QUALIFICATION AND SEISMIC DESIGN OF MODULAR FRAMING SYSTEMS IN NUCLEAR POWER PLANTS

M.Sc. Ertugrul Karabaki[1], Dr.-Ing. Frank Häusler[2], Dr.-Ing. Viktor Mihajlov[3], Dipl.-Ing. Stephan Hempel[4]

[1] Team Manager Research & Development Industrial LEVIAT, Langenfeld, Germany (ertugrul.karabaki@leviat.com)
[2] Team Manager Research & Development Anchoring & Fixing LEVIAT, Langenfeld, Germany (frank.haeusler@leviat.com)
[3] Senior Research & Development Engineer Industrial LEVIAT, Langenfeld, Germany (viktor.mihajlov@leviat.com)
[4] Manager Safety Related Structures LEVIAT, Artern, Germany (stephan.hempel@leviat.com)

INTRODUCTION

The innovative LEVIAT - HALFEN POWERCLICK (PC) system together with LEVIAT - HALFEN anchor channels HZA-PS, has become a proven technology for pipe supports in large industrial plants. This system has been developed to meet the high demands of building a simple, permanently adjustable, versatile, time- and cost-effective support system for use in modern plant construction. Pre-assembled connection hardware guarantees easy storage on site, no small parts to lose on site, simplifying handling at every stage of the project, quick assembly, optimal adjustment range and less weight than conventional steel structures.

Four available profile sizes (22, 41, 63 and 100) contribute to the process of quickly finding the most economical solution for the required application. All profile sizes are compatible and can be combined with each other. Secondary components can be fixed at any position alone the profile. Those connections remain adjustable.

All Leviat products have all the necessary quality certificates as well as certificates related to the design and calculation of prefabricated pipe supports without welding on site, suitable for all important requirements in the power and process industries.

GENERAL PC

The LEVIAT - HALFEN PC system enables construction of different types of frame or cantilever pipe support structures using only two pre-assembled components and one profile type:

- LEVIAT–Halfen PC profiles used as structural columns or beams elements within the supporting structure,

- LEVIAT–Halfen PC foot connectors that enable the connection between the supporting structure and the supporting surface (floor, walls, ceiling, or I-beams),

- LEVIAT–Halfen PC edge connectors that enable the connection between the structural column and beam elements.

Figure 1. LEVIAT – HALFEN POWERCLICK components.

Depending on the type of profile, four PC variants are available: light-duty PC systems containing the PC22 and PC41, the PC63 medium-duty system and the PC100 heavy-duty systems.

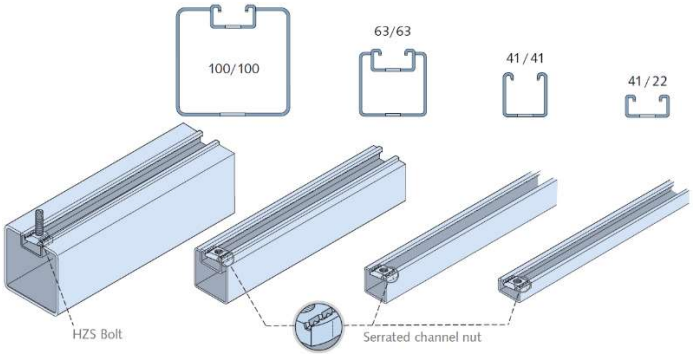

Figure 2. LEVIAT – HALFEN POWERCLICK profiles.

All profile sizes are compatible and can be combined with each other as it is presented on the figure below.

