

# Experimental Study on Precast Beam-Column Joint Method using Fiber Reinforced Plastic Sheet (CFRPS)

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## Abstract

Precast concrete was the major material on civil structures, due to the quality, short time construction and green construction. Conventional connection methods of precast beam-column, done by cast the joint in site (wet connection), but difficult to found the connection as strong as the monolith connection. Research of Carbon Fiber Reinforced Plastics Sheet (CFRPS) on precast beam-column connection have been presented where maximum capacity of the CFRPS connection, C1B0, was 21.8 kN or 90.6% to the monolith connection, 24 kN [5]. This proposed research done to upgrade the capacity of CFRPS connection. New specimen created to handle the weakness of the connection. C2B3, was the specimen of 150mmx200mmx1500 mm precast beam and 150mmx450mmx2750mm precast column, connected by two layers of CFRPS U-shape supported by three belts tested so far. Test result rose the higher capacity than monolith and C1B0. The C2B3 was 33.0 kN of loads capacity or 137.5% respectively to the monolith capacity.

**Keywords:** Connection, dry connection, CFRPS, U-shape, belt

## INTRODUCTION

Manufacturing stage of precast element is done at the factory. Casting components running under controlled of materials and cast in to the required mould of shape and sizes. While casting, the vibrator is used to vibrate the concrete paste aim to removes any honeycombing inside the components. After 24 hours of casting, the casted components were released from the mould and transported to the curing tanks or steam curing. After complete the fabrication stages, the components would transport to the site of construction using heavy trucks. At the construction site, erection will be done using cranes with skilled employment and then assembly to be a monolith structure. So, the construction procedure includes fabrication, transporting into the site and assembling the components.

Due to the procedures, precast concrete gave advantages such as high quality, short time construction and green construction [1, 8]. Other side, precast concrete also gave the disadvantage such as, need heavy equipment and skill employment, breakages of members while handling and transportation, and the difficulty to make the connection precast members as strong as monolith connection. The problem leads the structure to be a non-monolith construction.

There are two ways to assembly the members, wet connection and dry connection. Wet connection done using grouting cement mortar at the point of joint. Dry connection done without grouting, but used mechanical joint, melting and others [1, 4]. This paper will present the dry connection of precast beam and column using CFRPS where the members connect in a wrap of CFRPS U-shape and support by three belt at the end and middle of the U-shape. Passed research also have been using CFRPS on beam column joint but as a strengthening material and not as a connection material [1, 2, 3, 6, 7, 8, 10] phase.

## Connection Beam-Column Precast

Based on the procedures of components assembly, the connection can be shared into the wet connection (wet joint) and the dry connection (dry joint). The principle of connection designed is easily to implement as simple as possible but required to the connection criteria such as strength, ductility and energy absorption. Good precast connection is a connection that can behave as a monolithic connection. Choosing of connection type based on considerations of ease implementation, low price, high quality and short duration of installing.

Dry Connection is applied with using of an iron plate or bolt as a connector between precast concrete components. The use of these methods should be analyzed with computer models due to the behave of the joint, weather it could behave as a monolith joint. The wet connection is applied with casting the overlap of reinforcement at the end of each precast concrete components. Wet connection is highly recommended for

buildings in earthquake prone areas as it can make the individual components into a monolith precast concrete.

There are three main types of precast connections, namely:

1. Typical Joint System, which is a type of dry connections that use mechanical connectors such as elbows, connecting plates, channel bars, anchor, bolts and dowel bars. The connection then grouting with mortar filler.
2. Emulative Joint System, which is a type of wet connection with the reinforcement of overlap and casted in place to form a monolithic connection between precast elements.
3. Mechanical Joint System, which is a type of dry connection with bolts or steel connectors are placed at the ends of the elements to be joined. Connection solved by tightening bolts or welding [4]

The main parameters need to be considered from a connection are:

1. Strength, which is the maximum force that can be carried of the joint. Things that need to be taken is calculating to get the maximum load, collapse mode and mechanism of connection resistance and the properties of the connection itself.
2. Ductility, which is the ratio of maximum plastic deformation (ultimate displacement) to theyielding limit (yield displacement). Ductile connection is divided into:
  - a. High ductility, which is joint with displacement ductility ratio of 4.5
  - b. Medium ductility, which is joint with displacement ductility ratio of 3.0
  - c. Low ductility, which is joint with displacement ductility ratio of 1.5
  - d. If the displacement ductility ratio below 1.5, the connection is classified as a brittle connection [4]

This classification refers only to the ductility of the connection and not to the overall ductility of the structure.

