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Improvement in Bending Performance of Reinforced Concrete Beams Produced with Waste Lathe Scraps

Memduh Karalar [1], Yasin Onuralp Özkılıç [2,*], Ahmed Farouk Deifalla [3], Ceyhun Aksoylu [4], Musa Hakan Arslan [4], Mahmood Ahmad [5] and Mohanad Muayad Sabri Sabri [6]

[1] Department of Civil Engineering, Faculty of Engineering, Zonguldak Bulent Ecevit University, Zonguldak 67100, Turkey
[2] Department of Civil Engineering, Faculty of Engineering, Necmettin Erbakan University, Konya 42000, Turkey
[3] Structural Engineering and Construction Management Department, Future University in Engineering, Cairo 11835, Egypt
[4] Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University, Konya 42130, Turkey
[5] Department of Civil Engineering, University of Engineering and Technology Peshawar (Bannu Campus), Bannu 28100, Pakistan
[6] Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia
* Correspondence: yozkilic@erbakan.edu.tr

Abstract: In this study, the impacts of different proportions of tension reinforcement and waste lathe scraps on the failure and bending behavior of reinforced concrete beams (RCBs) are clearly detected considering empirical tests. Firstly, material strength and consistency test and then 1/2 scaled beam test have been carried out. For this purpose, a total of 12 specimens were produced in the laboratory and then tested to examine the failure mechanism under flexure. Two variables have been selected in creating text matrix. These are the longitudinal tension reinforcement ratio in beams (three different level) and volumetric ratio of waste lathe scraps (four different level: 0%, 1%, 2% and 3%). The produced simply supported beams were subjected to a two-point bending test. To prevent shear failure, sufficient stirrups have been used. Thus, a change in the bending behavior was observed during each test. With the addition of 1%, 2% and 3% waste lathe scraps, compressive strength escalated by 11.2%, 21.7% and 32.5%, respectively, compared to concrete without waste. According to slump test results, as the waste lathe scraps proportion in the concrete mixture is increased, the concrete consistency diminishes. Apart from the material tests, the following results were obtained from the tests performed on the beams. It is detected that with the addition of lathe waste, the mechanical features of beams improved. It is observed that different proportions of tension reinforcement and waste lathe scraps had different failure and bending impacts on the RCBs. While there was no significant change in stiffness and strength, ductility increased considerably with the addition of lathe waste.

Keywords: reinforced concrete; beam; lathe waste; recycled; scrap; steel; fiber

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1. Introduction

Today, steel scrap is one of the industrial products pro-created on the lathe and known as waste materials. It is known that these waste materials, unlike other wastes, do not have a good scrap value and are not reused properly. In the literature, it has been seen that waste materials can be used efficiently in reinforced concrete [1–11]. Investigations have shown that the physical features of steel scrap provide additional reinforcement to the concrete, which in turn provides additional tensile strength of the concrete [12–15]. It is obvious that the number of waste fibers procreated from various metal industries will increase as the population and number of industrial activities increases [3]. Due to lack of tensile strength of the concrete, it is strengthened by reinforcement bars, fibers, or polymers [16–20]. It has been shown by the tests that industrial waste fibers can also be used to produce high strength fiber reinforced concrete after their use [21].

The use of a fibrous material in concrete, such as turned steel scrap, aids to reduce the main solid waste from the steel fabrication industries [22]. Prasad et al., 2020 [22] and Maanvit et al., 2019 [23] found that some mechanic characteristics such as such as compressive, split tensile, bending strength and modulus of elasticity of the concrete are reasonably improved for 1.5% addition of lathe steel scrap to M30 grade of concrete. Similarly, Malek et al., 2021 [24] used three different contents of addition metal chips (5%, 10% and 15% of cement weight) as substitutes for fine aggregate, and they found that with the addition of lathe waste, the density reduced, but mechanical features improved. Furthermore, Maanvit et al., 2019 [23] suggest that separate from all these features the usage scrap material in the structure leads to a giant advantage to the environment so that it can improve the features of concrete same as by using manufactured fibrous material so that it can be diminished the cost of structure inventively.

Kumar et al. [25] showed that when waste steel scrap which was replaced with fine aggregative materials in amounts of 4%, 8%, and 12% by form of cement, the maximum mechanical strength was recognized at 8% presence of metal scraps with the conventional concrete and it was detected that the compression, split tension, and bending strength of the concrete was enhanced by 11.68%, 20.82% and 24.65%, correspondingly with addition of 8% steel scraps in concrete. Vijayakumar et al. [26] detected that the addition of lathe scrap in concrete has increase the performance of beam in bending by 40% when compared with plain cement concrete. There is only a significant rise in the split tensile strength of concrete with lathe scrap. Furthermore, the mechanical features of the concrete are improved by increasing the proportion of the lathe scrap from 0.5% up to 1.5%. Its demonstrations slight reduction in the mechanical strength from 1.5% to 2.0%.

Ramachandran et al. [14] found that the compressive strength and split tensile strength can be escalated by 1.20% replacement of coarse aggregate using steel scraps in concrete. Akshaya et al. [27] detected that the bending behavior of the concrete is im-proved by the adding of lathe waste up to 1.5% and it can increase concrete structural strength, minimize steel reinforcements, and decrease failure width when used as concrete reinforcements. Kumutha and Vijai, [28] detected that the addition of steel fibers to plain concrete up to 0.5 vol% increases its compressive and bending strength, but further addition does not. Sudhakar et al. changed the nature sand with lathe scraps by way of the following proportion (5%, 10%, 15% and20%) and they detected that it gives more strength than conventional concrete and with a greater availability of materials in lathe workshops.

As shown from these works, there are many investigations related with empirical tests on strength features of concrete with steel scrap. Additionally, there are several investigations regarding the performance of concrete with lathe waste in the literature [2,3,22,29–31]. Nevertheless, in the literature, insufficient researches studied the impacts of different proportion of tension reinforcement and waste lathe scraps on the bending behavior, or the failure of RCBs. Furthermore, there are very limited investigations about the impact of waste lathe scraps proportion, replacing fine aggregate, on the total weight of concrete structures in the past. Consequently, this investigation affords many important supports to the literature.

