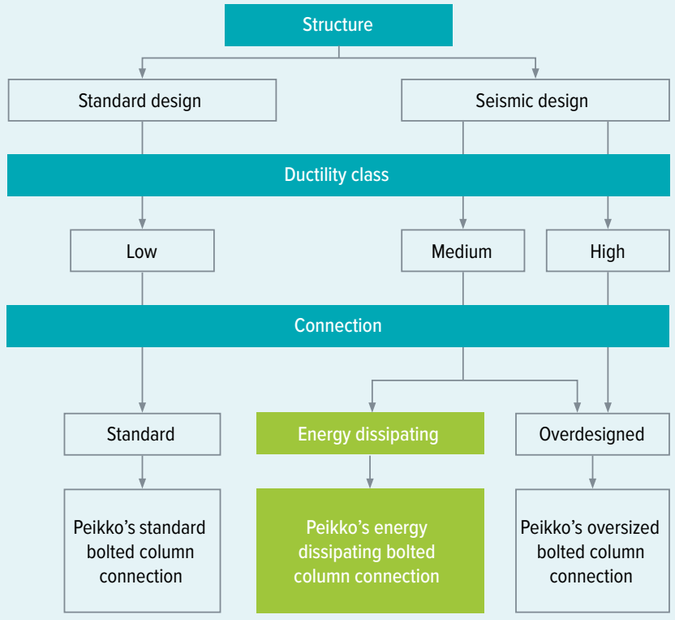


FIGURE 6. (A) COMPARISON OF THE HYSTERESIS CURVE OF PC1 AND CIP1 SPECIMENS; **(B)** COMPARISON OF THE BACKBONE CURVES.

FIGURE 8. FLOWCHART SHOWING THE DIFFERENT DESIGN OPTIONS FOR BOLTED COLUMN CONNECTIONS.



DESIGN GUIDELINE

Peikko's Column Connection for seismic applications has been approved for use in mediumductility class structures designed with a behavioural factor of up to 4 according to [5]. In fact, the design ductility of the HPKM®–HPM®-EQ connection can be assumed to be equal to 4 for compression ratios of up to 15%, or 3 otherwise, based on the test results above. This covers most of the cases for all the structural types identified by the Code, for which the connection can be considered energy-dissipative. If the American approach is adopted, the connection can be used in intermediate moment resisting frames according to [1].

Moreover, the static performance of Peikko's Column Connection and its single components is fully covered by European Technical Approvals ETA-13/0603 [7] and ETA-02/0006 [6].

Moreover, the static performance of Peikko's Column Connection and its single components is fully covered by European Technical Approvals ETA-13/0603 [7] and ETA-02/0006 [6].

If the design requirements are different, such as high ductility class structures and/or higher behaviour factors according to [5] and special moment resisting frames according to [1], it is possible to use Peikko's standard Column Connection by adopting an overdesigned solution. However, such requirements are rarely adopted because they might lead to extensive reinforcing detailing and increased displacement demand on both structural and non-structural elements.

Figure 8 shows the different design options for precast structures with bolted column connections. Depending on the ductility class requirements, the connection can be designed as standard, energy dissipating or overdesigned. For medium ductility requirements, the HPKM®–HPM®-EQ connection is an excellent choice.

TECHNICAL DOCUMENTATION

The safety of Peikko's Column Connection for precast concrete structures in seismic zones has been validated by serious research, which was carried out under the supervision of a highly-respected third party. The Politecnico di Milano has issued a signed recommendation document as an outcome of the research program (Figure 9a). This document describes the tests performed, comments the results and provides indications regarding the design of such connections.

The recommendation document and the technical manual for Peikko's Column Connection for seismic applications (Figure 9b, [18]) are both available at www.peikko.com. To ensure proper detailing and design, Peikko also offers clear design guidance and the latest expert know-how for seismic precast frame connections.

SYSTEM BENEFITS

The use of Peikko's Column Connections for seismic applications offers several advantages compared with other solutions. For energy dissipating connections, the design is made more efficient by skipping the over-strength factor and matching the capacity of the column. This can lead to smaller column cross-sections than the overdesigned ones, thereby resulting in concrete volume savings of up to 20% .

A further 50% can be saved in costs thanks to the reduced excavation depth for foundations and the self-supporting connection. In fact, the foundation height is limited by using anchor bolts with headed studs. This is particularly beneficial compared with the protruding bar system. Column installation on the construction site is also quick and easy, with no need for temporary bracings.

