Post-fire Flexural Testing and Rating of Prestressed Concrete Bridge Girders

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Background

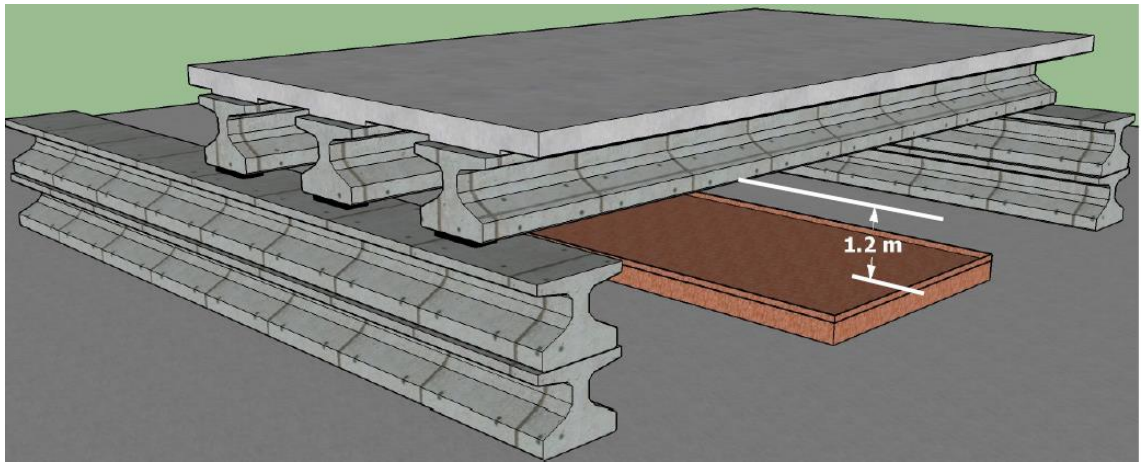
- Bridge fires are caused by crashing of fuel tanker trucks, wildfire and arson.
- Survey of DOTs showed that fire caused more bridge collapse than earthquake.
- Fire hazards on bridges is given less attention, even though it can cause significant economic and public impact.
- I-85 Bridge collapse in Atlanta caused 20% increase in the unit cost/mile for shipping of items, with rebuilding cost of $16.6 M.

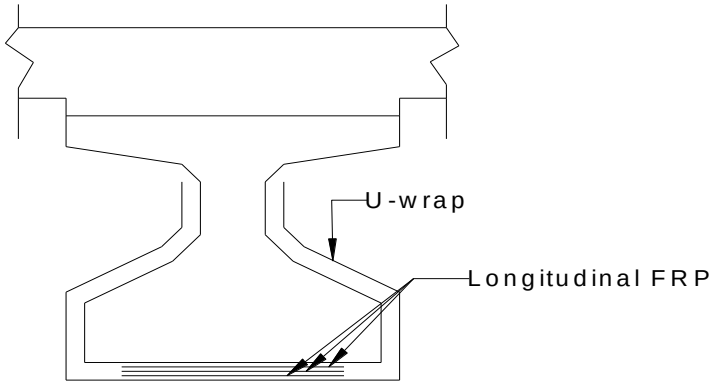
Objectives

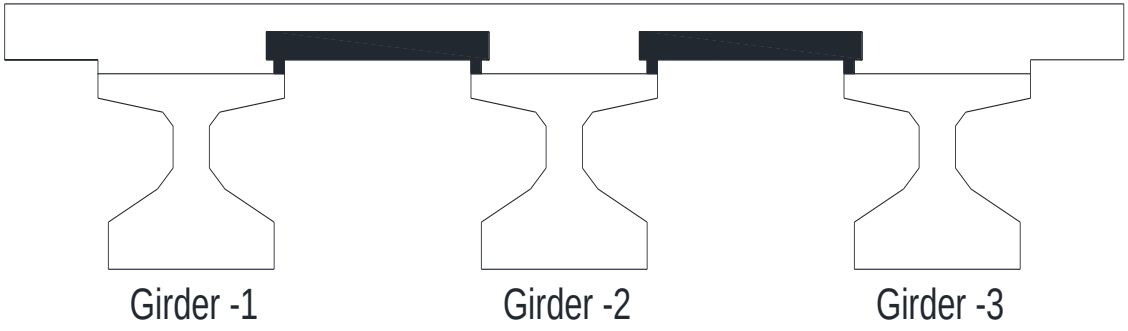
- Evaluate the in-fire and post-fire performance of a typical full-scale one-span I-girder bridge under open fuel fire.
- Determine the post-fire residual strength and rating of precast prestressed I-girders.
- Performance of CFRP laminate strengthening and fireproofing in fire.

