CROSS AUS
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

The Institution of Structural Engineers

CROSS Newsletter

CROSS-AUS Newsletter 8 | **October 2022**

Editorial

Welcome to all our CROSS-AUS subscribers, whether you are in Australia, New Zealand, the UK, USA, or at any other location, with an interest in making structures safer!

Since the launch of CROSS-AUS in September 2018, the number of subscribers to our newsletters has steadily grown to a good level but we are still far from reaching the whole of the engineering and built environment community. Checking the CROSS websites, we can see that many thousands of users are visiting each month destined for the safety report pages, showing CROSS should be seen as a knowledge hub for professionals.

Locations where the email with our last CROSS-AUS Newsletter (August 2022) was opened were: Australia 51%, USA 21%, UK 14%, NZ 8%, Turkey 2%, and Others 4%.

If we assume there are around 10,000 Structural Engineers in Australia and New Zealand, and many more who are involved in the construction industry as designers or constructors, there is clearly scope to expand our readership. So, do please pass on this Newsletter to any colleagues who are not already subscribers and encourage them to register via the **CROSS-AUS website>**.

Since our last newsletter, we are pleased to welcome the following additions to the CROSS-AUS team:

- Brian Uy as a Director of CROSS-AUS Ltd and the IStructE Company Representative
- David Hargreaves who has joined the team to review, edit and process our reports, and
- Gil Brock as a member of our Expert Panel.

CROSS is your safety community and there are several ways that you can **Get Involved>**. If you have an interest in promoting safer structures and would like to assist with the further development of CROSS-AUS, then please send us an email at **team.aus@cross-safety.org>**.

The American Society of Civil Engineers (ASCE) is holding its **9th Forensic Engineering Congress>** in Denver on 4-7 November and CROSS will be strongly represented. Alastair Soane, Principal Consultant CROSS, will be one of the keynote speakers and a further 9 papers will be presented by speakers from the CROSS international community, including Phil Latham, Director CROSS-AUS.

In this newsletter, we publish three reports that deal with three different, but important topics:

- **Report 1056 - Production of as-constructed drawings.** This was one of the issues raised in the **Sheldon Weir Building Confidence Report>**, and it is an area of practice that needs to be addressed. There is a range of views as to who should be responsible for the production of a reliable set of as-constructed drawings and CROSS-AUS encourages you to provide feedback on your experience on this matter.
- **Report 1084 - Condition assessments of exposed lightweight canopy roofs.** This report highlights the importance of considering the maintenance requirements when designing such structures. Many CROSS reports express concerns about maintenance and the CROSS-AUS report **Maintenance of multi-storey buildings>** invited feedback on whether a "maintenance manual" should be provided for all structures.
- **Report 1122 - Punching shear in concrete slabs at perimeter columns.** Punching shear is a brittle (non-ductile) failure and the reporter's experience is that some engineers appear to lack an understanding of the requirements of AS3600. This is another example of the importance of having a good understanding of structural design principles or as stated by T. Y. Lin many years ago: ***To engineers who, rather than blindly following codes of practice, seek to apply the laws of nature.***

CROSS-AUS has now published a total of 39 reports in our 8 Newsletters that cover a range of issues, some dealing with particular issues and others of a more general nature. One of our recent reports, **Modelling of structures>**, has generated considerable interest with over 1,000 views on the website, and many likes, clicks and comments on LinkedIn.

More reports on structural safety are always needed and, if you have a concern or observe a safety-related incident, please go to the **CROSS-AUS website>** where guidance is given on how to make a confidential report.

Mike Fordyce
Director, CROSS-AUS Ltd

Contents

Reporting to CROSS

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team.aus@cross-safety.org

Production of as-constructed drawings

CROSS Safety Report Report ID: 1056

The reporter is concerned about who should be responsible for producing accurate "as-constructed" drawings. The reporter's experience is that the as-constructed drawings are typically likely to be incomplete and contain errors. If the as-constructed drawings do not accurately record the works as constructed, there could be serious consequences for any future building works, including where such works rely on the accuracy of the drawings.

