CROSS Safety Alert

Lessons learned from the 2018 Florida bridge collapse during construction

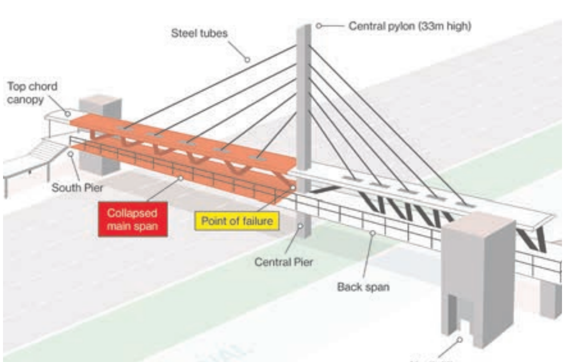
This month we present key elements of a CROSS Safety Alert from December 2020 detailing the failures and lessons learned from the Florida bridge collapse in 2018.

Abridged report

This was a bridge of an unusual design and was being constructed in an unusual manner. The main 53m prestressed precast concrete span truss was in position when cracks appeared at a node and over a period of almost three weeks they visibly worsened until collapse occurred.

The Florida International University procured a new footbridge to connect facilities over a main road, and a bespoke reinforced concrete post-tensioned structure was developed **(Figure 1)**. This comprised two spans, one with a 53m long reinforced concrete truss main span and a similar, but shorter, second span. The self-supporting pylon and steel tubes are non-structural architectural features.

The first span was cast off site and moved into position by self-propelled modular transporter (SPMT). During lifting, the end diagonals cantilevered from the inboard SPMT supports in tension, so they were post-stressed to bring them back into compression during the temporary condition.



↗FIGURE 1: Illustration of Florida bridge structure showing main span

When the main span rested onto the supports, the end diagonals returned to compression in the permanent condition, with the tension rods destressed.

As soon as the bridge had to support its own weight, cracks appeared at the nodes.

Over the next 19 days, the cracks grew until the bridge collapsed. The construction and inspection firms working on the bridge were aware of the cracks, and reported the cracks to the design firm, asking for guidance. In this instance, for this particular design-and-build contract, the engineer of record (EOR) inspected the cracks. The National Transportation Safety Board (NTSB) report[1] stated that *'…The EOR repeatedly indicated that the cracks were of no safety concern…'*.

On the morning of the collapse, a decision had been made to re-tension the bars in the distressed diagonal under compression thus leading to further compression.

On Thursday 15 March 2018, during the re-tensioning operation, the main span collapsed onto a live road.

Only two of the eight traffic lanes were closed at the time of collapse. Eight vehicles, stopped below the bridge at traffic lights, were fully or partially crushed. One bridge worker and five vehicle occupants died. Eight people were injured. The investigations began.

Causes and lessons learned

Structural design

As stated in the NTSB report, the identified probable cause was that the bridge had structural deficiencies. There was, according to NTSB, an underestimation of loads and overestimation of capacity, with incorrect loads and load factors being adopted. These two reported design issues resulted in a node that lacked the capacity to resist the shear force, causing distress in members which could not accommodate the forces.

It was reported by NTSB that inadequate peer-review checking was carried out; the checker was only contracted to check the finished structure, not the structure during construction. Review of cracks and changes to tensioning procedure were reportedly not subject to peer-review checking.

It is highly likely that the location of service voids, placed so close to the node which failed, was a contributory factor, as it appears these were not accounted for in the design. It is essential that non-structural service voids are placed only in locations with the written permission of the structural designer, to ensure adequate consideration of structural strength.

Checking the design and design check category

In Florida, a purpose of the structural peer review is to provide independent verification that the structural design is in general conformance with the governing requirements, in this case, American Association of State Highway and Transportation Officials, LRFD Bridge Design and Florida Department of Transportation specifications, protocols and guidelines.

This is loosely translated in the UK to a 'design check'. The need for appropriate levels of design check category for infrastructure development is well established in the UK.

Typically, complex or unusual designs, or designs which involve significant departures from current standards, or novel methods of analysis or those which require considerable exercise of engineering judgement, will require Category 3 design checks.

