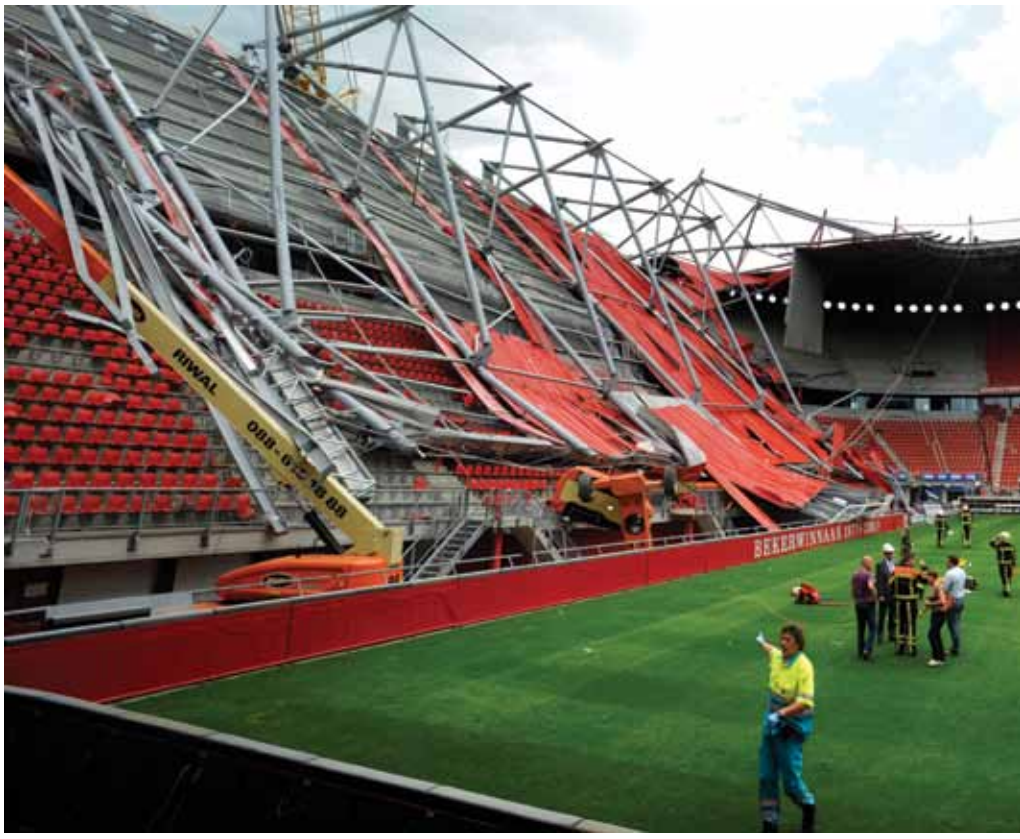
De Grolsch Veste stadium failure

Sean Brady provides an overview of the technical and human factors that contributed to the partial collapse of Dutch football team FC Twente's stadium roof.



One of the key advantages of steel as a construction material is its efficiency. Steel structures utilise relatively slender members, but it is also this advantage that increases steel's susceptibility to stability failures. The forensic engineering literature cites many examples of such failures, particularly during a project's construction phase.

The profession was reminded of this vulnerability in July 2011, when the roof of an extension to the De Grolsch Veste stadium in the Netherlands collapsed during construction. The failure resulted in two fatalities. In July 2012, following a year-long investigation, the Dutch Safety Board released its investigation report[1].

The collapse occurred during construction works to extend the stadium's existing L-shaped grandstand configuration into a U-shaped configuration. The works commenced in February 2011, following a previous extension performed in 2008. The main contractor outsourced construction to two subcontractors: the first to complete construction of the concrete stand and the second to complete construction of the steel roof. Both subcontractors had also performed the work on the 2008 extension.

The collapse occurred when the project was at an advanced stage. Around noon on 7 July 2011, construction workers were working both on top of and beneath the extended roof structure when it collapsed, resulting in 12 workers falling from a height. Two were killed and nine injured, some critically.

"Tellingly, the last of these cables was removed on the day of the failure"

The Dutch Safety Board's investigation examined both the technical and human factors that contributed to the failure.

Technical factors

From a technical perspective, the investigation concluded that the cause of the failure was the insufficient stability of the incomplete roof structure, with three key factors playing a role in the collapse:

- Elements required for stability were missing from the roof structure. Temporary bracing, in the form of steel cables, was utilised to maintain stability during construction, and it appears that these cables were removed before the permanent bracing was complete. Tellingly, the last of these cables was removed on the day of the failure
- The incomplete roof was subject to excessive loading. Prior to the roof's completion, the main contractor permitted the installation of a video wall, suspension bridges, and some roof sheeting. The investigation identified that this additional loading was sufficient to collapse the incomplete structure
- Dimensional deviations in the concrete structure resulted in a mismatch between the concrete and steel structures. The investigation found that these deviations, combined with a lack of ability to adjust the steel structure, necessitated the steel contractor to 'force fit' some of the steel components, thus introducing additional loading into the structure, and reducing the overall load carrying capacity of the roof

Human factors

The investigation concluded that the main contractor allowed work that should have been undertaken sequentially, to be undertaken simultaneously. It appears that because of time pressure associated with ensuring the stadium was 'football-ready', the main contractor abandoned the original construction sequence. The investigation

Figure 1
Collapse resulted in two fatalities and nine injuries

determined that 'the main contractor did not assess whether these changes would affect the safety of the workers performing the work'[1]. Fundamentally, the investigation concluded that the main contractor put an incomplete steel structure into use without checking if it was safe to do so.

Furthermore, the investigation concluded that 'duties, and therefore responsibilities, in the construction process had not been properly assigned or were not properly performed'[1]. For example the steel contractor's assembly plan, which was accepted by the main contractor, did not address the strength of the roof structure through its various stages of construction. Also, the main contractor was required to ensure that the concrete stand had the correct dimensions; however, no measurements were undertaken by the main contractor, and the steel contractor commenced construction of the steel structure without undertaking any independent dimensional checks. The investigation concluded that the project did not have 'an unambiguous framework in which it was clear to all parties what was expected of them and what they could expect of others'[1].

The investigation also concluded that 'the construction work was inadequately coordinated and checked'[1], with such obligations being the responsibility of the main contractor. Ironically, the investigation identified that the high level of trust that existed between the parties, as a consequence of their work together on the 2008 extension, played a role in the lack of checking and coordination: the level of trust resulted in a failure to monitor the performance of a number of responsibilities key to maintaining structural safety.

Figure 2
Insufficient stability of roof structure

Figure 3
Technical and human factors contributed to failure

The collapse of the De Grolsch Veste stadium, however, was not an isolated incident in recent Dutch construction. The failure of a 300 square metre concrete floor during the construction of the B-Tower building occurred in Rotterdam in 2010, and as with the De Grolsch Veste stadium, elements essential for the stability of the building were missing, with a lack of proper control being cited as a factor in the collapse.

Unfortunately, the lessons learned from both failures are all too familiar, and they serve to remind us of the importance of coordination, communication, checking, and quality assurance in ensuring structural safety.

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1) Dutch safety Board (2012) *Roof collapse during extension work at the stadium of FC Twente in Enschede the Netherlands*. Available at: http://www.onderzoeksraad.nl/docs/rapporten/Samenvattig_Rapport_Grolsch_Veste_EN_DEF_web.pdf (Accessed: 10 October 2012).