Continuous beam and slab behavior in composite bridge support area without using expansion joint

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Abstract. In a conventional bridge system, there is an expansion joint and a dilatation between superstructure and substructure. If it is not maintained properly, the damage can occur around the expansion joint and on the support. To overcome this problem an alternative type of structure is needed to provide better behavior in the support area. In this study, the type of continuous bridge without an expansion joint is used. Different from continuous bridges in general, in this case, two bearings are used on the pier to facilitate execution. Tests are conducted on two specimens with different types of connection so it is expected to give a significant difference of connection behavior. In the implementation of the test, gravity load is given with a displacement control method. The test results obtained that the ability to receive load of composite beam with steel profile connection has a higher capacity than composite beams with reinforced concrete connection. As for the stiffness value, composite beams with reinforced concrete connection have a higher value than the composite beam load with steel profile connection.

1. Introduction
In a conventional bridges, steel or concrete girder is positioned as a simple beam. The advantage of the system is an easy construction method. In that bridge system there is an expansion joint and a dilatation between the upper structure and the lower structure. If not treated properly the damage can occur around the expansion joint and on the support. On the other side, expansion joints can cause inconvenience to road users [1]. The most widely used method to overcome this problem is an integral bridge system, which is a single span bridge or many spans built without movable deck joints on the pier or abutments. This bridge has superior earthquake performance [2] [3]. The first integral bridge was Teens Run Bridge, built in 1938 in Eureka, Gallia Country, Ohio [4]. Besides, there is a semi-integral bridge. In this system the upper structure is permitted to move independently of the lower structure [5] and another system structure is the use of a link slab. It is necessary to choose the bridge type by considering many things. Bridge span is limited in relation to the weight and length constraints of structural components when transporting to the construction site [6]. The type of bridge developed in this study is a continuous bridge type. Different from continuous bridges in general, in this case two bearings are used on the pier to facilitate execution. For the development of the bridge system, especially in the support area, it is necessary to conduct testing in order to obtain good structural behavior and be able to overcome problems that occur on bridges with conventional systems.
2. Methodology

2.1 Model of Bridge and Specimen

The prototype bridge structure used as the object of the study is a composite girder with two spans of 20 m long. The dimension of the prototype structure is based on the Standard of Composite Girder with a bridge span between 8 m to 20 m [7]. The specimen model is designed using a 1:2 scale (half scale), which means that the entire length dimension of the specimen is half the length dimension of the prototype structure [8].

![Prototype Structure and Moment Section due to Gravity Load](image)

Preliminary analysis of the prototype structure was carried out by assuming composite beams as cross-section beams arranged through the transfer of concrete material into steel with concrete wing width divided by modular ratio \( n = \frac{E}{E_c} \) [9]. The extreme values of positive and negative factored moments in Figure 1 (b) are 957.52 kN.m and -1430.36 kN.m, respectively, indicating that if the same steel profile dimensions are used, the potential damage due to extreme loads occurs in the profile connection area. Therefore testing is focused on taking sub assemblage in the support area. The test object is the sub-assemblage from the support part as stated in Figures 2 and 3 for specimen 1 and Figure 4 and 5 for specimen 2.

![Girder Support Sub Assemblage with Steel Profile Connector](image)

![Slice A](image)

![Girder Support Sub Assemblage With Reinforced Concrete Connector](image)

![Slice B](image)
2.2 Test
In the model structure, the profile used is IWF 300-150-6.5-9, with a plastic moment valued at 145.04 kN.m. If over-steak L (Figure 2 and 4) is used along 900 mm, the plastic moment will be reached at P test load (representing dead load and live load) of 159.7 kN which works on both ends of over-steak L. In the course of testing, gravity load is given with a displacement control pattern in order to obtain the relationship between load - displacement in the softening level so the load capacity ($P_{\text{max}}$) and displacement capacity ($\Delta_{\text{max}}$) of the specimen is known.

2.3 Instrumentation
The relationship between load - displacement in non-linear conditions is arranged by measurement of displacement due to P load using LVDT. To obtain the relationship between stress-strain material in non-linear conditions used post yield type strain gauge installed on steel profile and reinforcing steel.

