

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

Suspended Steel Roof Collapse: Rainwater Ponding and Hanger Bolt Failure

Kemper Arena, Kansas City, Missouri, USA | 4 June 1979

Learn from Failure
Improve the System
Prevent Recurrence

CASE STUDY NO:	IMBF-SF-001
COUNTRY:	United States of America
YEAR:	1979
STRUCTURE TYPE:	Long-span arena; steel roof hung from external steel space-frame trusses
TECHNICAL CATEGORY:	Steel roof systems / Bolted tension connections / Ponding

CONNECT • COLLABORATE • CREATE • CONSTRUCT • CERTIFY+

Rev 00 | 04 October 2026 | Educational / Technical Reference (Research Draft)

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

A DOCUMENT CONTROL AND STATUS

Document No.	IMBF-SF-001
Revision	Rev 00
Publication date	04 October 2026
Prepared for	Indian Metal Building Forum, Resource Centre, Technical Knowledge Series
Series	Series A: Failure Case Studies (IMBF-SF)
Status	Educational / Technical Reference
Subject	Kemper Arena roof collapse, Kansas City, Missouri, USA, 4 June 1979

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.

Disclaimer

This document has been prepared by the Indian Metal Building Forum (IMBF) as an educational and technical knowledge resource. The case study is based on publicly available reports, engineering publications, investigation findings and other referenced sources. IMBF has not conducted the original investigation and does not represent this publication as the official investigation report. IMBF was not the manufacturer, designer, contractor or investigator of the structure.

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.

IMBF does not accept responsibility for engineering decisions made solely on the basis of this educational document. Photographs, drawings and third-party material remain subject to their respective copyright and usage conditions.

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?	About 60 m x 65 m (200 ft x 215 ft) of the suspended roof fell into the arena during a storm. [S1]
Where?	Kemper Arena, Kansas City, Missouri, USA.
When?	4 June 1979, at about 6:45 pm local time. [S1] [S6]
What structure?	An indoor arena whose flat roof, about 97 m x 108 m, hung on 42 hangers from three external steel space-frame trusses. [S1]
What failed?	The bolted connection of one hanger, made with ASTM A490 high-strength bolts, followed by the neighbouring hangers. [S1]
Why?	Rainwater ponded on a roof designed to hold storm water, wind added load and pushed the water toward one area, and the hanger bolts had been weakened by about five years of fluctuating load. The hanger system had no redundancy. [S1]
Consequence?	Partial roof collapse; the pressure wave blew out some walls. The arena was not in use and no injuries were reported. It reopened on 20 February 1980. [S1] [S6]
Main lesson	A roof that can hold water, hung on a few non-redundant tension connections that see fluctuating load, can fail well below its static design load. Drainage, ponding stability, fatigue and redundancy must be checked together.

