The Effect of Construction Joint on Behavior of Reinforced Concrete Dapped End Beam

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Abstract. This research aims to investigate experimentally the attitude and performance of hybrid reinforced concrete Dapped End Beams. The study consists of testing thirteen specimens, all of which have similar dimensions (1000 * 120 * 250 mm). Three specimens were considered as control specimens (non-hybrid concrete) and the other specimens were strengthened in (nb and D-region) by using two types of concrete (high-strength concrete, steel fiber reinforced concrete) and with construction joint. The experimental results showed that the presence of the construction joint in the reentrant corner of specimens with non-hybrid normal concrete and specimens with non-hybrid high strength concrete leads to a decrease in strength of about (33%) and (6%), respectively and does not lead to a decrease in strength in the concrete specimens reinforced with steel fibers. Also, the presence of the construction joint in the D-region in normal non-hybrid concrete specimens and non-hybrid high strength concrete specimens as well as non-hybrid steel reinforced concrete specimens leads to an increase in the strength of about (0.5%), (10%) and (1%), respectively.

Keywords: Dapped End Beam, Hybrid Concrete, High-Strength Concrete (HSC), Steel-Fiber Reinforced Concrete (SFRC).

1. Introduction

The dapped-end beams with reentrant corner are the precast members of concrete structures provides an economical and efficient means of connecting pre-cast to pre-cast and pre-cast to cast in site concrete members. The Features of using reinforced concrete dapped-end beam are, increase the lateral constancy of the structure elements at the support and to decrease the overall height of the precast concrete floor. Several researchers have studied the behavior and strengthening of Dapped end beams. Mattock and Chan [1] were one of the researchers examined "Eight dapped ends were tested, four being exposed to vertical load only, and four to a combination of vertical and horizontal loads". Liem [2] studied “four rectangular beams having both end dapped” these beams have the same dimensions and reinforcement details as the "Mattock models", except for replacing the horizontal reinforcement with inclined reinforcement. Two thin stemmed dapped end beams with different forms and reinforcement by using STM models studied by Peter [3]. Mohammed [4] By using the nonlinearity ANSYS programs, these samples were analyzed taking two values for the compression strength, “a/d” ratio and the main bars and examining their effect on two samples of dapped-end beams. Mohammed and Mahmoud [5] was made comparisons between three dapped-ends girders by using nonlinear finite
element models ANSYS program “numerical results” and experimental results. Huang [6] proposed alternative strengthening method by using externally bonded FRP composites were schemes with (0°/90°) wrapping way. Tan [7] studied strengthening of dapped ends by using many practical methods of strengthening with different FRP composites. Huang and Nanni [8] studied the behavior of DEB that strengthened with two ways, internal steel bar and external bonding (CFRP) laminates. Qasim [9] studied 14 specimens to ‘investigate practically the attitude of self-compacting reinforced concrete DEBs strengthened with CFRP sheets and, then theoretically by ANSYS 15.0 software’. Gold [10] test theoretically the methods FRP strengthening on the double tees dapped end beams such as: external posttensioning, steel plate and steel angle bonding and external bonded FRP reinforcements. Dăescu [11] tested seventeen models to estimating the strengthening systems considering the ultimate capacities and the failure modes. The variables considering in this research are the type of composite materials and their orientation of strengthening sketch by numerical simulations. The dapped end beam applications are usually used in bridge girders [3], parking structures and strap footings. RC-DEB are comforted at end parts and supported by columns [2], cantilevers and T-beams or corbel as shown in figure (1).

2. Experimental Work

2.1 Specimens Description

Thirteen of reinforced concrete dapped end beams were tested beneath the effect of one point loading in this study. The dimensions of all beams were (120mm) width, (250mm) height, and (1000mm) length. The nib dimensions were (150mm) length and (150mm) depth. Specifics of the beam samples are shown in figure (2). The samples have been divided into four flocks (A, B, C and D). The first group contains three specimens of normal concrete only, one of them is a control and the other contains a construction joint in two different locations. The second group contains three specimens of high strength concrete only, one of them is a control and the other contains a construction joint in two different locations. The third group contains three specimens of steel fiber concrete only, one of them is a control and the other contains a construction joint in two different locations. The fourth group contains four samples hybridized with two types of concrete and contains a construction joint. Figure (3) Shows Specifics of hybrid concrete Dapped end Beams. Characteristics of Tested Beams are shown in Table (1). The half of the model has been studied for several reasons, including the symmetry between the two ends of the model in terms of the applied load and the rebar, in addition to economic benefits, as it leads to a reduction in cost and the use of half facilitates the process of transferring and examining the models.
Figure (2) Details of Reinforcement and Loading of the Beams

Figure (3) Hybrid and Construction Joint Details of Dapped End Beams

Table (1) Characteristics of Tested Beams

| Parametric | Description |
|------------|-------------|
| Joint      |             |
| NSC        |             |
| HSC        |             |
| SFRC       |             |
2.2 Materials

2.2.1 Cement
Ordinary Portland cement (O.P.C) KARASTA (ASTM Type I) manufactured in Iraq was used to form concrete. The cement test was in conformity with the (Iraqi standard No.5/1984) [12].

