

# INDIAN METAL BUILDING FORUM

## IMBF

Connecting India's Metal Building Ecosystem

5C FRAMEWORK: CONNECT • COLLABORATE • CREATE • CONSTRUCT • CERTIFY+

### RESOURCE CENTRE

Technical Knowledge Series

## STEEL STRUCTURE FAILURE & LESSONS LEARNED

### Stadium Roof Collapse during Construction: Loads Applied before the Steel Structure was Stable

De Grolsch Veste stadium (FC Twente), Enschede, The Netherlands | 7 July 2011

Learn from Failure  
Improve the System  
Prevent Recurrence

|                            |                                                                        |
|----------------------------|------------------------------------------------------------------------|
| <b>CASE STUDY NO:</b>      | IMBF-SF-008                                                            |
| <b>COUNTRY:</b>            | The Netherlands                                                        |
| <b>YEAR:</b>               | 2011                                                                   |
| <b>STRUCTURE TYPE:</b>     | Cantilever steel roof of a stadium stand extension, under construction |
| <b>TECHNICAL CATEGORY:</b> | Steel erection / Temporary stability / Construction sequence           |

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IMBF publishes this educational case study. IMBF was not the designer, builder or investigator of the structure.

## A DOCUMENT CONTROL AND STATUS

|                  |                                                                                                      |
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| Subject          | Roof collapse during extension work at the FC Twente stadium, Enschede, The Netherlands, 7 July 2011 |

### Technical review status

- ☒ Research Draft (compiled from referenced public sources; not yet reviewed)
- ☐ Technical Review
- ☐ IMBF Approved for Publication

*This draft must not be marked approved until an authorised IMBF reviewer has checked it against the primary investigation report listed in the Source Register.*

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The technical explanations and lessons presented are intended for general educational and professional-development purposes. They shall not be used as a substitute for: project-specific structural design; engineering calculations; site investigation; competent structural-engineering review; statutory approval; manufacturer instructions; applicable codes and standards; independent inspection; accredited testing or certification.

Readers must verify project-specific requirements with qualified professionals and the applicable statutory and code requirements. Where facts are uncertain or disputed, this document identifies them as such.

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**How to read the references.** Tags such as [S1] point to the Source Register on the last page. Text marked "IMBF interpretation" is engineering commentary by this series and is not a finding of the original investigators.

## 1 EXECUTIVE SUMMARY

| Question               | Answer                                                                                                                                                                                                                        |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>What happened?</b>  | The steel roof of a stand extension collapsed while workers were on and under it. [S1] [S2]                                                                                                                                   |
| <b>Where?</b>          | De Grolsch Veste football stadium, Enschede, The Netherlands. [S1]                                                                                                                                                            |
| <b>When?</b>           | 7 July 2011, at about noon. [S1] [S2]                                                                                                                                                                                         |
| <b>What structure?</b> | A cantilevering steel roof with steel sheeting over a stand extension. Extension works began in February 2011. One source gives 11 bearing frames in the 2011 extension. [S2] [S4]                                            |
| <b>What failed?</b>    | The incomplete roof structure: one roof beam or truss failed and that part of the roof collapsed progressively. [S4] [S5]                                                                                                     |
| <b>Why?</b>            | The roof was not yet stable on its own. Elements needed for stability were missing, temporary stabilising elements had been removed to ease other work, and nearly all the permanent loads were already on it. [S2] [S3] [S6] |
| <b>Consequence?</b>    | Two workers died. The number of injured is given as 9 in an engineering paper and 16 on the Safety Board web page. [S1] [S3]                                                                                                  |
| <b>Main lesson</b>     | A steel structure is weakest while it is being built. Stability at every stage must be designed, drawn and controlled, and loads must wait for it.                                                                            |