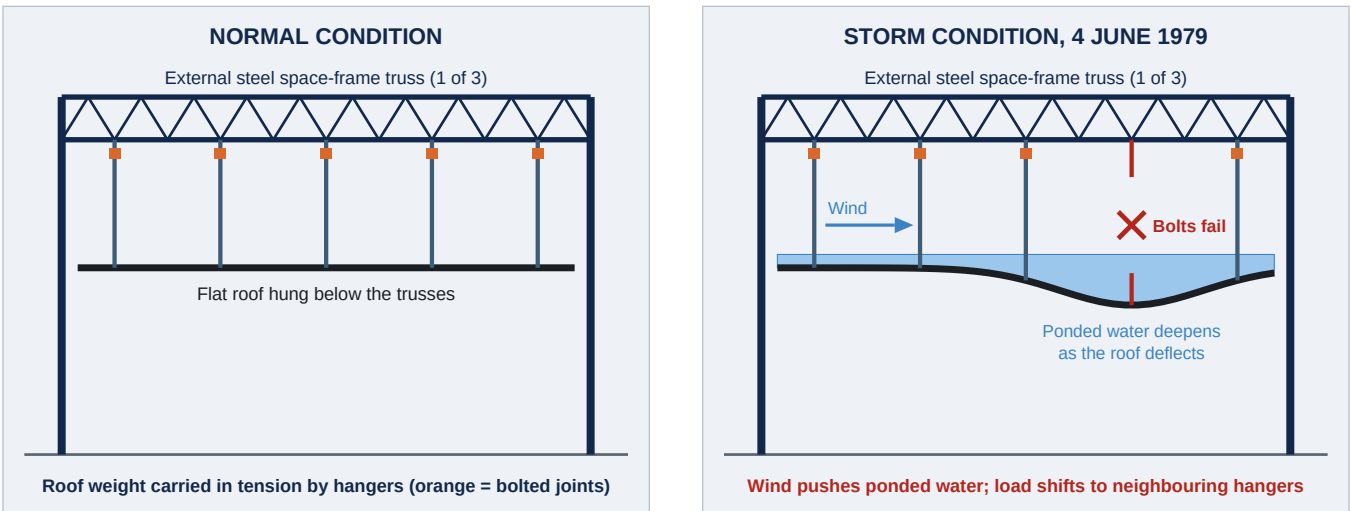


Figure 1. Original IMBF schematic of the load path and the reported failure sequence. Conceptual, not to scale; member arrangement simplified.

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	Indoor arena for sport and public events.	[S1] [S6]
Structural system	Flat roof suspended on hangers from three large external steel space-frame cantilever trusses, giving a column-free interior.	[S1]
Roof plan	About 97 m x 108 m (324 ft x 360 ft).	[S1]
Main trusses	Three trusses, each 16.5 m (54 ft) wide, spaced 30 m (99 ft) apart, built from pipe sections up to 1.2 m (4 ft) in diameter.	[S1]
Hangers	42 hangers; each carried about 622 kN (140 kips) in tension.	[S1]
Hanger bolts	ASTM A490 high-strength bolts. Bolt diameter, number per hanger and installed pretension: Not established in the available source.	[S1]
Roof drainage	Roof designed as a temporary storm-water reservoir. Eight drains of 130 mm (5 in) diameter; the local code is reported to have required eight times as many. Water could overflow at scuppers once depth exceeded 50 mm (2 in).	[S1]
Height / floors	Not established in the available source.	-
Steel grades	Not established in the available source.	-
Stage at failure	In service for about five years. Opening year is given as 1973 in [S1] and as 1974 in [S6]; the sources differ.	[S1] [S6]
Conditions at failure	Rainfall reported at about 100 mm (4 in) per hour with wind gusts to about 112 km/h (70 mph).	[S1]

3 FAILURE TIMELINE

DESIGN	Roof hung from external trusses on 42 bolted hangers; roof used as a temporary storm-water reservoir with eight drains. [S1]
PROCUREMENT	Not established in the available source.
FABRICATION	Not established in the available source.
ERECTION	Erection details: Not established in the available source. Arena opened 1973/1974 (sources differ).
DEFECT / CHANGE	About five years of wind-induced load cycles on the hanger connections; fatigue weakening reported. Drain provision reported far below the local code requirement. [S1]
TRIGGER EVENT	4 June 1979, about 6:45 pm: intense rain and gusting wind. Water ponded and wind pushed it toward the area that failed. [S1]
LOCAL FAILURE	One hanger fractured under the combined wind and ponded-water load. [S1]
PROGRESSIVE FAILURE	With no redundancy, neighbouring hangers were overloaded and failed in turn. [S1]
COLLAPSE	About 60 m x 65 m of roof fell into the arena; some walls were blown out. The external trusses are reported to have remained standing. No injuries. [S1] [S6]
INVESTIGATION	Report to the city by J. L. Stratta dated 7 August 1979 [S3]; separate report by Weidlinger Associates for a subcontractor [S1].
CORRECTIVE ACTION	Hangers and bolts replaced and drains added [S7]; press reports describe welded hanger connections and structural monitoring [S6]. Reopened 20 February 1980. [S6]