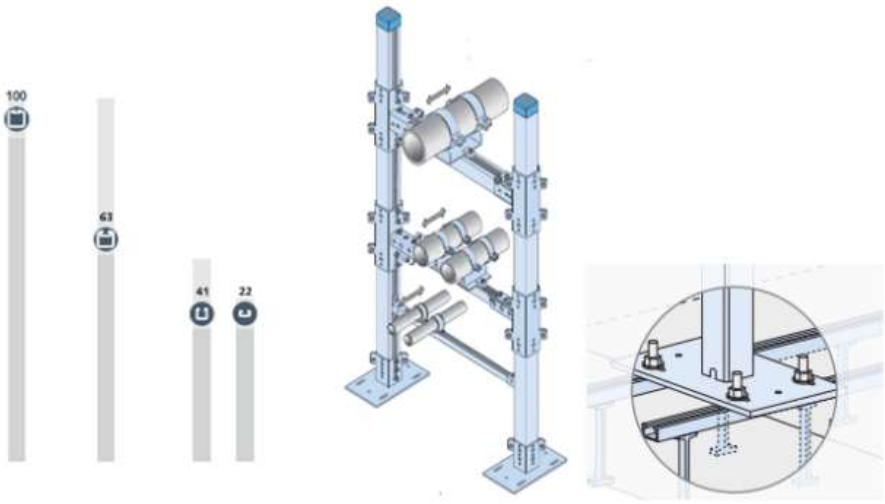

Figure 3. POWERCLICK compatibility.

POWERCLICK PROFILES PC63 PC 100

The PC63 and PC100 systems are using closed section profile which are offering high torsional stiffness. These profiles are made of 2 laser welded profiles (HZM 41/22 channel which provides the fixing slot and outer “C” profile). Based on hefty number of metallographic examinations, extensive experimental research and detailed finite element analysis, a special destructive procedure was developed for proving the quality of the laser seam.

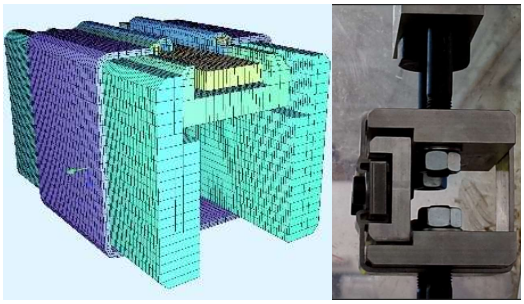

Figure 4. Pulling device for weld test.

In addition, micrographic image analysis and computed tomography are performed to ensure consistent laser seam quality for each batch produced.

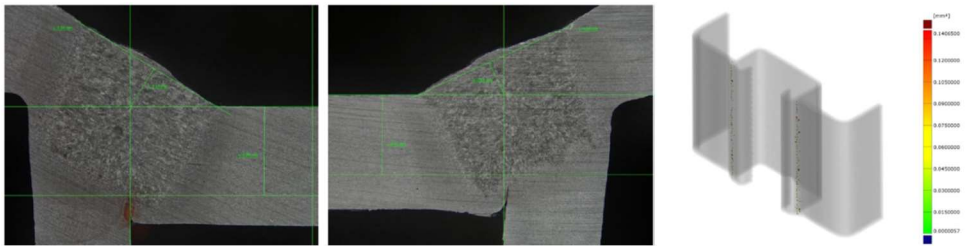

Figure 5. Weld micrographic and computed tomography images.

PRE-ASSEMBLED CONNECTORS

All connectors are designed to provide easy assembly that does not involve any type of drilling or on-site welding. The connection is established using clamping screws that do not require highly skilled craftsmen. The profiles can be fixed by simply inserting them into the connector brackets with the slot facing up, down or to either side as shown in the picture below. This allows the creation of various shapes of 2D and 3D support frame structures. The foot connector can be fixed to both concrete and steel structures. It is available with various base plates suitable for attachment to all standard I-beams with flange widths up to 300 mm. The direction of the channel slot is independent of the orientation of the base plate.

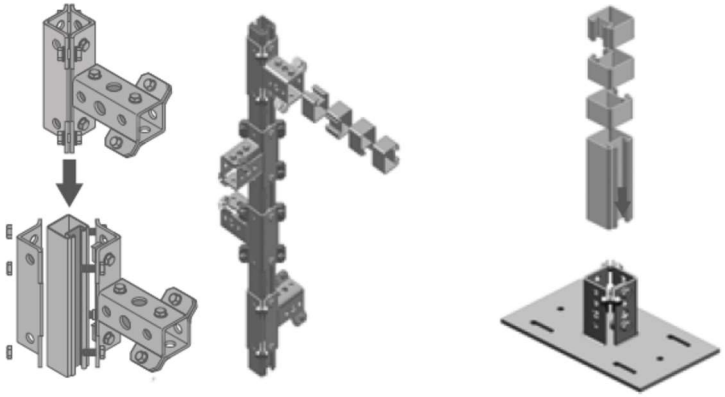

Figure 6. Assembly possibilities.

