

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

Steel Space-Truss Roof Partial Collapses: Ice Ponds behind Parapets after Snowfall

Industrial plant with space-truss roof | Turkey (site not named in source)

Learn from Failure
Improve the System
Prevent Recurrence

CASE STUDY NO:	IMBF-SF-006
COUNTRY:	Turkey (inferred from source; site not named)
YEAR:	Not established (study published 2016)
STRUCTURE TYPE:	Low-slope steel space-truss roof on steel columns, industrial plant
TECHNICAL CATEGORY:	Steel roof systems / Ice and water accumulation / Roof drainage

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

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DOCUMENT CONTROL AND STATUS

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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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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
What happened?	A steel space-truss roof of an industrial plant partially collapsed twice after exceptional snowfalls. [S1]
Where?	An industrial plant. The source checks the structure against Turkish steel design codes; the site is not named. [S1]
When?	Not established in the available source. The study was published in 2016. [S1]
What structure?	Mero-type double-layer grid space truss 2 m deep, low-slope lightweight roof covering 26,080 sq m, on steel columns 16.3 m high, with 0.9 m parapets along the perimeter and a siphonic roof drainage system. [S1]
What failed?	Space-truss members in the edge regions of the roof. Which members failed first: Not established in the available source.
Why?	Ice ponds formed at the roof edges. Radiant heaters mounted on the roof structure heated only parts of the roof, so snow melted unevenly and the water ran to the edges, while the siphonic drainage froze. [S1]
Consequence?	Two partial roof collapses. Casualties: Not established in the available source.
Main lesson	A parapet, a low slope and a drain that can freeze turn a roof into a tank. Building services that heat the roof change the load on the structure.

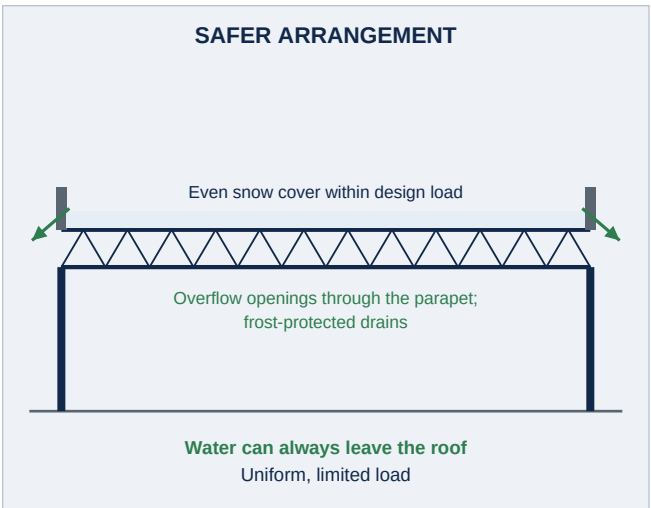
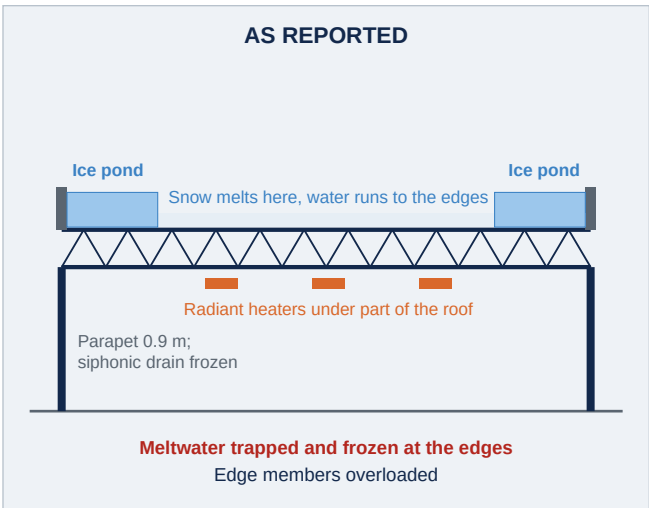


Figure 1. Reported cause: uneven heating melts snow, meltwater collects and freezes behind the parapets at the roof edges. Original IMBF schematic; conceptual, not to scale.