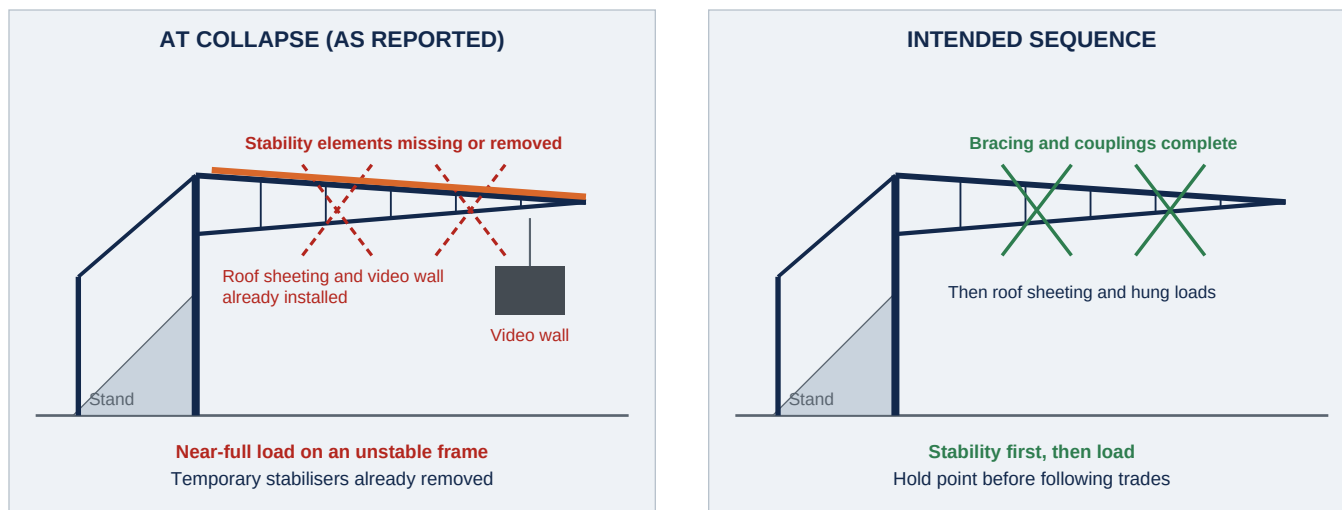


Figure 1. State of the roof at collapse as described in the consulted summaries, and the intended sequence. Original IMBF schematic; conceptual, not to scale.

## 2 PROJECT BACKGROUND

Only data found in the consulted sources is listed. Missing data is stated as not established rather than estimated.

| Item                                                  | Verified data                                                                                                         | Source             |
|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|--------------------|
| Purpose                                               | Football stadium; extension to raise capacity.                                                                        | [S3]               |
| Roof system                                           | Cantilevering steel roof structure with corrugated steel sheeting.                                                    | [S4]               |
| Extension frames                                      | 11 bearing frames in the 2011 roof extension.                                                                         | [S4]               |
| Programme                                             | Works began February 2011, after an earlier extension in 2008.                                                        | [S2]               |
| Loads on the roof                                     | Roof covering and a video wall had been installed; a secondary source gives about 35 t of covering and an 8 t screen. | [S6]<br>(tertiary) |
| People exposed                                        | Workers on top of and beneath the roof; 12 fell from height.                                                          | [S2]               |
| Stage at failure                                      | Under construction; main bearing structure only partly finished.                                                      | [S3]               |
| Spans, member sizes, steel grades, connection details | Not established in the available source.                                                                              | -                  |

