# THREADED ROD CONTINUITY OF PRECAST PRESTRESSED GIRDERS

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## ABSTRACT

This paper reviews earlier research on Precast Prestressed Girders Continuity System done by the University of Nebraska and introduces a new design detail by placing Threaded Rods (TR) above the girder top flange. The new TR continuity system has the benefits of the post-tensioning continuity system but at a lower cost and using a simpler construction approach. This paper presents current continuity methods, and describes the construction procedures and system detailing. Testing procedure of two full-scale specimens is described. The TR continuity was proven to be very efficient.

**Keywords:** Threaded Rod, Continuity, Precast Prestressed Girders, Diaphragm

**BACKGROUND**

Utilizing precast prestressed bridge girders efficiently with larger spans, or spacing girders, are alternative modern bridge design trends to optimize the bridge cost. Creating girder continuity over the pier is one of the ways for precast concrete industries to compete with steel bridges. Continuity between precast prestressed concrete beams can be developed in several ways as described in the three methods that follow.

1. CONVENTIONAL CONTINUITY METHOD FOR SIDL AND LL

In this system, continuity is developed by adding longitudinal bars in the deck slab over the pier as shown in Fig 1. Girder weight and deck weight are applied to a simple span system. However, superimposed dead loads (SIDL) and live loads (LL) are applied to the continuous system created by the reinforcement bars in the deck slab. The capacity of the negative section is limited by the maximum number of steel bars that can be placed in the deck slab. One of the frequent problems with this method is developing cracks at the bottom fiber of the diaphragm due to the large positive moment at the diaphragm caused be time dependent prestress losses.

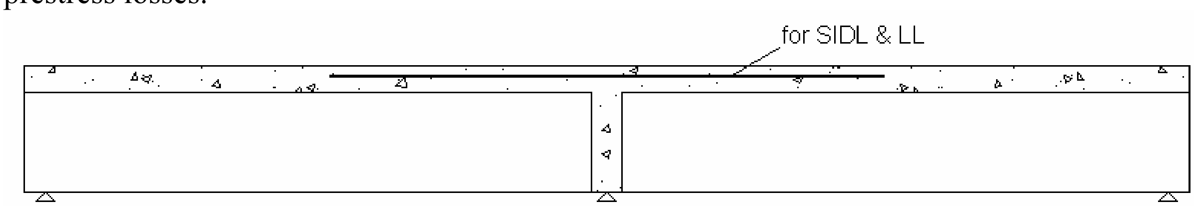


Fig. 1 Conventional Bridge Continuity

2. POST-TENSIONING CONTINUITY SYSTEM

Creating continuity using post-tensioning have the deck weight, SIDL, LL loads applied to the continuous system. Fig 2. shows the typical post-tensioning profile for a two-span bridge. This method is structurally efficient with premium cost.

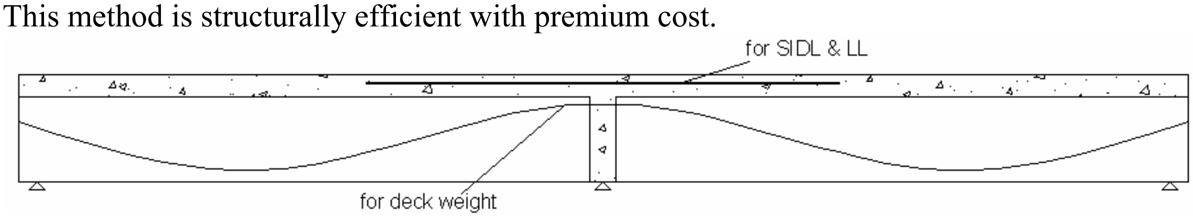


Fig. 2 Post-tensioning Continuity System

In 1966, Burns [1] tested continuity details in precast prestressed concrete bridge girders by using approximately 2 in. square rods in place of deformed bars to develop continuity. The rods in this detail were post-tensioned. In 1993, Tadros [2] developed a new technique for creating continuity in prestressed concrete bridge girders to avoid post-tensioning. The essence of the system is the creation of continuity at interior supports by coupling top end strand extensions.