CROSS recommends that the design check category for both permanent works and temporary works is reviewed by a multidisciplinary team including principal designer, designer, principal contractor (PC) and client as appropriate. This should include the potential to upgrade the design check category of temporary works, which involve permanent works in temporary conditions, to the same category as the permanent works.

Importantly, any changes to the agreed sequencing of installation shall be both designed and checked, prior to execution.

Site supervision and independent checking of execution of the works

In Florida (and elsewhere in the USA), the EOR is a professional engineer who is responsible for the preparation, signing, dating, sealing and issuing of any engineering document(s) for any engineering service or creative work.

There is no such equivalent position in modern contract procurement in the UK; however, there is a similarity with more traditional forms of procurement, where a resident engineer would be appointed to undertake aspects of the above, or a clerk of works be appointed to undertake independent overview.

Indeed, in the UK, there are numerous examples, including in reports to CROSS, where a designer has handed to the PC a pack of construction information prior to execution, and that is the last of the designer's involvement. A collaborative working arrangement, where the designer has a presence on site to expedite design decisions, and to relay design intent to improve outcomes for all parties, is preferred.

Despite what happened here, CROSS believes a representative from the designer's organisation must attend site in similar circumstances; to ensure construction is in accordance with the design, to ensure clear communication of the design intent, to allow expeditious dialogue to facilitate change, and to act as an independent pair of eyes and ears to improve quality and spot the potential for error. Such interventions would enable a level of independence and help to ensure appropriately skilled persons, present on site, may see things that the untrained eye might not.

The measures would have a very small additional cost, yet they would result in significant gains to all parties.

Construction oversight

All parties apparently failed to recognise the bridge was in danger when inspected hours before the collapse. The construction engineer and inspector apparently failed to classify the cracks as structurally significant. In hindsight, the magnitude of the cracks warranted that the road be immediately closed, and the truss supported to reduce loads, pending evaluation.

The evaluation of the cracks, and the decision to re-tension the diagonal member, made by the EOR, constituted a change from the original design, and as such should have been subjected to an independent design check.

The design-and-build contractor failed to exercise its own independent professional judgement to close the road.

General measures

In addition to the above, CROSS recommends the following general measures:

- Projects should undertake 'what if' contingency planning. What can go wrong, and how do we prevent it or mitigate it? In the case of the Florida bridge, there were weeks to consider the consequential effects of the developing cracks.
- All increases in crack width, particularly those that occur over a short period of time, must be taken seriously and assessed by an expert.
- Due to the increasingly fragmented nature of the industry, it is often observed that engineering decisions are made by non-engineers, without consulting competent engineers. This results in significant safety risks due to non-engineers not understanding the implications of their decisions. This is a serious and widespread issue, which the industry needs to recognise, and find a way to prevent from happening.
- Design-and-build contract procurement methodology needs to ensure that there is an appropriate level of designer input and supervision on site, to assure quality and safety.
- Projects should check the alignment of the procurement strategy and contracts with the competence of those involved, and the complexity of the work.
- Train engineers to recognise, through learning and experience, the early warnings of failure.
- The industry must do more to ensure competency of individuals and companies is demonstrated.

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Conclusion

This Safety Alert touches on the main learnings from the event, while the references provide further details. This event occurred from a complex sequence of unfortunate events, but one thing is for certain: the warning signs of distress were clear, and the road traffic under the bridge could have, and should have, been stopped as a precautionary measure.

Decisions made on the day of the collapse, contrary to the approved design and unchecked, compounded the issues. This avoidable tragedy needs to be studied carefully and the above recommendations implemented by all organisations involved in the construction industry.

The full CROSS Safety Alert, including links to guidance mentioned, is available on the CROSS website at **www.cross-safety.org/us/safety-information/cross-safety-alert/lessons-learned-2018-florida-bridge-collapse-during**.

REFERENCE

1) National Transportation Safety Board. Investigative Update: Collapse of Pedestrian Bridge Under Construction, Miami, Florida (HWY18MH009)