Strength to a Double Tee

Structural engineers hold a load testing event in Colorado to assess the strength of precast concrete double tees.

By Evan Gurley and Kayla Hanson

What happens when 4,400-lb highway barriers are placed on top of a 10-ft-wide, 60-ft-long precast, prestressed concrete double tee? Engineers, precasters and students alike gathered in April 2014 at Colorado Precast Concrete in Loveland, Colorado, to find out.

What is a double tee?

Like the name implies, a precast, prestressed double tee resembles two side-by-side capital letter Ts. The two vertical leg sections are called webs or stems and the horizontal section is known as the deck or flange. Double tees are generally manufactured on pretensioning beds ranging from 200-500 ft long, although some producers use beds of different lengths. Beds are manufactured in the same orientation as double tees are to be installed in the field (the stems and lower surfaces of the flange are form finished and the top surface is finished manually).

Prestressing tendons are situated in the forms and are stressed prior to casting. These tendons consist of high tensile strength cables, typically of multiple strands. Each double tee's flange is cantilevered

Despite nearly 90,000 pounds of highway barrier resting on its surface, the double tee held together.

from the stem. Conventional reinforcing steel is then placed in the flange to resist tensile stresses. The reinforcing steel also helps resist flexural stresses from out-of-plane loads and provides protection from drying shrinkage cracking.

After the concrete cast into the forms reaches a specified compressive strength, the tendon ends are cut, placing the stems in compression. This compression shortens the lower section of double tee, resulting in upward camber, which counteracts dead loads, live loads and creep deflection.

Once the double tees are welded together, the double tee joints are treated and, if applicable, toppings are applied. Waterproofing membranes can also be used to protect the double tee from water penetration.

Double tees offer plenty of flexibility in design and construction, where they are an ideal choice for structures requiring long, uninterrupted spans and high load carrying capabilities. The design of a prestressed double tee allows the deck to act integrally with the superstructure, as prestressed double tees have a monolithic deck and stem design. The integral design provides a stiffer member, while the material-saving shape reduces the dead load. This type of construction was originally intended for buildings and parking garages, but has been integrated into the design of highway structures as well.

Typical dimensions of prestressed double tees are:

- Stem depth: 12-34 in. (up to 5 ft)
- Flange width: 8-10 ft (up to 15 ft)
- Span length: 25-55 ft (up to 80 ft or more)

Under pressure

On April 17, 2014, the northern division of the Structural Engineers Association of Colorado hosted a double tee load test event at Colorado Precast Concrete in Loveland, Colorado. A full-size 10DT24+2 double tee (see "Decoding the double tee") designed for a typical parking garage floor member was load tested to determine performance. Stresscon of Colorado Springs supplied the 10-ft-wide, 60-ft-long double tee for the demonstration.

Decoding the double tee

10DT24+2

10 – Width of precast section (ft)
DT – Description of section (in this case, "DT" means Double Tee)
24 – Depth of precast section (in.)
+2 – Topping

The double tee was loaded to service level, 85%, ultimate, 110% and failure. Testing procedures closely followed those found in Chapter 20 of ACI 318, "Building Code Requirements for Structural Concrete," except for the 24-hour applied load time and the response measurement, which were a result of time restrictions.

The objective of the testing was to determine the structural performance of a common double tee designed for a typical parking garage floor member while showing deflection and rebound. The double

PHASE AND LOAD TYPE	NUMBER OF BARRIERS	DEAD LOAD	LIVE LOAD	PROJECTED MOMENT	ACTUAL MOMENT	CHANGE IN DEFLECTION	TOTAL DEFLECTION
1 Typical Condition	4	8 psf	30 psf	534 kip·ft	493 kip·ft	N/A	0.03"
2 Code Level Service	7	8 psf	40 psf	580 kip·ft*	597 kip·ft**	0.80"	0.83"
3 85% of Ultimate	9	8 psf	40 psf	654 kip·ft	653 kip·ft	1.26"	2.09"
4 100% of Ultimate	11	8 psf	40 psf	769 kip·ft	768 kip·ft	2.84"	4.93"
5 110% of Ultimate	12	8 psf	40 psf	846 kip·ft*	830 kip·ft**	1.61"	6.54"

Table 1 – 10DT24+2 Load Test Results

*The Projected Moment is due to loads indicated in the loading diagrams available at precast.org/loadtest.

**The Actual Moment is due to test loading.

tee was loaded with 4,400-lb highway barriers for the five different loading phases, where the factored service load was determined to be 29,300 lbs. Barriers were loaded on the double tees with weights corresponding to the five different phases.

When loading the double tee at 85% of ultimate, 1 in. of deflection and 1 in. of rebound was recorded when barriers were removed. Test results showed the resiliency and the safety factor engineered into the design of the precast member. The double tee finally reached the failure phase when 20 barriers (88,000 lbs) were loaded, causing the double tee to deflect more than 44 in. and touch the ground. Although it was deemed failed, the double tee still held together despite nearly triple the calculated service load resting on the surface.

Tee time

Today, double tees are an ideal solution for projects involving bridges, parking decks, flooring and roofing systems, industrial buildings and more. No matter what the application, double tees are spanning longer distances and performing at higher levels than ever before. ps

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All photos courtesy of NPCA staff.

Want to see the load test in action? Visit precast.org/loadtestvid

Double Tee Advantages

Precast, prestressed concrete double tees offer many advantages, making them suitable for construction of elevated parking decks as well as the substrate for waterproofing, roofing systems and buildings. The combination of robust reinforcing steel and the depth of the legs/stems allows the double tee to support loads over long spans. With their efficient cross section and high section modulus, precast double tees have been designed to span 80 ft or more.

Additional advantages include:

- Low initial project cost and little maintenance throughout the life of the product.
- Faster fabrication and erection, speeding up the construction process compared to cast-in-place structures.
- Higher durability and sound resistance, including the ability to withstand wind, road salt, earthquakes and even fire.
- A column-free solution.
- Simplified frame, design and construction.
- Openings for service pipes/ducts incorporated.
- Use of precast elements in frame is possible.

References

ACI 318 – Building Code Requirements for Structural Concrete