2. Aim of Investigation

The studies that replace waste lathe material with fine aggregate are mostly undertaken in the field of materials engineering. However, it is very important for structural engineering to determine how the behavior of a structural element made of this material will change under loads. Based on this motivation, the main idea of this study is to investigate the effect of concrete produced with the additive of waste turning material on beam bending behavior. For this purpose, total 12 various 1/2 scaled RCBs (100 × 150 × 1000 mm) were procreated in the lab. First of all, reference concrete beam (BREF) is procreated in detail. Then, three different proportions of tension reinforcement were used in RCBs to investigate the impact of tension reinforcement on the failure and bending attitude of RCB. One of the most significant purposes of this investigation is to perceive the impact of waste lathe scraps proportions on the consistency of fresh concrete. For this purpose, 12 different concrete specimens for various waste lathe scraps (0%, 1% 2% and 3%) were located in RCBs. Then, procreated RCBs were related to bending and failure testing in a fully organized lab, and vertical loads were applied to RCBs. According to empirical test consequences, bending and failures in the RCBs were inspected and presented in detail.

3. Materials and Method

A concrete mix was designed to obtain the correct proportions of cement, sand and aggregate for structural strength. The aim of the mix was to find the most effective that meets performance requirements (for hardened and fresh concrete (especially workability and desired strength). Blending requires the fibers to be evenly dispersed to prevent fiber separation or aggregation. Therefore, a maximum 3% volume ratio (V_f) of lathe waste was utilized. Three volume ratios of waste steel scrap were selected, 1%, 2%, and 3%, and added to concrete during mix by volume of concrete. The workability was significantly dropped after 2% V_f and it was difficult to work with 3% V_f lathe waste. Similiar problems were also indicated for different types of steel fibers [32,33].

In order to produce the RCBs, CEM I 32.5 type of Portland cement was utilized. The chemical features of this cement are given in Table 1. The water/cement ratio was selected as 0.6 to increase workability. On the other hand, cement/aggregate ratio was selected as 0.22. Fine aggregate was utilized with range of 0–4 mm while coarse aggregate was used with range of 5–12 mm. The fine/coarse aggregate ratio was 0.92. Lathe scraps were utilized in order to increase the bending performance of the RCBs. Lathe scraps used in this investigation were helical. The recycled lathe scraps were divided into small pieces before using it.

Table 1. Features of Specimens.

#	Name	Compression	Tensile	Proportion	V_f
1	BREF-1	2ϕ6	2ϕ12	0.0125	0%
2	BREF-2	2ϕ6	2ϕ10	0.0074	0%
3	BREF-3	2ϕ6	2ϕ8	0.0032	0%
4	BCNC-1	2ϕ6	2ϕ12	0.0125	1%
5	BCNC-2	2ϕ6	2ϕ10	0.0074	1%
6	BCNC-3	2ϕ6	2ϕ8	0.0032	1%
7	BCNC-4	2ϕ6	2ϕ12	0.0125	2%
8	BCNC-5	2ϕ6	2ϕ10	0.0074	2%
9	BCNC-6	2ϕ6	2ϕ8	0.0032	2%
10	BCNC-7	2ϕ6	2ϕ12	0.0125	3%
11	BCNC-8	2ϕ6	2ϕ10	0.0074	3%
12	BCNC-9	2ϕ6	2ϕ8	0.0032	3%

Waste steel scrap collected from a factory which utilizes a CNC machine for cutting steel and these wastes were directly brought to the laboratory. The effect of corrosion after mixing was not considered and waste steel scrap used was not corroded during storage. The shape of waste steel scraps was helical. The steel wires were divided into small pieces in order to increase workability. The average length of the lathe was around 30–50 mm. While the slump value of the reference sample was 19 cm, the slump value decreased to 17, 10, and 5 cm for V_f of 1%, 2%, and 3%. Figure 1 illustrates the steel lathe waste used in the preparation of the beams.

Figure 1. Waste steel scrap prepared for preparation of the concrete.

Compressive strength of the concrete with lathe was obtained from 15 × 15 × 15 cubic samples. The compressive strenght of 29.5 MPa, 32.8 MPa, 35.9 MPa and 39.1 MPa was measured for the concrete with 0%, 1%, 2% and 3% lathe steel waste. Moreover spltting tensile tests were performed using 10 × 20 cm cyclicendral samples. The splitting tensile strength of 2.83 MPa, 3.08 MPa, 3.29 MPa and 3.53 MPa was measured for the concrete with 0%, 1%, 2%, and 3% lathe steel waste.

After concrete testing, total 12 various 1/2 scaled RCBs specimens were produced in Necmettin Erbakan University and the tests were conducted in Civil Engineering Laboratary. The main variable of the investigation was the volume proportion of lathe waste while secondary parameter was considered as longitudinal reinforcement proportion. Three of these specimens were reference specimens without any lathe scraps while the other ones consisted of V_f proportion of 1%, 2%, and 3% lathe scraps. The features of the samples are depicted in Table 1.

The size of the specimens was selected as 100 × 150 × 1000 mm. In order to obtain bending behavior stirrups were selected as ϕ6/100 mm and also the shear span to effective depth (a_v/d) was selected as 3.1 in order to obtain shear failure [34,35]. Typical reinforcement layout is presented in Figure 2 and the test setup is depicted in Figure 3. The loading was applied using a servo-controlled hydraulic actuator which can measure both loading and displacement. In Figure 2, only the tension longitudinal reinforcement changes as 2ϕ12, 2ϕ10 and 2ϕ6, respectively. A model is shown as an example in Figure 2.

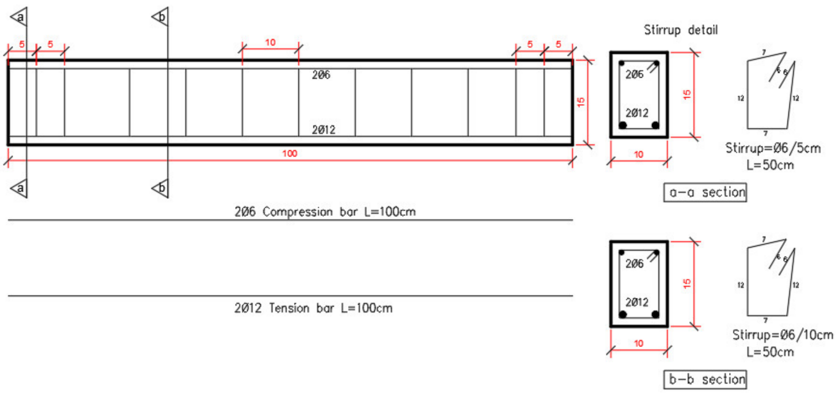

Figure 2. Reinforcement layout, Dimensions are cm.