## 3 FAILURE TIMELINE

|                     |                                                                                                                                                                                                          |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DESIGN              | Permanent roof designed to be stable once all steelwork was complete. Design of stability in intermediate stages: Not established in the available source.                                               |
| PROCUREMENT         | Not established in the available source.                                                                                                                                                                 |
| FABRICATION         | Not established in the available source.                                                                                                                                                                 |
| ERECTION            | Steelwork erected from February 2011. Several work phases ran at the same time under a tight deadline. [S2] [S6]                                                                                         |
| DEFECT / CHANGE     | Steel elements needed for stability were not yet installed; temporary stabilising ropes and bars were removed to make other work easier. [S2] [S6]                                                       |
| TRIGGER EVENT       | Roof covering and video wall placed on the incomplete structure, giving almost the full permanent load. [S3] [S6]                                                                                        |
| LOCAL FAILURE       | One roof beam or truss failed. [S4] [S5]                                                                                                                                                                 |
| PROGRESSIVE FAILURE | The failure spread through the connected frames. [S4]                                                                                                                                                    |
| COLLAPSE            | That part of the roof collapsed onto the stand. Two killed. [S1] [S3]                                                                                                                                    |
| INVESTIGATION       | Dutch Safety Board investigation, with technical analysis including finite-element validation of the most likely scenario; report published 3 July 2012. [S1] [S3] [S5]                                  |
| CORRECTIVE ACTION   | The Board addressed recommendations to the parties involved, including on realistic deadlines and a shared approach to safety. Details of rebuilding: Not established in the available source. [S2] [S6] |

## 4 WHAT FAILED?

| Element                     | Identification                                                                                                                         |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Primary failed component    | A roof beam or truss of the incomplete cantilever roof. [S4] [S5]                                                                      |
| Secondary failed components | Adjacent frames and roof sheeting of that part of the extension.                                                                       |
| Connection involved         | Stability couplings and bracing between frames (missing or removed). [S2]                                                              |
| Load path involved          | Roof loads -> roof beams or trusses -> columns and back structure -> foundations, with bracing needed to hold the trusses in position. |
| Failure mode                | Instability of an incompletely braced structure under near-full permanent load; progressive collapse. [S2] [S3]                        |

## 5 ENGINEERING FAILURE MECHANISM

**Incomplete structure.** A cantilever roof truss needs out-of-plane restraint from bracing and from its neighbours. Until those elements are fixed, each truss can sway or twist sideways under small disturbance. [S2] [S4]

**Temporary stability removed.** Ropes and bars that held the partly built roof were taken away to ease following trades. The permanent stability elements were not yet in place to replace them. [S6]

**Loads ahead of stability.** Sheeting and a video wall were installed on the unfinished frame. The investigation concluded that a partly finished main structure carrying almost all final permanent loads caused the collapse. [S3]

**Progressive collapse.** With frames tied together but not braced, failure of one member pulled down the rest of that part of the roof. [S4]

| Mechanism considered                            | Role in this case                   |
|-------------------------------------------------|-------------------------------------|
| Erection instability                            | Primary cause (reported). [S2] [S3] |
| Bracing missing or removed                      | Primary cause (reported). [S2] [S6] |
| Progressive collapse                            | Spread of failure (reported). [S4]  |
| Wind, snow, material defect, fatigue, corrosion | Not reported as factors.            |

## 6 ROOT-CAUSE ANALYSIS

| Area                       | Finding                                                                                                                         | Basis                            |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Design                     | Permanent design relied on complete steelwork; intermediate stages needed their own stability design.                           | IMBF interpretation of [S2]      |
| Material                   | Not reported as a factor.                                                                                                       | -                                |
| Fabrication                | Not established in the available source.                                                                                        | -                                |
| Welding                    | Not established in the available source.                                                                                        | -                                |
| Bolting                    | Stability couplings not installed at the time of collapse.                                                                      | Reported [S2]                    |
| Erection                   | Loads applied and temporary stabilisers removed before the structure was stable; trades overlapped.                             | Reported [S2] [S6]               |
| QA/QC                      | No effective check that the structure was stable before further work was released.                                              | Reported in summary [S2]         |
| Operation                  | Not applicable (under construction).                                                                                            | -                                |
| Maintenance                | Not applicable.                                                                                                                 | -                                |
| Management / communication | Tight deadline; several phases at once; changes to the work schedule without risk assessment; no collective approach to safety. | Reported [S2] [S6] (S6 tertiary) |

| Level               | Statement                                                                                                                                    |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Immediate cause     | Insufficient stability of the incomplete roof structure under the loads placed on it. [S2]                                                   |
| Contributing causes | Missing stability elements; removed temporary stabilisers; early installation of sheeting and video wall; overlapping trades. [S2] [S3] [S6] |

| Level      | Statement                                                                                                                                              |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Root cause | Construction sequence was changed under time pressure without anyone responsible for confirming stability at each stage. (IMBF interpretation of [S2]) |

