INTRODUCTION

Over half of the reports to CROSS are about events on site and this Newsletter has just that, with five of the eight featured reports describing issues that occurred during construction. Two are about design concerns and the other relates to an issue found in service. Sites can be dangerous and one of the reports is about a fatality that occurred outside the UK, but could happen anywhere, when a brickwork wall fell because some scaffold planks were leant against it. Another describes how an arrangement of precast slabs covering a shaft fell without warning due to a problem with reinforcement. A swimming pool roof fell when fixings, which were inadequate to start with, failed. Fixing failures are common and clearly not enough attention is paid to their selection, installation, or testing. Other reports are of bolt failures due to hydrogen embrittlement and stud failures through the use of unsuitable components. On the design front a report expresses another familiar concern which is that the outputs of computer analysis are not always correctly applied to the subsequently selected members of frames.

Whilst some themes are recurrent the cases are always slightly different which demonstrates the need for constant awareness, continuing engagement at every level, and learning lessons from experience. Published reports are on the web site data base, along with others, which can be used as resource for learning from the experiences of others. As ever thanks are due to those who submit reports and the volunteer experts on the CROSS panel who review them.

The success of the CROSS programme depends on receiving reports, and individuals and firms are encouraged to participate by sending concerns in confidence to Structural-Safety.

505 PRECAST CONCRETE COVER SLAB TO CIRCULAR SHAFT

An incident recently occurred on a project involving the construction of a 12.5m internal diameter x 12.5m deep storage shaft. The reporter says that the cover slab for the storage shaft was designed as an interlocking arrangement of seven precast concrete slabs with half joints between the individual units. Once the precast concrete slabs had been lifted into position above the shaft a layer of in-situ concrete was to be placed over them to form the finished composite cover slab. The cover slab was a bespoke design prepared by a specialist supplier who also manufactured the precast concrete slabs off site at their production facility. When the precast concrete slabs arrived on site they were lifted into place but approximately 10 minutes after the last slab had been placed, five of the seven slabs collapsed into the shaft. Fortunately no one was on the cover slab at the time of the collapse so no one was injured as a result of the incident. The investigation into the incident looked at a number of possible causes including design errors and low concrete strength but it very quickly became clear

Reports sent to CROSS are de-identified, categorised, and sometimes edited for clarification, before being reviewed by the CROSS panel of experts. The panel makes comments that are intended to assist those who may be faced with similar issues. In the Newsletters the reports are shown in black text and the comments are shown below these in green italics. Reports and comments are also given on the web site data base.

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What should be reported?
- concerns which may require industry or regulatory action
- lessons learned which will help others
- near misses and near hits
- trends in failure

Benefits
- unique source of information
- better quality of design and construction
- possible reductions in deaths and injuries
- lower costs to the industry
- improved reliability

Supporters
- Association for Consultancy and Engineering
- Bridge Owners Forum
- British Parking Association
- Communities and Local Government
- Construction Industry Council
- Department of the Environment
- DRD Roads Services in Northern Ireland
- Health and Safety Executive
- Highways Agency
- Institution of Civil Engineers
- Institution of Structural Engineers
- Local Authority Building Control
- Scottish Building Standards Agency
- Temporary Works Forum
- UK Bridges Board

From discussions with the specialist supplier and destructive examination of the failed precast concrete slabs on site, that the reinforcement in the half joints between the slabs had not been installed as per the design. Reinforcement had the correct cover but the bars were not the correct shape, diameter or spacing. The reasons for this were attributed to the fact that the units were manufactured over a holiday period when the usual steel fixers were unavailable. When bespoke concrete elements are constructed on site it is standard practice for the principal contractor to carry out a pre-pour inspection to check that the sub-contractor has fixed the reinforcement in accordance with the drawings, cover is correct etc. prior to placing concrete. It is the reporter’s opinion that when procuring bespoke precast concrete units manufactured off-site by a specialist supplier a risk assessment should be carried out to determine what level of inspection of the manufacturing process should be carried out by the purchaser. The reporter continues that third party accreditation and certification of the suppliers QA procedures should not be relied on as giving sufficient confidence that the manufacture of individual units has been carried out correctly. The reporter’s firm has subsequently carried out a thorough review of in-house processes covering testing and inspection and the way in which these deal with off-site manufacture.