![Figure 6 Position of Strain Gauge and LVDT (Steel Profile Connection)](image)

![Figure 7 Position of Strain Gauge and LVDT (Reinforced Concrete Connection)](image)

3. Results and Discussion

3.1 Test of Tensile Steel and Compressive Concrete
Test of reinforcing steel material is conducted at the Bandung Road and Bridge Research and Development Laboratory. The purpose of tensile test is to obtain the characteristics of the material in the form of a stress-strain relationship. The results of steel reinforcement and steel profiles tensile test shown in Figure 8.

![Figure 8 Relationship of Stress-Strain Steel](image)
The compressive concrete test is conducted at the Bandung Road and Bridge Research and Development Laboratory. The compressive test was conducted at the age of 3 days, 7 days, 28 days and at the time of structural testing. Compressive concrete specimen. The compressive test result is shown in Table 1.

| No  | Specimen        | Diameter (mm) | Length (mm) | Compressive Force Cor (kN) | Compressive Strength (N/mm²) |
|-----|-----------------|---------------|-------------|---------------------------|-----------------------------|
| 1   | Age of 3 days   | 150           | 300         | 286.07                    | 16.19                       |
| 2   | Age of 7 days   | 150           | 300         | 433.68                    | 24.54                       |
| 3   | Age of 28 days  | 150           | 300         | 562.13                    | 31.81                       |
| 4   | Age of 51.53 days | 150         | 300         | 567.65                    | 32.22                       |

3.2 Composite Beam Structure Test

The structure test of two composite girder specimen was conducted after the concrete age was 28 days. Two days of testing are required including the set up for each specimen. From the test results, it is expected to know the behavior of the structure system.

3.2.1 Relationship of Crack Load. The initial crack load due to monotonic load on specimen 1 and specimen 2 is 17.5 kN. At specimen 1 the maximum load is unknown because when the test does not reach the collapsed load, the last load that can be given is 190.35 kN while for the specimen 2 the maximum load is achieved at a load of 151.99 kN. The initial crack in specimen 1 (Figure 9) occurred at 10 minutes 55 seconds after the start of the test, while in specimen 2 (Figure 10) the initial crack occurred at 8 minutes 34 seconds after the start of the test.

3.2.2 Relationship of Deflection Load. From the test result, it can be seen the graph of load-deflection relationship that occurs on the beam, the graph is showing the deflection at yield and at the maximum load for each specimen. In addition, it can be known the value of stiffness as well. Graph of load-deflection relationship on each specimen shown in Figure 11.
Figure 11 Relationship of Load-Deflection Specimen

From the graph of load-deflection relationship above, the stiffness value of composite beam specimen can be calculated. The following values of composite beam specimen stiffness shown in Table 2 and Table 3.

Table 2 Initial Crack Stiffness

| Specimen | Load (kN) | Deflection (mm) | Stiffness (kN/mm) |
|----------|-----------|-----------------|-------------------|
| Specimen 1 | 17.5      | 0.95            | 18.42             |
| Specimen 2 | 17.5      | 0.91            | 19.23             |

Table 3 Stiffness after Cracking

| Specimen | Load (kN) | Deflection (mm) | Stiffness (kN/mm) |
|----------|-----------|-----------------|-------------------|
| Specimen 1 | 116.97    | 15              | 7.80              |
| Specimen 2 | 147.67    | 15              | 9.84              |

3.2.3 Relationship of Stress Strain. To find out the strain, strain gauge has been installed at several points of the specimen, namely the reinforcing steel and IWF steel profile (Figure 6 and Figure 7). After testing the structure of the composite beam, it can be seen the graph of stress-strain relationship that occurs in each specimen. For more details, the graph of the stress-strain test can be seen in Figure 12 and Figure 13.

Figure 12 Relationship of Stress-Strain Specimen 1
4. Conclusion
From the result of the tests that have been done, some conclusions can be drawn as follows:

1. The ability to receive load of composite beam with a steel profile connection is higher than composite beams with reinforced concrete connection with values of 190.35 kN and 151.99 kN respectively.
2. Composite beams with reinforced concrete connection have a higher stiffness value than composite beams with a steel profile connection with a ratio for initial crack conditions of 1.04 higher and for after crack conditions of 1.26 higher.

5. References
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