3. Deformation (displacement), which is the maximum deformation in a state of collapse or functional boundaries.
4. Decay, which is strength loss through the load cycles compared to the force level.
5. Damage (damage), which is esidual deformation at unloading compared to the maximum displacement and/or details of rupture [4].

In order to protect the concrete edges of column and beam against spalling, due to the concentration of stresses under the flexural deformation of beam and column, proper provisions shall be adopted. These provisions shall prevent the application of strong pressures on a strip of the bearing area close to the corner. The width a of this strip should correspond to the concrete cover to the confining reinforcement and indicatively should be not lesser than 20 mm. Possible solution that can be taken are with a chamfered edge, with the

edge protected by a cold formed steel angle properly anchored to the column, with an interposed deformable rubber pad and with an interposed rigid steel plate.

### EXPERIMENTAL PROGRAM

The experimental program includes a total of two specimens of precast RC beams and columns that are connected by U-shape CFRPS, C1B0 and C2B3. C1B0 is the connection using U-shape without belt as shown in Fig. 1 and C2B3 is the connection of two layers of CFRPS U-shape supported by three belts as shown in Fig. 2. As a control specimen, used MN, the monolith connection of beam-column as shown in Fig. 3. All the specimen tested, under the setup as shown in Fig. 4, caption after tested.

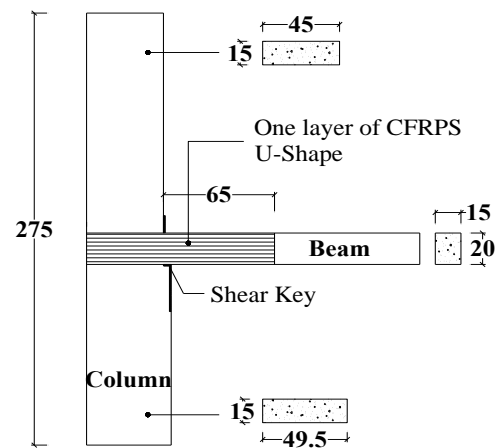


Figure 1: Typical of specimen C1B0 (units: cm)

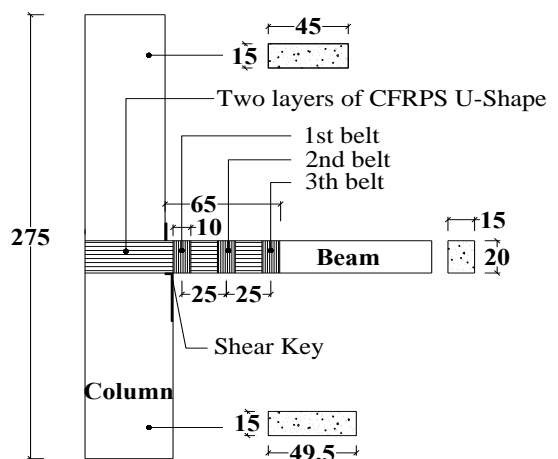


Figure 2: Typical of specimen C2B3 (units: cm)

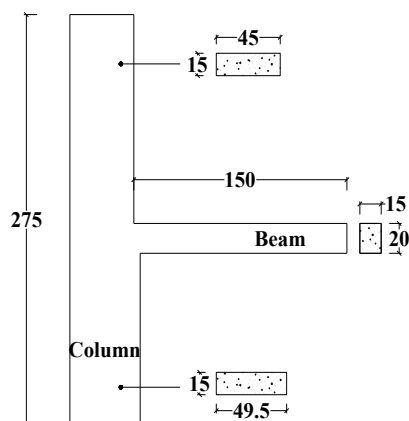


Figure 3: Typical of control specimen MN (units: cm)



Figure 4: Test setup

## RESULTS AND DISCUSSION

All the test result of specimens summarizes in Table 1.

