Leviat
A CRH COMPANY

Considerations for

Building Safer Structures with Proven Punching Shear Solutions

White paper, November 2025

Contents

Project: Kuggen Location: Gothenburg, Sweden
Leviat Solution: Halfen HDB Shear Reinforcement

Riverlight, London, UK

Foreword

"Punching shear has long been misunderstood, and at times overlooked, in structural design. As our understanding of concrete behaviour has advanced, design codes and standards have strengthened requirements for punching shear verification, and companies such as Leviat have developed both physical and digital tools that help specifiers and end users resolve these issues simply, safely and efficiently.

This white paper explains the mechanism and consequences of punching shear, sets out practical solutions with real project examples for new build and retrofit, and summarises the relevant codes and standards—with particular reference to the second generation of Eurocode 2 and how its treatment of punching shear differs from the first generation.

Whether you are involved in the process of designing or constructing a building, we trust that you will find the content of this white paper of interest."

Hervé Poveda,
Head of Research & Development, Leviat

Introduction

The construction industry faces increasing demands for safety, efficiency, and compliance in reinforced concrete design. One of the most critical challenges is punching shear.

As projects grow in scale and complexity, with thinner slabs, wider column grids, heavier loads, and greater use of post-tensioned floors, the risks associated with punching shear are becoming more significant. At the same time, the introduction of the second generation of Eurocode 2 will bring important changes to how the industry addresses design methods and reinforcement requirements.

This white paper explains why punching shear is a critical consideration in reinforced concrete design, shows its consequences through real examples, and identifies effective measures for prevention. It takes a forward-looking perspective, drawing on lessons from past failures, the development of global codes and standards, and Leviat's expertise in reinforcement systems.

Digital tools are now fundamental to reinforced concrete design. As codes evolve and designs become more demanding, software is essential for accuracy and clarity. Leviat provides engineers with resources that enable efficient, reliable, and code-compliant design.

The purpose of this white paper is to equip engineers, designers, contractors, and specifiers with the insight needed to address punching shear risks effectively, in alignment with evolving standards, sustainability objectives, and industry best practice.

Understanding why punching shear matters

What is punching shear?

Punching shear is a local failure of reinforced concrete slabs at points of concentrated loading, typically where slabs are supported by columns. When the shear stresses around the support exceed the capacity of the slab, a cone-shaped failure surface forms around the column.

The risk increases as slabs are designed to be thinner, column grids become wider, and floor loads heavier. Punching shear is a serious concern because it develops suddenly, usually without warning, and has the potential to trigger wider progressive collapse.[1]

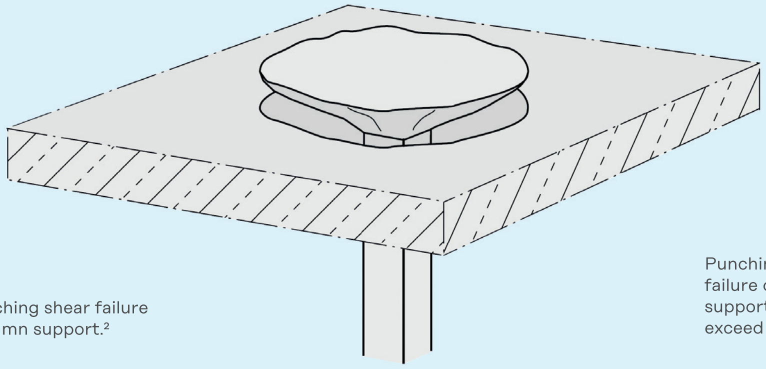


Figure 1. Typical punching shear failure surface around a column support.[2]

Punching shear is a sudden local failure of a slab around a column support when shear stresses exceed capacity.[2]

Why it is a structural safety risk

Punching shear is one of the most critical safety concerns in reinforced concrete slabs because of the way it develops. The failure mechanism may be brittle, developing with little deformation or visible warning. [1] When the slab fails, it does so suddenly, and the localised collapse at a column can propagate into a progressive failure of the wider structure.[1,3]

This makes punching shear a serious risk, as a relatively small area of slab can compromise the safety of an entire building. High-profile collapses in shopping centres, residential towers, and airport terminals have demonstrated that when punching shear is overlooked or underestimated, the consequences can be severe.

Today's design trends increase the importance of addressing this mechanism. Thinner slabs, wider column grids, heavier floor loads, and post-tensioned construction all raise the stresses at slab–column connections.[1,3] As a result, punching shear must remain a design priority for any project where reinforced concrete flat slabs are used.

Ancon Shearfix

This is a shear stud rail system, sometimes called SSR on drawings.

Used within a slab to provide additional reinforcement around columns, Ancon Shearfix is the ideal solution to the design and construction problems associated with punching shear.

Real-world failures and lessons

The risks associated with punching shear are not theoretical. The consequences of punching shear failure are well documented across different building types and regions, illustrating the consequences when this failure is underestimated or overlooked.

Sampoong Department Store, Seoul (1995)

The collapse of the Sampoong Department Store in Seoul remains one of the most serious structural failures in modern history, killing more than 500 people.

Investigations showed that punching shear at slab-column connections was a critical factor. The effective slab depth was reduced during construction, the column sizes were smaller than designed, and a change of use increased the floor loads well beyond the original assumptions. [4]

The case demonstrates how changes to the structure's design, compounded by alterations during construction and changes in use, can significantly increase the risk in punching shear failure. It highlights the importance of maintaining safety margins in design and of addressing visible signs of structural distress without delay. [4]

The Sampoong Department Store collapse remains one of the most tragic structural failures in modern history.[5]

Charles de Gaulle Airport Terminal 2E, Paris (2004)

A section of the vaulted concrete shell roof of Terminal 2E collapsed just 11 months after opening and left four casualties. Investigations and subsequent reliability studies found that the structure had been inadequately reinforced, with long-term deflections and shear stresses underestimated during design. The collapse occurred in the area around footbridge connections, where additional forces concentrated.[6]

The case demonstrates how complex architectural forms, such as thin concrete shells with openings and penetrations, demand rigorous verification of punching shear and long-term deformation. It underlines the importance of reliability-based assessments in supplementing standard code checks for large public structures.[6]

Charles de Gaulle Airport Terminal – Photo: Jorge Láscar "Airport Charles de Gaulle – panoramio," Wikimedia Commons, licensed under CC BY 3.0

Champlain Towers South, Florida (2021)

The sudden collapse of a residential tower in Surfside, Florida, caused 98 fatalities and brought global attention to reinforced concrete safety. The official investigation, led by the U.S. National Institute of Standards and Technology (NIST), is ongoing. Preliminary assessments have identified multiple possible contributing factors, including deterioration of concrete, reinforcement corrosion, and the performance of slab-column connections in the pool deck area, where punching shear has been suggested as a possible mechanism.[7]

This case demonstrates that punching shear remains a critical concern in modern residential and mixed-use buildings. It also shows how poor maintenance, and environmental exposure can interact with design weaknesses to increase the risk of failure.[7]

The site of the Champlain Towers South partial collapse in Surfside, Florida.
Credit: National Institute of Standards and Technology (NIST), U.S. Department of Commerce.