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	Industrial plant.	[S1]
Roof system	Mero-type double-layer grid steel space truss, 2 m deep; low-slope, lightweight roof.	[S1]
Covered area	26,080 sq m in total.	[S1]
Columns	Steel columns 16.3 m high.	[S1]
Parapets	0.9 m high along the building perimeter.	[S1]
Drainage	Siphonic roof drainage system.	[S1]
Heating	Radiant heaters mounted on the roof structure, heating the roof discontinuously.	[S1]
Material	Tensile tests were made on primary load-carrying members; results: Not established in the available source.	[S1]
Plan dimensions, spans, steel grades, node details, date	Not established in the available source.	-

3 FAILURE TIMELINE

DESIGN	Low-slope space-truss roof with perimeter parapets and siphonic drainage. Design loads and ponding provisions: Not established in the available source. [S1]
PROCUREMENT	Not established in the available source.
FABRICATION	Not established in the available source.
ERECTION	Not established in the available source.
DEFECT / CHANGE	Radiant heaters on the roof structure heated parts of the roof only. [S1]
TRIGGER EVENT	Exceptional snowfalls. [S1]
LOCAL FAILURE	Meltwater collected at the edge regions and froze into ice ponds; the siphonic system froze. Edge members overloaded. [S1]
PROGRESSIVE FAILURE	Spread within the affected edge regions; extent: Not established in the available source.
COLLAPSE	Two partial collapses of the roof. [S1]
INVESTIGATION	Site investigation, code-conformity check of members to Turkish steel design codes, and tensile tests of member material. Published in a peer-reviewed journal. [S1]
CORRECTIVE ACTION	Repairs and changes made: Not established in the available source.

4 WHAT FAILED?

Element	Identification
Primary failed component	Space-truss members at the roof edge regions. [S1]
Secondary failed components	Adjacent grid members and roof covering in the collapsed zones.
Connection involved	Mero-type node connections; role in the failure: Not established in the available source.
Load path involved	Ice and water -> roof sheeting -> purlins or top-layer nodes -> space-truss members -> columns.
Failure mode	Member overload under concentrated ice-pond load, leading to partial collapse. Exact mode: Not established in the available source.

5 ENGINEERING FAILURE MECHANISM

Uneven melting. Where heaters warmed the roof from below, snow melted. Where the roof stayed cold, it did not. The meltwater flowed down the low slope to the cold edges. [S1]

Trapped water. A 0.9 m parapet stops water leaving over the edge. With the siphonic drains frozen, the only outlet was blocked, so water depth could build far beyond a uniform snow load. [S1]

Ice ponds. The collected water froze. Ice is much denser than fresh snow, so a modest depth gives a high load, concentrated on the edge bays. [S1]

Light roof, low reserve. A lightweight space truss has little dead load, so an unplanned live load is a large fraction of what the members were sized for.

Mechanism considered	Role in this case
Ice / water accumulation (ponding)	Primary cause (reported). [S1]
Snow loading	Source of the water and trigger (reported). [S1]
Member buckling or connection failure	Likely member-level mode; not established in the abstract.
Corrosion, fatigue, wind, erection instability	Not reported as factors.

6 ROOT-CAUSE ANALYSIS

Area	Finding	Basis
Design	Roof geometry (low slope plus parapet) allowed water to be retained; no overflow provision reported.	IMBF interpretation of [S1]
Material	Material tested by the investigators; no defect established in the abstract.	Reported [S1]
Fabrication	Not established in the available source.	-
Welding	Not established in the available source.	-
Bolting	Not established in the available source.	-
Erection	Not established in the available source.	-
QA/QC	Interaction between heating system and roof loading was not identified before the failures.	IMBF interpretation
Operation	Radiant heaters heated the roof discontinuously.	Reported [S1]
Maintenance	Siphonic drainage froze; snow and ice were not managed on the roof.	Reported [S1]
Management / communication	Structure, drainage and heating were designed as separate packages.	IMBF interpretation

Level	Statement
Immediate cause	Overload of edge-region space-truss members by ice ponds. [S1]
Contributing causes	Exceptional snowfall; discontinuous heating; frozen siphonic drainage; perimeter parapets; low roof slope. [S1]

Level	Statement
Root cause	The roof could retain meltwater with no fail-safe outlet, and the effect of building services on roof loading was not considered. (IMBF interpretation of [S1])

7 FIVE-WHY ANALYSIS

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

WHY 1	Why did parts of the roof fall? Because edge members were overloaded by ice ponds.
WHY 2	Why did ice ponds form? Because meltwater ran to the edges, could not drain and froze.
WHY 3	Why could it not drain? Because the siphonic system was frozen and the parapets blocked any overflow.
WHY 4	Why was there meltwater under snow in freezing weather? Because radiant heaters warmed only parts of the roof.
WHY 5	Why was this not foreseen? Because drainage, heating and structure were not checked together for winter conditions.
ROOT SYSTEMIC / CAUSE	Roof drainage without a fail-safe overflow, and no cross-discipline review of roof loads.