4 WHAT FAILED?

Element	Identification
Primary failed component	Bolted connection of one roof hanger (ASTM A490 bolts in tension). [S1]
Secondary failed components	Adjacent hangers on the same part of the roof, then the roof framing and deck they carried. [S1]
Connection involved	Hanger-to-structure tension connection. Exact connection geometry: Not established in the available source.
Load path involved	Roof deck and framing -> hanger (tension) -> external space-frame truss -> truss supports -> foundation.
Failure mode	Fracture of bolts under fluctuating tension (fatigue-weakened), triggered by ponding plus wind; then progressive (disproportionate) collapse for lack of an alternative load path. [S1]

5 ENGINEERING FAILURE MECHANISM

Ponding. A flat, flexible roof deflects under water. The deflection makes a deeper pool, which adds load, which adds deflection. If the roof is not stiff enough, or water cannot leave fast enough, the loop does not settle. Here the roof was meant to retain water and had few drains, so depth could build quickly in a heavy storm. [S1]

Wind. Gusts added fluctuating force on the suspended roof and pushed the ponded water toward the area that failed, concentrating load on a few hangers. [S1]

Bolt tension and fatigue. Each hanger carried its load through bolts in direct tension. When the applied tension rises and falls with every gust, the bolt sees a stress range at the thread root. Over years, cracks can start and grow there even though the peak load is far below the static strength. The source notes that A490 bolts are not recommended for

variable or fatigue loading. [S1]

Progressive collapse. When one hanger let go, its load moved to its neighbours. They had no reserve for it and no alternative path existed, so the failure spread until about an acre of roof had fallen. [S1]

Analysis lesson. The reviewing engineers reported that the roof had to be analysed in three dimensions, not two, to see its true flexibility and ponding sensitivity. [S1]

Mechanism considered	Role in this case
Ponding	Primary load amplifier (reported). [S1]
Wind loading	Trigger and source of load cycles (reported). [S1]
Bolt tension / fatigue / fracture	Initiating component failure (reported). [S1]
Progressive collapse	Spread of failure (reported). [S1]
Buckling, weld failure, corrosion, snow, erection instability	Not reported as factors in the consulted sources.

6 ROOT-CAUSE ANALYSIS

Area	Finding	Basis
Design	Roof used as a water reservoir with limited drains; ponding sensitivity needed 3-D analysis; hanger system had no redundancy; bolts placed in fluctuating direct tension.	Reported [S1]
Material	A490 bolts used where load varied. No material defect is established.	Reported [S1]
Fabrication	Not established in the available source.	-
Welding	Not reported as a factor.	-
Bolting	Tension connection exposed to load cycles. Installation pretension and inspection records: Not established in the available source.	Reported [S1]
Erection	Not established in the available source.	-
QA/QC	No record found, in the consulted sources, of in-service inspection of the hanger connections.	IMBF interpretation
Operation	Storm with intense rain and strong gusts while the arena was unoccupied.	Reported [S1] [S6]
Maintenance	Whether hanger bolts were ever checked or re-tensioned in service: Not established in the available source.	-
Management / communication	Storm-water retention, roof drainage and structural design were not resolved as one problem.	IMBF interpretation

Level	Statement
Immediate cause	Fracture of the bolts at one hanger under combined ponded-water and wind load. [S1]
Contributing causes	Ponding on a roof with few drains; wind piling the water; fatigue weakening of bolts over about five years; bolt type unsuited to variable load. [S1]
Root cause	A roof system in which water retention, flexibility, fluctuating bolt tension and absence of redundancy were not assessed together, so one connection failure could bring down a large area. (IMBF interpretation of [S1])

7 FIVE-WHY ANALYSIS

IMBF interpretation built on the findings reported in [S1].

