

CROSS Safety Report

Punching shear assessments of flat slabs supporting out of line columns

This month's report discusses punching shear assessments of flat slabs used as transfer slabs to support transferred columns.

Report

Through peer review work, the reporter says their firm has observed transfer slabs analysed using a finite element analysis model (which provides reactions on the supporting columns) to obtain moment plots for determining the bending reinforcement. These reactions are put into spreadsheets, the reporter continues, that are only intended to quantify the shear

reinforcement for a flat slab with a uniform load, amplified with beta factors. This underestimates the localised shear stress between non-aligned columns as it ignores the shear concentration between them.

The reporter explains that, for cases where a transfer slab supports a transferred column and there is close proximity between the transferred column and the supporting column, there is a highly stressed zone of concrete between the two columns (see **Figures 1, 2 and 3**).

Whether a local inclined strut calculation or a punching shear assessment of the transfer slab is required, the reporter continues, depends on the proximity of the columns. However, even for transferred columns spaced apart in the range normally applicable to punching shear, they add that the punching shear stresses can be significantly higher than the stresses obtained from a conventional assessment (intended for flat slabs with uniform loading and without transferred elements).

The reporter explains that, to allow for uneven distributions of shear stress around the support, design shear stress in a conventional punching shear assessment for a uniformly loaded slab takes into account the reaction around the column in question along with a magnification of the load. They add that the issue with transfer

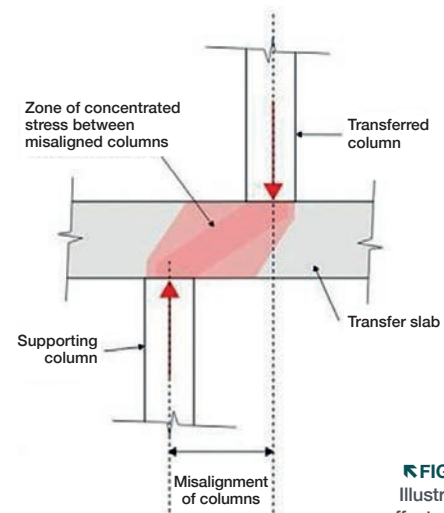


FIGURE 1:
Illustration of
offset columns

Key learning outcomes

For designers:

- | Be aware of the background to codes and of the principles behind computer modelling systems
- | When using codified rules outside of situations for which they were written, the validity of these rules needs to be questioned and checked using alternative methods
- | The use of standard calculations for symmetrical column arrangements (such as spreadsheets) should be questioned when the layouts are asymmetrical
- | Read and take note of the IStructE published guidance on this issue, *Design of transfer slabs* in November 2024.

slabs is that the load is concentrated by a transferred column, and the magnification of the reaction using the method contained within the Eurocode is not appropriate for estimating the additional design shear stresses from the transferred columns above.

The reporter further says that, if an assessment has not been carried out correctly, there is an unacceptable risk that the zone between the columns is highly stressed, exceeding the requirements in the codes of practice (for example, Eurocode 2). In such instances, even taking into account reductions in safety factors for the bespoke nature of the building structure under consideration, there may be undesirable over-stressing possibly leading to the need for remedial works.

Implementing remedial works, the reporter notes, has an impact on the building owner and tenants

of the building. It can be costly and disruptive to install, and can potentially change the floor layout in a negative way through loss of amenity to accommodate the new structure.

The reporter believes the likely causes of this problem are a lack of understanding, and code rules being misapplied to design conditions for which they were not intended. They are also concerned this may be an industry-wide issue so chose to submit a report to CROSS to encourage other engineers to undertake appropriate assessments for transfer slabs, and not repeat the errors they have witnessed.

The reporter advocates that guidance on the design of shear assessment of transfer slabs be

FIND OUT MORE ABOUT CROSS



SCAN ME

published by the IStructE (see **Expert Panel comments**) and should be included in university courses. They also suggest that, in code sections related to shear assessments, clear advice is needed to show that assessments for uniformly loaded slabs are not appropriate for elements with concentrated loads, such as transfer slabs, which instead require assessment using first principles.

The full CROSS Safety Report, including links to guidance mentioned, is available on the CROSS website (report ID: 1301) at www.cross-safety.org/uk/safety-information/cross-safety-report/punching-shear-assessments-flat-slabs-supporting-out-1301.