## 7 FIVE-WHY ANALYSIS

IMBF interpretation built on the findings reported in the cited sources.

|                       |                                                                                                                                          |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| WHY 1                 | Why did the roof fall? Because the partly built structure was not stable under the load on it.                                           |
| WHY 2                 | Why was it not stable? Because stability elements were not yet installed and temporary stabilisers had been removed.                     |
| WHY 3                 | Why was load placed on it? Because sheeting and the video wall were installed in parallel with steel erection to save time.              |
| WHY 4                 | Why was that allowed? Because no hold point required proof of stability before releasing following work.                                 |
| WHY 5                 | Why was there no hold point? Because the schedule was tight, phases overlapped, and no single party owned stability during construction. |
| ROOT SYSTEMIC / CAUSE | Schedule-driven sequence changes without engineering control of temporary stability.                                                     |

## 8 CORRECTIVE ACTION

### Immediate corrective action (as reported)

- Rescue and site made safe; national Safety Board investigation opened. [S1]
- Investigation report published on 3 July 2012 with findings on technical and organisational causes. [S2]

### Permanent corrective action (engineering remedy, IMBF interpretation)

- Prepare an erection method statement with a stability check for every stage, signed by an engineer.
- Do not remove temporary bracing or guys until the permanent stability system is complete and accepted.
- Release sheeting, cladding and hung equipment only after a recorded stability hold point.
- Appoint one party to coordinate structural safety across all contractors.

## 9 PREVENTIVE ACTION (CAPA)

| Problem                        | Root cause                        | Corrective action      | Preventive action                                           | Responsible party                         |
|--------------------------------|-----------------------------------|------------------------|-------------------------------------------------------------|-------------------------------------------|
| Structure unstable when loaded | Stability elements not installed  | Complete bracing first | Stage-by-stage stability design in the erection scheme      | Erector; erection engineer                |
| Temporary stabilisers removed  | Convenience of following trades   | Reinstate; stop work   | Permit system for removing any temporary works              | Site manager; temporary works coordinator |
| Loads applied early            | Parallel working to meet deadline | Resequence             | Hold point: structure handed over as stable before cladding | Main contractor                           |
| No one checked                 | Fragmented responsibility         | Appoint coordinator    | Named structural safety coordinator for the project         | Client; main contractor                   |
| Schedule pressure              | Unrealistic deadline              | Re-plan                | Programme reviewed for erection logic before contract       | Client                                    |

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## QA/QC FAILURE ANALYSIS: WHAT SHOULD QA/QC HAVE DETECTED?

Original QA/QC records are not available in the consulted sources. The table shows what a robust system should check on a similar structure (IMBF interpretation).

| QA/QC area                           | Check relevant to this type of failure                                                                                   |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Material certificates                | Grades on certificates match the design assumption.                                                                      |
| Traceability                         | Members, bolts and anchors traceable to their position.                                                                  |
| WPS / PQR and welder qualification   | Qualified procedures and welders for load-path welds.                                                                    |
| Welding inspection and NDT           | Critical welds inspected and tested to the specified extent.                                                             |
| Bolt certificates and installation   | Bolts, nuts, washers and anchors as specified; tightening recorded.                                                      |
| Dimensional inspection and alignment | Geometry, plumb and level within tolerance; deviations reported to the designer.                                         |
| Bracing                              | Permanent and temporary bracing and couplings verified complete, bay by bay, before release.                             |
| Coating                              | Protection complete; connections still inspectable.                                                                      |
| Drainage                             | Roof falls, drains and overflows as designed and working.                                                                |
| Erection sequence                    | Each stage checked against the erection scheme; no load from following trades before the stability hold point is signed. |
| As-built verification                | As-built condition compared with design assumptions and recorded.                                                        |