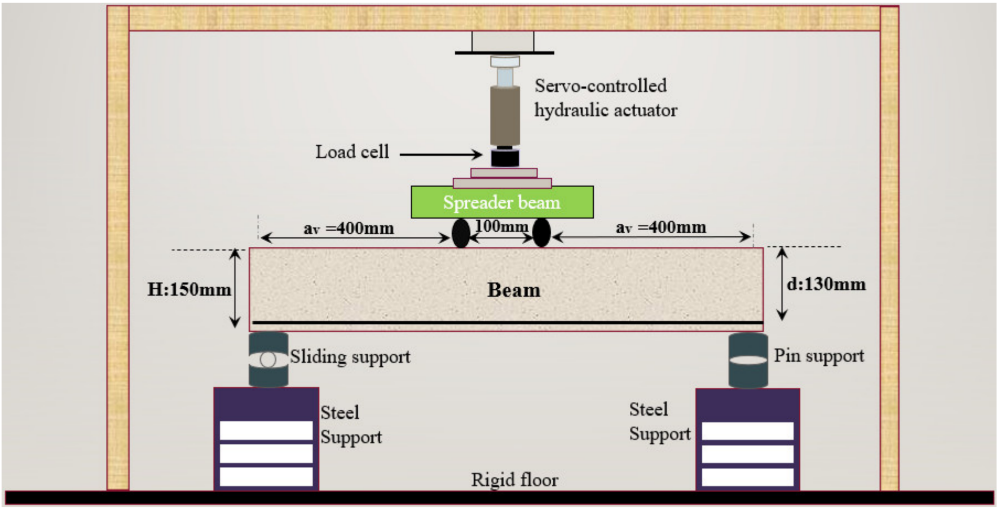

Figure 3. Test Setup.

4. Empirical Results and Discussion

In this part, the impact of different proportions of tension reinforcement and waste lathe scraps on the bending behavior of RCBs is clearly shown and evaluated in detail. For this purpose, the RCBs that are pro-created in the laboratory are tested to investigate the failure and bending attitude. After 12 various RCBs were arranged in the lab, these RCBs were related the failure and bending tests. These failures in the RCBs were evaluated in detail and it is obviously realized that each waste lathe scraps proportion had different failure and bending impacts on the RCBs. Additionally, during investigation, different bends were found for each RCBs with different waste lathe scraps proportions. Each RCB had dissimilar load carrying capabilities and these capacities are very significant to estimate the impact of waste lathe scraps proportion on the failure and bending behavior of reinforced concrete structures. In this investigation, 12 various RCBs were tested, as shown in Tables 2 and 3.

Table 2. Empirical results for load and displacement values.

Test Specimens	P_{max} (kN)	Displ. at Max Load (mm)	Rigidity (kN/mm) at (P_{max})	P_u (0.85 P_{max}) (kN)	Displacement at Yield δ_y (mm)	Rigidity (kN/mm) at Yield (0.85 P_{max})	δ_u (mm)	Ductility Ratio
BREF-1	51.91	8.57	6.05	44.12	4.89	9.02	17.72	3.62
BREF-2	45.29	13.59	3.33	38.49	5.01	7.67	27.66	5.51
BREF-3	35.44	15.61	2.26	30.12	3.81	7.89	70.20	18.40
BCNC-1	55.57	9.28	6.00	47.40	5.85	8.10	17.43	2.98
BCNC-2	45.93	18.05	2.54	39.04	5.32	7.33	33.08	6.21
BCNC-3	36.85	8.71	4.22	31.32	4.74	6.60	69.78	14.70
BCNC-4	58.96	11.70	5.03	50.11	7.10	7.05	19.88	2.79
BCNC-5	45.66	11.10	4.11	38.81	5.70	6.80	44.26	7.76
BCNC-6	37.20	43.99	0.84	31.62	4.19	7.54	71.30	17.01
BCNC-7	62.61	11.97	5.22	53.22	7.13	7.46	20.17	2.82
BCNC-8	46.84	33.28	1.40	39.82	6.82	5.83	51.62	7.56
BCNC-9	38.47	45.76	0.84	32.70	4.53	7.20	73.18	16.12

Table 3. Empirical test results for energy dissipation capacities.

Test Specimens	Max. Dipsl. (mm)	Energy Consumption at P_{max} (kJ)	Energy Consumption at 0.85 P_{max} (kJ)	Plastic Energy Consumption (kJ)	Total Energy Consumption (kJ)	Failure Type	Ductility Level
BREF-1	26.67	0.292	0.117	0.968	1.085	Shear	Partially Sufficient
BREF-2	31.23	0.474	0.100	1.105	1.205	Flexure	Sufficient
BREF-3	70.94	0.467	0.062	2.246	2.308	Bending	Sufficient
BCNC-1	23.80	0.496	0.155	0.880	1.035	Shear	Deficient
BCNC-2	49.28	0.667	0.104	1.688	1.792	Bending	Sufficient
BCNC-3	69.78	0.211	0.076	2.311	2.387	Bending	Sufficient
BCNC-4	26.61	0.711	0.213	0.951	1.164	Shear	Deficient
BCNC-5	61.59	0.352	0.114	2.233	2.347	Bending	Sufficient
BCNC-6	72.97	1.50	0.069	2.452	2.521	Bending	Sufficient
BCNC-7	30.29	0.689	0.211	1.203	1.414	Shear	Deficient
BCNC-8	63.74	1.356	0.153	2.436	2.588	Bending	Sufficient
BCNC-9	74.66	1.590	0.080	2.564	2.643	Bending	Sufficient

4.1. Impact of Different Proportion of Tension Reinforcement on Waste Lathe Scraps

In this part, the impact of different proportions of tension reinforcement on the failure-bending behavior of RCBs is clearly evaluated in detail as follows.