3. THREADED ROD CONTINUITY SYSTEM

In 1998, a non post-tensioning TR continuity system was developed by UNL researchers. This method made girders continuous due to deck weight. TR is embedded in girder ends and coupled over piers. The entire system is then continuous due to deck load, SIDL and LL. The Clarks Viaduct is the first bridge in the United States using this continuity system. This design detail works well except for alignment problems. The following figure shows the negative moment reinforcement in the girder line over the pier, which consists of TRs in the girders top flanges and reinforced bars in the deck slab.

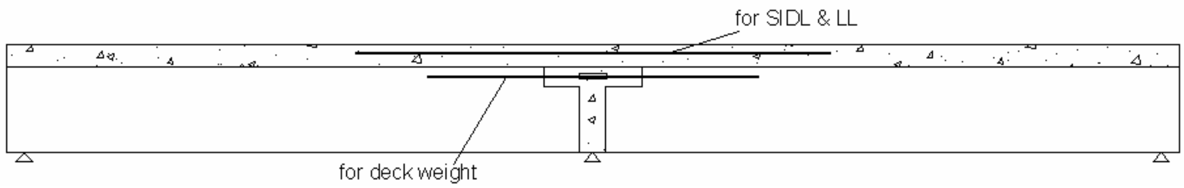


Fig. 3 Threaded Rods in the Girder Top Flanges

Further simplification to this method was investigated by UNL, by placing TR above the girder top flange, leaving 0.75" clear spacing between TR and girder top flanges. This new design simplifies girder fabrication, makes the girders easier to ship and handle, eliminates misalignment of threaded rod ends in the field, and increases negative moment capacity with larger effective depth. Fig. 4 shows the layout of the negative reinforcement.

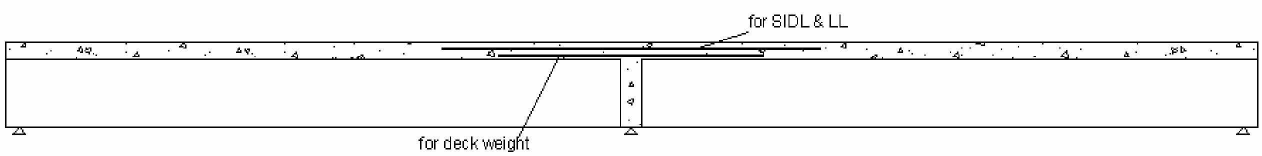


Fig. 4 Threaded Rods above the Top Flange

**ADVANTAGES OF THE PROPOSED CONTINUITY SYSTEM**

Similar to the post-tensioning continuity system, the precast girders in the proposed continuity system are designed as simple spans due to girder self-weight, and continuous for the deck weight, SIDL and LL (which constitutes two thirds of the total loads). The advantages of this new simplified threaded rod method over the current method are:

- It simplifies girder fabrication and makes the girders easier to ship and handle, which leads to lower costs.
- It is more efficient due to the larger depth of the threaded rods.

Table 1 shows a comparison between post-tensioning continuity and TR continuity in terms of cost, need for special requirements, and design of sections.

Table 1 Comparison between Two Continuity Systems

| | Post-Tensioning Continuity | TR Continuity |
|---|---|---|
| Cost, including material and labor | \$3.0/lb × tendon weight | \$1.35/lb × TR weight |
| Girder cross section | The web should be larger than 6 in.; End block for hardware anchorage is necessary. | C shaped bar needs to be embedded in the top flange, no extra concrete involved |
| Special requirements | Requires a specialty contractor to conduct the post-tensioning and special grouting | No post-tensioning or special grouting is required. |
| Design method | Prestressed member analysis | Reinforced member analysis at the negative moment sections; Prestressed member analysis at the positive moment sections |

**TR CONTINUITY STANDARD**

Fig. 5 and 6 show cross sections of the girder line at the pier location in which 10 TRs are shown. The maximum number of TRs which can be installed above the girder top is 10-1 3/8”ϕ for this method.