Determining the load transfer, which is happening in the PC connectors, from the frame beam elements to the frame column elements, as well as the distribution of the frame forces to the support surface, becomes complicated task due to the connection variants that these connectors offer. For this reason, 112 full-scale tests were performed in the LEVIAT test facility under the supervision of the TÜV Rheinland Germany authority of which 57 tests were performed on edge connectors, 46 tests on foot connectors and 9 tests on a single span portal frame with 3 different spans. The connectors were tested for all 3 main force directions.

Figure 7. Tests of the foot connectors in in Pz, Py and Px direction.

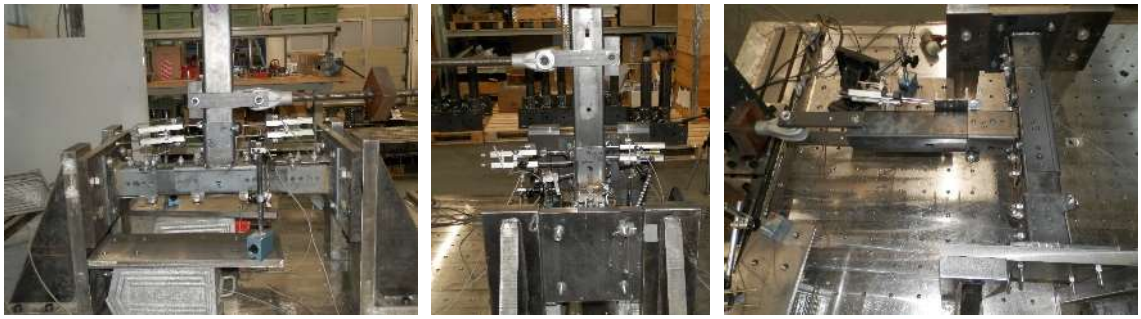

Figure 8. Tests of the edge connectors in Pz, Py and Px direction.

For characteristic profile setups, based on the experimental obtained results, the behaviour, characteristic failure modes as well the characteristic failure forces were determined for all force directions in the foot and edge connectors. Those results were used for calibration of the FE calculation models form which the force distribution was determined for different profile orientations. Those calculation models were used to determine the connector behaviour and the force distribution during simultaneous action of the forces in all 3 directions.

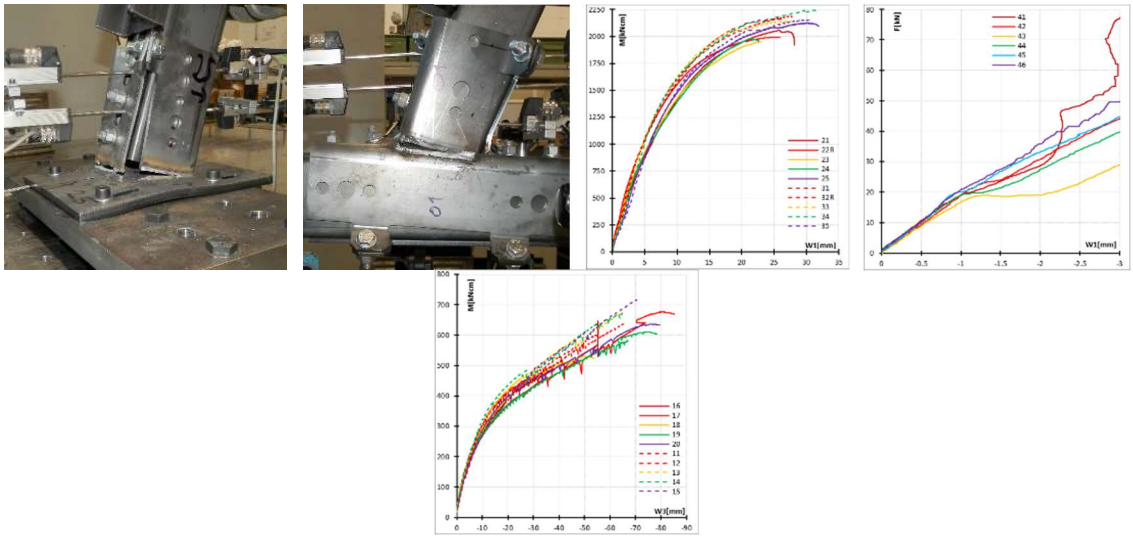

Figure 9. Typical failure modes and force-displacement behaviour of the connectors.