4.1.1. Case 1: RCB (BREF-1, BREF-2 and BREF-3)

As stated by empirical consequences, it is detected that there was noteworthy shear and bending failure in the reference RCB depending on the vertical load. Under vertical load, the maximum bending in the reference RCB was measured and these bendings were explicitly offered in this part as shown in Figure 4. It is shown in Figure 4 that serious failure might be detected in RCBs under vertical loads and noteworthy bending failures are shown in Figure 4. These places of failures are clearly shown as where vertical failures can occur in the RCB. In addition, the maximum distance between the vertical failures was as 720 mm in the reference RCB (Figure 5). According to Figure 4, it is detected that the maximum shear failures start from the place where the load is applied to the RCB and they continue to the bottom of RCB. In Figure 5, the load-bending graph is obtained for reference RCB. According to Figure 5, bendings escalated as rectilinear line until an accurate stage and end of this rectilinear line relates to 51.91 kN, 45.29 kN, and 35.44 kN for BREF-1, BREF-2, and BREF-3. Then, 8.57 cm, 13.59 cm, and 15.61 cm bending is detected at maximum vertical load for BREF-1, BREF-2, and BREF-3. After these loads, although the load diminished, the bending is slightly escalated. In detail, 26.67 cm, 31.23 cm, and 70.94 cm maximum bending for BREF-1, BREF-2and BREF-3 were detected at end of the test and RCB lost its load carrying ability at these bending values. These results provide data concerning the load carrying ability of the reference RCBs (BREF-1, BREF-2 and BREF-3).

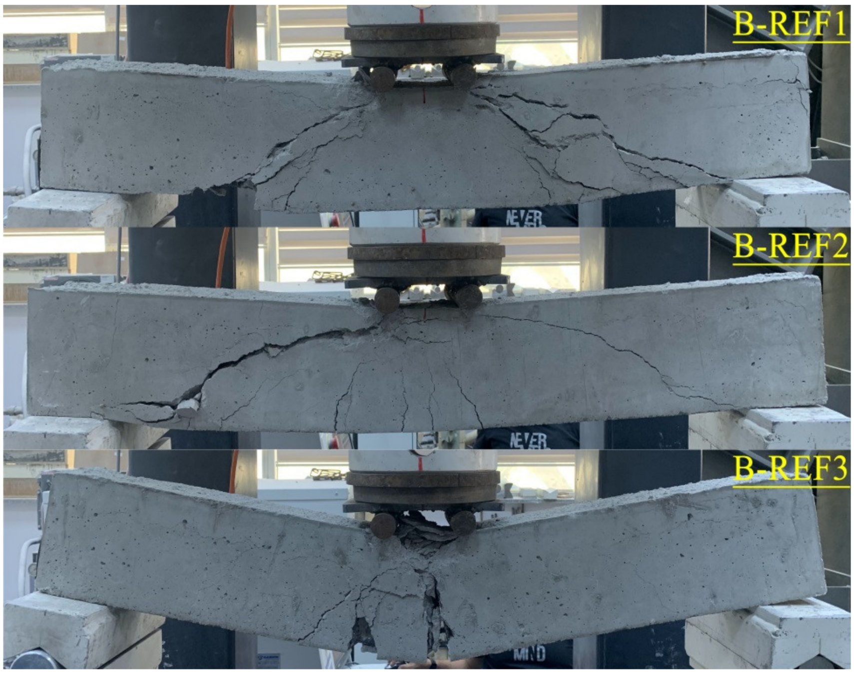

Figure 4. Failure and bending behavior of RCB for BREF-1, BREF-2 and BREF-3.

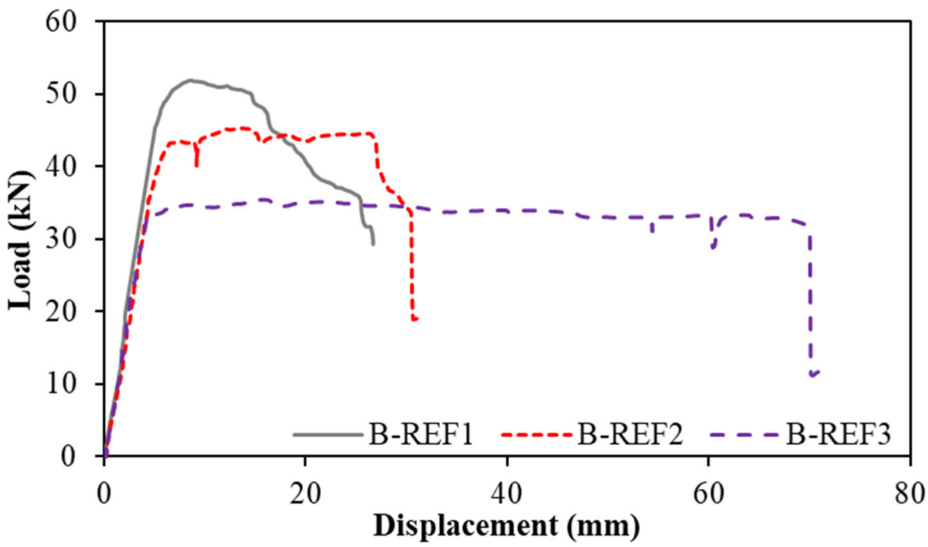

Figure 5. Load-Bending attitude of reference RCB for BREF-1, BREF-2 and BREF-3.