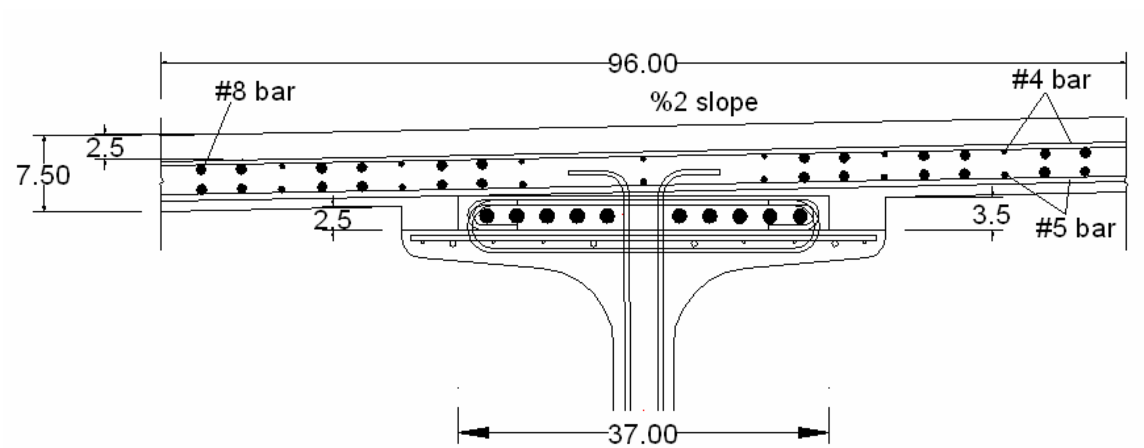


Fig. 5 Cross Section of a Girder Line with Haunch Thickness Greater than 2.5 in.

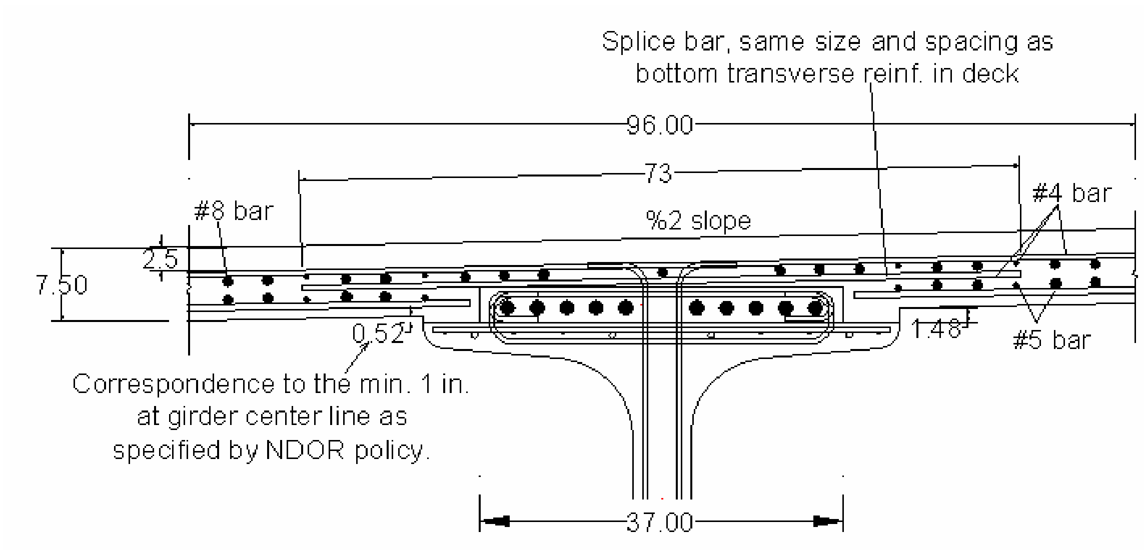


Fig. 6 Cross Section of a Girder Line with Haunch Thickness Less than 2.5 in.