The HPKM®–HPM®-EQ connection improves the overall efficiency on site and makes for faster construction. This is particularly important when there are several different workgroups and simultaneous processes. Moreover, because precast structures are made in factories, there is a high standard of quality control and workmanship, effectively eliminating problems that often arise when using an unskilled workforce.

From the structural point of view, the system is reliable thanks to clear design guidelines and a standard installation procedure. There is no way the system would behave differently from the way it was assessed during testing. The behaviour of the connection is also less dependent on the reinforcing details of the column than cast-in-situ joints. This means limited influence of transverse reinforcement and no rebar buckling. Furthermore, since deformations are lumped at joint level, no significant damage is expected to occur in the column, thus eventually limiting the cost of a post-earthquake repair intervention.

CONCLUSIONS

Peikko addressed the challenges of seismic design and the requirements imposed by the current Codes for precast structures with an extensive research program focusing on bolted connections. The cyclic performance by HPKM® Column Shoes and HPM®-EQ Anchor Bolts has been widely investigated. The experimental results showed that such connections can resist seismic loads with a satisfactory ductility and the same stiffness as cast-in-situ joints.

Under specific design conditions, Peikko's Column Connection for seismic applications can be considered as energy dissipative, thus avoiding oversized joints. This can lead to substantial savings, both in concrete usage and in the building process, making it a fast precast system for installation on the construction site.

In conclusion, research-based technical documentation, a guided design procedure and easy installation process at the precast factory and on the construction site now make the HPKM®–HPM®-EQ connection a safe, reliable and convenient solution for precast concrete structures in seismic areas.

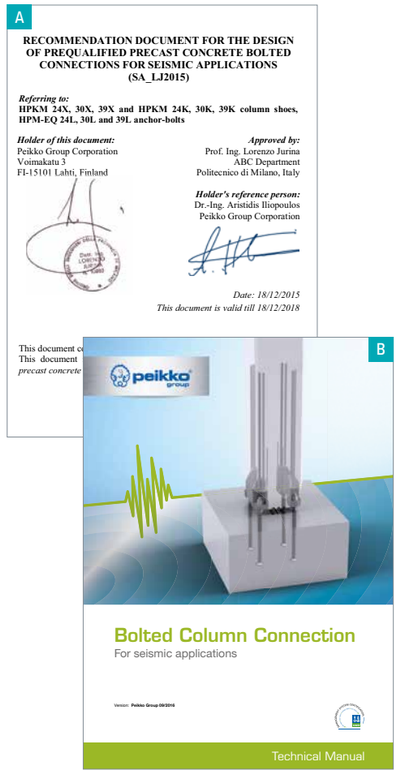


FIGURE 9. (A) RECOMMENDATION DOCUMENT AND **(B)** TECHNICAL MANUAL.

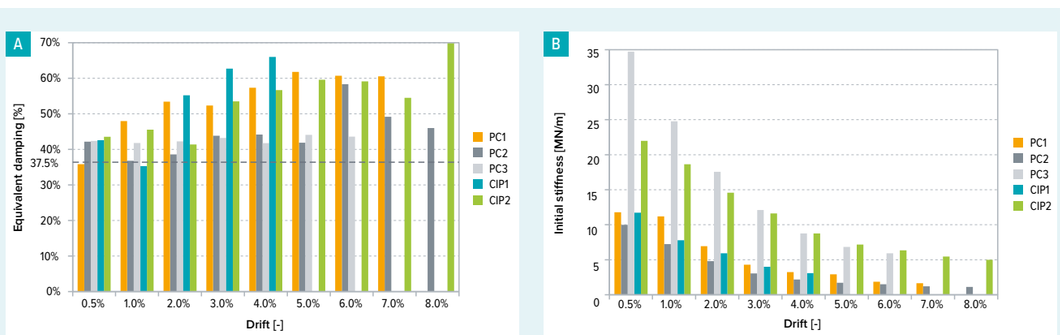


FIGURE 7. COMPARISON OF **(A)** THE DAMPING FACTOR AND **(B)** THE INITIAL STIFFNESS.

REFERENCES

[1] ACI (American Concrete Institute). (2014). Building code requirements for structural concrete, ACI318-14. ACI Committee 318.

[2] ACI (American Concrete Institute). (2013). Guide for Testing Reinforced Concrete Structural Elements under Slowly Applied Simulated Seismic Loads, ACI 374.2R-13. ACI Committee 374.

[3] Bianco, L., Santagati, S., Bolognini, D., and Nascimbene, R. (2009). "Seismic response of columns connected to the foundation through a fastening technique." Peikko News, No. 1: 13–20.