Comments
Reputable precast-concrete suppliers will have recognised QA processes to avoid such occurrences. Good practice may suggest that precast units should be checked on delivery although in this case the problems of incorrect shape, diameter or spacing might well not have been detected. Treatment of off-site manufactured bespoke products is somewhere between that for on-site construction and that for off-site manufacture of mass produced products. For construction on site a contractor would probably check everything, and for mass produced products a contractor would probably check little or nothing relying on third party product certification. The level of checking for bespoke items made off-site should be determined from a risk assessment process which evaluates likelihood and consequences of a non-compliant product. This might include the contractor making checks at the pre-cast works. Clearly whatever procedures should have been in place did not operate on this occasion, with potentially fatal consequences. It is reassuring that a thorough in-house review by the contractor took place to avoid a recurrence. A key question in any safety assessment is: “Do you know that what you thought was being constructed was actually constructed?” Another point is that half joints have a long history of problems partly because they are shallow and the numerical capacity tends to be sensitive to small errors in cover and the positioning of reinforcement. One of the most costly forms of failure is when a mass produced element has been wrongly designed or manufactured so that the defect is repeated multiple times. Car manufacturers sometimes have this problem resulting in mass recalls of vehicles.

499 Failure of high strength studs

A reporter's firm specified the use of M12 grade 8.8 threaded studs that were to be located in a tapped web of a parallel flange channel. This then supported an angle located a short but variable distance from the PFC. The stand-off arrangement was necessary due to a construction misalignment of the PFC and the original intent was that the angle should have been welded. The installation proceeded normally and the nuts were not over tightened. The firm then received reports that many of the studs were snapping overnight with the

A fractured stud
NEWS


This was originally published in November 2010 and has been updated to take account of an open letter issued by HSE in October 2014 to all parties involved in the design, specification, procurement and construction of timber framed structures. The full text of the letter is on the Structural Safety web site Fire risk in timber framed structures. Many fires occur during construction – see for example, The Structural Engineer Volume 92 (2014) Issue 8

Church building collapse

A company has been fined £8,000 after a two-storey portable building collapsed whilst more than 30 children and parents were playing in the lower room. Soon after installation both cabins “dropped” when a bolt on the jacking leg of the lower unit sheared off and the upper cabin came to rest on the roof of the lower cabin. The HSE investigators found that during refurbishment new inner sections of the jacking legs were installed but the original pins (used to adjust the height of the legs) could not be fitted due to the holes not being drilled to the correct size. Smaller bolts not designed for this purpose were used. It is very lucky, said HSE that the top cabin stayed in contact with three of the jacking legs as this prevented the full weight coming to rest on the wooden frame of the lower unit where children were playing.

Comments

The nature of the failure in this report would (without sight of a detailed metallurgical analysis) appear to be consistent with hydrogen embrittlement which is a phenomenon that afflicts particularly high strength steels as a result of poor process control during plating, and is not known to affect lower strength steels such as 8.8 grade, itself regarded as high tensile steel. Hydrogen embrittlement is a rare phenomenon which is partly characterised by a delay in the failure (which makes it all the more worrying). Whilst grade 10.9 material is capable of performing satisfactorily, designers should beware that ‘over strength’ is not always a good thing if it is achieved at the detriment of ductility. An internet search will produce several references to the phenomenon of hydrogen embrittlement for those requiring further information on the phenomenon. It seems unusual that such studs were intended to be part of a chemical anchoring system. Most carbon steel studs supplied for this purpose are manufactured to 5.8 or 8.8 steel rather than 10.9 grade which is not needed to match the strength of the resin bond. Chemical anchor applications should be designed in accordance with a European Technical Approval/Assessment (ETA) which specifically details how to approach stand-off fixings. The requirements placed on the manufacturer to obtain the ETA would ensure correct manufacturing processes were employed to remove any risk of hydrogen embrittlement and other manufacturing defects.

See also report 490 Bolt failures due to hydrogen embrittlement.

