Connection system of precast beam and column with wet joint for short span bridge

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Abstract. The objective of this study is to see whether or not there is a difference in the flexure behavior between three-supported continued segmental precast concrete beam joined with a cast in place. The formation of the bond is 90° vertical combined with 45° against the horizontal reinforcement, making use of the beam as the formwork. The monotonic pressure was applied constantly at one stage until the beams reached the ultimate. The result of the experiment showed that the flexure behavior of the three-supported continued pre-cast beams joined with the cast in place at the condition before cracks (elastic) had the same trend as that of monolith beam at the base area, as well as at the supporting points. However, before passing the yielding condition (the pulling reinforcer yielded), the precast beam had broken into pieces at the supported area, while the monolith beam had a trend in elastic condition, yielding condition, and ultimate condition. The ductility value of the pre-cast beam was 1.33 (at the base area) and 1.5 (at the supported area). The ductility value of the pre-cast beam was 1.0 at the base as well as at the supported area. This means pre-cast beams reach ultimate before the iron reinforcer yield (the ultimate structure is collapse). The cracking patterns showed that at the joined area the bonding failed to happen between the pre-cast beam and the bonding agent.

1. Introduction

Beam flexural behavior can be known from the amount of the load (gravity, lateral) that works on the beam giving rise to the torque, curvature, deflection, rotation, ductility, and cracked patterns. According to Park and Pauly (1975), curvature ($\phi_{crack}$, $\phi_y$, $\phi_u$) is the response of each concrete strain condition and steel against the effective height of the beam in each load condition (elastic, yield, and Ultimate).

Deflection is a large decrease in the beam due to the load read on the dial gauge. The torque is an analysis of reinforced concrete sections that use data from direct measurements of concrete strain readings and steel strain on the stain meter at each stage of loading. Rotation (angle magnitudes) is round the corners of both edges. The ductility (ductility deflection index) is the ratio of beam deflection when destroyed to beam deflection when the tensile reinforcement reaches melting. A crack pattern through direct observation of the microscope crack detector, with an accuracy of 1 divs = 0.02 mm.
2. Experimental study

2.1 Fabrication of the test specimens
The dimensions of the beams and precast bridge columns are made to observe deflections, torques, curvature, rotation, ductility, and cracked pattern, as can be seen in Figure 1. In addition to the monolith, the method is made as a comparison and the details in Figure 1

![Figure 1](image1.png)

**Figure 1.** The dimension of the Prefabricated Concrete Bridge Portal

Information:
The spindle in the joint area is made ½ the distance from the precast spindle (see detail. B-B)

2.2 Beam testing
Beam testing can be detected from measuring devices mounted on a beam testing scheme and the placement of the strain gauges and dial gauges shown in Figure 2

![Figure 2](image2.png)

**Figure 2.** Position strain gauge and dial gauge

Information:
A = B = D = E = steel strain gauge patch in reinforcement
C = F = concrete strain gauge patch in surface concrete
Ø = Dial gauge
3. Analysis of experimental result

3.1 Load – deflection
The early collapse of beams marked with lending and concrete strain was increased but a constant steel strain and followed by cracks were increasingly widened to enter concrete press areas. The correlation between load and deflection base area for both models of Beams are shown in Figure 3 with an average difference of \( \frac{6}{7.3} = 82\% \). The collapse of the beams on the focus before the melt pull.

![Figure 3. Correlation of Deflection Load in the Base Area](image)

**Table 1. Deflection of Beams in the Base and Support Areas**

| Type of Beam | Location     | Deflection (mm) |
|--------------|--------------|-----------------|
| BM-0         | Support      | 6.00            |
|              | Mid Span     | 8.00            |
| BP-TL        | Support      | 7.30            |
|              | Mid Span     | 8.52            |

3.2 Moment - curvature
The relation between bending moment and curvature are reviewed in the Center and base areas (under centralized load \( P \)) due to centralized loads (\( P \)) and analyzed resulting in concrete strain (\( \varepsilon_c \)), compressed steel Strain (\( \varepsilon_s \)), tensile steel strain (\( \varepsilon_s \)), moment (\( M \text{-kgm} \)) and curvature (\( \Phi \text{-rad/M} \)) shown in Table 2

