

Experimental Study on Mechanical Coupler Splices in Reinforced Concrete Beams Under Cyclic Flexural Loading

ABSTRACT

This study presents an experiment on the utilization of rebar waste as a mechanical coupler splice material on the reinforced concrete beam. The purpose of using rebar waste is to save costs in a construction project. Experiments were conducted with 3 test specimens, which are reinforced concrete beam without coupler splice (B-13NC), reinforced concrete beam with 19 mm diameter coupler splice (B-13C19) and reinforced concrete beam with 22 mm coupler splice with welding (B-13C22W). Each coupler splice was installed in the plastic hinge area of the beam to determine the maximum capability of the coupler splice. Tests were conducted under cyclic flexural loading on the reinforced concrete beam.

The results showed that the 22 mm diameter coupler splice at B-13C22W has almost the same strength as the reinforced concrete beam without coupler splice (B-13NC). However, the 19 mm diameter coupler splice has a significant decrease in strength, which is more than 30% of the strength of the reinforced concrete beam without a coupler splice (B-13NC). This experiment also shows that the utilization of a coupler splice in the reinforced concrete beams results in a decrease in structural ductility.

Keywords: Reinforced Concrete; Coupler; Ductility; Stiffness; Strength.

1. INTRODUCTION

The beam is a structural element that is subjected to forces acting transversely to its axis, resulting in bending moments and shear forces span-wise [1]. As a crucial component of structural frameworks, beams function to channel loads from floor plates to vertical supports such as columns. Typically, beams are cast monolithically with slabs, and structural reinforcement is placed either at the bottom or both at the top and bottom. The primary stresses experienced by beams include compressive and tensile forces, which are attributed to the influences of bending or lateral forces [2].

The main reason for the large amount of rebars waste in a structural project is that there is rebars that are not in accordance with specifications and mistakes in cutting steel rebars[3].

Research has been conducted on mechanical coupler in test specimens of rebar with diameters of 20 mm, 25 mm, and 32 mm. The test outcomes suggest that the application of

mechanical coupler splice exhibits a strength comparable to uninterrupted rebar, with failures occurring outside the joint area[4].

Experimental has been conducted on reinforced concrete beams with two types of coupler connections: the tapered coupler and the parallel coupler. The tests revealed a reduction in flexural strength of 3-8% in reinforced concrete beams with either type of coupler splice as compared to beams without such connections, indicating that the inclusion of coupler splice does not result in a significant decrease in performance[5].

In this research, an experiment will be conducted on the utilization of waste rebar steel, which is no longer reusable, as a material for mechanical coupler splice in reinforced concrete beams. The use of waste rebar steel is expected to help save on construction project costs.

2. MATERIAL AND METHODS

2.1 Specimen Details and Parameters

This research tested 3 test specimens of reinforced concrete beams with each having the same size and with the same concrete quality. The difference between the 3 specimens is the rebar splice model dimension. The purpose of the rebar splice placed in the plastic hinge area is to compare the ability of the specimen with the coupler splice and the specimen without the coupler as in Table 1.

Table 1. Types of joints in the RC beams

Number	Specimen	Splice Coupler Model
1	B-13NC	Without Coupler
2	B-13C22W	Coupler $\varnothing 19$ mm without welding
3	B-13C19	Coupler $\varnothing 22$ mm with welding

The coupler splice is made of waste of rebar with a length of 60 mm and then the pieces of steel rebar are drilled with a diameter of 13 mm, the size of which is adjusted to the rebar that will be given a connection. After the rebar is drilled, a thread is made on the inner surface of the coupler splice and for the steel rebar to be connected, a thread is also given on the outer surface. Details of the coupler splice dimensions can be seen in figure 1.