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## IMBF OPTIMIZATION STRATEGY

| Area                 | Optimisation                                                                                               |
|----------------------|------------------------------------------------------------------------------------------------------------|
| Design               | State design assumptions on the drawings and have them checked independently.                              |
| Fabrication          | Flag critical members and connections on shop drawings; raise a query for anything unclear.                |
| QA/QC                | Add hold points for the items that govern stability and load path to the Inspection and Test Plan.         |
| Erection             | Erection scheme with stage stability checks; permit to remove temporary works; hold point before cladding. |
| Digital traceability | Link inspection records, changes and approvals to each member in the model.                                |
| Inspection           | Risk-based plan: non-redundant members and connections get the most attention.                             |
| Maintenance          | Give the owner an inspection and maintenance manual naming the critical items.                             |
| Cost                 | The cost of a check, a brace or an extra bolt is small against the cost of a collapse.                     |
| Safety               | Higher review level where people work under or occupy the structure.                                       |
| Productivity         | Parallel working is planned from the stability sequence, not imposed on it.                                |

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## DIGITALIZATION

- Erection sequence modelled in 4D so that each stage can be checked for stability and clashes between trades.
- Digital permit and hold-point sign-off before temporary bracing is removed or cladding starts.
- QR code or barcode on main members linking to drawings, certificates and inspection records.
- Heat-number and lot traceability for steel, bolts and anchors.
- Mobile inspection checklists with photographs at each hold point.

DESIGN

Assumptions, critical items and limits recorded in the model.

FABRICATION

Parts marked and traced; changes raised formally.

|                           |                                                                    |
|---------------------------|--------------------------------------------------------------------|
| INSPECTION                | Checklist and photo evidence at hold points.                       |
| DISPATCH                  | Scan-out against the erection sequence.                            |
| ERECTION                  | Scan-in; stability and connection completion recorded.             |
| FINAL INSPECTION          | As-built condition verified against design assumptions.            |
| DIGITAL AS-BUILT / RECORD | Handed to the owner with operating limits and inspection schedule. |

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## INDIAN CONTEXT: WHAT SHOULD INDIA LEARN FROM THIS FAILURE?

- Most steel building collapses in India happen during erection: rafters and columns stood up without bracing, or sheeting started before bracing is complete.
- PEB erection manuals call for a braced bay to be completed first and for temporary guys until then. This must be enforced on site, not left to the erection crew.
- Tight handover dates push cladding, crane beams, solar and services work onto frames that are not yet stable. The programme must protect the stability sequence.
- Lifting plans exist for heavy picks, but a temporary stability plan is equally necessary and is often missing.
- One named person should be responsible for structural stability during erection across all agencies on site.

| Reference                     | Subject                                          | Relevance to this case                                          |
|-------------------------------|--------------------------------------------------|-----------------------------------------------------------------|
| IS 800                        | General construction in steel: code of practice  | Member, connection and stability design.                        |
| IS 12843                      | Tolerances for erection of steel structures      | Erection tolerances.                                            |
| IS 7205                       | Safety code for erection of structural steelwork | Safe erection practice and temporary stability.                 |
| IS 875 (Part 3)               | Wind loads                                       | Wind on partly erected frames.                                  |
| IS 2062                       | Hot-rolled structural steel                      | Material conformity.                                            |
| Project specification and ITP | Contract documents                               | Where responsibilities, hold points and limits must be written. |

Clause numbers are deliberately not cited. Standard titles and current editions must be confirmed against Bureau of Indian Standards publications at technical review.