8 CORRECTIVE ACTION

Immediate corrective action (as reported)

- Site investigation, member code check and material tests by the investigators. [S1]
- Repair and modification of the roof: Not established in the available source.

Permanent corrective action (engineering remedy, IMBF interpretation)

- Provide overflow openings or scuppers through parapets, set low enough to limit water depth to what the structure can carry.
- Protect drains from freezing where the climate requires, and keep a gravity overflow as back-up to siphonic systems.
- Check edge bays for drift and for retained water or ice up to the overflow level.
- Review heating layouts so that the roof is not partly melted from below, or insulate accordingly.

9 PREVENTIVE ACTION (CAPA)

Problem	Root cause	Corrective action	Preventive action	Responsible party
Ice ponds at edges	Meltwater trapped by parapet	Add overflow scuppers	Overflow level and capacity as a design-review item	Structural designer; architect
Drain blocked	Siphonic system froze	Trace heating or thaw procedure	Gravity back-up to siphonic drainage	Drainage designer
Uneven melting	Heaters on roof structure	Revise heater layout or insulation	Services-structure interface check for roof loads	Services designer; structural designer
Edge members overloaded	Load not in design	Strengthen edge bays	Design case for retained water or ice at parapets	Structural designer
No warning	No winter roof inspection	Inspect after heavy snow	Owner roof-load and winter inspection plan	Owner; facility manager

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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	All permanent and temporary bracing installed and connected before load is applied.
Coating	Protection complete; connections still inspectable.
Drainage	Drain and overflow count, level and capacity checked; frost protection verified where required.
Erection sequence	Work follows the approved sequence; changes approved in writing.
As-built verification	As-built condition compared with design assumptions and recorded.

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IMBF OPTIMIZATION STRATEGY

Area	Optimisation
Design	Treat retained water and ice behind parapets as a load case; always provide a gravity overflow.
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	Follow a written erection sequence with temporary stability designed by an engineer.
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	Winter plan: inspect roof edges and drains after heavy snow; clear ice dams.
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	Standard, pre-checked details reduce redesign, site improvisation and rework.

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DIGITALIZATION

- Roof-edge water or ice level sensors with alerts to the facility manager.
- 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.
- Changes, queries and approvals logged in a shared cloud record.

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?

- Snow regions in the Himalayan states have the same risk for steel sheds and space-frame roofs with parapets.
- Elsewhere the same mechanism works with monsoon rain: a parapet roof with blocked or undersized drains ponds water quickly.
- Siphonic drainage is now common on large industrial and logistics roofs. It needs a separate overflow path because it can block.
- Rooftop equipment, hot process areas and solar arrays change how water, dust or snow collects on a roof.
- PEB roofs with internal valley gutters and parapet facades should be checked for a blocked-gutter condition.

Reference	Subject	Relevance to this case
IS 800	General construction in steel: code of practice	Member, connection and stability design.
IS 875 (Part 2 and Part 4)	Imposed and snow loads	Roof loads, including accumulation where drainage is obstructed.
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.