Pipers Row Car Park, Wolverhampton, UK (1997)

The partial collapse of the Pipers Row multi-storey car park in Wolverhampton highlighted that punching shear risks are not limited to high-rise or complex structures. The failure occurred under dead load alone, when local deterioration of the concrete at a slab-column connection led to a sudden punching shear failure. Analysis confirmed that freeze–thaw cycles over three decades had reduced bond and anchorage, leaving the connection critically weak.[8]

The lesson from this case is that punching shear must be considered in all reinforced concrete flat slab projects, regardless of their scale or complexity.[8]

J.G.M. Wood, Pipers Row Car Park, Wolverhampton: Quantitative Study of the Causes of the Partial Collapse, SS&D Contract Report to HSE (1997)

Summary

These examples, drawn from different decades, regions, and building types, underline a consistent lesson – punching shear can arise from inadequate design, construction deficiencies, changes in use, or long-term deterioration. It is sudden, often without visible warning, and has the potential to cause catastrophic collapse. Ensuring that punching shear is rigorously addressed in design, detailing, and maintenance is essential to structural safety.

Where it matters in today's projects

- **High-rise and mixed-use** — Large floor grids, service penetrations and flat soffits increase punching shear demand, particularly where slabs are kept thin to maximise floor-to-floor height.
- **Transport hubs and car parks** — Transfer slabs, ramps and concentrated vehicle loads create highly variable shear forces around columns.
- **Industrial, healthcare, and data centres** — Heavy equipment, plant rooms and frequent change-of-use introduce high point loads and future risk if not reinforced correctly.
- **Foundations and footings** — Strong column reactions at the base of structures generate high shear stresses in slabs and pile caps.
- **Retrofit and repurposing** — Existing slabs often face new demands that exceed their original design, such as the higher vehicle weights associated with electric cars in multi-storey car parks. These added loads can push older structures beyond their punching shear capacity. Leviat's Aschwanden RINO system provides proven retrofit reinforcement options, enabling engineers to strengthen and adapt existing slabs safely.

Leviat's commitment to safety

Punching shear is a safety-critical issue, and Leviat provides expertise in its design approach to punching shear, and in the development of robust punching shear reinforcement solutions. For decades, systems such as Halfen HDB and HDB-Z, Aschwanden DURA and Ancon Shearfix have been developed and refined in line with evolving design codes. Today, within Leviat, these solutions are supported by global inhouse technical knowledge, advanced design tools, and clear, practical guidance materials for engineers.

Leviat's support goes beyond supplying reinforcement components. It is about ensuring that the risks of punching shear are understood, addressed, and managed in practice. By combining trusted solutions with technical leadership, we help engineers, designers, and contractors deliver safer, more efficient, and code-compliant structures.

In the next section, we outline how Leviat strengthens structures with proven reinforcement systems, supported by expertise that gives engineers the confidence to design with clarity and compliance.

How Leviat strengthens structures with proven solutions

The limits of traditional punching shear reinforcement

Historically, engineers have relied on stirrups, bent-up bars, or rebar cages to provide punching shear resistance in flat slabs. While effective in principle, these methods present significant challenges in modern construction. They are complex to install, time-consuming, and in many cases impractical for thin slabs or areas subject to high concentrated or tensioned loads.

Independent testing has also shown that traditional methods do not consistently achieve the safety margins required by current design standards. Evaluations carried out for the European Technical Approval ETA-12/0454 demonstrated that stirrup reinforcement did not meet the reliability levels specified in Eurocode 2, while prefabricated stud rail systems such as Halfen HDB did.[2]

In addition to improved performance, prefabricated systems deliver major advantages in constructability. The BRE Best Practice Guide ‘Prefabricated punching shear reinforcement for reinforced concrete flat slabs’ highlighted that prefabricated punching shear reinforcement can be installed up to nine times faster than traditional links, significantly reducing site labour and construction time.[3]

A Stirrups according to EN 1992-1-1:2011-01 without NA(D) German National Annex

B Halfen HDB Shear rails – HDB approval ETA-12/0454

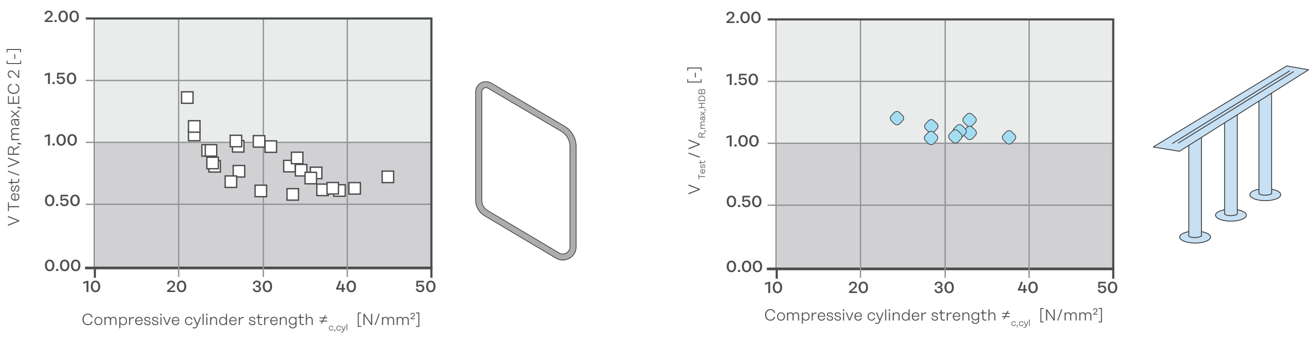


Figure 2. Comparative test results: stirrups vs. HDB shear rails.[2]

Leviat's solutions for punching shear reinforcement

Leviat designs and manufactures a global portfolio of proven punching shear reinforcement systems, delivered under trusted product brands such as Halfen, Ancon, and Aschwanden. These systems are tested, code-compliant, and supported by advanced design tools that make specification straightforward and reliable. Compared with traditional stirrups or cages, they offer faster installation, more efficient use of materials, and verified safety performance. [2,3]

Stud rail systems

Leviat provides two proven stud rail systems. Both deliver the same structural performance, but differ in delivery model, certification, and market practice - allowing Leviat to provide tailored solutions across regions.

“At Leviat, we offer a wide range of proven punching shear reinforcement solutions. Our HDB-Z system, in particular, enables our partners to build safely and economically.
By reducing foundation heights, it lowers both excavation volume and concrete usage, allowing for more cost- and time-efficient construction without compromising structural safety.”