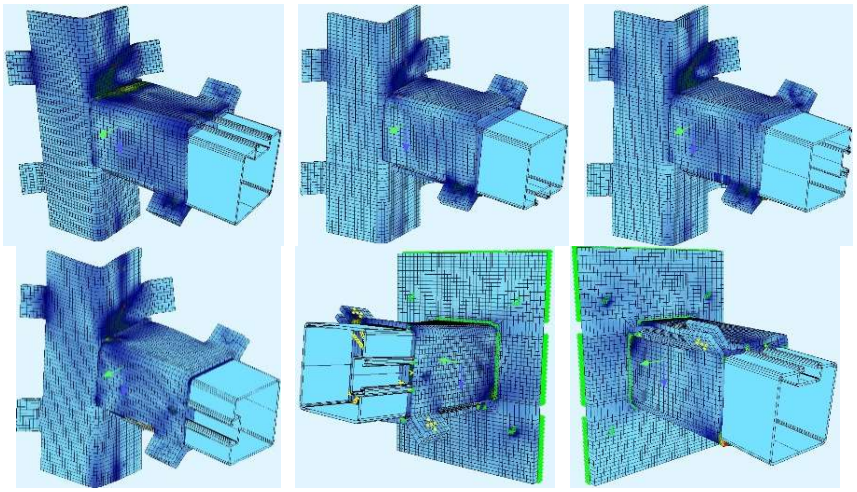

Figure 10. Finite element models.

Knowing the experimentally determined failure modes, the FE models were concentrated in the force distribution in the critical connector sections during the simultaneous force action in all direction and during different profile orientation. Using those results a special simplified calculation procedure is developed to resolve the complex load transfer which is happening in the PC connectors. The experimental results were used to obtain the connector stiffness which can be used in the static and dynamic calculation beam models. The calculation procedure was confirmed on a full scaled frame test.

Figure 11. Full frame tests.

Based on all these results the structural design procedure of all Powerclick components, based on design codes DIN EN 1993 and DIN EN ISO 13480-3 is derived.

SEISMIC DESIGN OF MODULAR FRAMING SYSTEM POWERCLICK

The components and building structures, required for compliance with the protective goals, are defined as safety-related components and building structures. All safety-related components and building structures as well as safety related fastenings require a seismic design considering the design basis earthquake (DBE) or safe shutdown earthquake (SSE). The design basis earthquake shall be specified by evaluating deterministic seismic hazard assessment (DSHA) as well as probabilistic seismic hazard assessment (PSHA). According to the German KTA rule KTA 2201.1 (2011) DSHA and PSHA result in the site-specific intensity with the corresponding ground acceleration response spectrum and the corresponding rigid-body accelerations (PGA: peak ground acceleration). Response spectra for building parts or substructures as well as the corresponding natural frequencies form the basis for further dimensioning of the frame system POWERCLICK. The results of corresponding load combinations of

dead weight and dynamic effects are criteria when selecting the type of the frame system. Another additional criterion for selection may be a “hot design” based on a fire protection report. Particularly due to the high rigidity of the frame cross-sections, the POWERCLICK system proves to be very robust with high load margins when calculating the resistance under earthquake effects. The same applies to fire effects up to 400° Celsius (Project experiences with the dimensioning of POWERCLICK from the requirements of a German nuclear facility).

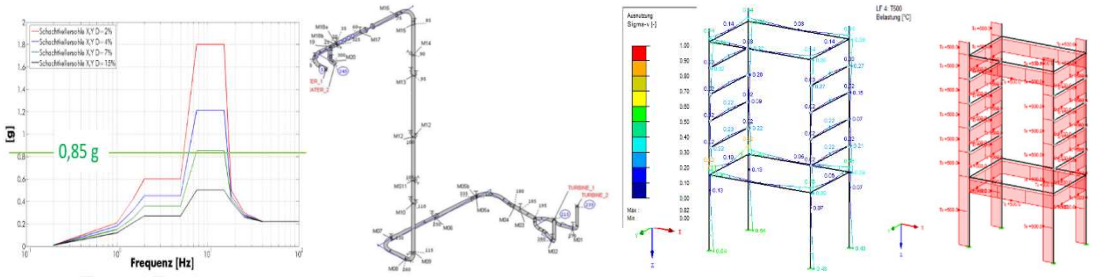

Figure 12. Modelling from dynamics and fire.