## 14 IMBF PREVENTION CHECKLIST

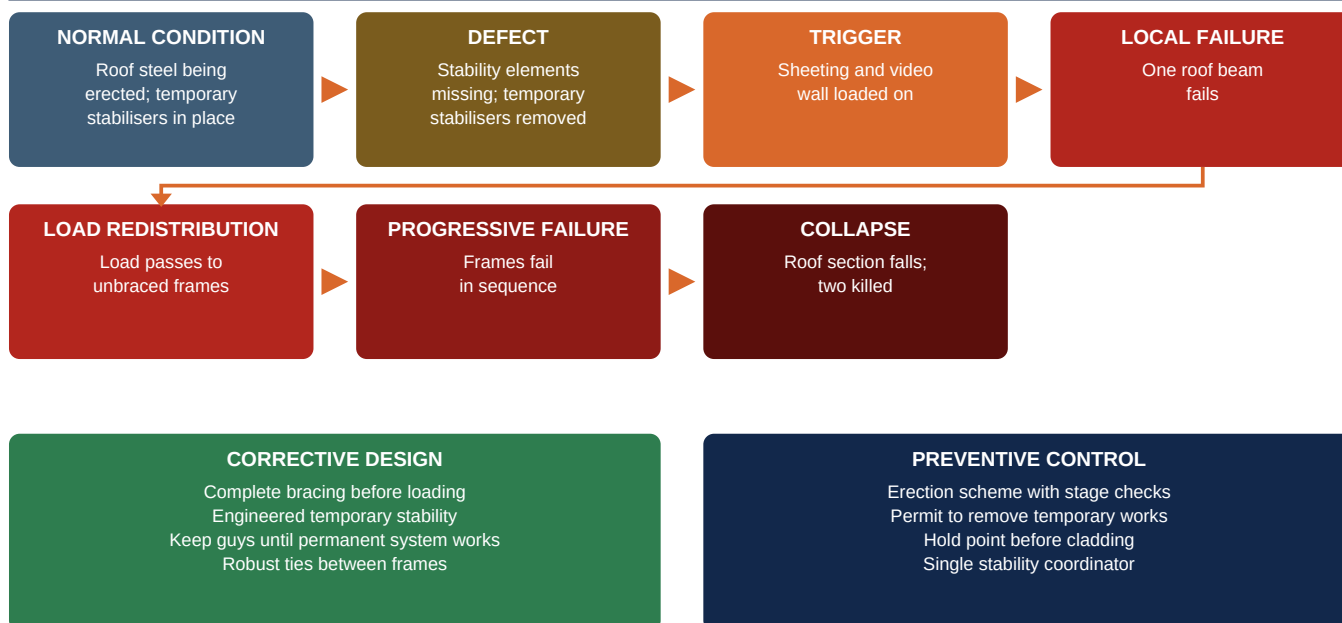
| Inspection point       | Required check                                                                         | Status                   | Remarks |
|------------------------|----------------------------------------------------------------------------------------|--------------------------|---------|
| Design review          | Design assumptions listed and independently checked                                    | <input type="checkbox"/> |         |
| Connection review      | Critical connections designed for real forces                                          | <input type="checkbox"/> |         |
| Material traceability  | Certificates on file; items traced to position                                         | <input type="checkbox"/> |         |
| Welding                | Qualified WPS and welders                                                              | <input type="checkbox"/> |         |
| NDT                    | Critical welds tested                                                                  | <input type="checkbox"/> |         |
| Bolting                | Bolts and anchors as specified; tightening recorded                                    | <input type="checkbox"/> |         |
| Dimensional inspection | Geometry within tolerance                                                              | <input type="checkbox"/> |         |
| Bracing                | Braced bay complete first; temporary guys kept until permanent bracing is accepted     | <input type="checkbox"/> |         |
| Erection sequence      | Stage-by-stage stability checked; no cladding or hung load before stability hold point | <input type="checkbox"/> |         |
| Coating                | Protection complete                                                                    | <input type="checkbox"/> |         |
| Drainage               | Drains and overflows clear and working                                                 | <input type="checkbox"/> |         |
| Final inspection       | Open findings closed before handover                                                   | <input type="checkbox"/> |         |
| As-built documentation | As-built records and maintenance manual handed to owner                                | <input type="checkbox"/> |         |

## 15 PHOTOGRAPHS

No third-party photograph is reproduced in this document. Published photographs and report figures exist, but their copyright and publication permission were not established for this series, so they are not used. All figures here are original IMBF schematics.