Bernhard Schipek,
Country Manager, Austria

Halfen HDB (including HDB-Z for foundations)

A stud rail system for flat slabs and foundations, widely used across continental Europe and the Middle East. Halfen HDB rails containing two, three or four studs per unit, which are stocked and combined to create the required layout. This reflects the more standardised specifications common in Continental European markets.

The HDB-Z variant is optimised for in-situ and precast foundations, reducing foundation depth and delivering savings in excavation, time, and material. HDB systems hold European Technical Assessment (ETA) certification, ensuring suitability across the EU market.

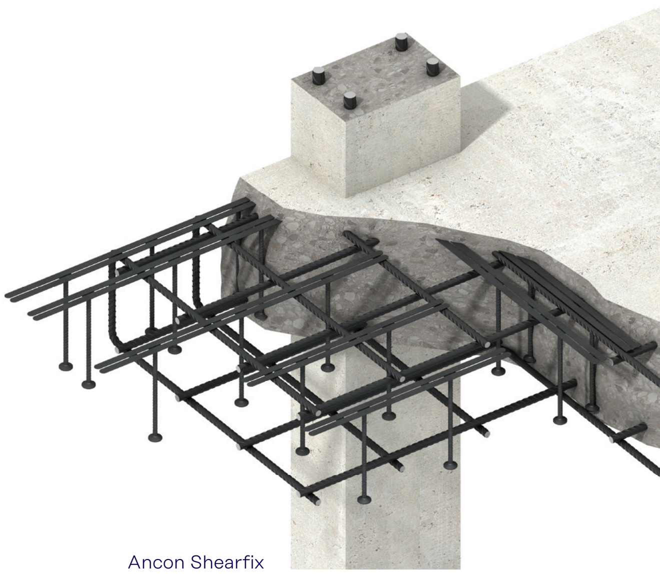
Halfen HDB

Halfen HDB-Z

Ancon Shearfix

A stud rail system for flat slabs and slab–column connections, used mainly in the UK and Australia. Unlike the modular Halfen HDB system, Ancon Shearfix rails are made to order: studs are pre-manufactured, then welded to rails to match each project's layout. This flexibility suits markets where architectural variation and non-standard slab-column details are more common.

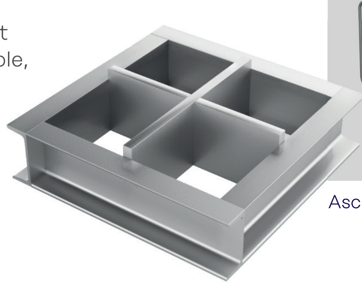
Ancon Shearfix removes the need for drop panels or enlarged column heads, with layouts calculated using Ancon Shearfix enhanced design software.[9] Certification reflects national practice: in the UK through CARES Technical Approval, and in Australia there is no mandatory third-party certification, though it is increasingly valued.



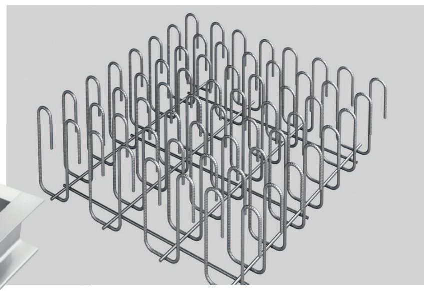
Ancon Shearfix

Aschwanden DURA

A complete system for high-load applications in new build projects. Aschwanden DURA includes prefabricated stirrup cage, and DURA Steel Heads, designed to carry very large shear forces at slab-column supports. Extensively tested at EPFL, EMPA, and HSLU in Switzerland, the system is flexible, compliant with SIA 262, and supported by dedicated design software.



Aschwanden DURA Head



Aschwanden DURA Cage

Aschwanden RINO

An innovative retrofit solution for strengthening existing flat slabs. The Aschwanden RINO system includes RINO Exo, with an externally mounted steel head, and RINO Bar, a retrofitted reinforcement solution installed within the slab. RINO has been developed specifically for refurbishment and repurposing projects, providing engineers with reliable strengthening options where new loads are introduced to existing structures.

Aschwanden RINO System

Summary

Together, these systems provide engineers with solutions for both new construction and retrofit, ensuring reliable performance and compliance with local design codes.

Prefabricated stud rails can be installed up to nine times faster than traditional stirrups[3] and, as demonstrated in ETA-12/0454 testing, deliver the safety margins required by Eurocode 2.[2]

Product brand	System	Application	Regions
Halfen	HDB	Reinforcement of column heads in flat slabs, transfer slabs and foundation rafts. Suitable for use with internal, edge and corner columns.	Europe, Middle East
Halfen	HDB-Z	In-situ and precast foundations	Europe, Middle East
Ancon	Shearfix	Reinforcement of column heads in flat slabs, transfer slabs and foundation rafts. Suitable for use with internal, edge and corner columns.	UK, Australia
Aschwanden	DURA (Stud rails, cages, steel heads)	High-load slabs, special structures, new build	Switzerland, Europe
Aschwanden	RINO (Exo, Bar)	Retrofit and refurbishment of flat slabs	Switzerland, Europe

Photo: Donal McCann

Ulster Hospital, Belfast, Northern Ireland

Expertise in real-world case studies

Leviat's reinforcement systems are in use worldwide, supporting safe and efficient flat slab construction in residential, commercial, and refurbishment projects. These projects demonstrate Leviat's ability to deliver safe, efficient, and code-compliant reinforcement solutions across regions and applications, from new-build to retrofit projects across different regions.

Kings Dock Mill, Liverpool, UK

Ancon Shearfix was installed to reinforce 700 mm slabs at column heads. Prefabricated rails reduced reinforcement congestion and cut installation time from a week to a single day, keeping the project on schedule.[10]

King's Dock Mill construction site in Liverpool, featuring the installation of the Ancon Shearfix punching shear reinforcement.

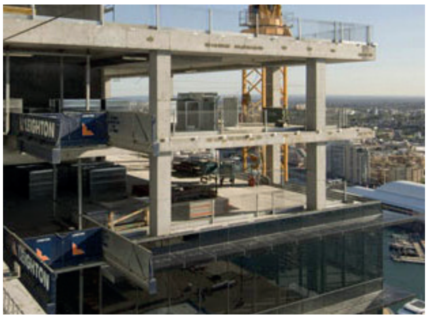
Edgewater apartments, Newport Quays, Port Adelaide

Post-tensioned flat slabs with spans up to 9 m were reinforced with Ancon Shearfix, eliminating the need for column capitals. Structural engineers Wallbridge and Gilbert used Leviat's Ancon Shearfix software to simplify design and ensure compliance.[13]