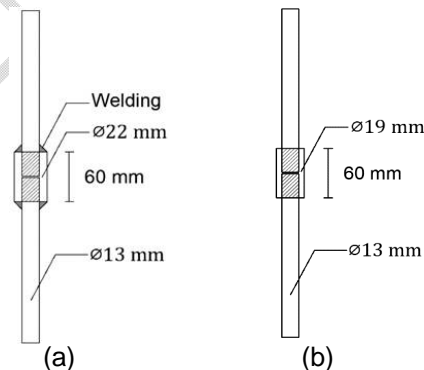


Fig. 1. (a) Coupler splice details on B-13C22W (b) Coupler splice details on B-13C19

The test specimen is a reinforced concrete beam with dimensions of 200 x 300 mm with a height of 1350 mm. The beam uses 13 mm diameter rebar and uses 10 mm rebar. The coupler splices are placed on the plastic hinge beam so as to maximize the ability of the coupler splices. In order for reinforced concrete beams to be tested under cyclic load, a concrete foundation that is directly connected to the beam is required. The reinforced

concrete beam has a foundation with a cross section size of 1200x700 mm with a concrete foundation thickness of 350 mm. Calculation of flexural and shear reinforcement in accordance with standard test methods[6]. Details of reinforcement and dimensions of test objects can be seen in figure 2.

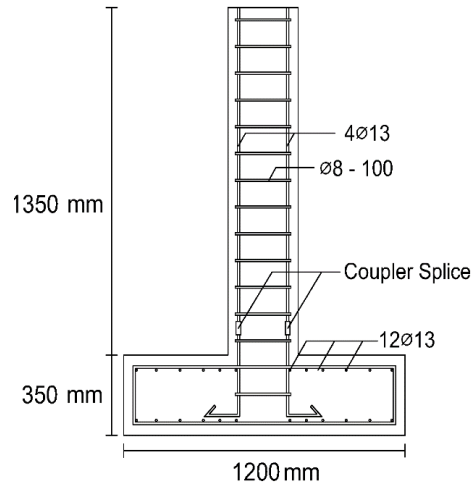
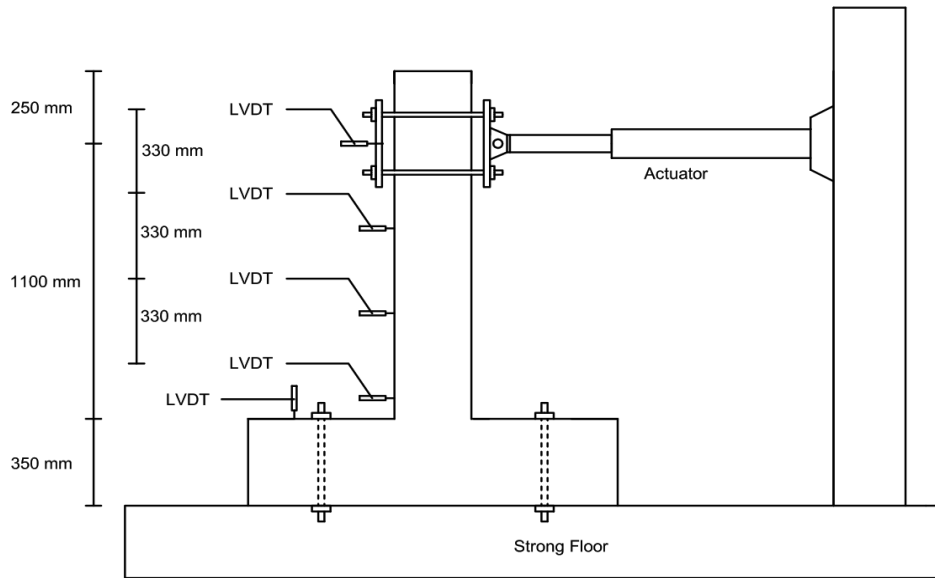


Fig. 2. Rebar details and location of coupler splice on test specimens

2.2 Setup of Test Models

Testing was implemented by applying lateral loads using a cyclic method to determine the capacity of coupler splice under seismic loads. Six anchor points were created on the foundation, where nuts and bolts were installed to secure the specimen to the strong floor, ensuring the test object did not lift during cyclic loading. An actuator with a capacity of 25 tons was used to apply push and pull loads to the beam. The loading point was located at 1100 mm from the bottom end of the beam, as shown in figure 3.