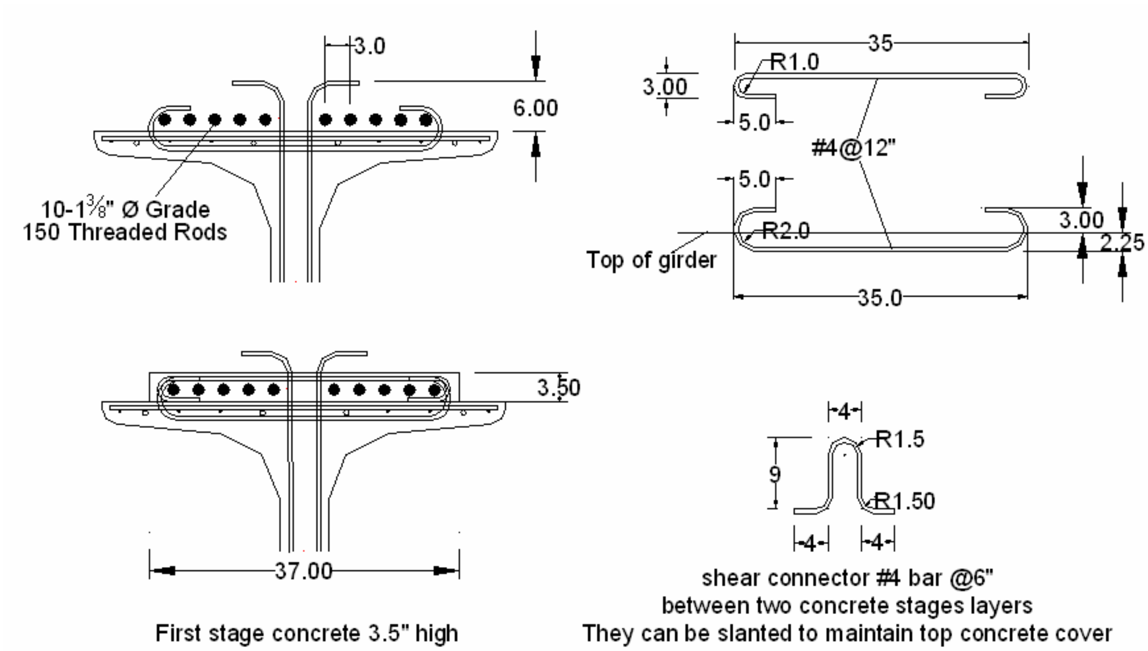


Fig. 7 Simplified Threaded Rods Method Detail

The simplified TR method involves the following steps:
1. Erecting precast girders with C shape bars embedded in the top flanges, and installing the TRs
2. Forming for 37 in. wide and 3.5 in. high concrete on the top flange of the girders around TRs and installing the shear connectors as shown in Fig. 7
3. Installing the hat bars on top of the TRs and tying them with the embedded C bars as in Fig 7

4. Pouring concrete into the form made in Step 2 together with the diaphragm (Stage I pouring)
5. Waiting until concrete is dry, installing deck reinforcement and pouring the deck (Stage II pouring)

## TESTING

In 1998, the UNL research group conducted a full scale testing of the TR continuity system [3] with TR embedded in the top flanges of the girders. The testing was successful and several bridges was built in Nebraska using this system. The Clarks Viaduct Bridge and Platte River East Bridge are examples of these bridges.

The new TR continuity details test was conducted using a set up similar to that of the previous test (see Fig. 8). The testing specimen consisted of two bridge girders connected with the TRs details and supported on a common support at the location of the connection simulating the pier. The load was applied vertically from hydraulic jack at one end of the specimen and supported vertically at the other end. The load was applied twice. The first time was to simulate the moment due to deck weight and the second time was to simulate moment due to the total weight. The first loading was applied after the first stage concrete was cast and the second loading was applied after the second stage concrete was cast.

Fig. 8 Test-Setup

FIRST FULL SCALE TEST – NU 2000

The first specimen was tested on June13th, 2005 at the University of Nebraska structural lab. The specimen consisted of 2-25 ft NU2000 connected with 4- 1 3/8 in. diameter G150 TR. Precast girder concrete strength was 10 ksi, and CIP topping concrete was 7.5 ksi for stage I concrete and 6.4 ksi for stage II concrete. The cross section is shown in Fig. 9 and 10.