WHY 1	Why did the roof fall? Because one hanger connection fractured and the others could not carry its load.
WHY 2	Why did the hanger connection fracture? Because its bolts, already weakened by fatigue, met a peak load from ponded water and wind.
WHY 3	Why were the bolts fatigued? Because they worked in direct tension that rose and fell with wind for about five years, a duty the bolt type was not recommended for.

WHY 4	Why was the peak load so high? Because the roof was designed to hold water, had few drains, and was flexible enough for ponding to grow.
WHY 5	Why did one failure become a collapse? Because the hanger system had no redundancy or alternative load path.
ROOT SYSTEMIC / CAUSE	Drainage, structural flexibility, connection fatigue and robustness were treated as separate questions instead of one system check.

8 CORRECTIVE ACTION

Immediate corrective action (as reported)

- Hangers and bolts were replaced and additional roof drains were installed. [S7]
- Press reports describe the rebuilt hanger connections as welded instead of bolted and the roof as fitted with sensors to detect structural weakness. [S6]
- The arena reopened on 20 February 1980. [S6]

Permanent corrective action (engineering remedy, IMBF interpretation)

- Provide positive drainage: slope the roof to drains and add independent secondary (overflow) drainage sized for blocked primary drains.
- Check ponding stability with the real three-dimensional stiffness of the roof and its supports.
- Detail tension hangers so that fluctuating load does not cycle the fastener: adequate preload, stiff joint plies, or a detail rated for fatigue.
- Give the hanger system an alternative load path so that loss of any one hanger does not overload its neighbours.
- Make critical connections inspectable and include them in a periodic inspection plan.

9 PREVENTIVE ACTION (CAPA)

Problem	Root cause	Corrective action	Preventive action	Responsible party
Water ponded on the roof	Roof retained water; few drains; flexible roof	Add drains and overflow paths	Ponding check and secondary drainage as a design-review hold point	Structural designer; plumbing / drainage designer
Hanger bolts fractured	Fluctuating tension on bolts not suited to it	Replace with fatigue-rated connection detail	Fatigue assessment for every tension connection that sees wind or dynamic load	Structural designer; connection designer
Collapse spread	No redundancy in hanger system	Add alternative load path	Robustness (member-removal) check for suspended and long-span roofs	Structural designer; independent reviewer
Weakening went unnoticed	No in-service check of critical connections	Inspect and re-tension or replace	Inspection and maintenance manual listing critical connections and intervals	Owner; facility manager
Disciplines worked apart	Drainage and structure not coordinated	Joint design review	Interface matrix signed by all design disciplines before issue for construction	Project manager; lead designer

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

Records of the original QA/QC are not available in the consulted sources. The table shows what a robust QA/QC system should look for on a similar structure (IMBF interpretation).

QA/QC area	Check relevant to this type of failure
Material certificates	Bolt, nut and washer certificates match the specified grade and are suited to the load type.
Traceability	Bolt lots traceable to each critical connection.

QA/QC area	Check relevant to this type of failure
WPS / PQR and welder qualification	Required for any welded hanger detail; not reported as a factor here.
Welding inspection and NDT	Tension-critical welds fully inspected where welded hangers are used.
Bolt certificates and installation	Pretension method specified, calibrated and witnessed; snug-tight bolts not accepted in fatigue-sensitive tension joints.
Dimensional inspection and alignment	Hanger lengths and roof levels within tolerance so that load is shared as designed.
Bracing	Lateral restraint of the suspended roof against wind sway as designed.
Coating	Protection at connections, with no coating hiding thread or plate defects.
Drainage	Number, size and level of drains and overflows checked against drawings and code; water test before handover.
Erection sequence	Hangers loaded in the planned sequence; no hanger overloaded temporarily.
As-built verification	As-built roof levels and drain positions surveyed; deviations returned to the designer.