**Table 2a. Correlation of Moment – Curvature of Cracked Condition, Elastic**

| Type of Beam | Location | \( P \) (kg) | \( \varepsilon_c \) | \( \varepsilon_s \) | \( \varepsilon_s \) | Torque (kgm) | \( \Phi \) (rad/m) | Percent M to BM-0 (%) |
|--------------|----------|--------------|---------------------|---------------------|---------------------|---------------|---------------------|-----------------------|
| BM-0         | Support  | 611.9979     | 0.000420            | 0.000192            | 0.000140            | 141.3120      | 0.004708            | 100                   |
|              | Mid Span | 611.9979     | 0.000343            | 0.000081            | 0.000173            | 217.470       | 0.003969            |                       |
| BP-TL        | Support  | 557.0540     | 0.000094            | 0.000429            | 0.000120            | 134.6253      | 0.004023            | 89.02220776           |
|              | Mid Span | 557.0540     | 0.000095            | 0.000074            | 0.000061            | 207.9250      | 0.001200            |                       |
Table 2.b Correlation of M – Curvature of Cracked Condition, Reinforcement Melting (Yield)

| Type of Beam | Location   | P     | Ec  | ɛs  | ɛe  | Torque  | φ       | Percent M to BM-0 |
|--------------|------------|-------|-----|------|------|---------|---------|------------------|
| BM-0         | Support    | 2699.8660 | 0.002631 | 0.002149 | 0.001296 | 623.4066 | 0.036769 | 100              |
|              | Mid Span   | 2699.8660 | 0.002112 | 0.001367 | 0.001796 | 959.2805 | 0.030062 |                  |
| BP-TL        | Support    | 1985.5950 | 0.001884 | 0.000687 | 0.000675 | 598.4795 | 0.012131 | 90.54421760     |
|              | Mid Span   | 1985.5950 | 0.001884 | 0.001186 | 0.001134 | 885.4954 | 0.033062 |                  |

Table 2.c Correlation of M – Curvature After Cracked, Collapse Condition (Ultimate)

| Type of Beam | Location   | P     | ɛc  | ɛs  | ɛe  | Torque  | φ     | Percent M to BM-0 |
|--------------|------------|-------|-----|------|------|---------|-------|------------------|
| BM-0         | Support    | 2727.3380 | 0.002634 | 0.002199 | 0.001494 | 629.7699 | 0.037177 | 100              |
|              | Mid Span   | 2727.3380 | 0.002164 | 0.001477 | 0.001845 | 969.0415 | 0.030838 |                  |
| BP-TL        | Support    | 2013.0670 | 0.002106 | 0.001069 | 0.000975 | 594.8228 | 0.024423 | 89.81070100     |
|              | Mid Span   | 2013.0670 | 0.003164 | 0.001413 | 0.001134 | 815.2563 | 0.033062 |                  |

From Table 2.b, it can be seen that the beam with the best ability is a monolith beam with a reinforcement (BP-TL) in the crack condition, elastic (crack), having an ability of 90.54% under the monolith beam (BM-0). This situation is also in the melting and collapse condition.

3.3 Load – Rotation

The correlation of load and rotation for all models is shown in Figure 4 and the analysis is shown in Table 3. The tendency of the load and rotation relationships of the two beams as in the load and deflection relationship.

From table 3 It can be seen that the prefabricated beam rotation is greater than the monolith beam. That is, judging from the value of the beam rotation, the monolith beam has a better ability than the precast beam because the rotation reaches the maximum, the precast beam has collapsed due to the unfavorable connection strength.
3.4. Ductility

The deflection ductility index ($\mu$) or displacement ductility is a comparison of the beam deflection at the time of being crushed against the deflection of the beam when the tensile reinforcement reaches melting point. The magnitude of the experimental test index ductility for each model is given in Table 4.

| Type of Beam | Location  | $P$  (kg) | $\phi$ (rad/m) | Percent M to BM-0 (%) |
|--------------|-----------|-----------|----------------|----------------------|
| BM-0         | Support   | 2727,3380 | 0,044612       | 100                  |
|              | Mid Span  | 2727,3380 | 0,037006       | 100                  |
| BP-TL        | Support   | 2727,3380 | 0,039572       | 88,7026915           |
|              | Mid Span  | 2727,3380 | 0,039120       | 85,45347967          |

From Table 4 it is known that failure occurs on precast beams with pass reinforcement because it has the same ductility index equal to 1.0.