Key Learning Outcomes

For clients, building owners, and managers:

- Include the submission of as-constructed drawings as a contractual obligation and define the parties responsible for their production and verification as an as-constructed record
- Building owners and managers should ensure that as-constructed drawings are retained for future purposes

For civil and structural design engineers:

- Where production of as-constructed drawings is your responsibility, maintain comprehensive records of changes carried out during the works in order to facilitate their production
- Issue changes to design by way of the working drawings. In situations where last minute changes are required on-site, amend and reissue the working drawings within a predetermined timeframe

For contractors:

- Where production of as-constructed drawings is your responsibility, appoint an engineer to oversee the maintenance of comprehensive records of on-site changes and for the production of as-constructed drawings

For certifiers:

- Withhold the issue of Certificates of Occupancy until satisfactory receipt of as-constructed drawings

For regulatory authorities:

- Consider mandating the submission and retention of as-constructed drawings as a standard building works requirement

R Full Report

Based on their experience of working on projects using a Design & Construct form of contract, a reporter is concerned about responsibility for producing accurate "as-constructed" drawings.

The reporter's experience is that the onus is placed on the consultant to produce the as-constructed drawings and to pass these to the client. However, these are likely to be incomplete and contain errors if they

What should be reported to CROSS?

Structural failures and collapses, or safety concerns about the design, construction or use of structures.

Near misses, or observations relating to failures or collapses (which have not been uncovered through formal investigation) are also welcomed. Reports do not have to be about current activities so long as they are relevant.

Small scale events are important - they can be the precursors to more major failures. No concern is too small to be reported and conversely nothing is too large.

Your report might relate to a specific experience or it could be based on a series of experiences indicating a trend.

have not been produced or considered by the contractor who actually built the project.

The reporter believes that there are inherent safety risks with this approach if the as-constructed drawings are not an accurate record of the works as actually constructed. For example, there could be serious consequences for any future building works that rely on the accuracy of these drawings.

It is the reporter's opinion that a number of issues may have contributed to this situation including a lack of professionalism in the industry (particularly when using Design & Construct forms of contract) and a lack of mandatory enforcement by regulatory and other governing bodies.

The reporter proposes that it should be mandatory for accurate as-constructed drawings to be produced for Class 2 - 9 structures by the contractor. In addition, the reporter proposes a requirement that the contractor signs the drawings to signify that the drawings are a true and accurate record of the works as-constructed.

C Expert Panel Comments

The question of as-constructed drawings is a serious problem in the industry. Whilst the submission of accurate as-constructed drawings may be contractually mandated, this is often not enforced.

Reliable as-constructed drawings are extremely important so that all buildings can be responsibly and safely managed, renovated and demolished. Particularly in New Zealand, the lack of accurate "As Builts" hinders the seismic assessment of existing structures. They are also imperative in the burgeoning area of forensic structural engineering, where practitioners spend their working lives examining defects in structural members and determining the safety or otherwise of the building or structure.

Typical risks associated with as-constructed drawings include:

- non-recording of changes made to the design during construction;
- non-recording of late design changes on the drawings, typically when such changes have been recorded in the form of sketches and site instructions;
- human factor failures including pressures to comply with schedule and cost, affecting adequate recording of as-constructed details or their quality and clarity; and
- as-constructed drawing control may not be exercised by the builder if the construction is non-compliant. i.e., there is a conflict of interest.

Poor quality as-constructed drawings

One of the drivers of poor quality as-constructed drawings is that they are typically produced after practical completion when many of the personnel with first-hand knowledge of changes have left the project.

The designer may be cut off from the construction process and this raises the question as to who certifies the as-constructed drawings as being a true record of the construction. By not being party to the site quality programme and physically verifying that construction is following the design intent, the designer cannot know if the issued for construction (IFC) drawings are suitable for use as the as-constructed drawings. The preferred contractual arrangement would be for the designer to be engaged during construction to inspect regularly, or as a minimum at distinct stages, to check on quality on site and to ensure changes are "red-lined" on the construction drawings. Those drawings could then be used as the basis for production of the as-constructed records.

Responsibility for as-constructed drawings

For Design and Construct projects, the responsibility for the production of as-constructed drawings should rest with the Contractor, as suggested by the reporter. With this form of contract, the Contractor has assumed responsibility for the design and the Contractor's Engineer is best positioned to produce the drawings.

Where required by legislation, Building Certifiers should be insisting on complete as-constructed drawings before Certificates of Occupancy are issued. Where the Certifier is engaged by the Contractor or Developer, pressure is often exerted on them to issue Certificates of Occupancy prior to receiving such drawings. Such pressures are difficult to counter, exposing a weakness in the private certification process.