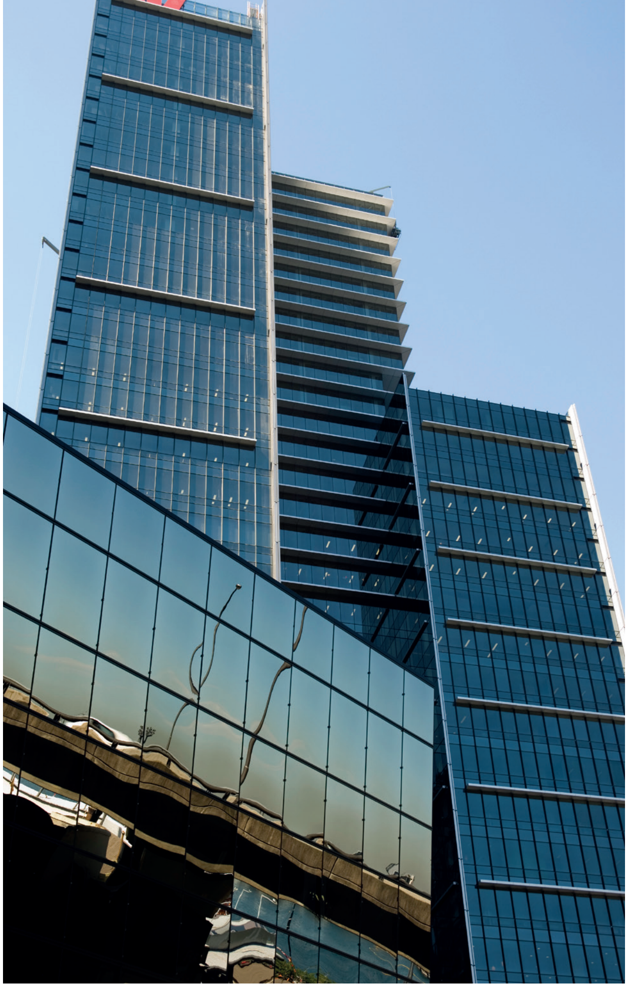
An Ancon Shearfix Punching Reinforcement system has been installed in a $1.5 billion waterfront development at Newport Quays, Port Adelaide.

Westpac Place, Sydney, NSW, Australia

Stud rails provided reliable punching shear resistance in one of Sydney's largest commercial office towers. Leviat's Ancon Shearfix design software optimised layouts, streamlining integration into floor plans.[11]



Westpac Place, Sydney[12]



Kuggen office building, Gothenburg, Sweden

Halfen HDB shear reinforcement transferred column loads in this award-winning office building, where offset floor slabs created high shear demands at slab–column connections.[14]

Kuggen, Gothenburg, Sweden[14]

Global reach and local knowledge

Leviat operates across all major construction markets, combining international expertise with local technical support. Our reinforcement systems are designed and tested to comply with leading design standards, including Eurocode 2 in Europe, ACI 318 in the United States, and AS 3600 in Australia.

This global capability is matched by regional insight and agility. In the UK and Australia, Ancon Shearfix is manufactured to align with national requirements and is certified by CARES. In continental Europe, Halfen HDB and HDB-Z systems hold European Technical Assessments, ensuring recognised compliance with Eurocode 2. In Switzerland and Germany, Aschwanden solutions reflect local practice, while retrofit systems such as RINO address the specific needs of refurbishment projects.

By manufacturing locally and providing design support through regional engineering teams, Leviat ensures that reinforcement solutions are both globally consistent and responsive to local codes and construction practice. This dual approach provides clarity for engineers and confidence that every project benefits from tested solutions and verified compliance.

Summary:
Solutions and guidance

Leviat provides proven reinforcement systems — HDB, HDB-Z, Ancon Shearfix, DURA, and RINO that are supported by global expertise and local technical knowledge. These systems across a number of our product brands: Ancon, Aschwanden and Halfen address the demands of both new construction and retrofit, ensuring safe, efficient, and code-compliant structures.

Our role extends beyond the manufacture of reinforcement. We support engineers, designers, contractors, and specifiers with guidance, technical resources, and digital tools that help ensure reinforcement products are specified and delivered to the highest standards of safety and performance.

> "Across the industry, we're seeing a growing focus on safety, sustainability, and efficiency. Engineers and contractors are looking for solutions that deliver reliability without adding complexity. What sets Leviat apart is how we combine proven reinforcement systems with technical guidance and design support — helping our customers meet these expectations with confidence."

Vita Mikutaite,
Technical Sales Manager, UK

Design tools that make smart engineering simple

Why design tools matter in punching shear

Manual design is prone to error, time-consuming, and impractical for modern projects where slabs vary in geometry, loading, and detailing. The more complex the building, and the greater the number of slab–column connections, the more important it becomes to use software to manage these calculations consistently and reliably.

Specialist design tools address this challenge by automating verification, producing clear documentation, and allowing reinforcement layouts to be optimised. They have become essential in modern practice, where project schedules demand fast, transparent, and code-compliant design.

Leviat software solutions

Leviat provides free-to-use software that simplifies the design and specification of punching shear reinforcement. The Ancon Shearfix design software, for example, allows engineers to model slab–column connections in accordance with either Eurocode 2 or AS 3600, depending on whether the project is located in the UK or Australia, and determine the optimum reinforcement layout for each situation. The Halfen HDB design software similarly enables verification of punching shear resistance for Halfen systems, including DURA Steel Heads and HDB double-headed anchors, in accordance with relevant approvals and technical reports.

The software guides engineers through the process of entering slab and loading data, automatically checks punching shear requirements, and generates an optimised studrail layout. Outputs include calculation sheets, parts lists, and DXF files for direct integration into project drawings, ensuring reinforcement layouts are documented clearly and accurately.

For integration into modelling workflows, Ancon's punching shear methodology is also available within Bentley's RAM Concept, a widely used concrete floor slab modelling tool. This allows engineers to carry out punching shear analysis and detailing directly within their structural models, aligning reinforcement design with broader project workflows.

By automating these complex checks, the software gives engineers clarity and confidence that punching shear reinforcement is correctly designed, documented, and ready for specification.

> "As design codes evolve, our responsibility is to stay ahead—translating regulatory changes into practical, reliable tools for engineers. At Leviat, we work closely with industry bodies and technical committees to ensure our solutions remain fully aligned with current and emerging standards such as Eurocode 2. This approach allows us to lead with confidence in both product design and digital integration."
>
> **Mark Boeschoten,**
> **Global Group Product Manager,Anchoring & Connection**

Upcoming trends and considerations

Digital design is advancing rapidly, with increasing integration between specialist reinforcement tools, structural analysis software, and Building Information Modelling (BIM). For punching shear, software is already indispensable, and its role will grow as design requirements become more demanding.

BIM-enabled reinforcement modelling

The next step is the direct export of reinforcement layouts from design tools into BIM models. For stud rails, this means each slab–column connection could be represented in the model as an intelligent object, reducing manual transfer errors and improving coordination.

