Fixing Failures – Case Study 2

Collapse of a pre-cast concrete section – Ireland 2002

An article for the
Construction Fixings Association

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This is the second case study in the "Fixing Failures" series intended to illustrate some of the factors which can contribute to fatal outcomes if Best Fixings Practice is not followed. This case is still under pending legal action so not all the facts are apparent at the time of writing but enough is known of certain aspects for them to be used to prompt discussion of examples of practices that are best avoided. Nothing stated here is intended to imply a conclusion on the part of the CFA or the author as to the actual cause of the accident as there are various factors involved.

Background

This accident happened on the 12th December 2002 on a site under construction in Southern Ireland. The anchors concerned were "Throughbolt" type expansion anchors fixing steel angles to a concrete wall. These angles were carrying pre-cast concrete landings which in turn were carrying pre-cast concrete stair units. Failure of the anchors resulted in progressive collapse of the landing and stair units. This all resulted in injury to two construction workers and the death of a third.

One aspect of the failure is that anchors of a certain type and size had been specified whereas an anchor of a different type and of a shorter length had been used.

In this case the actual cause of the accident may have been associated with the way in which the pre-cast units were handled into place but even so the change of specification of the anchors, especially with respect to the reduced embedment depth, leaves open the possibility that no failure might have occurred had the correct type and length of bolts been used.

Loads during erection/installation

The failure of fixings involved in structural connections does occasionally occur during the erection phase. This may be because the erection process has been done in such a way that excessive loads are applied through the fixings or because the higher than service loads, which are unavoidable during erection, have not been taken into account during the specification phase.

A typical example of the first of these is the erection of steel columns. Imagine such a column on a square base plate fixed into a concrete foundation with four anchor bolts. The column will usually be located on central packers while the fixings are put in place and the column itself is temporarily supported until the process is complete and the space under the base plate can be grouted up. In one case investigated by the author the contractor was having difficulty locating the top of the column with a purlin attached to the next column. A crane was therefore used to simply pull the top of the column into line. The bending moment of the force generated by the crane was enormous compared with the resistance offered by the fixings, especially as the column was supported only on central packers so the moment arm was only half what it might have been had the grouting under the base plate already been completed.

The column collapsed and a worker on a ladder leaning against the column at the time was injured.
The designer could hardly be expected to predict the actions of the contractor who simply did not think about the effect of what he was doing on the fixing bolts.
In other cases it may be that the contractor assumes that the specifier has taken into account the forces which are predictable during the erection phase and which may well be higher than the in-service loads. But this assumption, like most assumptions, is dangerous and it may be that these loads have been ignored by the specifier who has assumed that the installing contractor will take special measures. The designer may even be unaware of the specific erection process and the affect this may have on the loadings. This is one area where responsibilities need to be clearly understood by all involved.

Changing specifications

In the case cited here not only was the make of fixing changed but a fundamental aspect of the specification, the length, was changed. The length of a fixing affects the embedment depth which directly affects the performance, especially regarding tensile loads. Of course it is always possible that a short version of a fixing from one manufacturer may have similar performance to a longer version from another but that is unlikely and, as far as is known to the author, not the case here. It has been suggested that the ultimate performance of the fixings actually used exceeded the claimed performance of the fixing specified but this, even if it were true, was not known to the contractor when he changed the specification. When ever a specifier selects a fixing his choice should be based on a thorough consideration of all the necessary factors to be taken into account, see[1].

The specifier will usually state that the fixing to be used is type XYZ "…or similar approved". If an alternative is to be considered then before the alternative can be "approved" the same selection process must be repeated. All too often an alternative fixing is proposed because it is slightly cheaper - fair enough - and justified on the grounds that it has similar performance as stated in a catalogue. This does not check enough of the performance criteria to be sure that the new fixing will offer the same safety margin in the actual conditions of the job where edge distances, centre spacings, actual concrete strength, loading direction and several other factors will influence the load capacity. Nor does a simple proof test on site; as is sometimes requested to validate a change of specification. The determination of recommended loads for fixings is a complicated business and does not involve global safety factors as such but they usually work out to be in the order of four : one i.e. a margin of 300% above the applied load. A proof test to a margin of 50% above the applied load goes nowhere toward proving the margin the industry requires. Anchor performance and the safety margin between applied load and ultimate load are affected by so many factors that the only way to be sure that a particular anchor is suitable is to carry out a full selection process according to the design method required by the manufacturer.

Conclusion

Maintaining the safety margin by either sticking to the original specification or by a thorough redesign would either have prevented this accident or at least eliminated the change of specification from the investigation.

[1] CFA Guidance Note: Anchor Selection.

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