Benefits of CROSS

- Share lessons learned to prevent future failures
- Spurs the development of safety improvements
- Unique source of information
- Improved quality of design and constructon
- Possible reduction in injuries and fatalities
- Lower costs to the industry

Supporters of CROSS-AUS

- Australasian Certification Authority for Reinforcing and Structural Steels (ACRS)
- Consult Australia
- Engineers Australia (EA)
- Engineering New Zealand (ENZ)
- Institution of Structural Engineers (IStructE)
- Structural Engineering Society New Zealand (SESOC)

As the use of BIM becomes more commonplace, this should make the process of production of as-constructed drawings easier; however, the responsibility for the upkeep of the BIM model still needs to be defined and apportioned.

Beyond the mandatory production of as-constructed drawings, mandatory submission and retention of as-constructed documentation is equally as important. Experience indicates that as assets are bought and sold or transferred, and/or asset managers come and go, the as-constructed drawings are more likely to be misplaced. It is uncertain how this could be ensured without the involvement of approval authorities (e.g. Councils) acting as a centralised repository.

The panel notes that whilst it is good policy for updated shop drawings to be retained and form part of the documentation for the building, these should not be used as a substitute for formal as-constructed drawings.

Reports, Guidance, and Legislation

The responsibility for the production and retention of as-constructed documentation in Australia was one of the issues raised in the **Shergold Weir Building Confidence Report (BCR)>**, which noted that:

'A full set of final documents for a Commercial building which includes all relevant documents for the ongoing management of the building is not usually collated and passed on to the owner or subsequent purchaser. This makes it difficult for owners to verify how decisions were made and to adequately ensure that safety systems are properly maintained over the life of the building.'

Recommendation 20 of the BCR states:

'That each jurisdiction requires that there be a comprehensive building manual for Commercial buildings that should be lodged with the building owners and made available to successive purchasers of the buildings.'

With regard to record keeping, the BCR notes with respect to Recommendation 12 that:

'Unfortunately, despite requirements for record creation and keeping, key information is not readily accessible or auditable.'

Recommendation 12 states:

'That each jurisdiction establishes a building information database that provides a centralised source of building design and construction documentation.'

In response to the BCR, **the Australian Building Codes Board (ABCB) Implementation Team>** has produced a series of guidance documents for consideration by State and Territory Governments, including: **Building Manuals – Model guidance on BCR recommendation 20 (Guidance Document)>**. This is a comprehensive document and includes 6 Principles for Building Manuals.

Principle 2 is titled "Responsibility for compiling building manual information". It states that:

'Building manual information is compiled and checked by the statutory building surveyor as part of the building approval process prior to issuing an occupancy approval.'

With respect to Principle 2, the Guidance Document recommends the passing of a legislative provision to the following effect:

'The building approval applicant must provide all required building manual information to the statutory building surveyor prior to the application for an occupancy approval.'

(Note: in the proposed legislative provision, the building approval applicant would be the individual or entity, such as the building owner or an agent of the owner, who applies for the building approval.)

In the comments to Principle 2, the Guidance Document states that:

'On projects involving complex documentation, the building approval applicant may appoint the lead designer, project manager or builder to take on the role of coordinating or preparing building manual information documents for submission to the statutory building surveyor.

Ultimately, the practicalities of how the building manual information will be compiled for checking by the statutory building surveyor will depend on contractual obligations between parties and on digital document retention and sharing practices.'

The **Design and Building Practitioners Act 2020 (NSW)>** (the **Act**) has

News & Information

ASEC2022: Engineers Australia will host the **Australasian Structural Engineering Conference>** from 9 - 10 November 2022, under the theme, 'engineering resilience.'

Jane Entwistle, President IStructE is the keynote speaker on Wednesday 9 November. As a Conservation Accredited Engineer Jane particularly specialises in working on historic structures.

Karlie Collis, Director CROSS-AUS, will present a paper on "Safety of structures in the climate emergency" on Thursday 10 November.

National Construction Code: NCC 2022 is now available on **NCC Online>**.

NCC 2022 will be adopted by the states and territories on 1 May 2023.

Building Ministers also agreed to transitional arrangements for the following specific requirements:

- New livable housing requirements commence 1 October 2023
- New energy efficiency and condensation mitigation requirements commence 1 October 2023
- New lead-free plumbing product requirements commence 1 September 2025.

Until these adoption dates, NCC 2019 Amendment 1 remains in-force.