11 IMBF OPTIMIZATION STRATEGY

How can the Indian metal building industry optimise the system so that this failure pattern does not recur?

Area	Optimisation
Design	Treat roof drainage as a structural load case. Standardise a ponding and overflow check for low-slope and long-span roofs, including PEB roofs with valley and boundary gutters.
Fabrication	Shop-assemble or trial-fit critical tension connections; mark them as critical on shop drawings.
QA/QC	Add hold points for bolt pretension and for drainage completeness to the Inspection and Test Plan.
Erection	Pretension bolts with a calibrated, recorded method; survey roof levels after cladding.
Digital traceability	Link bolt lot, tightening record and inspector to each critical connection.
Inspection	Risk-based plan: few, highly loaded, non-redundant connections get the most attention.
Maintenance	Clean drains and gutters before every monsoon; inspect critical connections at fixed intervals.
Cost	A secondary drain or an extra hanger costs little against the loss of a roof and of the building's use.
Safety	Check occupancy risk: a long-span public roof deserves an independent design review.
Productivity	Standard, pre-checked connection and drainage details reduce redesign and site rework.

12 DIGITALIZATION

- QR code or barcode on every hanger, beam and column, linked to its drawing and inspection record.
- Heat-number traceability for steel and lot traceability for bolts.
- Weld and bolt-tightening records captured on a mobile checklist with photographs.
- BIM model carrying drainage, structure and connection data in one place, kept as the digital as-built record.
- Cloud document store so that the owner inherits the inspection history at handover.

DESIGN	Model with critical connections and drainage tagged.
FABRICATION	Parts marked with QR codes; heat and lot numbers recorded.
INSPECTION	Mobile checklist; photo evidence; NDT and dimensional reports attached.
DISPATCH	Scan-out against packing list.
ERECTION	Scan-in; bolt pretension and alignment recorded per connection.

FINAL INSPECTION

Roof levels, drains and overflows verified; water test.

DIGITAL AS-BUILT /
RECORD

Handed to the owner with the maintenance and inspection schedule.

13

INDIAN CONTEXT: WHAT SHOULD INDIA LEARN FROM THIS FAILURE?

- Monsoon rainfall intensity makes roof drainage a first-order structural issue for large low-slope metal roofs, valley gutters and parapet-bounded roofs.
- Blocked gutters and downpipes are common in service. Design for a blocked primary drain and provide overflow weirs or spouts.
- Suspended and long-span roofs for stadia, airports, exhibition halls and metro stations rely on a small number of tension connections. These need a fatigue and robustness check, not only a static strength check.
- High-strength bolts in tension joints must be pretensioned and inspected by a recorded method. Site practice varies widely and deserves an explicit hold point in the ITP.
- Owners should receive an inspection and maintenance manual that names the critical connections.

Reference	Subject	Relevance to this case
IS 800	General construction in steel: code of practice	Design of members and connections, including fatigue and serviceability considerations.
IS 875 (Part 2)	Imposed loads	Roof loads, including accumulated water where drainage can be obstructed.
IS 875 (Part 3)	Wind loads	Wind pressure and dynamic effects on large and flexible roofs.
IS 1893	Earthquake-resistant design	Not a factor in this case; listed for completeness of the lateral-load check.
IS 2062	Hot-rolled structural steel	Material grade and quality for members and plates.
IS 4000 and IS 3757	High-strength bolts: practice and product	Installation, pretension and product requirements for high-strength bolted joints.
Project specification and ITP	Contract documents	Where the hold points for drainage, bolting and as-built survey 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