That is, for precast beams with reinforcement (BP-TL) in the following condition:
1. On the verge of collapse when the steel of reinforcement reaches melting.
2. Structural collapse occurs brittle.
3. The collapse occurs suddenly after the melting steel reinforcement.

3.5. Crack pattern

In Figure 5, there is a bending crack that continues to go near the axis of the beam and towards sliding bending. Due to the addition of the load, the bending shear crack becomes larger and leads to the concrete compressive area and causes the beams to break. It can be concluded that the monoliths beam crack pattern (BM-0) is an ideal model for the comparison of precast beams.

In the precast beam with reinforcement (BP-TL), occurs the same crack with BM-0, which is a bending crack that continues towards the near-axis of the beam and towards the sliding, forming a flexural shear crack. Due to the addition of the load, the bending shear crack becomes larger and leads to the concrete compressive area and caused the beam to become crushed. On the unfractured area, there is no crack, indicating that the reinforcement system that is used does not affect the flexural strength of the beam. Cracks occur in the area of the connection line, starting from the top side, radiating to approach the axis of the beam, toward the horizontal (sliding crack) after the reinforcement is approaching yielding.

| Table 4. Deflection Ductility Index ($\mu$) |
|------------------------------------------|
| Type of Beam | Location  | $\mu$ (x0,01 mm) | $\mu$ (x0,01 mm) | $\mu$ (ductility) |
|--------------|-----------|------------------|------------------|-------------------|
|              | Collapse  | Beam            | Yield Strain     |                   |
| BM-0         | Support   | 300              | 200              | 1.5               |
|              | Mid Span  | 400              | 300              | 1.333333333      |
| BP-TL        | Support   | 366              | 360              | 1.016666666      |
|              | Mid Span  | 208              | 200              | 1.04              |

| Table 5. Beam Crack Width |

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From Table 5 It appears that the smallest crack width on the BP-TL type of experimental beam is 0.92 mm (supported) and 0.86 mm (mid span) above the width of the crack beam monoliths (BM-0).

The experimental results above which consist of load and deflection relationships, moment and curvature relations, load and rotation relationships, ductility, crack widths show that:

1. Monolith beams (BM-0) have the level of quality as planned to withstand gravity loads.
2. Beam precast with reinforcement (BP-TL) have an average quality of 87% when compared to the results of plans, theoretical and monolithic beams, and have sufficient ability to withstand gravity loads, when viewed from deflection ductility and crack width. This means that the load that works on precast is quite safe when reduced by 80% of the load acting on a monolith beam.

4. Conclusion

Based on the results of experimental studies on the design of the connection system between the beam and precast column on the structure of the short span bridge with a cross-section connection method when compared with conventional systems (monoliths) it can be concluded as follows.

1. In the system of beams and non-precast columns (monoliths) have a good ability to withstand the gravity load when viewed from the deflection, curvature, rotation and deflection ductility of 1.5 (on the bar area) and 1.33 (on the base area).
2. In precast specimens with the connection system between the beam and precast column on the bridge structure shows behavior that resembles the behavior of monolithic specimens. A striking difference in the amount of load that occurs, where the ability of the precast beams and columns has a capability of 87% when compared to conventional systems and has a deflection ductility of 1.0 (should be > 1)
3. A series of precast beams and columns have conditions: (1) on the threshold of collapse before the reinforcement reaches melting and (2) The collapse of the structure occurs in a way.
4. The failure of the Precast column and beam on the connection area is caused not due to the reinforcement system but due to the connection material because there is no good unity between precast and the connection material (shear cracking occurs). The proposed advice is the need for advanced research on the connection material so that it has a good ability (monoliths) in uniting precast concrete.

Monolith beams (BM-0) have the level of quality as planned to withstand gravity loads.

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