Table 1. Test result of the specimens

| No. | Specimen | Maximum Loads |            | Displacement |            |            | Ductility |            |                  |
|-----|----------|---------------|------------|--------------|------------|------------|-----------|------------|------------------|
|     |          | (kN)          | Ratio (%)* | Max. (mm)    | Ratio (%)* | Yield (mm) | Value     | Ratio (%)* | Category         |
| 1   | MN       | 24            | 100        | 44.7         | 100        | 10.49      | 4.3       | 100        | Medium ductility |
| 2   | C1B0     | 21.8          | 90.6       | 31.4         | 70.2       | 7.79       | 4         | 93         | Medium ductility |
| 3   | C2B3     | 33            | 137.5      | 50.56        | 113.1      | 10.785     | 4.7       | 109.3      | Medium ductility |

\* compare to the monolith connection

Table 1, shown that C2B3 was better than MN in behavior of connection. Load capacity of C2B3 was 33.0 kN respectively, pass over the load capacity of monolith connection. The used of two layers U-shape and three belts (C2B3) success in upgrading the load capacity 137.5% respectively, compare to the monolith connection. Even the displacements 113.1% respectively and ductility 109.3% respectively, compare to the monolith connection. Increasing of load capacity caused by no debonding occur as like as happened on C1B0. The U-shape and precast concrete composited by epoxy, so the strength of bonding depends on concrete, epoxy and CFRPS characteristics. While the loads applied, specimen suffered by tensile stress and handled by the bonding stress between U-shape and precast concrete. As the loads increased, the stress also increased and on the maximum load the specimen failure.

According to Table 1, displacement of C2B3 was 50.6 mm respectively, pass over the monolith connection, 44.7 mm respectively, indicated that C2B3 more flexural than MN. On the monolith connection load was handled by large section of concrete but with little of tensile modulus. Different with C2B3, where loading handled by little section of epoxy-CFRPS but high of tensile modulus. Due to the test result of Table 1, the rigidity of C2B3 was higher than MN, so C2B3 had a big capacity of loads that make it reached a big displacement too.

Other side, ductility of C2B3 was 4.7 respectively also pass over the MN ductility, 4.3 respectively. Case indicated, C2B3 more ductile than MN. The C2B3 had maximum displacement higher than MN, and both had near similar of yield displacement. It means that range of maximum and yield displacement of C2B3 was longer than MN. Surely, C2B3 could gave higher ductility than MN, because ductility is the ratio of maximum displacement to the yield displacement. As known than displacement ductility of MN was 10.5 mm and C2B3 10.8 mm. respectively. Ductility of MN is medium ductility and the C2B3 is high ductility [4].

Failure mode of C1B0 caused by debonding of U-shape as shown in Fig.5. The caption shown that debonding occur as long as the U-shape was not handled as the effect of no belts supported. Debonding initially at the point of joint and then run slowly into the way of beam and column while the loading increased. Finally, under 21.8 kN of loads U-shape was in a big trouble of debonding. At the time, displacement was 31.4 mm. Even the concrete cover was also corrupted, as the effect of lower quality of concrete to the epoxy.



Figure 5: End of the failure of C1B0

Failure mode of C2B3 is not by debonding of U-shape in the area of beam but caused by concrete cracked. Debonding stress was handled by the three supported belts as shown in Fig. 6. Other side, failure of C2B3 also caused by partial cut off of the U-shape at the column area. The cut off happened beyond the maximum loads and initially by partial debonding in the area of column. This problem could be repair using high strength concrete and more thick of U-shape.



**Figure 6:** End of the failure of C2B3

## CONCLUSIONS

Due to the discussion, concluded that C2B3 was better than monolith connection, shown in several behaviors. Load capacity, displacement and ductility had passed over the monolith connection's. So, the connection using CFRPS is probably use as a dry connection of precast beam column. Beside the performance, the proposed connection is also easy and simple to apply.

## SUGGESTION

Research about long life of the connection beyond variety of environment is needed.

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