LOAD TRANSFER FROM THE FRAMING SYSTEM INTO THE REINFORCED CONCRETE

HALFEN anchor channels HZA-PS are a compatible anchoring system for the Modular Framing System POWERCLICK. The HALFEN anchor channels HZA-PS are suitable for applications in safety relevant areas of Nuclear Power Plants and other nuclear facilities meeting the high requirements for extraordinary impacts from external and internal loads e.g. earthquakes, plane crash or explosions with a low probability of occurrence (≤10-4 / year). In this way, the static and seismic loads from the Framing system POWERCLICK can be transferred directly to the HALFEN anchor channels HZA-PS and safely transferred into the reinforced concrete (TR 049; AFCEN-code RCC-CW). Load capacities and test procedures for seismic performance categories were described in the SMIRT26 paper “QUALIFICATION AND DESIGN OF ANCHOR CHANNELS IN NUCLEAR POWER PLANTS”.

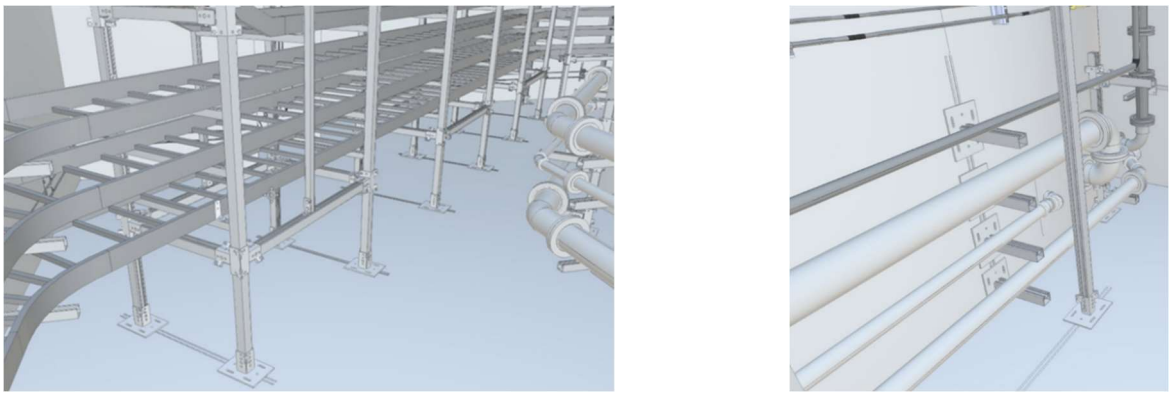

Figure 13: Anchoring POWERCLICK frame systems to HALFEN anchor channels HZA-PS (nuclear facility Germany).

CONCLUSION

Bringing all the advantages, plant operators are having extremely positive experiences during the operation and within the framework of local technical approval procedures with the regulatory experts. Application areas of Powerclick modular support system throughout different industrial sections is increasing due to the clear design procedure and highly flexible assembly with no welding processes on site.

REFERENCES

DIN EN 1993 (2010). *Design of steel structures*.
DIN EN 13480-3:2017-12. *Metallic industrial piping - part 3*.
AFCEN-code RCC-CW (2021). *Rules for design and construction of PWR nuclear civil works*., afcen, Paris.
TR 049 (2016). *Post-installed fasteners in concrete under seismic action.*, European Organization for Technical Approval, Brussels.
SMIRT26 (2022). *QUALIFICATION AND DESIGN OF ANCHOR CHANNELS IN NUCLEAR POWER PLANTS*.
KTA 2201.1 (2011). *Design of Nuclear Power Plants against Seismic Events; Part 1: Principles.*, Safety Standard of the Nuclear Safety Standard Commission (KTA), Salzgitter.