4.1.2. Case 2: RCB (BCNC-1, BCNC-2 and BCNC-3)

As stated by empirical results for BCNC-1, BCNC-2 and BCNC-3, it is detected that there were significant shear and bending failures in the RCB depending on the vertical load. As shown in the Figure 6, the bendings in the RCB are detected under the vertical loads. According to Figure 6, it is observably presented that noteworthy failures (vertical and shear) are detected in the RCB. The fracturing of the reinforced concrete occurring in the bending zone depending on the vertical load is seen in the Figure 6. This crushing is important because of the influence of the protective behavior of stirrups and reinforcements on the bending behavior of RCBs. In Figure 6, important vertical failures are found in the middle of the RCB and these failures are so considerably vital to estimate the failure attitude of RCBs with different proportion of tension reinforcement. As detected in Figure 7, deformations recorded by LVTD are offered graphically and this graph is very noteworthy to estimate the load-bending attitude of RCB with different proportion of tension reinforcement. According to Figure 7, bendings escalated as a rectilinear line until an accurate stage and end of this rectilinear line relates to 55.57 kN, 45.93 kN, and 36.85 kN for BCNC-1, BCNC-2and BCNC-3. Then, 9.28 cm, 18.05 cm, and 8.71 cm bending was detected at maximum vertical load for BCNC-1, BCNC-2 and BCNC-3. After these loads, although the load diminished, the bending is slightly escalated. In detail, 23.80 cm, 49.28 cm, and 69.78 cm maximum bending for BCNC-1, BCNC-2 and BCNC-3 was detected at ultimate of the test and RCB lost its load carrying ability at this bending values. These results undoubtedly show considerable significant data about the load carrying ability of the reference RCBs (BCNC-1, BCNC-2 andBCNC-3). Furthermore, these results appearance the impact of different proportion of tension reinforcement on the bending-load attitude of the RCB. While compared RCB with different proportion of tension reinforcement, significant failure and bending differences are detected under the vertical load. Additionally, less bending is detected in the RCB for BCNC-1 as compared with BCNC-2 and BCNC-3.

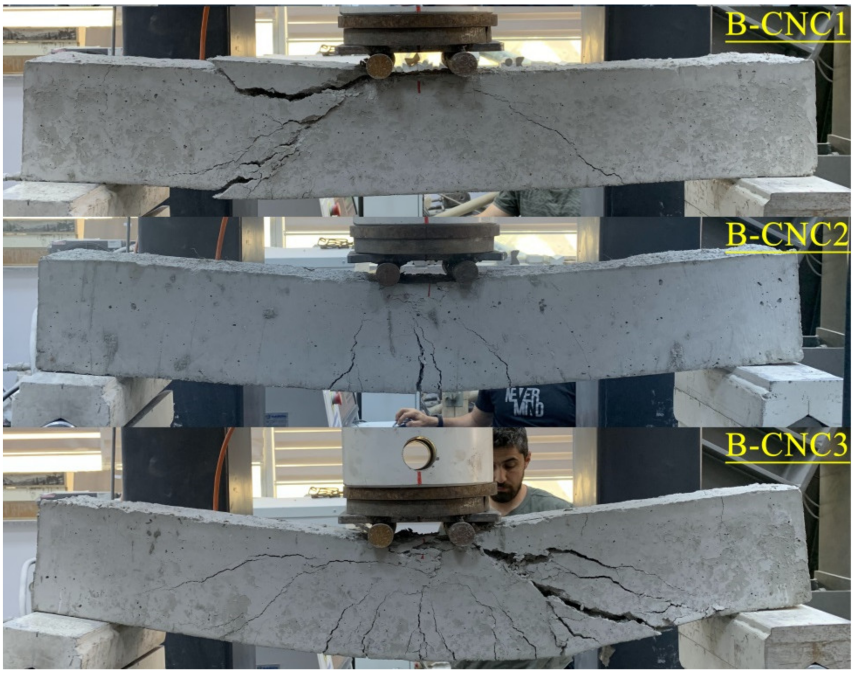

Figure 6. Failure and bending attitude of RCB for BCNC-1, BCNC-2, BCNC-3.

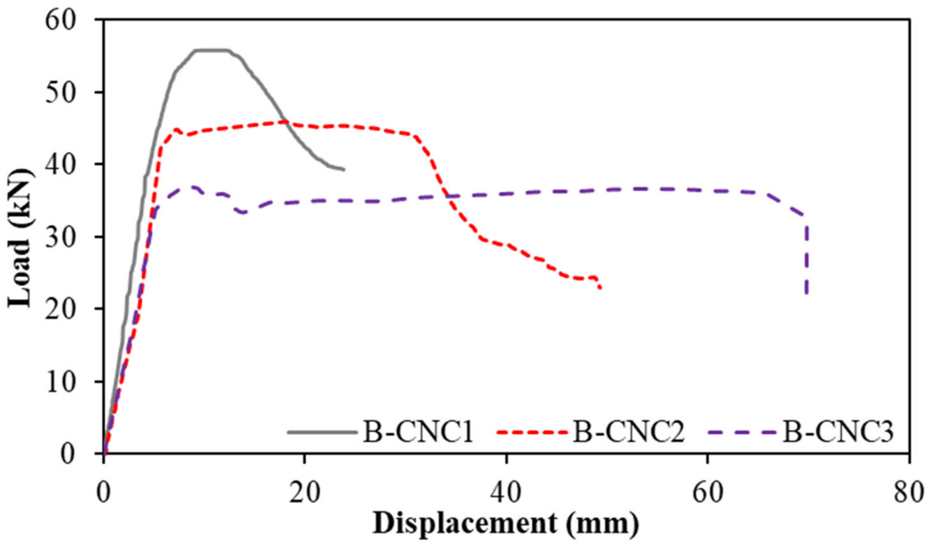

Figure 7. Load-Bending attitude of reference RCB for BCNC-1, BCNC-2 and BCNC-3.

4.1.3. Case 3: RCB (BCNC-4, BCNC-5, BCNC-6)

As stated by empirical results for BCNC-4, BCNC-5 and BCNC-6, it is detected that there were noteworthy shear and bending failures in the RCB depending on the vertical load. As shown in the Figure 8, the bendings in the RCB are detected under the vertical loads. According to Figure 8, it is observably presented that noteworthy failures (vertical and shear) are detected in the RCB. The fracturing of the reinforced concrete occurring in the bending zone depending on the vertical load is seen in the Figure 9. According to Figure 9, bendings escalated as rectilinear line until an accurate stage and ultimate of this rectilinear line relates to 58.96 kN, 45.66 kN, and 37.20 kN for BCNC-4, BCNC-5and BCNC-6. Then, 11.70 cm, 11.10 cm, and 43.99 cm bending was detected at maximum vertical load for BCNC-4, BCNC-5 and BCNC-6. After these loads, although the load diminished, the bending is slightly escalated. Hence, 26.61 cm, 61.59 cm, and 72.97 cm maximum bending for BCNC-4, BCNC-5 and BCNC-6 was detected at ultimate of the test and RCB lost its load carrying ability at these bending values. These results undoubtedly show considerably significant data regarding the load carrying ability of the reference RCBs (BCNC-4, BCNC-5 and BCNC-6).

