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

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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.
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 1131°C.
- 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.
Girder-1 (with CFRP, no 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.

![Graph showing temperature over time]
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

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<th>$\phi_s$</th>
<th>$\phi$</th>
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<th>$\gamma_{DC}$</th>
<th>$M_{DC}$ (kip.ft)</th>
<th>$\gamma_{DW}$</th>
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<th>$\gamma_L$</th>
<th>$M_{LL+IM}$ (kip.ft)</th>
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## Operating Level

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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!