For those who wish to use the new provisions refer to the **article on using NCC 2022 prior to 1 May 2023>**.

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brought about a raft of changes including requirements regarding the documentation of structures. For further details of the Act, refer to the NSW Fair Trading website **Design practitioners' obligations>**.

Conclusion

In conclusion, it is recommended that occupancy of the building or the use of the structure should not be permitted until the as-constructed drawings have been submitted and accepted by the appropriate building or controlling authority. On large projects, a requirement for the progressive hand-over of as-constructed drawings, linked to progress payments, could go some way to overcoming the problem identified by the reporter. Further, it may be that independent quality assurance including recording of the as-constructed works could be contractually required, especially for high-risk structures.

Note: As noted in the BCR this is an area of practice that needs to be addressed and there appears to be a range of views as to who should be responsible for the production of a reliable set of as-constructed drawings. Accordingly, CROSS-AUS encourages you to provide feedback on your experience on this matter.

Submit Report

Submit Feedback

Non-Structural Elements:

Attention is drawn to the following related to the design and performance of **"non-structural elements"**:

- A recent **NZ Society for Earthquake Engineering>** webinar on the **"Seismic performance of non-structural elements">** presented by Jan Stanway and Dr Jitendra Bhatta.
- CROSS-AUS report **"The reliability of technical data for proprietary products">** raised concerns about the technical data provided for some products that are used to brace non-structural elements (such as suspended building services within ceiling spaces)

Condition assessments of exposed lightweight canopy roofs

CROSS Safety Report Report ID: 1084

A reporter has identified several issues with lightweight canopy roofs using profiled steel sheeting or sandwich panels, and in many cases with the roof sheeting underslung from the structure. Concerns raised include excessive deflections, corrosion at critical locations, and lack of regular inspections and maintenance.

Key Learning Outcomes

For designers and specifiers:

- Identify a suitable maintenance regime in the specification, including safe access and cleaning requirements
- Specify fixing details and materials

For builders:

- Seek certification from a qualified structural engineer prior to making any changes to the specified works
- Carry out replacement works with like-for-like materials and details, unless otherwise certified by a qualified structural engineer

For owners and asset managers:

- Ensure that specified maintenance inspections are adhered to at nominated intervals by suitably qualified personnel
- Ensure regular cleaning of the roof structure

R Full Report

The reporter has undertaken a number of condition assessments of lightweight canopy roofs and has also been consulted when issues concerning structural performance have arisen with this type of roof.

In most cases, no urgent action in the interest of safety has been necessary, apart from two incidents of particular concern to the reporter.

Many of these canopies are constructed with roofing sheets underslung below structural beams and purlins, leaving the main structural elements exposed. The primary supports in some cases are individual cantilever columns; others may have a pair of columns.

The roofing material is usually profiled steel sheeting but on some occasions it consists of sandwich “polypanels” (aluminium facings with a polystyrene core).

In one case, the canopy fascia was supported by heavy-gauge profiled ceiling sheets which cantilevered 2m to support concealed gutters and fascias. The upper profiled roof spanned 2m, supported on double cold-formed girts with a timber-formed fascia supported on the lower heavy-gauge ceiling.

The reporter was called in after the fascia sagged following replacement of ageing ceiling structural members with lightweight 0.45mm Base Metal Thickness (BMT) steel-profiled roofing sheets. Fortunately, no one had accessed the cantilever roof!

The reporter also visited a site in a corrosive environment involving underslung polypanels supported by stainless steel fixings. Some sagging had been observed after heavy rainfall; and there was significant corrosion and loss of support at some polypanel fixings.

Corrosion at the bases of cantilever posts has been encountered on several occasions.

The reporter is concerned that such conditions may lead to structural issues. Factors that may have contributed to the observed conditions include design issues, and a lack of ready access for inspection, maintenance and cleaning.

> **concerned that such conditions could lead to partial structural collapse**

Potential lessons are:

- need for regular inspections;
- corrosion should be addressed early;
- ceiling and roofing replacement should be with materials with at least similar strength and stiffness as the original materials; and
- areas of potential corrosion in highly-loaded locations should be readily accessible.

C Expert Panel Comments

This report highlights the need to design using durable materials appropriate for the environment, and to specify regular inspection of the structure by a qualified structural engineer with an appropriate maintenance program (particularly if exposed to the weather), including requirements for safe access.