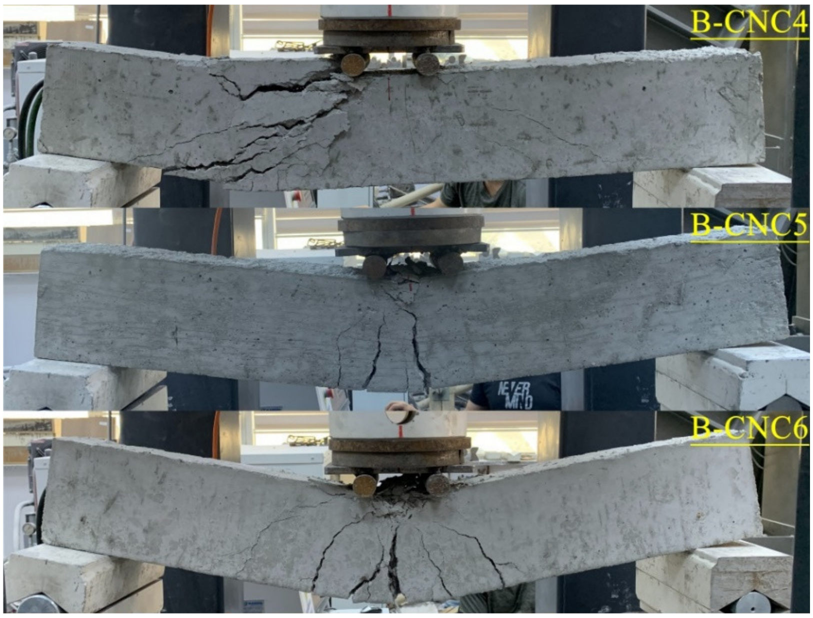

Figure 8. Failure and bending attitude of RCB for BCNC-4, BCNC-5, BCNC-6.

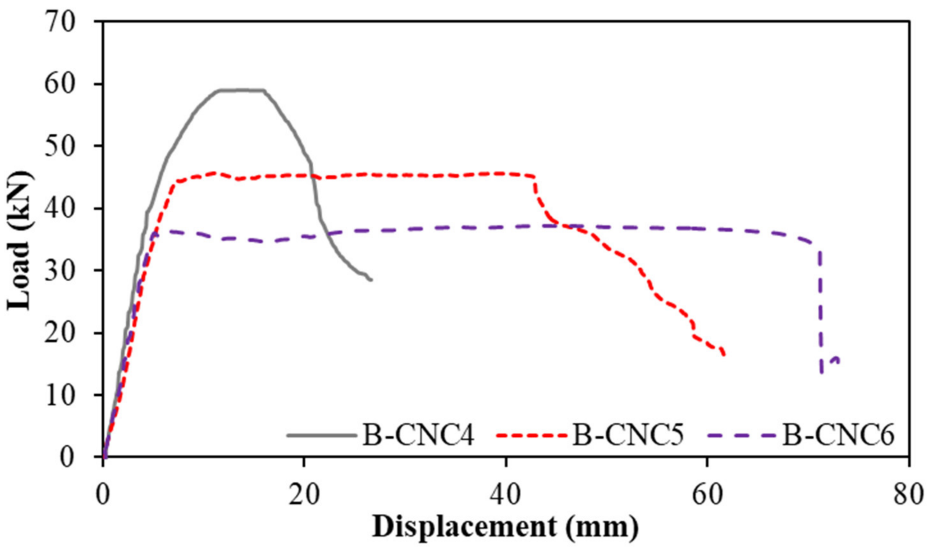

Figure 9. Load-Bending attitude of reference RCB for BCNC-4, BCNC-5 andBCNC-6.

4.1.4. Case 4: RCB (BCNC-7, BCNC-8 and BCNC-9)

As confirmed by empirical results for BCNC-7, BCNC-8 andBCNC-9, it is noticed that there were remarkable shear and bending failures in the RCB depending on the vertical load as shown in the Figure 10. The failures of the reinforced concrete occurring in the bending zone depending on the vertical load is seen in the Figure 10. According to Figure 11, bendings escalated as rectilinear line until an accurate stage and ultimate of this rectilinear line relates to 62.61 kN, 46.84 kN, and 38.47 kN for BCNC-7, BCNC-8, and BCNC-9. Then, 11.97 cm, 33.28 cm, and 45.76 cm bending is detected at maximum vertical load for BCNC-7, BCNC-8and BCNC-9. After these loads, although the load diminished, the bending is slightly escalated. Hence, 30.29 cm, 63.74 cm, and 74.66 cm maximum bending for BCNC-7, BCNC-8and BCNC-9 were detected at the ultimate of the test and RCB lost its load carrying ability at these bending values. These results indicate the impact of different proportions of tension reinforcement on the bending-load attitude of the RCB.

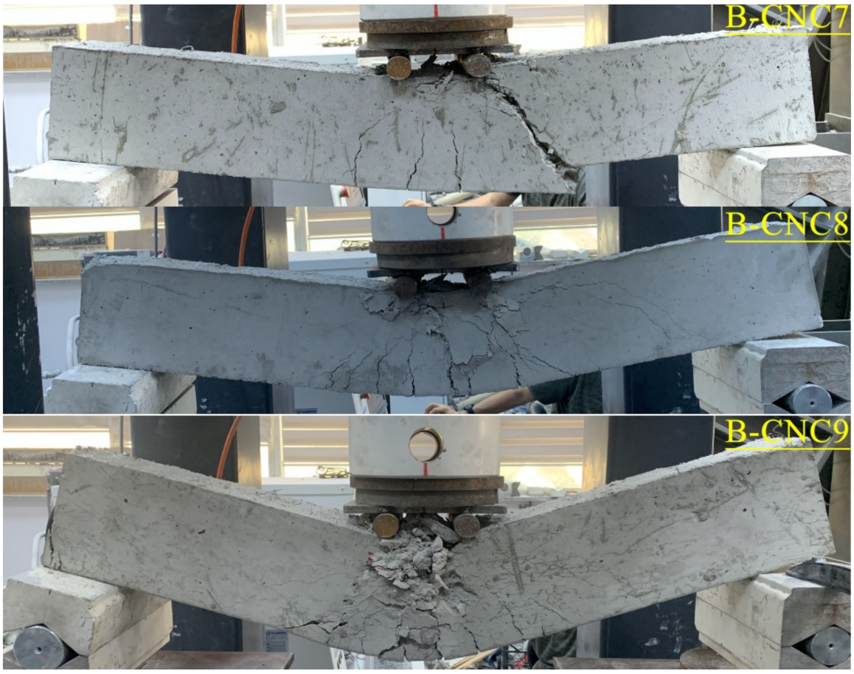

Figure 10. Failure and bending attitude of RCB for BCNC-7, BCNC-8, BCNC-9.