[4] CEN (European Committee for Standardization). (2004). Eurocode 2: Design of concrete structures. General rules and rules for buildings, EN 1992-1-1:2004.

[5] 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.

[6] ETA-02/0006 (European Technical Approval). (2012). Peikko HPM/L Anchor Bolt for the connection of prefabricated reinforced columns.

[7] ETA-13/0603 (European Technical Approval). (2013). Column shoe for connecting columns to concrete structures.

[8] FEMA P-750 (Federal Emergency Management Agency) (2009). NEHRP recommended seismic provisions for new buildings and other structures.

[9] GB (Guobiao National Standard of the People's Republic of China). (2010). Code for seismic design of building, GB50011-2010. China Architecture and Building Press.

[10] ICBO (International Conference of Building Officials) Evaluation Service. (1995). Acceptance criteria for ductile connectors in precast concrete special moment resisting frames, AC41.

[11] Jurina, L., Camnasio, E., Radaelli, E., Bianco, L., and Montenovo, S. (2016). "Experimental comparison between precast and cast-in-situ column-to-foundation connections." Proc., CTE2016, 27-28 October 2016, Roma (in Italian).

[12] Jurina, L., Iliopoulos, A., Bianco, L., Montenovo, S. and Radaelli, E. (2014). "An experimental investigation on the seismic response of bolted column-to-foundation connections." Proc., Giornate AICAP2014, 22-24 May 2014, Bergamo (in Italian).

[13] Jurina, L., Iliopoulos, A., Camnasio, E., Bianco, L., Montenovo, S. and Radaelli, E. (2014b). "On the seismic behavior of column to foundation connections." Proc., CTE2014, 6-8 November 2014, Milano (in Italian).

[14] NTC (Nuove Norme Tecniche per le Costruzioni). (2008). D.M. 14/02/2008.

[15] NZS (New Zealand Standards). (2004). Structural Design Actions, Part 5, Earthquake Actions New Zealand, NZS 1170.5:2004.

[16] Peikko Group Corporation (2012). HPKM® Column Shoe for bolted connections. Technical Manual.

[17] Peikko Group Corporation (2009). HPM and PPM® bolts. Technical Manual.

[18] Peikko Group Corporation (2016). Bolted Column Connection for seismic applications. Technical Manual.

PEIKKO DESIGNER® LINKED TO TEKLA STRUCTURES

A new tool to transfer information from structural design software to 3D models! Peikko Designer® has 20,000 registered users, which demonstrates the interest and need for this type of design tool and motivates us to make further investment in improvements. This tool link is a remarkable step for Peikko in making design faster, safer, and more efficient.

In fall 2016, Peikko released a function to export Column Connection designs from Peikko Designer® into Tekla Structures. Peikko is among the first to release this type of tool for use with a 3D modeling software and Peikko Designer®, a free design application.

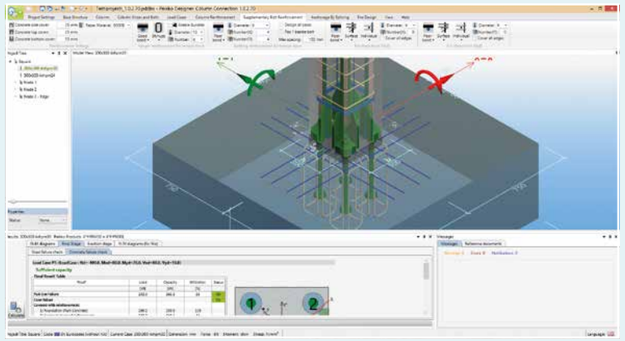
BENEFITS FOR YOU

When concrete column connections with Anchor Bolts and Column Shoes are designed with Peikko Designer®, the complete solution can be exported into a 3D model, including optimized supplementary reinforcement. The export can include several different column connection design cases and one case can be used in the model in several places.

In comparison with previous practices, this saves time and reduces the risk of mistakes.