The reporter has identified a particular issue with lightweight canopies or awnings, where the sheeting, sometimes made of sandwich panels (also known as "laminate panels" or "polypanels"), is often affixed below the supporting framework with fixings invisible from below. Due to this type of arrangement, the sheeting or façade commonly suffers from:

- corrosion of the fasteners on the topside which are difficult to access or check for condition, resulting in urgent maintenance only after significant distortion is observed; and
- de-lamination of sandwich-type sheeting panels if the fasteners have only been attached to the topside skin and not through the panel. In addition, sandwich panels with leaking screw fixings can waterlog and de-laminate leading to sagging due to water pooling internally and compromise the glued bonding. Attention to appropriate sizing and sealing of fixings is required.

It should further be noted that expanded polystyrene sandwich (EPS) panels are not permitted as a roofing material in certain construction (e.g., Types A and B) and care should be taken to avoid material non-compliance.

A further issue of undiscovered corrosion of the frame (in addition to the fixings) can also occur with exposed structures of this nature where the frame cannot be easily inspected.

Such issues highlight the following potential problems:

- designers not clearly disseminating maintenance requirements or clearly specifying connection details or fixing requirements;
- builders not adhering to design specifications or making changes to fixing details and not receiving approval by the designer for the change; and
- owners not understanding or realizing the maintenance requirements of the building's components and not employing suitably competent persons to undertake inspection and maintenance of the building, including its awnings and canopies.

Finally, the reporter has identified a situation in which replacement works were undertaken with materials of a lesser strength than that of the original design, highlighting the fact that any replacement should always be with elements of equal or greater strength than the original, unless otherwise certified by a qualified structural engineer.

Submit Report

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Punching shear in concrete slabs at perimeter columns

CROSS Safety Report Report ID: 1122

A reporter raises concerns about the underestimation of bending moments in perimeter columns when assessing punching shear in adjacent concrete slabs. Punching shear failures can be brittle and catastrophic. The report proposes that designers need to include the appropriate ultimate moment in the design actions. The reporter's experience is that some engineers appear to lack an understanding of the requirements in AS3600 with regard to stiffness of perimeter columns that could lead to punching shear failures.

Key Learning Outcomes

For structural and civil design engineers:

- Clauses and information in design codes and standards must be interpreted to comply with principles of structural design, and not to provide results preferred by designers
- Values of bending moment used for assessment of punching shear in slabs must be determined using worst-case scenarios of stiffnesses of connecting columns
- Failure to provide adequate reinforcement to resist punching shear may result in brittle failure and sudden catastrophic collapse of concrete slabs

R Full Report

As a forensic structural engineer with many years of design experience, the reporter has observed that shortfalls in punching shear capacity appear to be increasingly commonplace in Australian apartment buildings and especially at perimeter columns of buildings. This is often in areas where slab depths are reduced due to balcony set-downs, and bending moments are relatively high as columns are loaded from one side only. The reporter has discovered errors in design which have led to these problems. In many cases, this has been a failure to design for the correct value of bending moment at the slab and column interface.

Calculation of section stiffness

When performing linear-elastic analysis and considering how stiffness should be apportioned to columns and slabs AS3600:2018.2.4.1 gives clear direction. It states that:

'The stiffness assumptions chosen shall be consistent with loading conditions, and shall generate critical worst-case actions under all failure modes to be considered. Where multiple degrees of stiffness are possible, the stiffness assumption chosen for the failure mode under consideration shall induce worst-case actions in the element being designed'.

For example, if a designer considers that the columns may be cracked under ultimate loads, then they need to establish by calculation that this will be the case. In those calculations, the relevant flexural tensile strength is the upper Characteristic Tensile Strength defined in AS3600, which is 1.8 times the default Characteristic Tensile Strength.

The maximum design actions for punching shear mode at the slab/column connection would be those that occur using the properties of the gross section of the column, assuming the column does not crack. If the column is found to crack under ultimate load, then the load condition immediately before the column cracks needs to be examined as it may represent the critical load condition for punching shear.

Redistribution of bending moments

In the reporter's experience, it is sometimes the case that engineers will argue that they have redistributed the bending moments away from the external columns. However, the reporter notes that although a degree of redistribution of bending moments is permissible for the purposes of flexural reinforcement, punching shear is a brittle (non-ductile) failure mode and no moment redistribution is permissible as part of its design process.