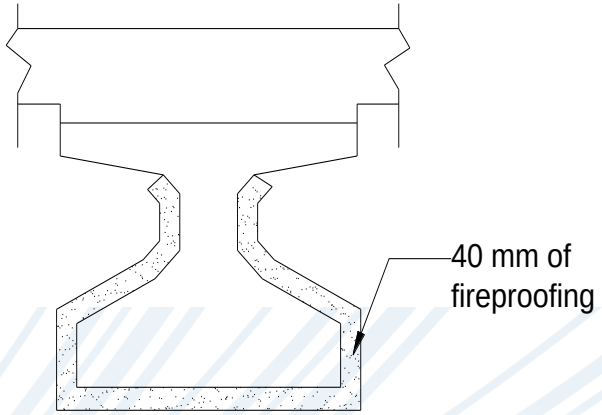
Test Bridge: Description

- 33 ft. (10.1 m) long and 18 ft. (5.5 m) wide.



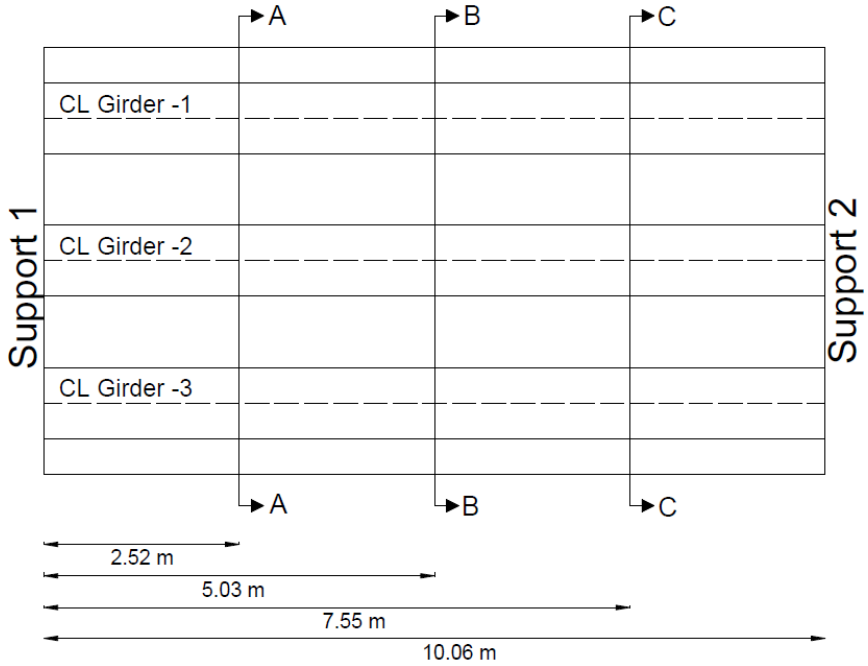


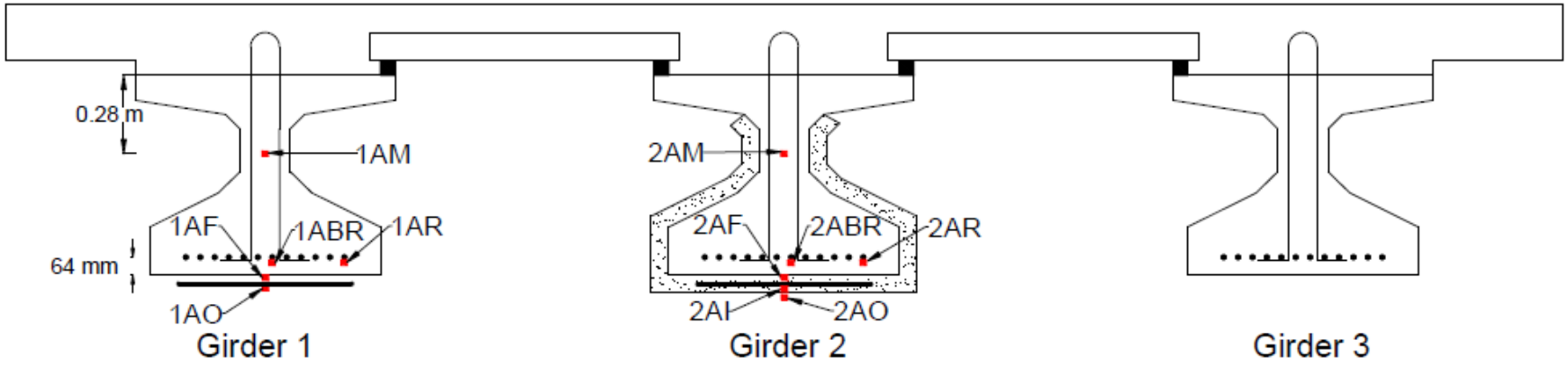




Test Bridge: Instrumentation

- 36 Type-K Inconel sheathed thermocouples installed.





Test Bridge: Construction