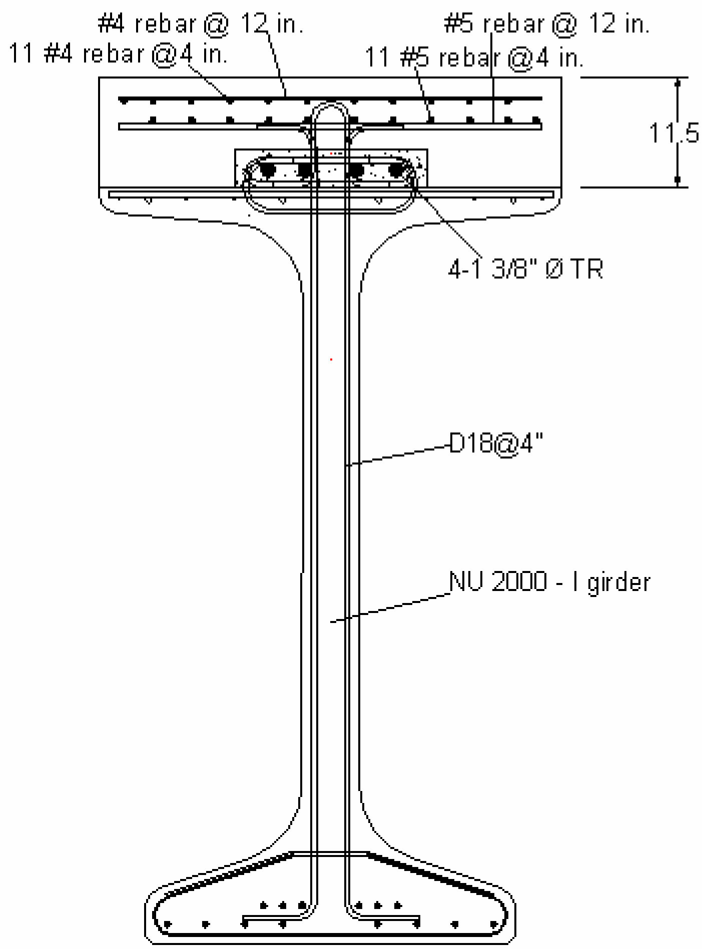


Fig. 9 First Specimen Cross Section Using NU2000

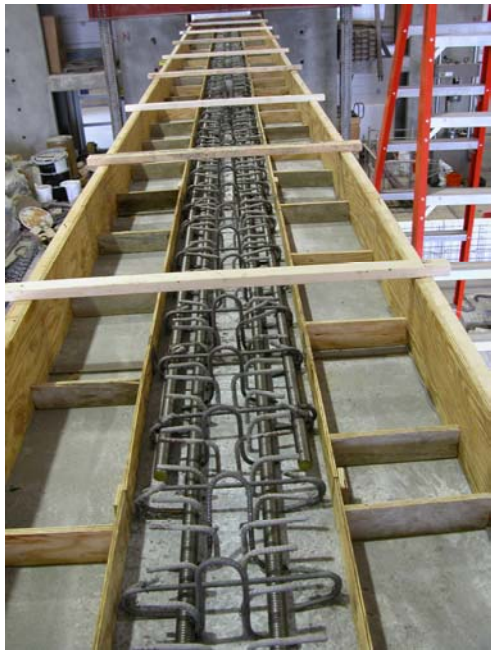

Fig. 10 TR Placed on the I-Girder Top Flange

SECOND FULL SCALE TEST – NU 1100

The purpose of conducting the second test was to test the horizontal shear capacity and the possible delamination with a large number of threaded rods and a shallower girder, as well as to investigate the feasibility of confining the bottom flange at the joint by using a steel tube.

**Testing the Specimen**

The specimen was designed to simulate the forces on the TR connection with a 140ft-140ft span bridge. The bridge girders were NU1100 spaced at 10 ft. The concrete strength was 10ksi for girders and 4ksi for CIP concrete. The bridge was designed using 10 Gr.150 TR above the top flange. This deck slab was 7 in. with 3 in. haunch at pier.

The deflection and TR's stresses in the designed bridge were compared to testing results. Fig. 11 and 12 show the specimen cross section and production, respectively.