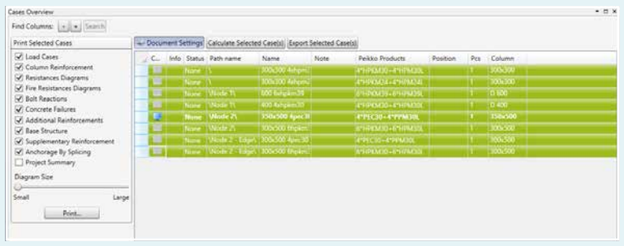
HOW TO USE

1



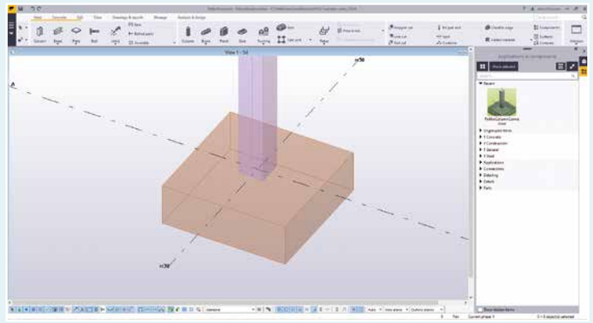
- Create the design in Peikko Designer® Column Connection. Define dimensions for concrete parts, select Column Shoes and Anchor Bolts, add loads and make the calculation.

2

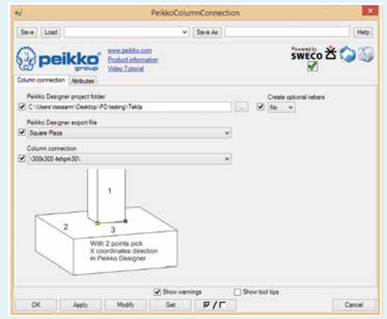


- Select the design cases you want to include in the export and click *Export Selected Case(s)* in the *Cases Overview Window*
- Save the export file. You can save the file to your desired location.

3

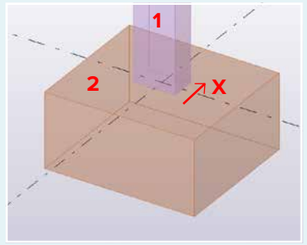


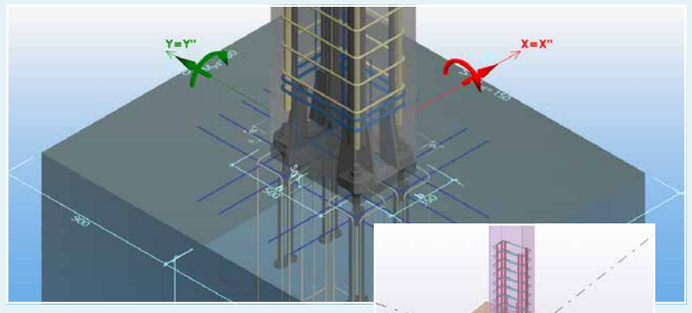
- Open the Tekla model and select the PeikkoColumnConnection plugin from Applications & Components. Make sure that the Peikko Embed plugins are also installed so that Anchor Bolts and Column Shoes are available.
- Select the export file location in the dropdown menus and click Apply and OK.

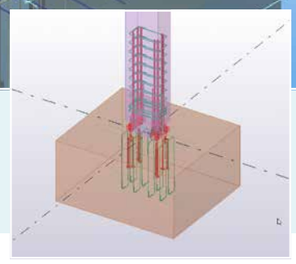


- Pick up the export file from the location you selected when saving it and select the design case. Click *Apply* to confirm the selections and then *OK* to finalize the selection.

4







- Go to the model. Firstly, click the column, secondly, the footing, and thirdly, select the direction of the x-axis that was used in Peikko Designer®.

DOWNLOAD PEIKKO'S TEKLA TOOLS FROM TEKLA WAREHOUSE AND PEIKKO DESIGNER® FROM
www.peikko.com/designtools

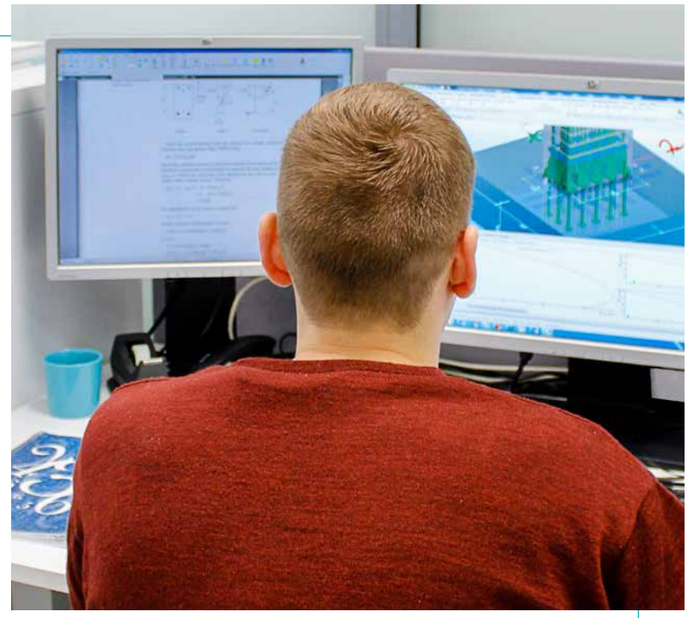
SUMMARY

By releasing this new feature, Peikko adds the possibility to link structural design and 3D modeling together. This speeds up the design process and improves reliability in the flow of information. We would be happy to hear your comments on this feature and your improvement ideas and needs.