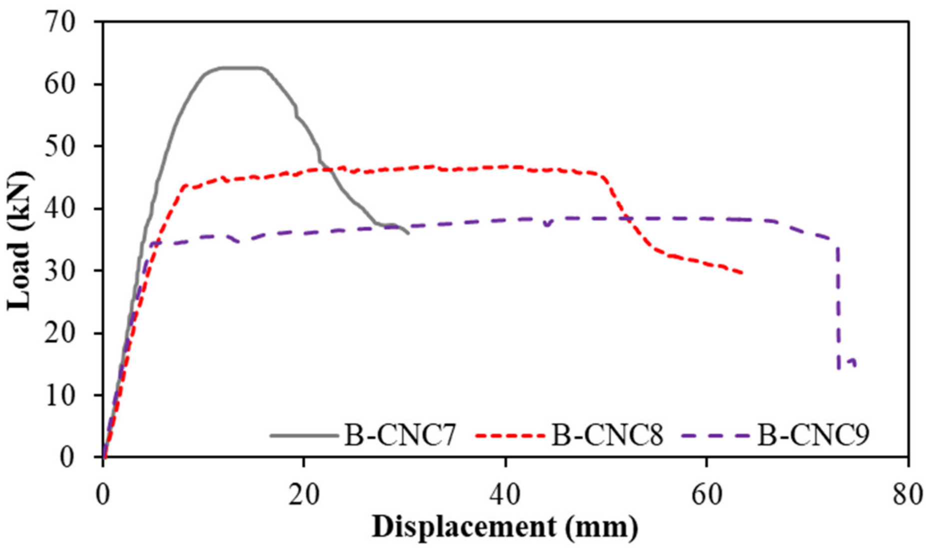

Figure 11. Load-Bending attitude of reference RCB for BCNC-7, BCNC-8 and BCNC-9.

4.2. Impact of Different Proportion of Waste Lathe Scraps Proportion

In this part, the impact of different proportion of waste lathe scraps on the failure and bending attitude of RCBs is obviously investigated in detail as follows.

4.2.1. Case 1: Failure and Load-Bending Attitude of Proportion of Waste Lathe Scraps for 2ϕ12 Tension Reinforcement

The impact of different proportion of waste lathe scraps on the failure and bending attitude of RCBs is obviously investigated. For this reason, proportions of waste lathe scraps are used as 0%, 1%, 2%, and 3% while tension reinforcement in the RCB is used constant as 2ϕ12. As stated by empirical results for BREF-1, BCNC-1, BCNC-4 and BCNC-7, it is detected that there were significant shear and bending failure in the RCB depending on the vertical load as shown in Figure 12. According to Figure 13, bendings escalated as rectilinear line until an accurate stage and ultimate of this rectilinear line relates to 51.91 kN, 55.57 kN, 58.96 kN, and 62.61 kN for BREF-1, BCNC-1, BCNC-4, and BCNC-7. Then, 8.57 cm, 9.28 cm, 11.70 cm, and 11.97 cm bending is detected at maximum vertical load for BREF-1, BCNC-1, BCNC-4and BCNC-7. After these loads, although the load diminished, the bending is slightly escalated. 26.67 cm, 23.80 cm, 26.61 cm, and 30.29 cm, maximum bending for BREF-1, BCNC-1, BCNC-4 and BCNC-7 was detected at the ultimate of the test and RCB lost its load carrying ability at these bending values. These results provide unquestionably significant data about the load carrying ability of the reinforcement RCBs (BREF-1, BCNC-1, BCNC-4 and BCNC-7) for different proportions of waste lathe scraps. As detected from the empirical results shown in Figure 13 and Table 3, for all proportions of waste lathe scraps used in the RCB, it is detected that shear type bending occurs in all RCBs. While comparing RCB with different proportions of waste lathe scraps, significant failures and bending differences are detected under the vertical load. As detected from the empirical test results, it is detected that the load–displacement ability of RCB is increased when the proportion of waste lathe scraps is increased.

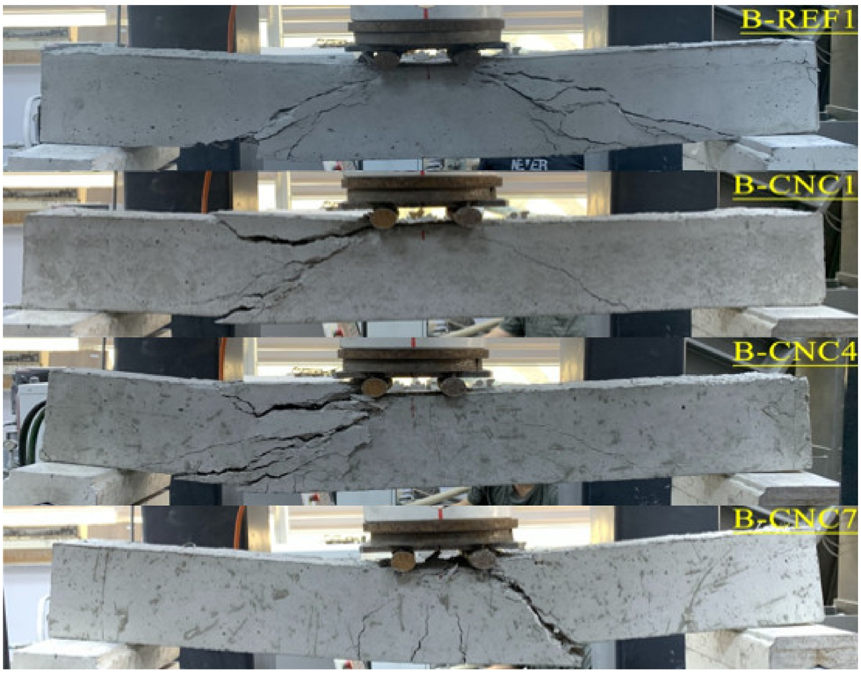

Figure 12. Failure and bending attitude of RCB for BREF-1, BCNC-1, BCNC-4, BCNC-7.