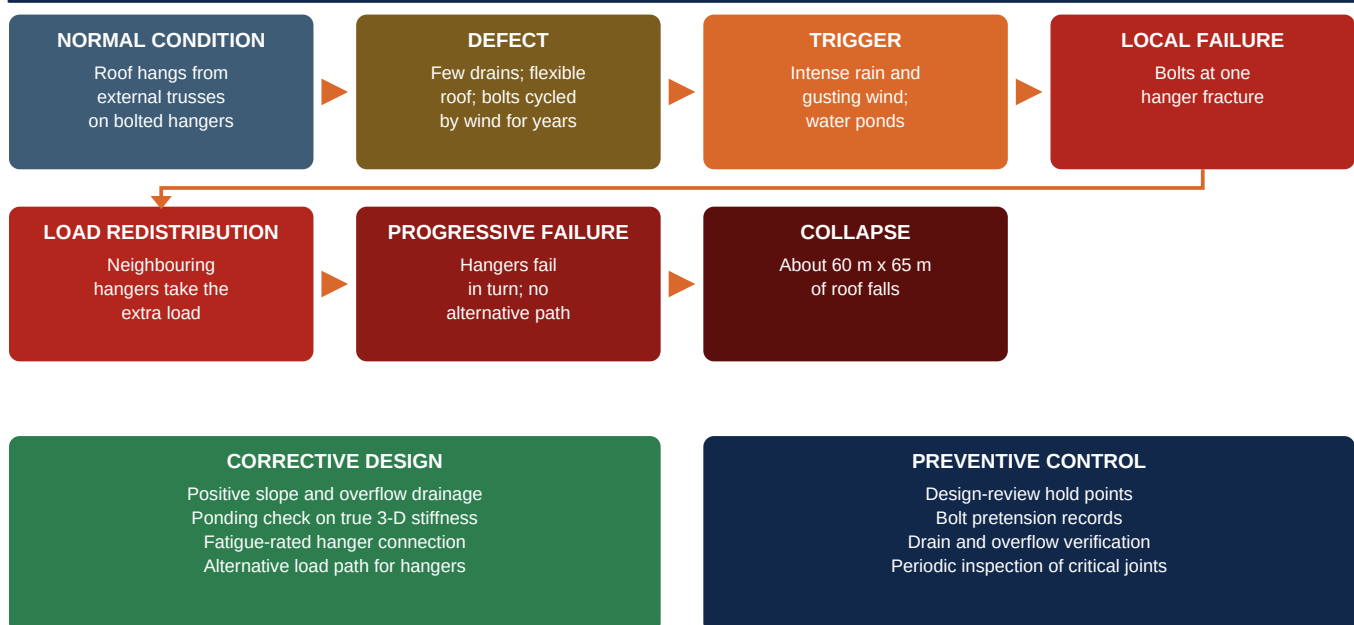
Inspection point	Required check	Status	Remarks
Design review	Ponding stability and overflow drainage checked; independent review for long-span public roofs	☐	
Connection review	Tension connections assessed for fluctuating load; fatigue-suitable detail	☐	
Material traceability	Steel heat numbers and bolt lots traced to critical connections	☐	
Welding	WPS / PQR and welder qualification valid for hanger and bracket welds	☐	
NDT	Tension-critical welds tested to the specified extent	☐	
Bolting	Pretension method calibrated, applied and recorded	☐	
Dimensional inspection	Hanger lengths and roof levels within tolerance	☐	
Bracing	Lateral restraint of roof installed as designed	☐	
Erection sequence	Hangers loaded in planned order; no temporary overload	☐	
Coating	Connections protected and still inspectable	☐	
Drainage	Drain and overflow count, size and level verified; water test done	☐	
Final inspection	Robustness: loss of one hanger does not cause collapse	☐	
As-built documentation	As-built survey and maintenance manual handed to owner	☐	

15 PHOTOGRAPHS

No third-party photograph is reproduced in this document. Published photographs of the collapse exist in newspaper and library archives, but their copyright and publication permission were not established, so they are not used. All figures here are original IMBF schematics.

Photo source	Copyright	License	Permission
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. Ponding is a stability problem: check it with the real stiffness of the roof.
2. A roof that stores water needs independent overflow drainage.
3. Bolts in fluctuating tension need a fatigue check, not only a strength check.
4. Non-redundant tension systems need an alternative load path.
5. Wind and water can act together; check the combination.

