CROSS Safety Report

MMC and robustness

This month we present a report relating to the design of a low-rise modular building and the requirement, or otherwise, for positive fixings between the superstructure and the substructure.

Report

A difference of opinion occurred between the reporter, a checking engineer working on behalf of the project's client, and the designer of a building. The building in question was a large two storey building to be constructed using some 100 modular units placed and connected together. The completed building would be approximately 100m long by 20m wide. The building was required to meet Consequence Class 2b requirements of the Building Regulations. The minimum required design life of the building was specified as 60 years. The detailed design of the building was undertaken by a contractor. The reporter undertook a check on the structural adequacy of the contractor's proposals.

The design showed the superstructure, comprised of connected modular units, supported on a substructure of reinforced concrete ground beams and piled foundations. Each modular unit was to have a loadbearing vertical column located at its four corners. The columns were to sit on, but were not fixed to, raised concrete plinths formed as part of the ground beams. The ground beams were not to be connected orthogonally to form a grid, but were discrete parallel concrete beams across the width of the building, under the line of the loadbearing structures over. There were no positive fixings proposed between the superstructure and the substructure.

The reporter noted the substructure design was extremely efficient with the separate parallel foundations running under the wall of each modular unit. Lateral stability in the vertical plane was provided through the racking resistance of a number of internal walls. Stability in the horizontal direction relied on the continuity of the connected steel modular frames at the ground floor level, since there were no foundations running laterally for the length of the building. The piles, however, had been designed for a lateral load and an eccentricity of vertical load.

The reporter accepted that the ground floor construction acted as a connected stiff diaphragm, however, they queried the lack of a positive fixing between the superstructure and substructure for the following reasons:

- →| It was unclear how uplift and lateral shear forces were transmitted to the foundations to ensure lateral and overall stability.
- →| The lack of positive fixings could mean the structure would not have adequate robustness to comply with the Building Regulations.
- →| With a lack of positive fixings, the completed building could want to 'wriggle' (move from its plinth locations) due to either temporary construction issues, creep, thermal movements or unforeseen effects.

The designer went on to show that there was sufficient dead load at primary supports so that uplift did not occur and that the lateral resistance, through friction generated from the dead load, was greater than the lateral force applied at the supports. Adequate factors of safety were therefore shown for global and local lateral stability.

Robustness requirements

The reporter considered that fixity to foundations was a requirement for robustness as required by the Institution of Structural Engineers publication, *Practical guide to structural robustness and disproportionate collapse of buildings*. The designer disagreed and was also of the opinion that the concrete plinths satisfied the 'key element' provision of the Building Regulations. The reporter, however, considered that the plinths were not a 'key element' as, in their view, this is a requirement for more significant loadbearing elements potentially subject to accidental loading from larger surface areas. The reporter considered that the plinths should be

Key learning outcomes

For structural and civil design engineers:

- →| Approved Documents are guidance
- →| Eurocodes and Institution guides are good practice, albeit that Eurocodes, as listed in Approved Document A, are the UK national standards
- →| Designers could consider making a case on merits, rather than endeavouring to comply with ill-fitting guidance
- →| It may be appropriate to consider the aims of the robustness rules and carry out a systematic risk assessment
- →| Further guidance on fixing superstructures to substructures when considering modern methods of construction would be helpful

considered minor elements in terms of overall stability, a view not accepted by the designer.

The designer did not consider that any post-construction issues, such as creep and thermal movement, were a risk to the project, although they did not provide any examples of similar completed projects to justify their case.

The designer did, however, propose a limited number of positional restraint fixings between the superstructure and substructure at both ends of the building. These were accepted as sufficient to show compliance by the certifying building control body.

Nevertheless, the reporter remained concerned. The reporter noted that Requirement A3 of the Building Regulations does not specifically require superstructure fixity to foundations but considered that fixity to foundations was a requirement for robustness as required by the Institution of Structural Engineers' publication, *Practical guide to structural robustness and disproportionate collapse of buildings*.