AI-assisted and generative design

Advances in artificial intelligence and generative design are shifting practice from verification towards optimisation. Early workflows already demonstrate how BIM–AI pipelines can propose reinforcement layouts that balance safety, constructability, and material efficiency. These developments will not replace engineering judgement, but they will provide powerful tools to guide engineers towards safer and more sustainable outcomes.[15]

Data interoperability and collaboration

Ensuring that reinforcement data carries not just geometry but also meaning is increasingly important. Techniques such as semantic enrichment help preserve metadata across platforms, while cloud-based collaboration platforms enable teams to co-author models in real time, keeping reinforcement aligned with the wider structure.[16]

Wider industry context

Beyond reinforcement, BIM itself is evolving. Digital twins, sustainability-linked modelling, and 5D BIM (integrating time and cost) are becoming mainstream, while regulatory drivers in many countries are accelerating adoption. These broader developments create an environment where reinforcement tools are expected not just to calculate, but to connect seamlessly with project data.[15,16]

Looking ahead

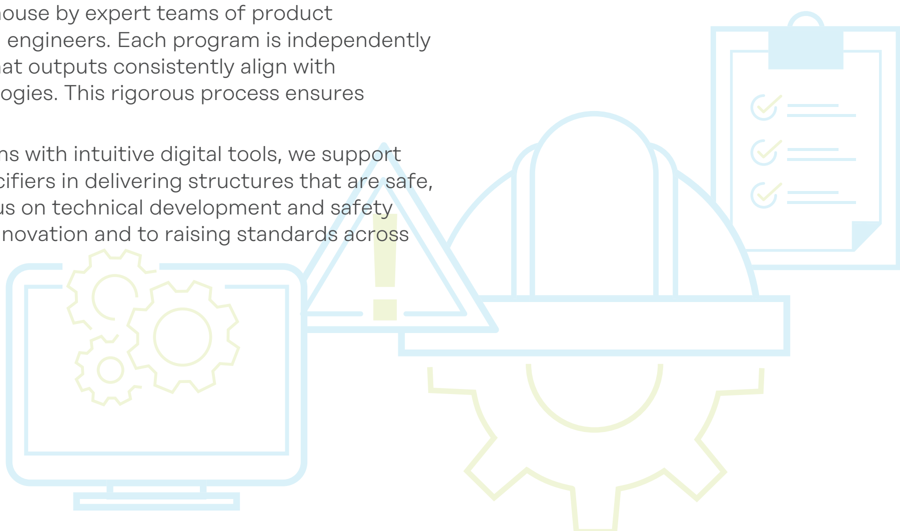
Adoption remains uneven across regions and contractors, but the trajectory is clear. Engineers and clients are seeking digital tools that deliver clarity, integration, and confidence. With the transition to the second generation of Eurocode 2, reinforcement design will also enter a new phase.

National annexes have not yet been published, but once they are confirmed, software updates can follow to support consistent adoption across markets. Leviat is closely monitoring these changes and will update its tools once requirements are confirmed, ensuring that users can adopt the new standards with confidence.

Commitment to safety and innovation

All Leviat design software is developed in-house by expert teams of product specialists, structural engineers, and digital engineers. Each program is independently checked by external engineers to ensure that outputs consistently align with recognised structural calculation methodologies. This rigorous process ensures accuracy and reliability in every design.

By combining proven reinforcement systems with intuitive digital tools, we support engineers, designers, contractors, and specifiers in delivering structures that are safe, efficient, and fully compliant. This dual focus on technical development and safety reflects Leviat's ongoing commitment to innovation and to raising standards across the industry.



Adapting to global codes and standards

Why design standards matter

Structural design standards are the foundation of safe and compliant construction. They ensure that critical elements such as punching shear reinforcement are designed to withstand the loads and conditions they will encounter in service. For reinforced concrete flat slabs, compliance with national and international codes is essential to structural integrity.

Applying the correct standards protects against design mistakes and unnecessary risk, while misapplication can lead to unsafe structures or inefficient reinforcement. Our role is to support the industry with compliant solutions, clear guidance, and digital tools that give confidence in specification.

Punching shear is addressed in all major reinforced concrete design codes worldwide:

Eurocode 2 (EN 1992) - The benchmark code for concrete design across the European Union, EFTA countries, and the UK.[17]

ACI 318 - Building Code Requirements for Structural Concrete (USA)[18]

AS 3600 - Concrete Structures (Australia)[3]
AS 3600:2018 sets out national provisions for punching shear and related checks in flat slabs and footings, forming the basis for structural concrete design in Australia.[19]

SIA 262 - Swiss Code for structural concrete governs concrete design in Switzerland, including punching shear checks for slabs and footings, based on the Critical Shear Crack Theory (CSCT).[20]

Other national codes

Adapted versions of these standards exist across Asia, the Middle East, and Latin America, often incorporating regional construction practices and material specifications.

Leviat operates globally, ensuring our reinforcement systems comply with the requirements of each market.

Across global construction markets, the underlying objective of punching shear design is the same — to ensure safe load transfer at slab–column connections. However, national standards approach this verification through different models and parameters.

Understanding these distinctions is essential for engineers working across region or referencing multiple codes in international projects.

Comparison of punching shear design rules for flat slabs in major global standards

The following table summarises the principal approaches to punching shear design in key international codes. It illustrates how each standard defines parameters, while maintaining the shared goal of structural safety and reliability.

Aspect	Eurocode 2 Gen 1	Eurocode 2 Gen 2	EOTA TR 065 (for ETA)	ACI 318	AS 3600	SIA 262
Distance to control perimeter	2d	0.5d	2d	0.5d	0.5d	0.5d
Inclusion of headed stud punching shear reinforcement	✗ (covered by CARES or ETA certification)	✓	✓	✓	✗ (relevant rules adopted from 'Lim & Rangan' research)	✓
Concentration of punching shear stresses at the corner of columns: long "blade" columns and large columns	✗ (included in current Ancon Shearfix software as "best practice" option)	✓	✗	✓	✓ long "blade" columns ✗ large column dimensions	✓
Factor accounting for eccentric shear	The design punching shear stress is increased by the factor β. $v_{Ed} = \beta \frac{V_{Ed}}{u_i d}$ $\beta = 1 + k \frac{M_{Ed}}{V_{Ed}} \frac{u_1}{W_1}$	The design punching shear stress is increased by the factor β_e $\tau_{Ed} = \beta_e \frac{V_{Ed}}{b_{0.5} d_V}$ $\beta_e = 1 + 1.1 \frac{e_b}{b_b}$	Refers to EC2 Gen 1 β factor. Introduces iterative calculation of β_{red} for outer perimeters.	The design punching shear stress is the sum of a shear component and a portion of the unbalanced moment. $V_u = \frac{V_u}{A_c} + \frac{\gamma_v M_u c}{J_c}$	Unbalanced moments are transferred to the side faces of the column through torsion. $V_u = \frac{V_{uo}}{1 + uM^*_v/(8V^* a d_{om})}$	The length of the control perimeter is reduced by the factor k_e (inverse of EC2 approach). $V_d = \frac{V_d}{k_e u}$ $k_e = \frac{1}{1 + \frac{e}{b}}$
Distance to first stud	≥ 0.3d; ≤ 0.5d	≥ 0.3d; ≤ 0.5d	≥ 0.35d; ≤ 0.5d	≥ 0.35d; ≤ 0.5d	≤ 0.5 x tangential stud spacing	≥ 0.3d; ≤ 0.75d
Maximum tangential stud spacing	1.5d: within 2d of column face 2d: beyond 2d of column face.	1st perimeter, $s_{t,max}$ = 0.75d ≤2d from column face, $s_{t,max}$ = 1.5d >2d from column face, $s_{t,max}$ = 3d	1.7d: within 1d of column face 3.5d: beyond 1d of column face.	2d	Lim & Rangan: min. 2 stud rails per column face.	0.75d
Maximum radial stud spacing	0.75d	0.75d	0.75d	0.75d, 500mm	Link spacing = slab depth, 300mm	0.75d

Eurocode 2:
What is changing and why it matters

Why a second generation?