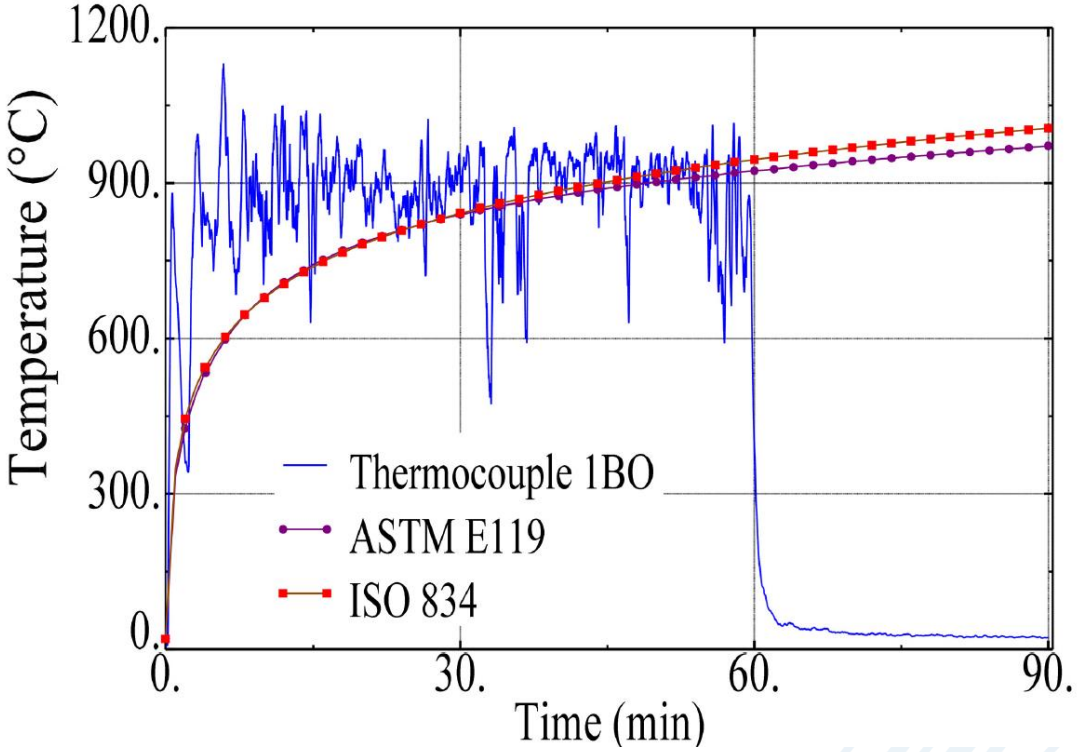
- 32 days to construct, test and demolish.
- Zipper barriers used to simulate vehicular live load.

Fire Test

- Two firefighter trucks and nine firefighters were at the scene.
- A minimal windy day selected.
- Test was conducted for an hour, burning 1140 gallons of fuel.