2.2.2 Water
Ordinary tap water was used in the washing operations of fine and coarse aggregates as well as in the process of mixing concrete and curing DEBs specimens.

2.2.3 Fine Aggregate
From Al-Ekhaider region, fine aggregates were provided which were used in this work. The tests result was obtained according to “(IQS limits No.45/1984)” [13].

2.2.4 Coarse Aggregate
From Al-Nibaai region, Crushed coarse aggregates were provided which were used in this work with a maximum aggregate size 10 mm. The results of the sieve analysis obtained were in compliance with “(Iraqi specification No. 45/1984)” [13].

2.2.5 Super plasticizer
Flocrete PC 200 is the plasticizer added to the concrete mixture to achieve highest concrete durability and performance. The guidance dosage of flocrete PC200 is (0.75 – 2.5) liter per 100kg of cementations materials in the mix.

2.2.6 Steel Reinforcing Bars
Three different diameters of deformed steel reinforcement are used in the present work. Longitudinal reinforcement includes two types of diameters 10 & 8 mm. The horizontal and vertical stirrups include reinforcing steel with a diameter of 6 mm, except for the steel reinforcement of hanger region, where the stirrups has a diameter of 8 mm. In Table (2) the returns of the steel reinforcement test are shown.

| Nominal diameter (mm) | Measured diameter (mm) | Yield stress (MPa) | Ultimate strength (MPa) |
|-----------------------|------------------------|-------------------|-------------------------|
| 10                    | 9.85                   | 585               | 725                     |
| 8                     | 8                      | 523               | 694                     |
| 6                     | 5.9                    | 560               | 607                     |

2.2.7 High performance steel fiber
NYCON-SF TYPE I “Hooked End” steel fiber have been used in present work in concrete mixtures as shown in Figure (4). One of the reasons that led to the use of steel fiber hook end is the increase in the tensile property because the failure occurs in the tensile region and improves the compressive strength of the concrete and does not cause agglomeration in the concrete mixture.
2.3 Concrete Mix Design

Three types of concrete were used in this research. The mixing proportions of each type were obtained after carrying out a number of experimental mixtures in order to obtain the required strength and the appropriate consistency, and also to satisfy the slump test. These mixtures are designed according to American Method of Mix Proportions Selection (ACI Committee 211.1-91)[14]. Table (3) shows the details of these mixtures.

![Figure (4) Steel Fiber Hooked End](image)

| Concrete type | Cement (Kg/m³) | Water (Kg/m³) | Sand (Kg/m³) | Gravel (Kg/m³) | Super plasticizer (%) | Steel fiber (%) | W/C ratio |
|---------------|----------------|---------------|--------------|---------------|-----------------------|----------------|----------|
| NSC           | 365            | 187.5         | 850          | 900           | ---                   | ---            | 0.51     |
| HSC           | 465.92         | 161.29        | 594.4        | 1037.22       | 1                     | ---            | 0.346    |
| SFRC          | 465.92         | 139.77        | 594.4        | 1037.22       | 1.5                   | 1              | 0.3      |

2.4 Formworks and casting process

All beams patterns were cast into plywood molds with dimensions (1000×120×250 mm). The dimensions of dapped end were (150mm) length, (150mm) depth and (120mm) width. Before casting, the molds are painted with oil to prevent adhesion with concrete after hardening. After that, the rebar is carefully placed and according to the design distances inside the molds, then we start the process of mixing the materials together and putting them in the molds as shown in the figure (5).
2.5 Test Setup and Instrumentation

2.5.1 Supporting and Loading Condition
At Al-Qadisiyah University, all beam samples were tested with a universal testing machine, the ultimate load of which was 1000kN. Beam support with the simply supported system and the plate used at supports between concrete and steel roller with dimensions of (200*100*10)mm to block local failure at the support and the loading point. The loading system was a one-point load and the support was in the shape of roller support at the un-dapped part of the beams section as shown in the figure (6).

2.5.2 Instrumentation Tools
During the test for all beams, two tools were used, the first is the Dial gauge to measure the amount of vertical deflection, and the second is the Cracking width Meter, to measure the width of the cracks, as shown in Figure (7).
2.6 Testing Procedure
Thirteen simply supported samples were tested under one point load until failure occurred by using a universal testing machine with an ultimate capacity of 1000 KN in Structures Laboratory of University of Qadisiyah. All beams were based on one side of hinge and on the other side roller. A bearing plate is placed between the concrete and steel at supports and load point to prevent local failure in the concrete. After that, the load is applied, and the reading of the initial deflection is recorded, as shown in Figure (8).