The first generation of Eurocode 2 was rooted in an empirical approach. Test data was analysed and adapted into provisions that worked well for most typical designs. In this approach, not all parameters were visible. While the first-generation rules were effective in most standard design scenarios, the rules proved less reliable when applied to new materials, unusual geometries, or the assessment of existing structures.[21]

For example, the influence of concrete aggregate size and reinforcement steel yield strength are hidden. When non-standard materials were used, engineers had no straightforward way to adjust the calculations to reflect their actual properties. Another example, specific to the section of Eurocode 2 dealing with punching shear, was the rule locating control perimeter at 2d from the column face. This provision lacked physical meaning, as it extended beyond the critical region where punching shear failure develops. [21]

Finally, it should be noted that while double-headed shear studs are now widely used in practice, the first generation of Eurocode 2 did not explicitly cover their use. Instead, it focused on shear links as the primary form of punching shear reinforcement. This gap was addressed through European Technical Assessment (ETA) and CARES certification of Halfen HDB and Ancon Shearfix, ensuring that these products met the required standards of safety and compliance.

A new design basis: The Critical Shear Crack Theory (CSCT)

The second generation of Eurocode 2 was developed to address these weaknesses, while also improving ease-of-use and incorporating advances in knowledge. At its core, the code adopts the CSCT, widely recognised as the state-of-the-art in punching shear design. [21]

Originally introduced in the Swiss Code for structural concrete (SIA 162), CSCT has since been further developed and validated through extensive research. The approach was adapted into an explicit, "closed form" to be suitable for codified design. [21]

To enhance ease-of-use, a simplified approach is presented in the main body of the second generation of Eurocode 2, with a more detailed option available in Annex I for existing structures, where geometrical and mechanical properties are known in detail. [21]

Impact on reinforcement design

It is our understanding that there are no concerns about the adequacy of punching shear designs produced under the first generation of Eurocode 2. A draft version of the UK National Annex has now been released, and our initial investigations suggest that punching shear reinforcement requirements for flat slab designs will increase. The final details will only be confirmed once the national annexes are formally published.

The aim of the second generation is to address the weaknesses of the first, making the rules more transparent, grounded in clearer physical principles, and aligned with current reinforcement practice, including explicit coverage of double-headed studs.

For simplicity we will refer below to the first generation of Eurocode 2 as Gen 1 and to the second generation of Eurocode 2 as Gen 2.

Key changes relevant to punching shear

Design procedure

Gen 1 permitted only a single-step design method. Gen 2 adds the option for iterative verification at each perimeter of reinforcement, encouraging the use of specialist software. [22,17]

We believe this significant change to design procedure may encourage engineers to use design tools and software. Companies providing such software will need time and resource to accommodate these changes in their software.

Calculation of design shear stress

Gen 2 allows τ_{Ed} to be calculated directly from detailed slab analysis (e.g. high-end global finite element models), providing closer alignment between analysis and design. [22]

Point of contraflexure factor

A new provision increases calculated punching shear resistance where the change of slab bending moment direction is close to the column location. This is particularly relevant to advanced slab modelling. [22]

8.4.3 (2) For distances between the centre of the support area and the point of contraflexure in the considered load combination a_p smaller than $8d_v$, the value of d_v in Formula (8.94) may be replaced by:

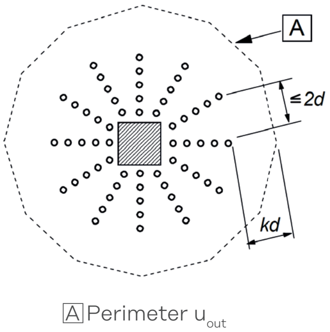
$$a_{pd} = \sqrt{\frac{a_p}{8} \cdot d_v} \qquad (8.97)$$

where

$$a_p = \sqrt{a_{p,x} \cdot a_{p,y}} \geq d_v \qquad (8.98)$$

Extent of shear reinforcement

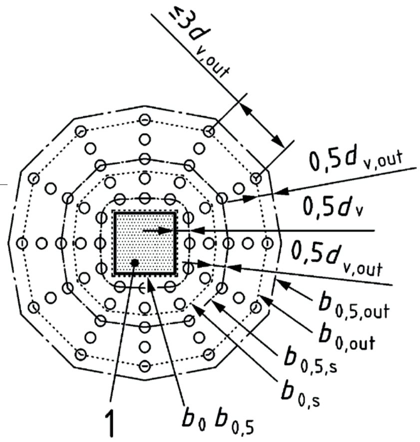
The outermost perimeter of shear reinforcement should extend closer to the outer control perimeter than in Gen 1, generally requiring longer stud rails and more reinforcement per column. [22]



Gen 1 Figure 6.22

Outermost perimeter of shear reinforcement should be ≤ 1.5d from outer control perimeter u_{out}

NB. The Eurocode recommended value for k is 1.5.



Gen 2 Figure 8.24

Outermost perimeter of shear reinforcement should be ≤ $0.5d_{v,out}$ from outer control perimeter $b_{0,5,out}$

Stud spacing

Tangential spacing rules are stricter in Gen 2. In Gen 1, the first perimeter allowed spacing up to 1.5d; Gen 2 reduces this to 0.75d, with subsequent perimeters limited to 1.5d. [22]

	Tangential spacing of shear reinforcement	
Gen 1	At a distance ≤ 2d from column face, $s_{t,max}$ = 1.5d At a distance > 2d from column face, $s_{t,max}$ = 2d	**9.4.3 Punching shear reinforcement** The spacing of link legs around a perimeter should not exceed 1.5d within the first control perimeter (2d from loaded area), and should not exceed 2d for perimeters outside the first control perimeter where that part of the perimeter is assumed to contribute to the shear capacity (see Figure 6.22).
Gen 2	First perimeter of studs, $s_{t,max}$ = $0.75d_v$ At a distance ≤ $2d_v$ from column face, $s_{t,max}$ = $1.5d_v$ At a distance > $2d_v$ from column face, $s_{t,max}$ = $3d_{v,out}$	**12.5.1 Punching shear reinforcement** The tangential spacing of shear reinforcement should be limited based on the distance to the column edge (see Figure 12.7 c). For shear reinforcement located at a distance ≤ $2d_v$ from the column edge, the tangential spacing should not exceed $1.5d_v$ and it should not exceed $0.75d_v$ and $0.5d_v$ for flat slabs and column bases, respectively, in the first perimeter. The tangential spacing of shear reinforcement should also meet the requirements of Figure 8.24.