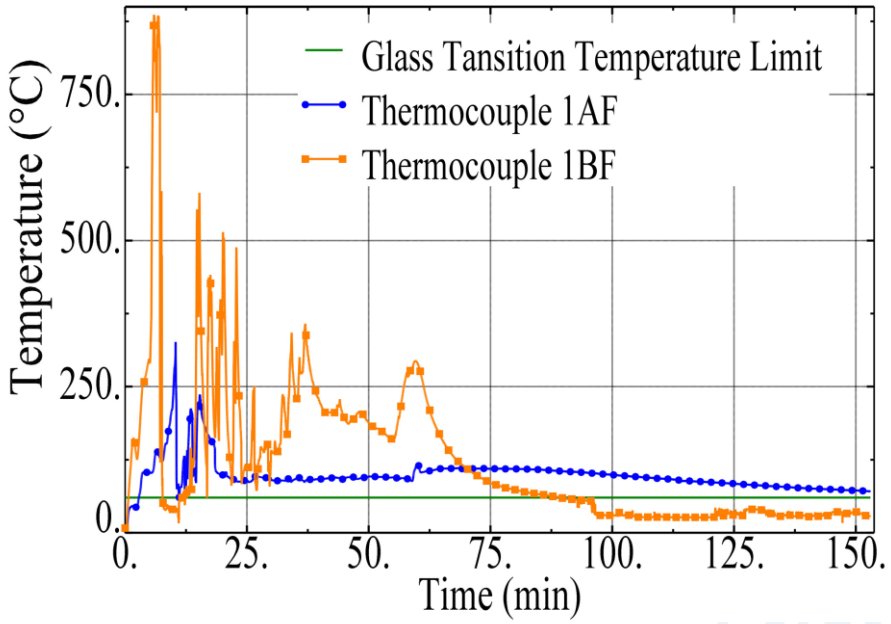
Fire Test

- Fire temperature reached as high as 1131ºC.
- Temperature difference of up to 640°C was observed within a one-minute interval.



Girder-1 (with CFRP, no fireproofing)

- Glass transition temperature, $T_{g,}$ of the epoxy (60°C) was exceeded 41 and 168 secs after the test began.
- CFRP fully debonded 6 minutes into the test.
- Temperature in the strands reached as high as 473°C; strands lose 70% of their strength at this temperature.



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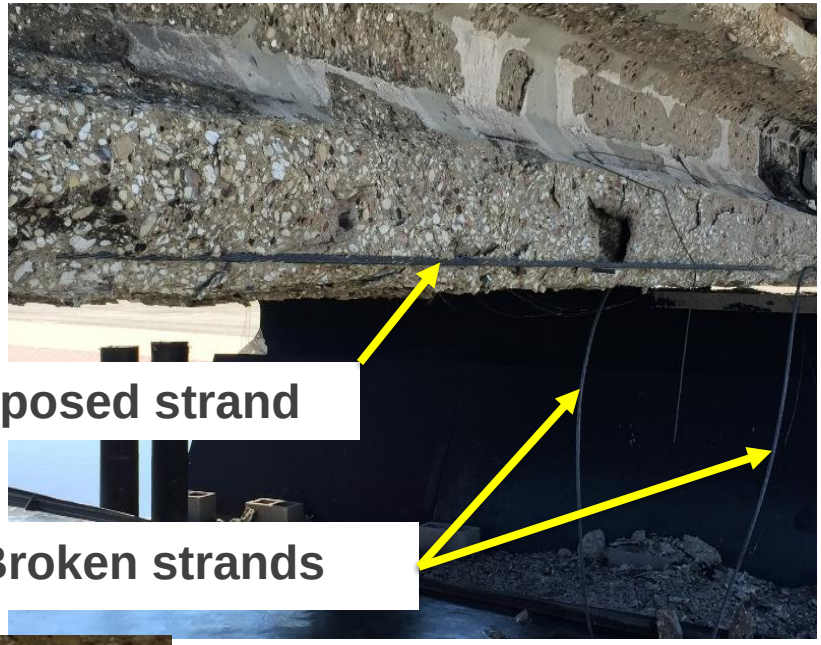
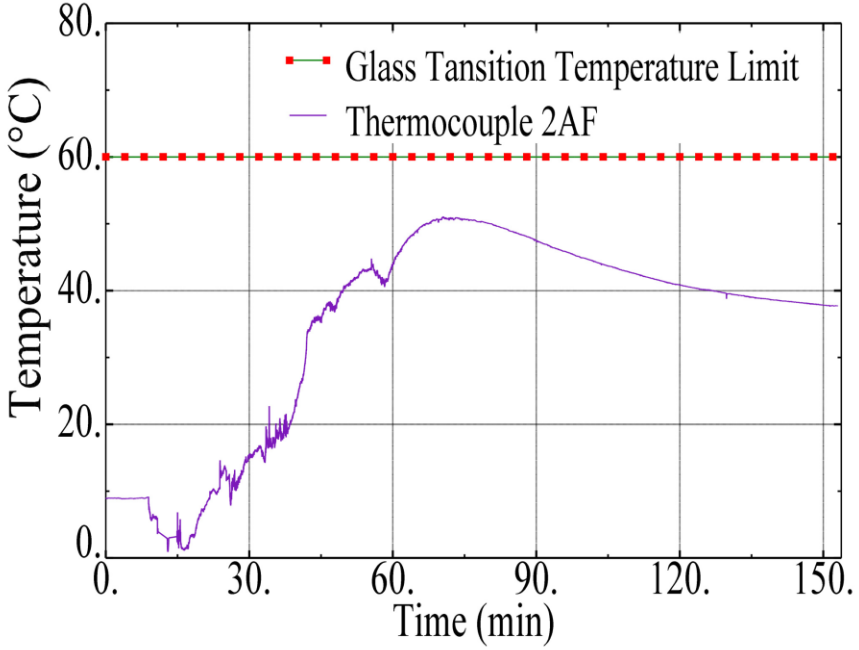