490 BOLT FAILURES DUE TO HYDROGEN EMBRITTLEMENT

A reporter recalls that in the 1970s he was working on bridge refurbishment project where a number of new, zinc electro-plated, bolts failed suddenly, often shortly after installation. It was found that hydrogen embrittlement was the principal cause and a secondary cause was the shape of the shoulder of the bolts which was too abrupt. His report was prompted by recently published reports on hydrogen embrittlement as the reason for some bolt failures and points out that this is not a new problem.

Comments

This issue appears to be linked to the ‘plating’ and echoes some other cases where embrittlement has been linked to galvanising of high strength materials. All bolts have numerous stress concentrations in them at changes in section and these have to be accommodated by local ductility. Risk factors are galvanising, high strength, hardness and bigger diameters (‘thick’ steel). Care should always be taken when using higher than normal strength materials. These may not behave in the same way as more typical strength materials, giving rise to problems which the designer may not have considered.

See also report 499 Failure of high strength studs.
372 Understanding the difference between analysis and design

A reporter regularly sees output from computer models which give the sway frame moments necessary for overall stability. However he also finds quite often that in the design the relevant members are not able to perform as in the model. There is a prevalence of composite design, which he uses himself, but often members are designed as composite when the model, and the frame stability, requires end moments. Concrete and tension don’t go together too well and he is sure that in almost all situations these members are designed as simply supported. What is going to happen in service?

Comments
Any analysis model is just that: a ‘model’. If the structure does not match the assumptions made for the model then the whole process is invalid. Some engineers do not ensure that the designed (and constructed) structure or element accords with the computer model from which the forces have been derived. A reviewer has found that this is particularly the case with member end and longitudinal restraint conditions. The classic view is that engineers should be able to check computer output against approximate hand calculations and they should certainly understand what they are doing. When large and unusual structures are involved the task becomes particularly important. Education and continual reminders are needed to ensure that computer aided design is carried out correctly.

426 Swimming pool ceiling partial collapse

Part of a ceiling above a swimming pool collapsed, injuring 4 people, says a reporter. The ceiling was a double skin plasterboard false ceiling, supported off hangars which were screwed into timber joists above. The ceiling had been installed approximately 12 years previously, and showed no signs of distress before collapse. Upon investigation, it was found that the number of hangars was too few for the load and this resulted in failure of the hangar fixings into the joists. It was also found that the joists had twisted due to lack of noggins/strutting. A contributing factor may have been that the area above the ceiling was used as a gym, with potential for vibrations from dropped weights. Although a structural engineer was involved, the design responsibility was with a specialist contractor. The ceiling was installed over a weekend, and there is no evidence of independent inspection. Building Control was carried out by an Approved Inspector. No detailed drawings were produced and the ceiling was not installed to manufacturer's standard details.

Comments
This is one of many instances of collapse of ceilings above swimming pools- sometimes with fatal consequences. The problems (and the consequences) are now sufficiently well-known for all owners of such buildings to be aware of the need to carry out a structural assessment of the ceiling or roof. CROSS has received a number of reports of ceiling collapses and the typical form is a progressive collapse precipitated by a single hanger failure. Such a failure might arise from a variety of causes but in a ceiling system, the distribution of load to any one hanger is fundamentally uncertain and could be significantly higher than assumed. It cannot be presumed that a tension system is ductile if the fixing of the hanger is the weak link. The location above a swimming pool suggests that corrosion or moisture degradation might also have been a contributory factor. There have been several cases of ceiling failure over swimming pools in stainless steel hangers, brought about by stress corrosion. Often fixings are not appropriate for dynamic and quasi dynamic loading situations. In this case it appears that investigations concluded that the gym above was a source of vibrations which could have loosened some fixings and led to progressive collapse. Designers need to be aware of all loading conditions which may potentially exist and choose appropriate products accordingly. Previous reports can be found by entering “ceiling” in the Quick Search Keyword box on the web site. The search can be refined using the Classification system.
476 CANTILEVERED BRICKWORK—FATAL COLLAPSE DURING CONSTRUCTION

A reporter from overseas describes how, in a block of flats consisting of load bearing brickwork and concrete floor slabs, a blade of 270mm cavity brickwork was built off the slab at a one course step in the slab between living rooms and outside balconies. There was a damp proof course, Z shaped, between the slab and the brickwork. The blade was 2.7m high and 1.4m wide and eventually would have been abutted by perpendicular 230 party walls on its centre line on both sides. It would also support a roof that would provide lateral stability. After the top lift of brickwork was 2 days old a bricklayer started setting out the base course of one of the abutting walls. While he was doing this a labourer leaned sixteen scaffold planks against the wall on the side remote from the bricklayer. The wall fell and killed the bricklayer.