Make your opinions count in future improvements by giving us feedback and improvement ideas at components@peikko.com.

PEIKKO DESIGN TOOLS UPDATES

Free design tools to optimize structural designs



Use our powerful software every day to make your work faster, easier and more reliable. Peikko Design Tools include design software, 3D components for several modeling softwares, installation instructions, technical manuals and product approvals of Peikko's products. All Peikko Design Tools can be accessed online at **www.peikko.com/designtools**.

LATEST IMPROVEMENTS IN PEIKKO DESIGNER®

The Punching Reinforcement module now enables design for ARMATA Punching Reinforcement according to ASTM standard 1044/A1044M-16a. The user can also define the shear rail arrangements, print a list of products to a separate document, and add color coding when using ACI design.

WE HAVE MADE IMPROVEMENTS TO THE COLUMN CONNECTION MODULE

- Calculation of supplementary reinforcement is optimized to reduce the amount of reinforcement needed.
- A note window has been added to the user interface to display design warnings, errors, and notifications arising during the modeling and calculation phases.

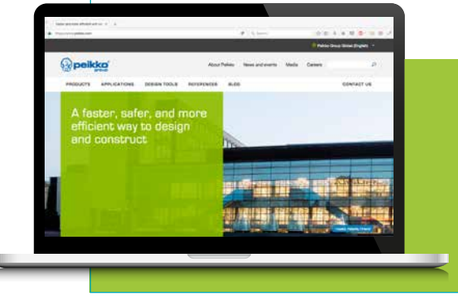
NEW DETAILS AND PRODUCTS AVAILABLE IN PEIKKO TOOLBOX FOR REVIT AND AUTOCAD

- Column Connections can be now made in Revit and AutoCAD using HPM® ACI Anchor Bolts and HPKM® ACI Column Shoes.
- DELTABEAM® details are available in DWG and PDF format in Peikko library.

DELTABEAM® PROFILES ARE NOW AVAILABLE IN ARCHICAD

BECO® BEAM SHOES AND COPRA® ANCHORING COUPLERS COMING TO TEKLA

Peikko will release a new plugin for COPRA® Anchoring Couplers and connection plugin with BECO® Beam Shoes during summer.



NEW DESIGN TOOL SECTION ON OUR WEBSITE

When our Group website at www.peikko.com was renewed late last year, also the Design Tool section was completely revamped. Now it is easier to search and find documents using a search panel. You can, for instance, access all information on the available design tools, view their release notes, watch tutorial videos on the design tools, and download tools.

www.peikko.com/designtools

NEW PRODUCTION UNIT TO SERVE THE RUSSIAN MARKET

Peikko Group has signed an agreement to purchase factory premises in St. Petersburg, Russia.

"We see a lot of market potential with localized manufacturing within the **Russia-Belarus-Kazakhstan customs union**. Now is the right time to update our premises to suit future needs. With the new premises, Peikko Russia's concrete connections manufacturing will significantly increase. The intention is also to start at a later date the manufacturing of DELTABEAM® Slim Floor Structures in St. Petersburg," stated **Topi Paananen**, CEO of Peikko Group Corporation.

The buildings will be jointly purchased with Meka Pro Oy, also a Finnish company. The premises comprise a total of 25,000 m² (29,900 sq yd) of manufacturing and office space. The up-to-date manufacturing premises are located in the northern part of St. Petersburg in the Parnas area. The seller of the real estate is a Russian subsidiary of SSAB. The closing of the real estate transaction is expected to take place during Q2/2017.

"We intend to use some 7,000 m² (8,400 sq yd) of these premises for our own operations. The installation of new machinery and the transfer of the existing machinery and operations from our current St. Petersburg unit will start during Q3. The new premises, with 5,000 m² (6,000 sq yd) more space than in our current small production unit, will increase safety and boost efficiency," added **Matvey Pirozhenko**, Managing Director of Peikko Russia.

Peikko has been in Russia with its own team since 2006.

www.peikko.com

peikko®