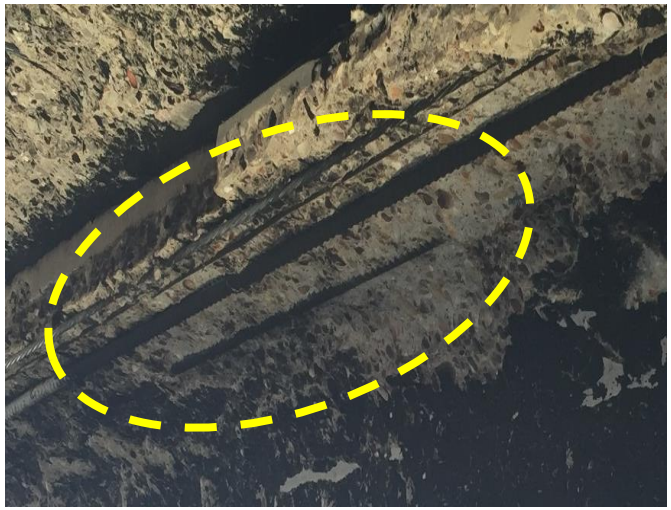
Girder-2 (with CFRP, fireproofing)

- Fireproofing kept the temperature at the CFRP-concrete interface below glass transition temperature.
- Maximum temperature in the prestressing strands was 48°C; strands retain 100% of their strength at this temperature.



Girder-3 (no CFRP or fireproofing)

- Had least fire exposure because of the prevailing wind...it sustained minimal damage.