According to the reporter:

1) The brickwork would have been stable if at least part of one of the abutting walls had been constructed integrally with the blade of brickwork.

2) The wall would not have been stable under design wind loads (for temporary structures) and should have been braced for this reason. Had this been the case the accident would probably not have occurred. One story high temporarily cantilevering walls are not commonly braced for wind loads but perhaps should be.

3) All operatives interviewed after the incident said the level of site supervision and safety was excellent. A progress photo which included the fatal wall was taken 10 to 20 minutes before the accident and there were no planks placed against the wall at that time.

Note that legal proceedings in this case have been completed.

Comments

Alas the temporary stability of all forms of structure continues to be an issue of concern. There are many reports of walls or other structures toppling under accidental loading when in an unfinished state. All structures should remain stable and able to transmit forces adequately at all stages of the construction (and arguably, deconstruction) and greater awareness of the risks through education, formal or through experience, is important. Cantilevers should always ring alarm bells particularly in the temporary stage because there is no redundancy and relatively small loads at the tip can precipitate failure. If the designer knew that the construction sequence would lead to an unstable wall, then he should have either redesigned the wall or made the risks clear on the drawings. If it was a ‘normal construction stage’ then, as it appears the court held, the contractor should have considered the various de-stabilising modes (wind and other lateral loads). This emphasises that common construction operations can lead to dangerous situations and constant awareness is necessary.

448 STABILITY OF TERRACED BUILDINGS

A reporter is concerned about a terrace of four buildings, the third of which is being opened up. Two of the others have no cross walls on the ground floor and he notes that the spine wall in the last building has also been removed. This leaves the front 8 or 9 metres of these buildings with nothing but the glass windows to provide resistance to sway. It is not, he says, a matter of conjecture that these buildings will eventually collapse. The only question is when. It might be 20 years but he would be very surprised if it were 100. He finds it very hard to believe that it is regarded as acceptable to remove stability of any building, let alone a whole row.

Comments

This is a well-known problem but such work is often carried out by a jobbing builder, without proper structural engineering input. Building Control may not be notified which means no one sees the ‘big picture’ of stability which should be considered for even the most minor of alterations. When there is a structural engineer it is their responsibility, even if appointed for only one unit within the terrace, to consider the wider implications of wall removal. A structural engineer becoming aware of the situation
as described has a duty to pass on any concerns to building control. When there is no engineer, which may well be the case, then overall stability can be compromised and there are many examples of uncontrolled modifications works leading to collapse. CIRIA are currently (April 2015) conducting a study into “Structural stability of buildings during refurbishment” and the findings and their recommendations will be important in casting more light on this issue. ‘Opening up’ may be fashionable but can be fatal (witness the typical soft storey collapses that occur in any earthquake). A common danger occurs in typical British semidetached houses where one (or both) houses decide to install wide, garden facing French windows in the back wall thereby compromising the back wall stability in side sway. The photograph is of a house in San Francisco where the ground floor had been opened up for garaging thereby creating a ‘soft storey’ which failed during an earthquake dropping the building by a complete storey.

475 BACKFILLED CANTILEVER BRICK WALL

A 230mm cantilevered brick wall approximately 1.6m high was built approximately 300 to 400 mm in front of a rock face. The space between the wall and rock face was backfilled (which was not the design intent) and it pushed the wall over. It was surprising that so little soil could generate sufficient pressure to topple the wall. However, the backfill was recently excavated clay that ‘bulked’ (expanded) after placement and created pressure between the rock and the wall.

Comments
The water pressure generated in a 100mm gap is just the same as if the gap were 1 km. If the designer of the wall was aware of its location it would be a reasonable expectation that he/she would highlight the risk of backfilling.

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HOW TO REPORT

Please visit the web site www.structural-safety.org for more information.

When reading this Newsletter online click here to go straight to the reporting page.

Post reports to:
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Comments either on the scheme, or non-confidential reports, can be sent to structures@structural-safety.org

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