Resistance formulae

The expressions for resistance with and without reinforcement ($v_{Rd,c}$ and $v_{Rd,cs}$) have been revised substantially. Aggregate size (d_{dg}) is a new input field, requiring careful consideration in design. [22]

	Gen 1	Gen 2
punching shear resistance without reinforcement	$v_{Rd,c} = C_{Rd,c} k (100\rho_l f_{ck})^{1/3} + k_1\sigma_{cp} \geq (v_{min} + k_1\sigma_{cp})$ (6.47)	$\tau_{Rd,c} = \frac{0.6}{\gamma_v} \cdot k_{pb} (100\rho_l \cdot f_{ck} \cdot \frac{d_{dg}}{d_v})^{1/3} \leq \frac{0.5}{\gamma_v} \cdot \sqrt{f_{ck}}$ (8.94)
punching shear resistance with reinforcement	$v_{Rd,cs} = 0.75 v_{Rd,c} + 1.5 (d/s_r) A_{sw} f_{ywd,ef} [1/(u_1 d)] \sin\alpha \leq k_{max} \cdot v_{Rd,c}$ (6.52)	$\tau_{Rd,cs} = \eta_c \cdot \tau_{Rd,c} + \eta_s \cdot \rho_w \cdot f_{ywd} \geq \rho_w \cdot f_{ywd}$ (8.104)

Studs vs. Links

Gen 2 introduces a new parameter ($d_{v,out}$) which is maximised through use of shear studs compared to links or stirrups. [22]

This, in turn, allows for more favourable calculations when double-headed shear studs are used: of the design shear stress at outer perimeters, of the length required for the outer control perimeter, of the minimum distance between the outermost shear perimeter and the outer control perimeter, and of the tangential spacing between studs.

The maximum permissible punching shear resistance for a reinforcement layout is also greater when studs are used. [22]

$$\tau_{Rd,max} = \eta_{sys} \cdot \tau_{Rd,c} \quad (8.109)$$

$$\eta_{sys} = 0.70 + 0.63 \left(\frac{b_o}{d_v}\right)^{1/4} \geq 1.0 \text{ for studs} \quad (8.110)$$

$$\eta_{sys} = 0.50 + 0.63 \left(\frac{b_o}{d_v}\right)^{1/4} \geq 1.0 \text{ for links and stirrups} \quad (8.111)$$

The current draft of the UK National Annex defines the η_{sys} values as on the right. The correct values to be used in the UK will be confirmed when the NA is published. These values are likely to vary between different Europeans countries and some countries may adhere to the Eurocode recommended values in the above equations (8.110) and (8.111).

$$\eta_{sys} = 0.77 + 0.69 \left(\frac{b_o}{d_v}\right)^{1/4} \geq 1.0 \text{ for studs}$$

$$\eta_{sys} = 0.55 + 0.69 \left(\frac{b_o}{d_v}\right)^{1/4} \geq 1.0 \text{ for links and stirrups}$$

Control perimeter location

Location of the control perimeter:

Gen 1: u_1 @ 2d from column face[17]

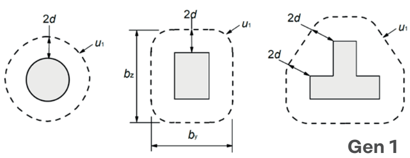


Figure 6.13: Typical basic control perimeter around loaded area

Gen 2: $b_{0,5}$ @ $0.5d_v$ from column face [22]

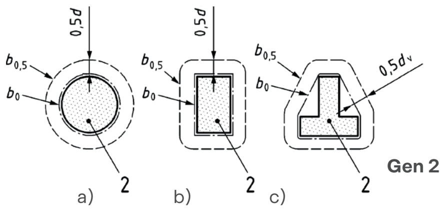


Figure 8.18: Typical control perimeters $b_{0.5}$ and b_0 around supporting areas (same perimeter shapes)

The location of the control perimeter set in Gen 2 more realistically models a potential punching failure. This was one of the goals achieved by the Eurocode 2 revision.

Large columns

Concentration of shear forces at column corners is now limited to a length of $3d_v$ along straight segments.[22] This formalises what was already considered best practice in many designs. In the Ancon Shearfix design software, there has long been an option to design to "best practice" or to "EC2." The "best practice" setting limits the length of the control perimeter at column corners, as now specified in Gen 2.

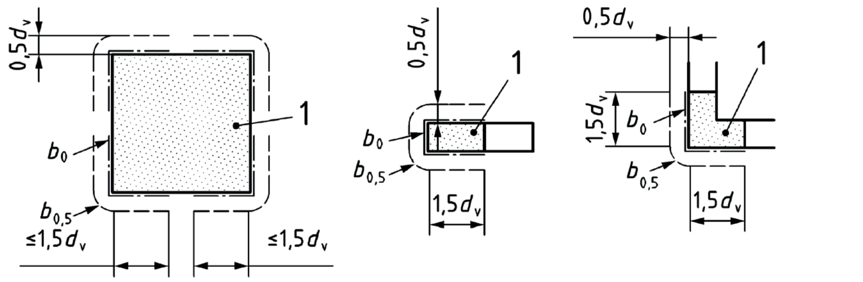


Figure 8.19: Length of control perimeter $b_{0.5}$ and support perimeter b_0 around supporting areas

β_e coefficient

The coefficient accounting for concentrations of shear force has been rewritten in Gen 2. It is simpler to calculate manually and easier to apply consistently.[22]

Key

1 supporting area

> The updates in the second generation of Eurocode 2 bring its punching shear design method in line with current expertise and research. Previously, several international codes had taken the lead in this area. With the upcoming release of the UK National Annex, we look forward to fully assessing the impact on current design practice and supporting accurate, confident application of the new code.