The reporter also noted that Appendix 6 of *BS EN 1991-1-7:2006+A1:2014 Eurocode 1. Actions on structures - General actions - Accidental actions,* states:

1. Each column and wall should be tied continuously from the foundations to the roof level.
2. In the case of framed buildings (e.g. steel or reinforced concrete structures) the columns and walls carrying vertical actions should be capable of resisting an accidental design tensile force equal to the largest design vertical permanent and variable load reaction applied to the column from any one storey. Such accidental design loading should not be assumed to act simultaneously with permanent and variable actions that may be acting on the structure.

In the reporter's opinion, the design did not appear to comply with the Eurocode or the Institution's guide, and further guidance is required regarding the connection of superstructure to substructures for modular building design.

Expert Panel comments

The reporter raises an interesting concern where consideration of the regulatory framework may be helpful. It should be remembered that requirements relating to buildings in England are generally laid down in the Building Regulations 2010. Most building works carried out in England must comply with the Building Regulations, other parts of the UK may have differing requirements. The *Manual to the Building Regulations* published by HM Government describes the regulatory framework.

Available guidance

The Building Act allows the government to publish Approved Documents for guidance alongside the regulations. These give detailed advice on how to meet the legal requirements of the Building Regulations for common situations in domestic projects but may not be relevant for all situations. Following the advice in Approved Documents is not mandatory but adherence does tend to demonstrate compliance with the regulations.

Approved Document A, generally refers to the relevant parts of Eurocodes for material dependent rules to satisfy the requirements. Eurocodes, as listed in Approved Document A, are the national standards. While engineers can design to any applicable standard, there may be an expectation that a structural design should meet the Eurocodes as a minimum or, where they do not, it be robustly demonstrated why an alternative approach is acceptable.

However, building types such as 'modular construction' are not wholly considered. For example, Eurocode 2 for the design of concrete structures, distinguishes between frame structures and panel structures. In addition, the Approved Documents are written for common building situations and the *Manual to the Building Regulations* highlights that the guidance may not apply to 'some buildings that incorporate modern construction methods'. This may mean there is more of an onus for the designer to consider the aims of the robustness rules, and potentially could be a reason to treat the building as a class 3 structure and carry out a systematic risk assessment.

The reporter raises requirements of a Eurocode and an Institution of Structural Engineers guide. These suggest something as good practice that is beyond the legal minimum. That is not an unusual circumstance. The question that arises is, would a failure to follow guidance lead to an unsafe structure?

A rationale for vertical tying is to hold the structure together in cases of internal blast where floors are lifted, reducing gravity compression, and allowing loadbearing walls to be pushed out. That concern might be overcome in masonry buildings if the loads are heavy enough (the gravity providing the tensile resistance) or might be intrinsically overcome with modular units where the whole structure just shifted up, and came down without disintegrating, and the structure said to be 'robust enough'. The task is to show the building will 'not collapse' and, in the example reported, a case might be made for that, without positive fixing between the substructure and superstructure. In some cases, designers should be making a case on merits, rather than endeavouring to comply with guidance that may not wholly cover the case in hand.

Stability must be assured

Clearly, stability must be assured. If the foundation mass is required to ensure stability, then the superstructure must connect to the substructure. There is, however, as the reporter concluded, no reason not to rely on friction to prevent sliding. It is interesting to note that other sources of guidance (*NHBC Standards 2022, SCI P302: Modular Construction using Light Steel Framing: Design of Residential Buildings* and SCI P284: *Modular Construction in Building Extensions*) generally require that lateral movement and uplift are prevented, but do not explicitly require framing to be tied to substructures.

While many designers, in cases such as the one reported, will feel there should be a positive fixing between substructure and superstructure, it is difficult to state with certainty that it is wrong not to provide positive fixing. The merits of each case need to be understood and it demonstrated that the requirements, including disproportionate collapse requirements of the Building Regulations, are achieved, either through adherence to relevant guidance or other methods.

As suggested by the reporter, further guidance and clarity on the need to fix superstructures to substructures when considering modern methods of construction would be helpful.

The full report, including links to guidance mentioned, is available on the CROSS website (report ID: 1179) at **www.cross-safety.org/uk/safety-information/cross-safety-report/modern-methods-construction-and-robustness-1179**.

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