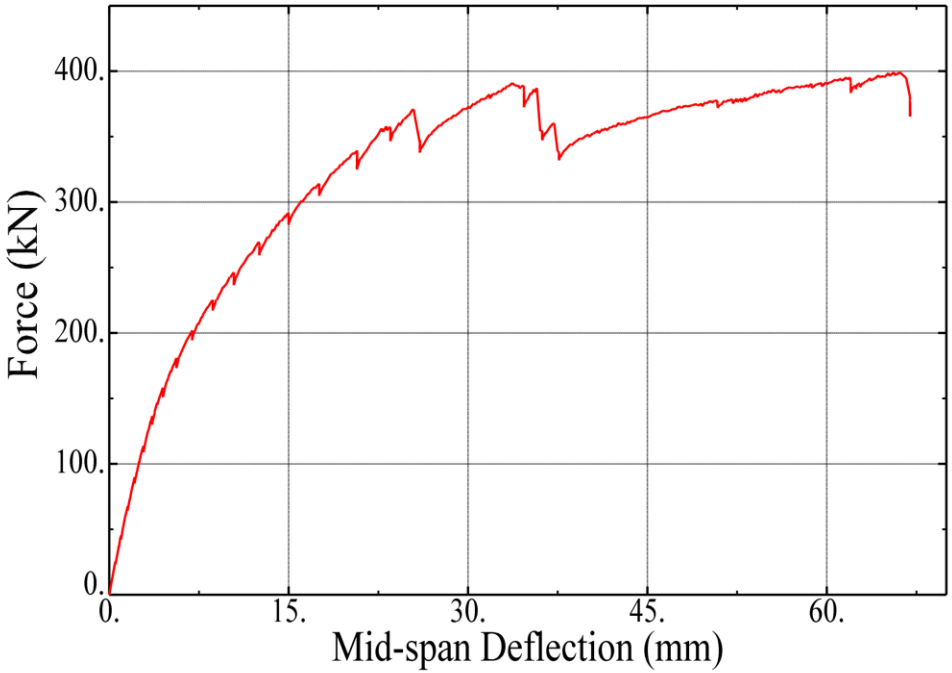
Residual Strength Test

Load cell

LVDT

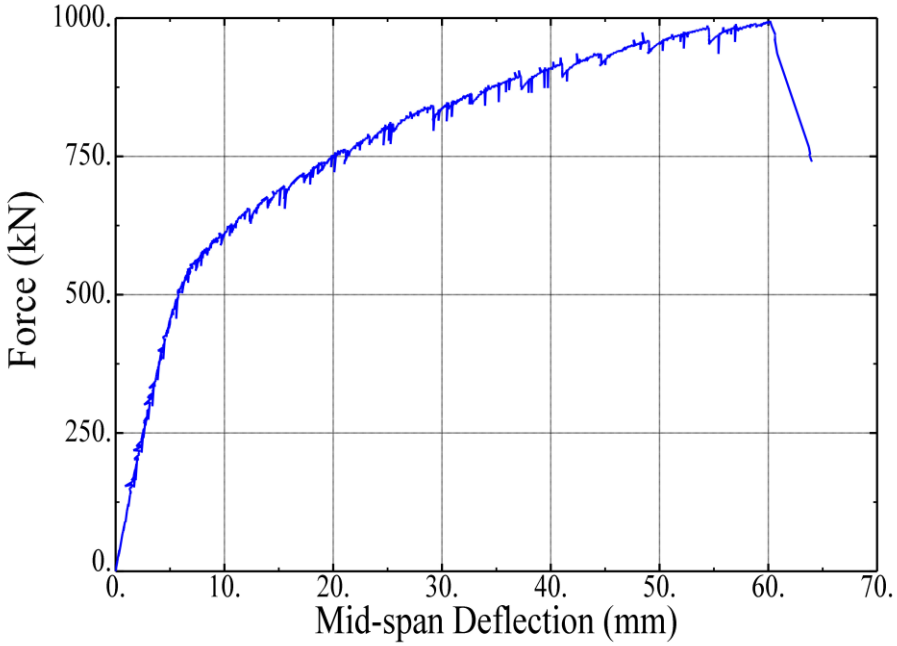
Girder-1 (with CFRP, no fireproofing)

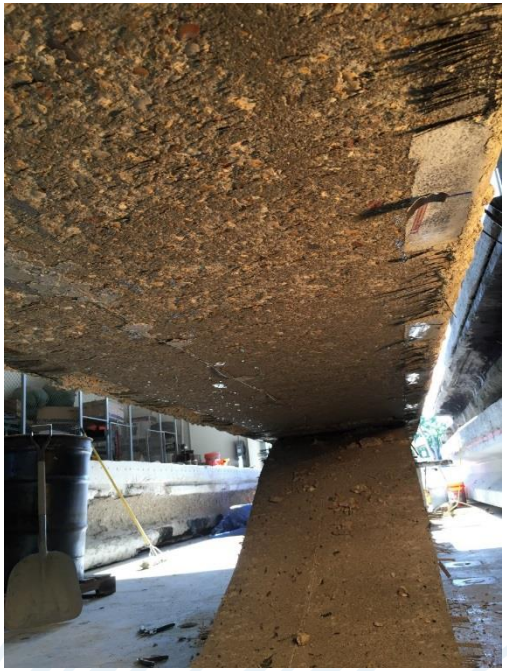
- Failed at a load of 90 kip (399 kN), corresponding to a bending moment of 707 kip-ft (958 KN-m).
- The undamaged nominal flexural capacity was 1780 kip-ft (2348 kN-m).
- Fire caused a 59% reduction in flexural strength.