![Universal Testing Machine Used in Test and Dial Gauge Location](image)

Figure (8) Universal Testing Machine Used in Test and Dial Gauge Location

3. Experimental Results and Discussion
All specimens were tested under the same type of loading and had different type of concrete and location of the construction joint, therefore; crack modes are observed. The maximum load, cracking load and deflection at maximum load and cracking load are shown in Table (4).

| Beams specimen | Crack Load Pcr (KN) | Ultimate Load Pu (kN) | Max. Deflection at construction joint of nib end (mm) | Max. Deflection at construction joint of full depth (mm) | Failure Mode |
|----------------|---------------------|------------------------|-----------------------------------------------------|-----------------------------------------------------|--------------|

Table (4) Experimental Test Results of Beam Specimens
3.1 Load-Deflection Curves

The effect of hybrid Concrete on behavior of dapped end beams was investigated in this research work with two types of concrete HSC and SFRC at nib and D-region. The experimental results of the load-deflection curves of all samples are shown in Figure (9-21).

| Sample | Load (kN) | Deflection (mm) | Load-Deflection Curve |
|--------|-----------|-----------------|-----------------------|
| N-CONT. | 58        | 15.61           | diagonal tension crack initiating from reentrant corner |
| N-S-J  | 77        | 10.91           | direct vertical shear crack between nib and un-dapped portion |
| N-B-J  | 63        | 11.74           | diagonal tension crack initiating from reentrant corner |
| N+H-S-J| 45        | 11.74           | diagonal tension cracks at reentrant corner and extended end |
| N+H-B-J| 59        | 23.6            | diagonal tension cracks at reentrant corner and extended end |
| H-CONT. | 60        | 19.07           | diagonal tension crack initiating from reentrant corner |
| H-S-J  | 59        | 21.20           | direct vertical shear and diagonal tension cracks |
| H-B-J  | 69        | 24.41           | diagonal tension crack initiating from reentrant corner |
| N+S-S-J| 67        | 22.43           | diagonal tension crack initiating from reentrant corner |
| N+S-B-J| 77        | 20.06           | diagonal tension crack initiating from reentrant corner |
| S-CONT. | 77        | 14.25           | diagonal tension crack initiating from reentrant corner |
| S-S-J  | 100       | 15.89           | diagonal tension crack initiating from reentrant corner |
| S-B-J  | 115       | 13.6            | diagonal tension crack initiating from reentrant corner |
Figure (9) Load-Deflection Curves of N-Cont. Specimen

Figure (10) Load-Deflection Curves of H-Cont. Specimen

Figure (11) Load-Deflection Curves of S-Cont. Specimen
Figure (12) Load-Deflection Curves of N-S-J Specimen

Figure (13) Load-Deflection Curves of N-B-J Specimen

Figure (14) Load-Deflection Curves of N+H-S-J Specimen
Figure (15) Load-Deflection Curves of N+H-B-J Specimen

Figure (16) Load-Deflection Curves of H-S-J Specimen

Figure (17) Load-Deflection Curves of H-B-J Specimen
Figure (18) Load-Deflection Curves of N+S-S-J Specimen

Figure (19) Load-Deflection Curves of N+S-B-J Specimen

Figure (20) Load-Deflection Curves of S-S-J Specimen
3.2 Failure Mode

The region of re-entrant corner is the first area where cracks are expected because the biggest stress is concentrated in this area known as D-region. There are several types of cracks that may appear in the DEB and these cracks occur respectively in the extended end and reentrant corner proposed by PCI [5]. Figure (22) shows the type of failure and the crack style of all samples.
4. Conclusions
1- It was found that the appearance of the construction joint in the reentrant corner with (NSC) and (HSC) in the entire specimen of non-hybrid affects the failure load as it leads to reducing it by about (33%) and (6%) respectively, but it does not lead to a decrease in the failure load with (SFRC).
2- It was observed that the construction joint when it appeared in the D- region in the three types of concrete throughout the whole specimen of non-hybrid, normal concrete, high strength concrete and steel fiber reinforced concrete leads to an increase in the failure load of about (0.5%), (10%) and (1%) respectively.
3- In the hybrid specimens, it was found that the presence of the construction joint between the two types of normal and high strength concrete, and in both sites, the reentrant corner and the D- region, it reduces the failure load by about (2%) and (3%) respectively, but when it appears in concrete reinforced with steel fibers with normal concrete reduces the failure load by about (2%) when present in the reentrant corner and the failure load increases by about (2%) when it appears in D- region.

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