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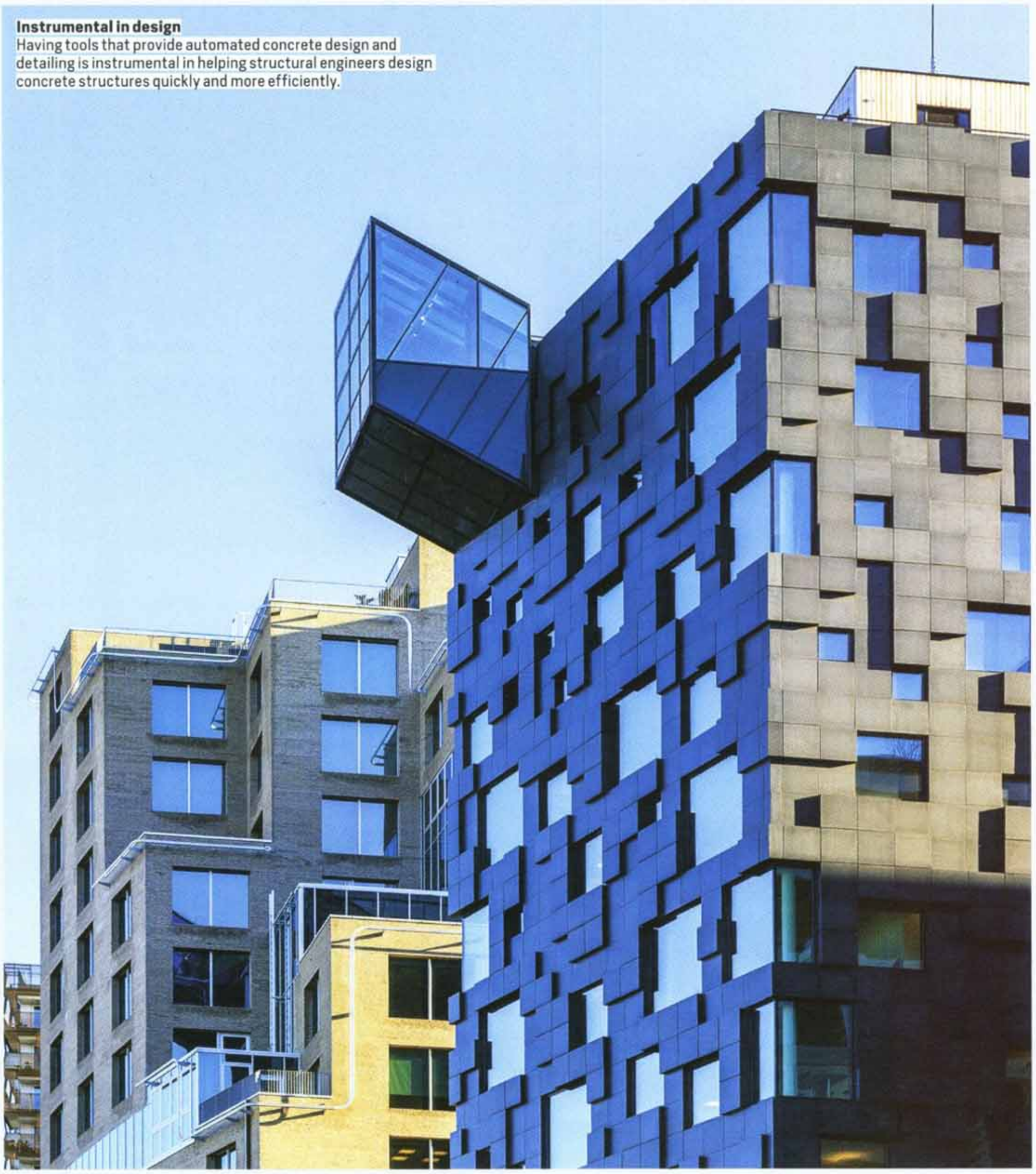
ACCURATE DEFLECTION CALCULATIONS FOR CONCRETE FLOORS

Jonathan Hirsch, structural software development manager with Bentley Systems, explains how computer design is playing a larger role than ever in concrete design and construction



Instrumental in design
Having tools that provide automated concrete design and detailing is instrumental in helping structural engineers design concrete structures quickly and more efficiently.