Girder-2 (with CFRP or fireproofing)

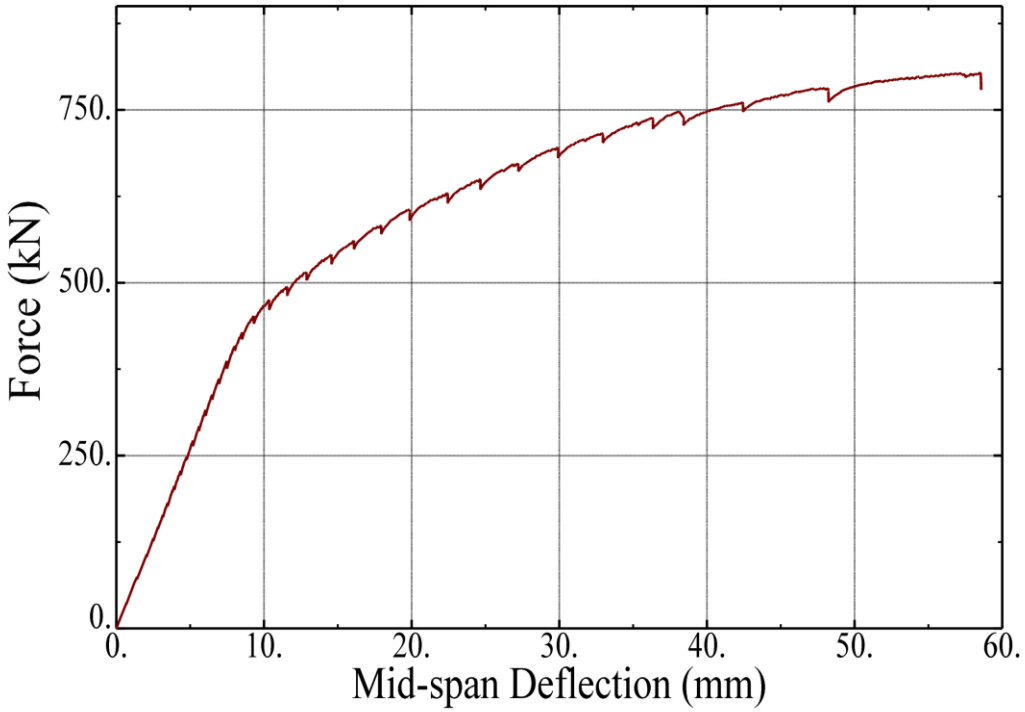
- Failed at a load of 224 kip (995 kN), corresponding to a bending moment of 1761 kip-ft (2388 kN-m).
- Calculated flexural capacity was 1780 kip-ft (2348 kN-m), only 1.7% more than the failure moment.
- Fireproofing was successful in protecting the CFRP, concrete, strands and mild reinforcement.





Girder-3 (no CFRP or fireproofing)

- Failed at a load of 181 kip (805 kN), corresponding to a bending moment of 1424 kip-ft (1930 kN-m).
- Calculated flexural capacity was 1384 kip-ft (1876 kN-m), 2.8% less than the failure moment.



Load Rating of Girders, Strength I

Inventory Level

Girder	ϕ_C	ϕ_s	ϕ	M_n (kip.ft)	γ_{DC}	M_{DC} (kip.ft)	γ_{DW}	M_{DW} (kip.ft)	γ_L	M_{LL+IM} (kip.ft	RF
1	0.85	0.85	1.0	707	1.25	105	1.50	0	1.75	275	0.79
2	0.95	0.85	1.0	1761	1.25	124	1.50	0	1.75	275	2.63
3	0.95	0.85	1.0	1424	1.25	124	1.50	0	1.75	275	2.07

Operating Level

Girder	ϕ_C	ϕ_s	ϕ	M_n (kip.ft)	γ_{DC}	M_{DC} (kip.ft)	γ_{DW}	M_{DW} (kip.ft)	γ_L	M_{LL+IM} (kip.ft	RF
1	0.85	0.85	1.0	707	1.25	105	1.50	0	1.35	275	1.02
2	0.95	0.85	1.0	1761	1.25	124	1.50	0	1.35	275	3.41
3	0.95	0.85	1.0	1424	1.25	124	1.50	0	1.35	275	2.68

Conclusions

- The pioneering study helped in understanding the response of concrete bridges to open hydrocarbon fires. May eventually lead to the development of bridge fire safety provisions.
- The rating factor for Girder 1 and test results clearly show the adverse effect of fire on the design load carrying capacity.
- From the performance of the girder without fireproofing, it is apparent that the nation's concrete bridges could be at a high risk of failure due to extreme hydrocarbon fire events.
- Precast bridge girders can retain their flexural capacities and integrity, including CFRP, concrete and the prestressing strands, with proper fireproofing application.

Acknowledgment

The study was performed at UT Arlington under a contract from the Texas Department of Transportation (TxDOT).

Questions?

Thank You!