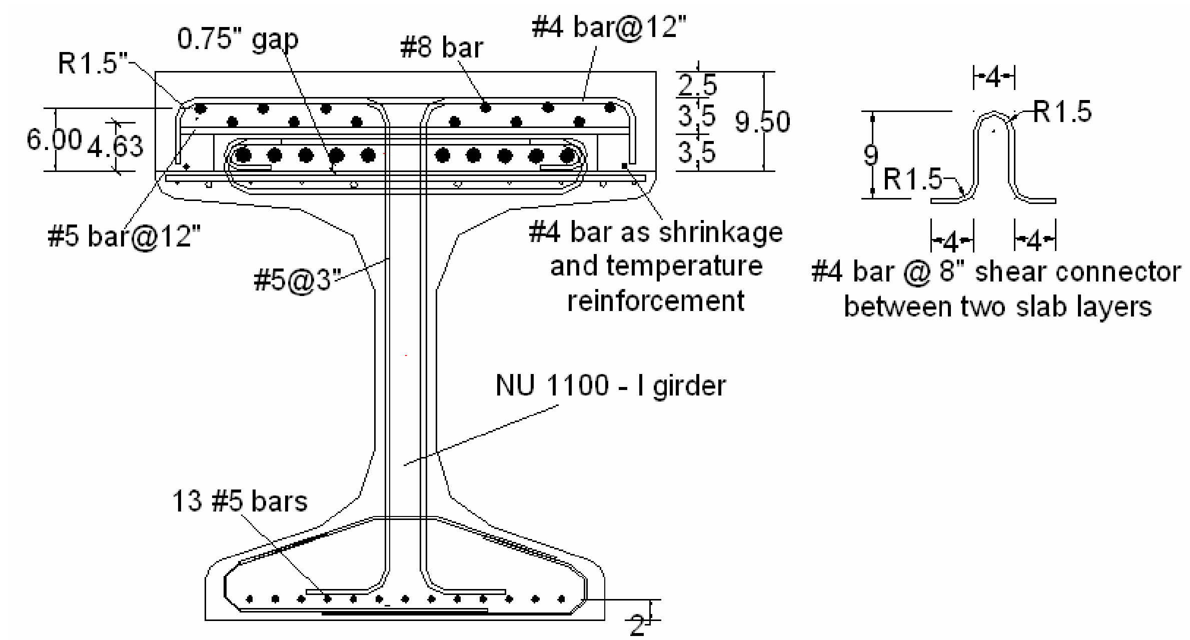


Fig.11 Specimen Cross Section Using NU 1100

Fig. 12 C Shape Confinement Reinforcement in the Top Flange

Welded steel boxes were used for confining the bottom concrete at the diaphragm. The boxes were made of nine 4 in. long steel tubes. The tubes were 0.5 in. thick, 5 in. high, 4 in. wide. The top side was cut into two half 1.5 in. diameter circles for concrete to drop in and fill the boxes, as shown in Fig. 13..

Fig.13 Confinement Steel Box Placed in Five in. Gap between Two Girders

After rods were installed on the girder top flanges, the concrete around TR were poured together with the diaphragm, as shown in Fig. 14.


Fig. 14 Pouring Concrete Around TRs

As soon as the concrete was hard, the specimen was preloaded by applying moment at TR connection from vertical load at the end of the 25 ft long girder to simulate the TR stress of the design bridge. Then a hydraulic jack was locked to keep the load on the specimen. Deck slab reinforcement was installed and CIP deck slab was poured. The specimen was tested for ultimate strength after 28 days of pouring the deck slab.,

**Test Results**

The load in the first specimen exceeded the ultimate capacity with no signs of failure or delaminations. The specimen did not fail due to the fact that the specimen deflection exceeded the jack extension.

In the second specimen, the failure negative moment was higher than what was needed for the design of the bridge being modeled with a specified joint concrete strength 6000 psi. However, compression failure happened at the girder bottom flange at the steel tube location. After testing, the confinement steel box was found to have air voids, which was an indication that steel boxes were not filled with concrete.

There are several test observations and recommendations for future testing:

- The proposed TR continuity method exhibited excellent performance. The girders had good ductility. The new design idea has proven to be very practical.
- The proposed continuity method of TR placed on the girder top flange is very simple for construction.
- There was a good bond between TRs and the surrounding concrete. The tested details provided the required horizontal shear capacity for the bridge being modeled.
- The box steel detail to confine the concrete in the joint between the bottom flanges is not practical due to the possibility of having non-consolidated concrete inside the box.. High strength grout (at least 10 ksi) can be used instead of the steel box confinement details.

## CONCLUSIONS AND RECOMMENDATIONS

The new continuity method utilizing HS TR on the girder top flange with the C shape confinement around them is highly recommended. This new continuity system successfully makes precast bridge girders continuous for deck weight.

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