The experiment utilized 5 Linear Variable Differential Transformers (LVDTs) installed horizontally to describe the overall displacement condition of the beam specimen during cyclic loading, and one installed vertically to ensure that the foundation did not lift during the cyclic loading.



The load application is done gradually and sufficiently slow so that the effects of dynamic inertia and strain rate effects on the material are ignored [7]. The cyclic loading curve can be seen in figure 4. By observing this curve, testing can be conducted by gradually applying push and pull loads with a certain drift ratio. The drift ratio is the ratio between lateral deflection and the height of the lateral load. The drift ratio can be calculated with the following equation below.

$$\text{Drift ratio} = \Delta/L \text{ (\%)} \quad (1)$$

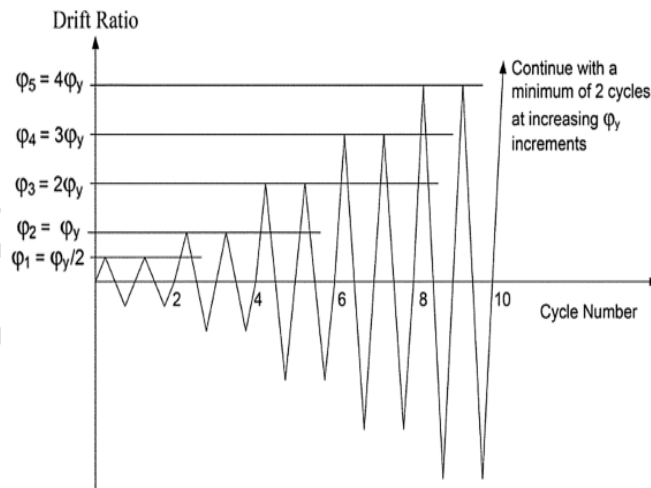


Fig. 4. Cyclic loading protocol

Cyclic loading tests on beam specimens were tested at the structural laboratory, Faculty of Engineering, GadjahMada University. Figure 5 is an overview of the test setup.

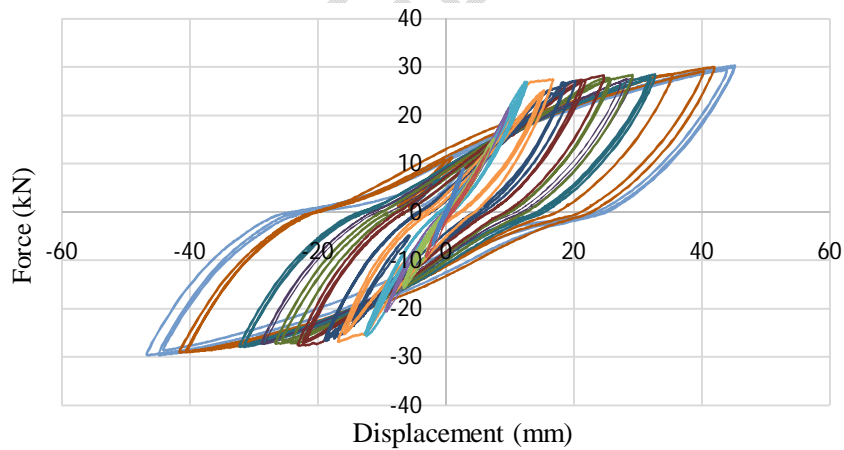


Fig. 5. Setting of test specimen

3. EXPERIMENTAL RESULTS

3.1 Hysteretic Loops

The hysteretic loops curves of test specimens B-13NC, B-13C22W and B-13C19 which are the ratio between load and displacement of the test results can be seen in figure 6. All loops in the test specimens show ductile behavior in the plastic hinge of the beams, where the structure does not show excessive strength degradation with increasing displacement. The area inside the loops shows that the energy dissipated by the plastic hinge is quite large.



(a) Hysteretic loops curve B-13NC