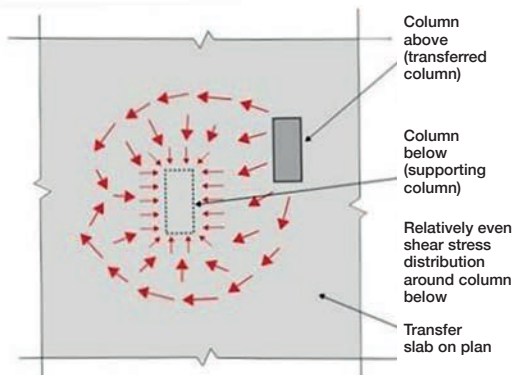


FIGURE 2: Shear stress distribution in slab

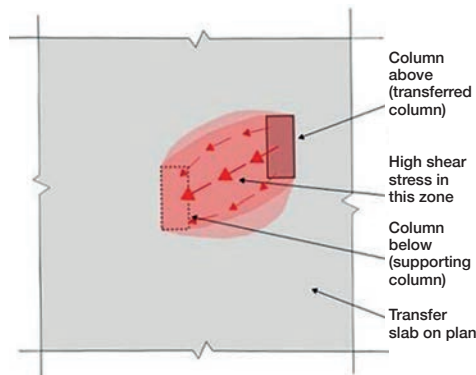


FIGURE 3: Region of high stress distribution

Further reading

CROSS Safety Reports:

- **CROSS Safety Report 1145:** www.cross-safety.org/uk/safety-information/cross-safety-report/further-example-incorrect-finite-element-modelling-1145
- **CROSS Safety Report 1220:** www.cross-safety.org/uk/safety-information/cross-safety-report/flat-slab-finite-element-analysis-assumptions-1220

The Structural Engineer:

- **Scrutinising software: Selection criteria, limitations and the prevalence of bugs:** [www.istructe.org/journal/volumes/volume-102-\(2024\)/issue-10/scrutinising-software-selection-criteria](http://www.istructe.org/journal/volumes/volume-102-(2024)/issue-10/scrutinising-software-selection-criteria)
- **Avoiding modelling errors: validation and verification:** [www.istructe.org/journal/volumes/volume-102-\(2024\)/issue-10/avoiding-modelling-errors-validation-verification](http://www.istructe.org/journal/volumes/volume-102-(2024)/issue-10/avoiding-modelling-errors-validation-verification)

IStructE guidance:

- **Design of transfer slabs:** www.istructe.org/resources/guidance/design-of-transfer-slabs

Expert Panel comments

The problematic reliance on finite element analysis (FEA) alone has been the subject of several CROSS Safety Reports (see **Further reading**).

When circumstances beyond the ordinary are encountered it seems that, rather than revert to first principles, some designers are more likely to resort to a FEA model in the belief that it will provide all the answers. This is not always the case, as highlighted by this report.

A safety concern mentioned by the reporter is that miscalculation may lead to remedial works being required. However it is known that punching shear failures can be sudden with little or no warning. There might be evidence of precursors to failure in the form of cracks in the slab adjacent to the column in question, but these might not be obvious and their relevance might not be recognised. It is therefore important to be in

a situation where the design is fundamentally sound and the risk of punching shear failure has been eliminated.

While FEA may well be the best way to determine the shear distribution around the critical perimeter, the problem is with applying code rules, such as those in Eurocode 2, to situations for which they were not written. The assumptions used in the background to the code may not apply. As always, the designer must be sure that their calculations adequately represent the distribution of forces and stresses by using alternative methods to validate computer models. These can include approximate methods.

The Institution of Structural Engineers published guidance on this issue, *Design of transfer slabs* in November 2024. To quote: 'This guidance has been produced by a cross-industry group in response to a gap

in advice in the application of standards in the design subject. In such circumstances engineers have adopted different methods. This guidance is aimed at ensuring that the design of new transfer slabs is consistent and robust, in accordance with current knowledge.'

The suggestion that there should be IStructE guidance has therefore now been met. A further quote from the guidance emphasises the safety-critical importance of good design: 'Designing a transfer slab requires the engineer to have great confidence in their understanding of short- and long-term concrete behaviour, design against disproportionate collapse and the behaviour of concrete in shear.'

Additionally, the October 2024 issue of *The Structural Engineer* included two useful papers referencing the use of computer programs (see **Further reading**).