Harriet Cotton,
Research & Development Engineer, UK

Comparison of Gen 1 and Gen 2 Eurocode 2 for stud rail systems

Aspect	Gen 1 (2004 + A1:2014)	Gen 2 (2023)	Impact for Designers
Design procedure	Single-step method only	Option for iterative verification at each reinforcement perimeter	Encourages use of software; more efficient designs
Design shear stress	Based on simplified perimeter method	Can be calculated directly from detailed analysis	Aligns with global analysis tools
Control perimeter location	u_1 at 2_d from column face	$b_{0.5}$ at $0.5d_v$ from column face	Control perimeter much closer to column
Large columns	Not considered	Shear concentration length limited to $3d_v$ per side	Formalises current good practice for large column punching shear design
β_e **coefficient**	More complex to calculate	Simplified formula for eccentric shear	Easier to calculate manually; more consistent outcomes
Extent of reinforcement	Outermost stud position was further from outer control perimeter	Reinforcement must extend closer to the outer control perimeter	Typically requires longer rails and more studs
Stud spacing	$\leq 2_d$ from column face, $s_{t,max} = 1.5_d$ $>2_d$ from column face, $s_{t,max} = 2_d$	1st perimeter, $s_{t,max} = 0.75d_v$ $\leq 2d_v$ from column face, $s_{t,max} = 1.5d_v$ $>2d_v$ from column face, $s_{t,max} = 3d_{v,out}$	Denser reinforcement layouts also affects detailing
Resistance formulae ($V_{Rd,c}$, $V_{Rd,cs}$)	Empirical formulae, fewer parameters	Revised formulae; aggregate size (d_{dg}) now included	Greater design control for engineer, requires updated software/calcs
Studs vs links and stirrups	Treated broadly equally	New $d_{v,out}$ parameter favours stud performance	Makes studs more efficient than links in design
Point of contraflexure factor	Not considered	New factor increases resistance where bending reversal occurs	Benefits advanced slab modelling

Sustainability and Code Evolution

The second generation of Eurocode 2 introduces refinements intended to improve the clarity and consistency of reinforced-concrete design. Its updated punching shear provisions are based on the CSCT, a mechanics-based model that more closely reflects observed slab behaviour in testing. This approach is expected to reduce uncertainty in punching shear assessment and allow engineers to design with greater precision, rather than relying solely on conservative empirical rules.

While the eventual impact on reinforcement quantities will depend on national annexes and project-specific conditions, the underlying aim is clear: a more transparent, physically grounded framework that supports efficient and reliable design. In practice, this precision may help avoid unnecessary material use, contributing indirectly to lower embodied carbon without compromising safety.

Material efficiency is only one aspect of sustainability. Modern punching shear reinforcement also supports broader lifecycle goals. Prefabricated stud rail systems enable thinner flat slabs without sacrificing strength, reducing the volume of concrete required in new builds. Where existing structures are adapted or repurposed, retrofit reinforcement can extend service life and avoid demolition, preserving the embodied carbon already invested in the structure. Leviat's Aschwanden RINO system, for example, allows existing slabs to be strengthened safely to accommodate new or increased loads, such as the heavier vehicle weights associated with electric vehicle parking decks.

Beyond reinforcement design, the second generation of Eurocode 2 provides greater flexibility to accommodate emerging low-carbon materials and new reinforcement types. Its structure allows for the specification of concretes with alternative binders, recycled aggregates, or corrosion-resistant steels, subject to validation in each national annex. This adaptability ensures that future innovation, whether in material science or digital design, can be integrated within a consistent safety framework.

Sustainable design begins with precision. By applying accurate mechanical models, optimising material use, and extending the life of existing assets, engineers can achieve measurable carbon reductions as a by-product of best design practice. In this way, punching shear reinforcement becomes not only a safeguard for structural safety but also a practical enabler of more responsible, resource-efficient construction.

Leviat supporting the Transition

We are committed to helping engineers adapt to the second generation of Eurocode 2 with confidence. Our software will be updated with due consideration to phasing-in of the standard in respective countries, and we are working closely with clients to provide training, technical guidance, and design support.

We will communicate with the industry as these updates are introduced, ensuring users understand when and how the changes will be implemented.

At the core of Leviat's digital support is a suite of specialist design software developed for our reinforcement systems, including the Ancon Shearfix Design Software, Halfen HDB Design Software, and Aschwanden DURA Design Software. These programs provide engineers with a dedicated tool for punching shear design. It simplifies the process of modelling slab–column connections, generates stud rail layouts in line with Eurocode 2, and ensures that reinforcement is fully documented for specification. Each tool simplifies documentation and specification, ensuring that reinforcement is both compliant and practical for construction.

For projects involving post-tensioned slabs, we also recommend the use of Bentley's RAM Concept, which enables detailed slab analysis and integrates reinforcement design within wider structural models. Together, these tools help engineers achieve clarity, efficiency, and certainty in their designs.

Collaboration with industry experts ensures that we remain at the forefront of code compliance and technical excellence.

> "The development of the second generation of Eurocode 2 is a positive step for the entire industry. By improving consistency and transparency, it strengthens confidence in reinforced concrete design and helps create safer, more reliable structures. These updates will ultimately benefit everyone - designers, contractors, and clients - and support higher safety and performance standards across Europe and the globe."

Bryan Jex,
Sales Director, Structural Connections, UK

Summary and outlook

Punching shear remains one of the most critical checks in reinforced concrete flat slab design. Past failures have demonstrated its consequences can be sudden and severe, and for modern buildings and infrastructure it continues to govern both safety and serviceability, requiring rigorous attention at every stage of design and construction.

The second generation of Eurocode 2 marks a step change in approach. By moving from empirical rules to the CSCT, the code brings greater transparency, accuracy and alignment with physical behaviour. The overall volume of reinforcement is not expected to increase significantly, but the changes are nonetheless important. They encourage the use of specialist software, require more rigorous detailing, and bring code provisions in line with modern reinforcement practice, including explicit recognition of stud rail reinforcement systems already widely used in practice.

For engineers and contractors, the challenge is managing this transition effectively. While national annexes will define the details, the direction of travel is clear. Design will increasingly depend on digital tools, iterative verification and closer integration with analysis models and BIM workflows. These trends also connect with sustainability drivers, as optimised reinforcement design reduces material use and helps lower embodied carbon.

Leviat is well positioned to support this change. Our portfolio includes trusted stud rail systems such as Halfen HDB and Halfen HDB-Z, and Ancon Shearfix, as well as punching shear reinforcement systems from Aschwanden, including DURA for high-load applications and RINO for retrofit and refurbishment projects. Our digital tools, including the Ancon Shearfix design software and integration with Bentley's RAM Concept, allow engineers to design, verify and document reinforcement with confidence. With global expertise combined with local technical support, we help clients adapt to the second generation of Eurocode 2 while maintaining safe, efficient and code-compliant outcomes.

Leviat's role extends beyond the supply and manufacturing of reinforcement. We partner with developers, architects, engineers and contractors to provide clarity in design, confidence in compliance and efficiency in delivery. Punching shear can be resolved through a combination of proven solutions, advanced digital tools and local technical expertise. Failures have shown that the consequences of punching shear can be sudden and severe, and for modern buildings and infrastructure it continues to govern both safety and serviceability.

Contributors

The research and insights presented in this white paper would not have been possible without the generous support of a range of contributors. We extend our sincere thanks to all those who shared their expertise, perspectives, and time to help shape and develop this work.

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