5 management lessons

1. Coordinate drainage and structural design formally.
2. Commission independent review for long-span public roofs.
3. Do not let an award-winning concept replace a robustness check.
4. Give the owner a maintenance manual at handover.
5. Act on unusual movement, noise or leakage reports.

5 QA/QC lessons

1. Verify drain and overflow count and level against the drawings.
2. Record bolt pretension for every critical tension joint.
3. Trace bolt lots to connections.
4. Survey as-built roof levels and report deviations.
5. Keep critical connections accessible for inspection.

5 preventive actions

1. Add a ponding and overflow item to every roof design checklist.
2. Classify and tag critical connections on drawings.
3. Schedule periodic inspection of hangers and bolts.
4. Clean drains before each monsoon and after storms.
5. Share failure cases through the IMBF Resource Centre.

18 IMBF KEY MESSAGE

"A roof rarely falls for one reason. At Kemper Arena, water that could not drain, bolts that were quietly fatiguing and a hanger system with no second load path met in a single storm. Drainage, connection design, inspection and robustness must be engineered and verified as one system."

19 SOURCE REGISTER

Ref	Source and organisation	Date	Used for	Consulted?
S1	Building Failure Cases: Kemper Arena. University of North Carolina at Charlotte with the ASCE TCFE Education Committee. Cites Levy and Salvadori (1992), Wearne (2000), Delatte (2009). https://engineering.charlotte.edu/research/areas/case-studies/asce-failure-case-studies/building-failure-cases/	Accessed 4 Oct 2026	Geometry, hangers, bolts, drainage, storm data, extent of collapse, reviewing engineers' findings	Yes
S2	Failure Case Studies in Civil Engineering, 2nd ed., "Kemper Memorial Arena Roof (1979)", pp. 95-97. ASCE Technical Council on Forensic Engineering. ISBN 978-0-7844-1255-8.	2013	Confirms the case is documented by ASCE	Contents page only
S3	Report of the Kemper Arena Roof Collapse of June 4, 1979, Kansas City, Missouri. J. L. Stratta; report to the city, 19 leaves. Catalogue record, Kansas City Public Library. https://kchistory.org/islandora/object/kchistory:96324	7 Aug 1979	Existence and date of the primary investigation report	Catalogue record only
S4	Why Buildings Fall Down, pp. 57-67. M. Levy and M. Salvadori. W. W. Norton.	1992	Cited by S1	No

Ref	Source and organisation	Date	Used for	Consulted?
S5	Beyond Failure: Forensic Case Studies for Civil Engineers, ch. 4. N. J. Delatte. ASCE Press.	2009	Cited by S1	No
S6	Hy-Vee Arena (formerly Kemper Arena). Wikipedia (tertiary); cites The New York Times, 6 June 1979, and Kansas City Times and Star, 1979-1980. https://en.wikipedia.org/wiki/Hy-Vee_Arena	Accessed 4 Oct 2026	No injuries; trusses remained; rebuilt connections; reopening date; opening year	Yes
S7	The Story of the Kemper Arena Roof Collapse. KC Yesterday (local-history article, tertiary). https://kcyesterday.com/articles/kemper-arena-roof-collapse	Accessed 4 Oct 2026	Repairs: hangers and bolts replaced, drains added	Search extract only

Limits of this draft: the primary investigation report [S3] and the books [S2] [S4] [S5] were not read in full. Figures taken from [S1], [S6] and [S7] should be checked against them at technical review. One press account gives the time of collapse as about 7:10 pm; [S1] and [S6] give 6:45 pm.

Final disclaimer. This IMBF publication is an educational resource based on referenced information. It is not a substitute for project-specific engineering design, statutory approval, inspection, testing, certification or professional advice. Readers must verify all project-specific requirements with competent professionals and applicable codes.