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## 16 ORIGINAL IMBF FAILURE DIAGRAM



Original IMBF schematic. Conceptual, not to scale.

## 17 LESSONS LEARNED

### 5 engineering lessons

1. Check stability at every erection stage.
2. Cantilevers need out-of-plane restraint from the first lift.
3. Temporary bracing is structural.
4. Permanent loads must wait for permanent stability.
5. Tied but unbraced frames fall together.

### 5 management lessons

1. Set realistic deadlines.
2. Do not overlap trades without a risk review.
3. Name one coordinator for structural safety.
4. Assess every schedule change for stability.
5. Build a shared safety culture across contractors.

### 5 QA/QC lessons

1. Inspect bracing completion bay by bay.
2. Sign a stability hold point before cladding.
3. Control removal of temporary works by permit.
4. Record deviations from the erection sequence.
5. Stop work when the sequence is broken.

### 5 preventive actions

1. Require an erection scheme for every steel job.
2. Train erectors on temporary stability.
3. Add stability to the pre-start briefing.
4. Audit sites for unbraced frames.
5. Share this case with erection contractors.

## 18 IMBF KEY MESSAGE

**"The finished roof would have stood. The half-finished roof, carrying the finished roof's load, could not. Temporary stability is engineering work, and the programme must be built around it."**

## 19 SOURCE REGISTER

| Ref | Source and organisation                                                                                                                                                                                                                                                                                                                                                                                   | Date               | Used for                                      | Consulted?                           |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----------------------------------------------|--------------------------------------|
| S1  | Collapsed roof Grolsch Veste, 7 July 2011. Dutch Safety Board (Onderzoeksraad voor Veiligheid), investigation page.<br><a href="https://www.onderzoeksraad.nl/en/page/1686/collapsed-roof-grolsch-vest-e-7-july-2011">https://www.onderzoeksraad.nl/en/page/1686/collapsed-roof-grolsch-vest-e-7-july-2011</a>                                                                                            | Report 3 July 2012 | Event, casualties, scope of investigation     | Search extract only; report not read |
| S2  | De Grolsch Veste stadium failure: technical and human factors. Engineers Ireland, Engineers Journal. Summarises the Dutch Safety Board report.<br><a href="https://www.engineersireland.ie/Engineers-Journal/Civil/de-grolsch-veste-stadium-failure-technical-and-human-factors">https://www.engineersireland.ie/Engineers-Journal/Civil/de-grolsch-veste-stadium-failure-technical-and-human-factors</a> | After 2012         | Technical cause, works dates, workers exposed | Search extract only                  |
| S3  | Collapse of the roof of a football stadium. H. Borsje, B. Renier, H. Burggraaf. IABSE Symposium Madrid 2014, pp. 1055-1062. DOI 10.2749/222137814814067257                                                                                                                                                                                                                                                | 2014               | Conclusion on cause; casualties               | Abstract only                        |
| S4  | Chapter "Roof of FC Twente Stadium" and related paper on human and organisational factors. Delft University of Technology repository.                                                                                                                                                                                                                                                                     | After 2012         | Structure description; progressive collapse   | Search extract only                  |
| S5  | Improving construction safety in complex building projects in the Netherlands. International Construction Law Review.                                                                                                                                                                                                                                                                                     | After 2012         | Summary of the Safety Board finding           | Search extract only                  |
| S6  | StadiumDB news reports, July 2012 and July 2014 (tertiary).                                                                                                                                                                                                                                                                                                                                               | 2012; 2014         | Loads, removed stabilisers, deadline pressure | Search extracts only                 |

*Limits of this draft: the Dutch Safety Board report was not read; this draft relies on search extracts of summaries and one conference abstract. Injury figures differ between sources (9, 12 fallen, 16). Tonnages and the removal of ropes and bars come from a tertiary source. The full report must be read before publication.*

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