Concrete design and construction is playing a larger role than ever in expanding global cities, which has brought about challenges and advances. An important aspect of concrete design is deflection calculations, and many applications available can help with accuracy. Here are a few things to consider before making your choice.

In any building design, providing the team with accurate deflection calculations for concrete floors is an important aspect of the serviceability design of the floor. If deflections are excessive, they can damage non-structural items attached to the floor, which would be a source of concern for the building's occupants. As building designs employ modern high-strength materials which result in thinner spanning members, the need for accurate deflection calculations is even more important for these deflection-sensitive floors.

Factors that must be considered when predicting accurate deflections include cracking, tension stiffening (and degradation over time), creep, shrinkage, internal restraint from reinforcement and associated shrinkage warping, external restraint (from rigid walls, for example) and load history. To complicate matters, many of the influencing factors are inter-related. For example, shrinkage can affect cracking, and cracking can subsequently affect creep.

The simplest codified approaches to predict deflections use span-to-depth ratio limits to prevent detailed deflection calculations. However, these methods are crude and tend to be conservative, and don't account for many of the important influencing factors mentioned above.

Therefore, it is frequently possible to use thinner members by performing detailed calculations. While modern computer programs allow more detailed calculations, many do not capture all the important behaviours. For

Maximising system efficiency
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detailed long-term curvature calculations, an application should do the following:

- Calculate cracking based on an expected modulus of rupture. For two-way slabs, be sure to account for the variation of stress perpendicular to the span.
- Tension stiffening, which is reinforcement that crosses cracks to transfer tension stress back into the concrete between the cracks, should be accounted for using reasonable means. The degradation of this effect, which is significant and believed to occur very rapidly, should also be considered.
- Consider the load history of the floor. If the floor is subjected to a load large enough to cause cracking at an early age, all subsequent loadings should consider that the floor has cracked. This affects the stiffness of the system for subsequent calculations, as well as the stress distribution that should be used for creep calculations.
- Consider creep effects, including creep recursion, which is the redistribution of stresses due to creep (and other effects) being incorporated into future creep calculations.
- Consider the restraint to shrinkage from reinforcement on the tension face, which tends to amplify deflections due to loads, a phenomenon sometimes referred to as shrinkage warping. This phenomenon can be handled by reducing the modulus of rupture. However, this approach is somewhat crude because this shrinkage behaviour is not directly associated with loading. A rigorous treatment of this effect is warranted.
- Externally restrained shrinkage movements, such as those that might be caused by rigid shear walls, can cause or influence cracking in a way that affects the stiffness of the system and thus amplifies deflections. Applications such as RAM Concept can account for this effect.

Once the long-term curvatures have been calculated, they should be incorporated into the deflection analysis in an appropriate way. Since cracking and long-term deformation can cause redistribution of forces within the floor, ideally the calculations should account for these effects as well.

When calculating early age deflections, be cautious of how they are used. Because of the steep gradient of early age creep and shrinkage curves, expect deflections to change rapidly during the early age phase. As such, a small difference in time can result in a relatively large change in deflection. If these deflections are being used to calculate differential limits, it might be wise to make some conservative assumptions when calculating early age deflections.

With the use of available deflection calculation technology and sound engineering judgement, deflection design and evaluation can be carried out in such a way to maximise system efficiency while mitigating risks.

Bentley recently acquired Indian firm S-Cube Futuretech's applications, which include RCDC, RCDC FE, RCDC Plan and Steel Autodrafter. These new offerings further solidify the company's strong position in the fast-growing global concrete design market. Having tools that provide automated concrete design and detailing is instrumental to helping structural engineers design concrete structures quickly and more efficiently in rapidly growing global cities. ■