Also, whilst AS3600:2018 permits moment redistribution away from (or towards) internal columns for the purposes of flexural design, it is the Reporter's view that it does not

> **punching shear is a brittle (non-ductile) failure mode and no moment redistribution is permissible as part of its design process**

permit redistribution of moments at external columns (see clause 6.2.7.1 of AS3600).

The reporter was recently handed a critique of a forensic report they had written that argued that their assessment of punching shear was overly conservative. The author of this critique considered that the column stiffnesses that the reporter had assessed as uncracked could be reduced by 60% through the use of Table 6.2.4 of AS3600. There were no calculations to support this view. Table 6.2.4 in AS3600 is located in a section entitled *"Stiffness of lateral force resisting elements"* which is included in the code for the assessment of *"inter storey drift, periods of vibration and distribution of internal actions"*. This section of the code is to be used for determining column stiffness in circumstances where reduced column stiffness acts to exacerbate problems such as P-Delta effects or vibration. It is not intended for use in assessing the distribution of moments under gravity loads.

Lateral load distribution

The reduced value of stiffness given in Table 6.2.4 of AS3600 is in any case only permitted to be used for assessment of lateral load distribution once the designer has shown by calculations that the sections will indeed crack under the relevant lateral loads (see clause 6.2.4.2 of AS3600). In such situations, cracking in columns makes the situation worse so that lower-bound cracking stresses apply. In the case in question, the lateral loads could be carried by substantial shear cores which would not crack under lateral loads, and the reporter concluded that the critique portrayed a disturbing lack of understanding of AS3600.

To provide a situation where lateral loads reduced column stiffness for the purposes of punching shear assessment, the reporter observes that a series of design events would be required whereby:

1. the lateral load causing the columns to crack occurred prior to any gravity load causing punching shear; and
2. the location of the cracks in the columns induced by the lateral load happened to be on the same side of the column as those that would be induced by gravity loads.

The reporter considers it should have been obvious to the engineer that such a proposition defies any logical reasoning. It is useful to remember that AS3600 provides a series of criteria that must be adhered to, and it pre-supposes a level of logical reasoning and design expertise. Serious design errors of the type described above can result if designers use any code or standard without having an understanding of building design based on first principles.

C Expert Panel Comments

The fact that this report is actually needed is a sad reflection on the current state of structural engineering both in Australasia and internationally as it is not confined to Australasia.

The shear provisions in AS3600 have changed significantly in recent years. However, whilst the rules for shear in beams were extensively modified in AS3600:2018, the rules for punching shear did not change except for the addition of a requirement for bottom face reinforcement at columns to attempt to make the punching condition more ductile. This rule is already being seen to be misinterpreted by some engineers, producing designs at increased risk of failure. Punching shear is listed for revision in the next review of AS3600 where it may be given further consideration with respect to behaviour under certain fire conditions.

> **This rule is already being seen to be misinterpreted by some engineers, producing designs at increased risk of failure**

Attention is drawn to the recently published commentary to AS3600:2018, which provides good advice for designers of slabs and beams.

Unfortunately, in practice, modelling of structures does not necessarily cover all load cases that designers need to consider. Careful design needs to be performed in conjunction with appropriate checking and review, particularly with shallow band beams or flat plates.

All design codes need to be "interpreted" by designers to apply the rules for each design situation. This interpretation requires the designer to have a good understanding of structural design principles and an ability to comprehend the rules. Both appear to be missing in this particular case. Design standards must be interpreted to suit principles of structural design, and not simply to suit results more convenient for designers.

We are aware of situations where punching shear has been designed for zero moment because it was the only way the slab could be made to work, and where major columns have been designed for zero moment because the beam connected to the column was designed assuming no fixity (even at internal columns).

As noted by the reporter, AS3600:2018 requires that, when carrying out a linear-elastic analysis: *'the stiffness assumptions chosen shall be consistent with loading conditions, and shall generate critical worst-case actions under all failure modes to be considered. Where multiple degrees of stiffness are possible,*

the stiffness assumption chosen for the failure mode under consideration shall induce worst-case actions in the element being designed. In the case of an assessment of bending moment in a slab, this could well involve design for uncracked column conditions'.

Previous CROSS reports

There have been several previous reports that refer to punching shear in flat slabs, including:

1050 Concerns about punching shear in a flat slab>

950 Inadequate punching shear reinforcement in flat slabs>

906 Missing punching shear reinforcement in concrete slabs>

886 Unconservative design of flat slab due to software modelling issues>

Submit Report

Submit Feedback

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