CROSS Safety Report

Unconservative design of flat slab due to software modelling issues

This month's report discusses how a design/modelling problem caused an under-designed reinforced concrete slab to be constructed.

Report

A reporter's organisation recently came across a design/modelling problem which gave highly unconservative analysis results. This caused an under-designed reinforced concrete (RC) slab to be constructed within a large domestic property.

Correct modelling of blockwork walls

A loadbearing blockwork wall, supported on a transfer slab, was mistakenly modelled as a concrete shell element within a 3D finite element (FE) package. A more realistic approach is to model such walls as a series of pin-ended columns.

When the transfer slab was exported to a 2D FE package for reinforcement and deflection checks, the 3D concrete wall element was converted to a line element of equivalent stiffness and incorporated within the 2D FE analysis.

The result of this was that the transfer slab was artificially stiffened by the line element, which was effectively acting as a very stiff beam with a depth equivalent to the height of the wall over. As such, both the long-term deflection prediction and the reinforcement demand was significantly underestimated.

Insufficient reinforcement in transfer slab

The already constructed slab was found to have around 50% of the necessary ultimate limit state design reinforcement and was about to receive a 75mm screed. Once the modelling error was discovered following observed excessive cracking to the supported masonry wall, temporary propping was installed.

Strengthening works required on site

A permanent strengthening solution was developed by way of a heavy steel transfer beam installed below the wall. Ceilings had to be removed and services diverted to achieve this.

To avoid such an error, when creating or checking a 3D FE model, it needs to be ensured that any loadbearing masonry wall that is transferred onto a slab below, or that is not vertically continuous down to foundation, is modelled as a series of individual pin-ended columns. This ensures that they act in the vertical loadbearing direction only, and thus cannot act as a deep beam.

Wall shell elements within a 3D FE model should only be used where a vertically continuous RC concrete wall is proposed, as otherwise they can artificially stiffen the structure by acting as deep beams. The design checker should also ensure that they see an extruded and annotated view of the 2D model, in order to verify that the structure has been modelled correctly.

> **"SAFETY DEMANDS THAT ALL MODEL OUTPUTS ARE SUBJECTED TO A SIMPLIFIED SANITY CHECK, WHICH APPEARS NOT TO HAVE HAPPENED**

Key learning outcomes

For civil and structural design engineers:

- If there is uncertainty with design outputs from a design software it is good practice to carry out hand calculation checks to verify the outputs
- Ensure that those using specialist software programs are suitably trained and competent to do so
- It is good practice to have in-house checking of designs carried out by a competent and experienced engineer. Particularly for critical elements such as transfer slabs

Expert Panel comments

There has been much disquiet expressed in engineering circles about the improper use of (or over reliance on) computer modelling with potential for results to be divorced from reality. This report is a classic illustration of the kind of problems that might arise. Safety demands that all model outputs are subjected to a simplified sanity check, which appears not to have happened.

Beyond that, the description of this model suggests an inappropriate level of refinement for the essentially simple task of designing an RC slab supporting a wall. If, however, the slab in question is complex with, for example, significant openings, then accurate modelling is all the more important.

There were a number of opportunities to discover this mistake. For example, as the wall was in the model, a very quick review of the stresses in the wall would have highlighted that they were inappropriate

for a masonry wall. This highlights the need to check the whole model during the design not just the element of immediate interest.

Modelling precast concrete planks

Similar errors can occur when concrete slabs are constructed from precast planks but modelled as a solid diaphragm leading to an underestimate in the loading to the supporting beams; a check of bending in the slab perpendicular to the span would have highlighted this. It is disturbing that such a slab can be detailed and constructed with only 50% of the required rebar without anyone in the office or on site thinking it looked odd.

Reflective thinking

The Standing Committee on Structural Safety (SCOSS) and CROSS have had a long-standing policy of endorsing third party checks for key structures. The rationale is to assure public safety. In 2016, SCOSS published a paper *Reflective thinking* (see **Further reading**) which looked at over-reliance on computer modelling and posed a set of questions for the designer:

- Is the model capable of satisfying the requirements? (the validation question)
- Is the model the most appropriate in the context?
- Has the software been validated and verified?
- Has the model been correctly implemented? (the verification question)

There is an overriding need in the construction industry to have sufficient checking by suitably qualified and experienced persons to uncover such serious errors.

The full CROSS Safety Report, including links to guidance mentioned, is available on the CROSS website (report ID: 886) at **www.cross-safety.org/uk/safety-information/cross-safety-report/unconservative-design-flat-slab-due-software-886**.

Further reading

- SCOSS Topic Paper: *Reflective thinking*: **www.cross-safety.org/sites/default/files/2016-12/reflective-thinking.pdf**
- Design of tall asymmetric structures (report ID: 238)
- Error in proprietary design program (report ID: 349)
- Understanding the difference between analysis and design (report ID: 372)
- Computer analysis and slab design twisting moments (report ID: 441)
- Incorrectly designed safety system (report ID: 527)
- Failure to check designs produced by software (report ID: 538)
- Columns missing due to 3D modelling (report ID: 614)
- Concrete grade confusion in software (report ID: 788)
- Dangerous design of a retaining wall (report ID: 989)
- Modelling of structures (report ID: 994)
- Potentially unsafe software design for steel beams (report ID: 1003)
- Concern over modelling of concrete frame building for construction stage (report ID: 1073)
- Potentially unsafe buckling resistance checks using software (report ID: 1075)
- Connection fixity considerations for steel frame modelling (report ID: 1139)
- Further example of incorrect finite element modelling (report ID: 1145)
- Understanding finite element analysis for pile caps (report ID: 1152)
- Combination load cases in proprietary software cause concern (report ID: 1170)
- Unqualified engineer's unsafe computer aided design of a retaining wall (report ID: 1210)
- Incorrect use of software for wind loads on solar panels (report ID: 1212)

What is CROSS?

Collaborative Reporting for Safer Structures (CROSS) helps professionals to make structures safer by publishing safety information based on the reports it receives and information in the public domain.

CROSS operates internationally in the UK, US, and Australasia. All regions cover structural safety, while CROSS-UK also covers fire safety.

How reporting to CROSS works

The secure and confidential safety reporting system allows professionals to share their experiences to help others.

Professionals can submit reports on safety issues related to buildings and other structures in the built environment. Reports typically relate to concerns, near misses or incidents. Find out more, including how to submit a safety report, at **https://bit.ly/cross-safety**. Your report will make a difference.

SCAN ME

CROSS
COLLABORATIVE REPORTING FOR SAFER STRUCTURES