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IMBF PREVENTION CHECKLIST

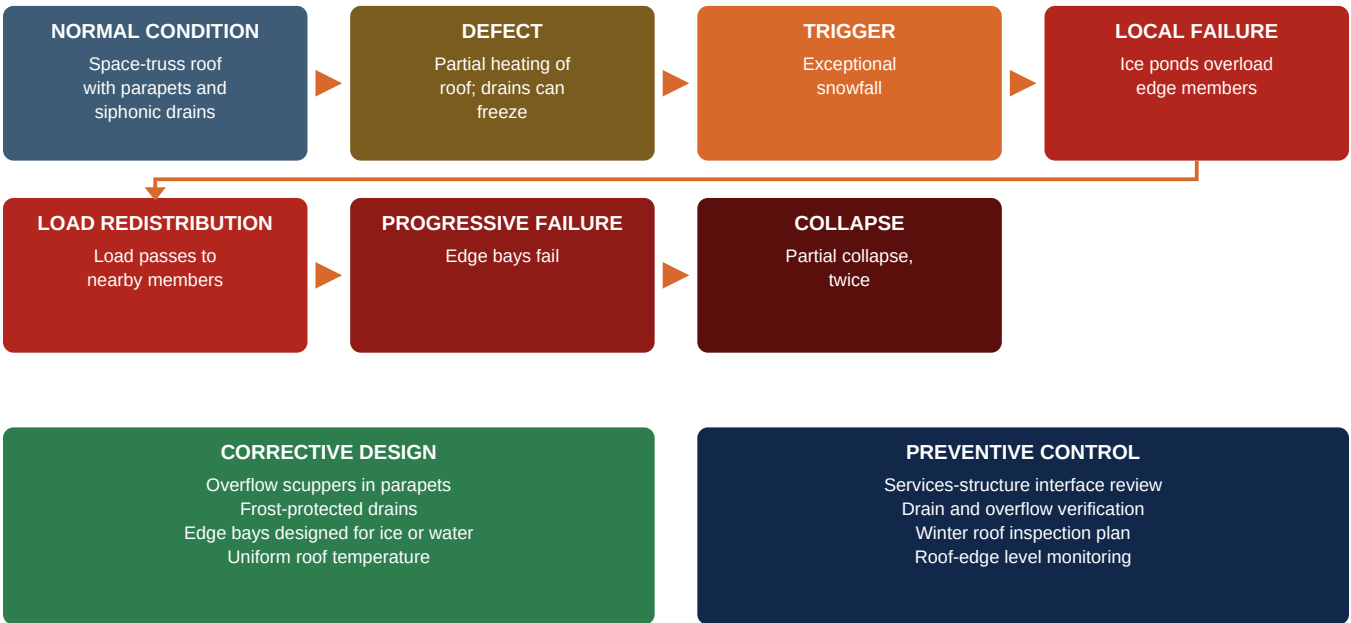
Inspection point	Required check	Status	Remarks
Design review	Retained water or ice at parapets checked; services interface reviewed	☐	
Connection review	Critical connections designed for real forces	☐	
Material traceability	Certificates on file; items traced to position	☐	
Welding	Qualified WPS and welders	☐	
NDT	Critical welds tested	☐	
Bolting	Bolts and anchors as specified; tightening recorded	☐	
Dimensional inspection	Geometry within tolerance	☐	
Bracing	All bracing installed and connected	☐	
Erection sequence	Approved sequence followed; temporary stability checked	☐	
Coating	Protection complete	☐	
Drainage	Overflow through parapets provided; drains protected from blockage and freezing	☐	
Final inspection	Open findings closed before handover	☐	
As-built documentation	As-built records and maintenance manual handed to owner	☐	

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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None reproduced	Not applicable	Not applicable	Not applicable

16 ORIGINAL IMBF FAILURE DIAGRAM



Original IMBF schematic. Conceptual, not to scale.

17 LESSONS LEARNED

5 engineering lessons

1. A roof that can hold water must be designed for that water.
2. Ice is far heavier than fresh snow at the same depth.
3. Provide a gravity overflow independent of the main drains.
4. Edge bays behind parapets need a specific load check.
5. Lightweight roofs have little reserve for unplanned load.

5 management lessons

1. Coordinate structure, drainage and heating design.
2. Give the owner a winter operating plan.
3. Budget for roof inspection and clearing.
4. Investigate the first partial failure fully before reuse.
5. Record changes to building services.

5 QA/QC lessons

1. Verify overflow level and capacity on site.
2. Check frost protection of drains.
3. Record heater positions against the roof design.
4. Inspect roof edges after the first winter.
5. Report unusual ice build-up to the designer.

5 preventive actions

1. Add scuppers to parapet roofs.
2. Add a back-up to siphonic drainage.
3. Monitor roof edges in winter or monsoon.
4. Review roof loads when services change.
5. Share this case with industrial building owners.

18 IMBF KEY MESSAGE

"The snow did not need to be record-breaking. Heat from inside the building, a parapet and a frozen drain were enough to turn it into ice ponds at the roof edge. Structure, drainage and building services must be designed together."

19 SOURCE REGISTER

Ref	Source and organisation	Date	Used for	Consulted?
S1	Partial collapses experienced for a steel space truss roof structure induced by ice ponds. F. Piroglu and K. Ozakgul. Engineering Failure Analysis, vol. 60 (2016). https://www.sciencedirect.com/science/article/pii/S1350630715301588	2016	All facts in this document	Abstract only; full text not read

Limits of this draft: this case rests on the published abstract of one peer-reviewed paper. Location, date, plan dimensions, member-level failure mode, casualties and repairs are not in the abstract and are marked as not established. The country is inferred from the reference to Turkish design codes. The full paper must be read before publication.

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