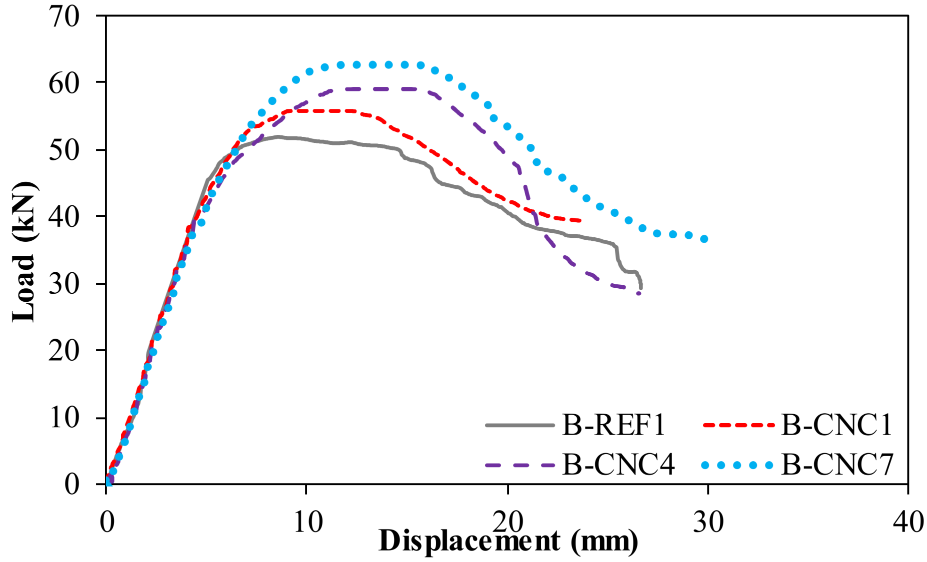

Figure 13. Load-Bending attitude of reference RCB for BREF-1, BCNC-1, BCNC-4 andBCNC-7.

4.2.2. Case 2: Failure and Load-Bending Attitude of Proportion of Waste Lathe Scraps for 2ϕ10 Tension Reinforcement

In this part of the investigation, while tension reinforcement in the RCB is used constant as 2ϕ10, proportions of waste lathe scraps are changed as 0%, 1%, 2%, and 3% to investigate impact of different proportion of waste lathe scraps on the failure and bending attitude of RCBs. As detailed by empirical results for BREF-2, BCNC-2, BCNC-5 and BCNC-8, it is detected that there was noteworthy shear and bending failure in the RCB depending on the vertical load, as shown in Figure 14. According to Figure 15, bendings escalated as a rectilinear line until an accurate stage and the ultimate of this rectilinear line relates to 45.29 kN, 45.93 kN, 45.66 kN, and 46.84 kN for BREF-2, BCNC-2, BCNC-5, and BCNC-8. Then, 13.59 cm, 18.05 cm, 11.10 cm and 33.28 cm bending is detected at maximum vertical load for BREF-2, BCNC-2, BCNC-5 and BCNC-8. After these loads, although the load diminished, the bending is slightly escalated. Hence, 31.23 cm, 49.28 cm, 61.59 cm, and 46.84 cm maximum bending for BREF-2, BCNC-2, BCNC-5, and BCNC-8 were detected at ultimate of the test and RCB lost its load carrying ability at this bending values. As detected from the empirical results as shown in Figure 15 and Table 3, while proportions of waste lathe scraps are used as 0%, it is detected that shear type bending occurs in RCB. On the other hand, while proportions of waste lathe scraps are changed as 1%, 2%, and 3%, failure type is detected as bending occurs in RCB. Furthermore, it is detected that significant failures and bending differences are detected under the vertical load while compared with RCB using different proportions of waste lathe scraps. Furthermore, as detected from the empirical test results, it is detected that load–displacement ability of RCB is increased as the proportion of waste lathe scraps is increased for all proportions except for 2% waste lathe scraps.

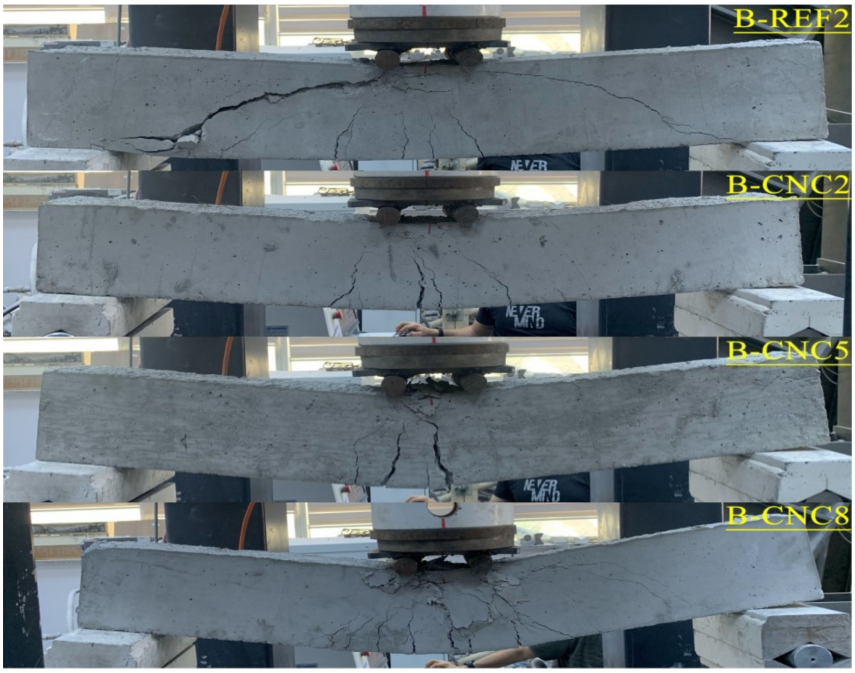

Figure 14. Failure and bending attitude of RCB for BREF-2, BCNC-2, BCNC-5, BCNC-8.

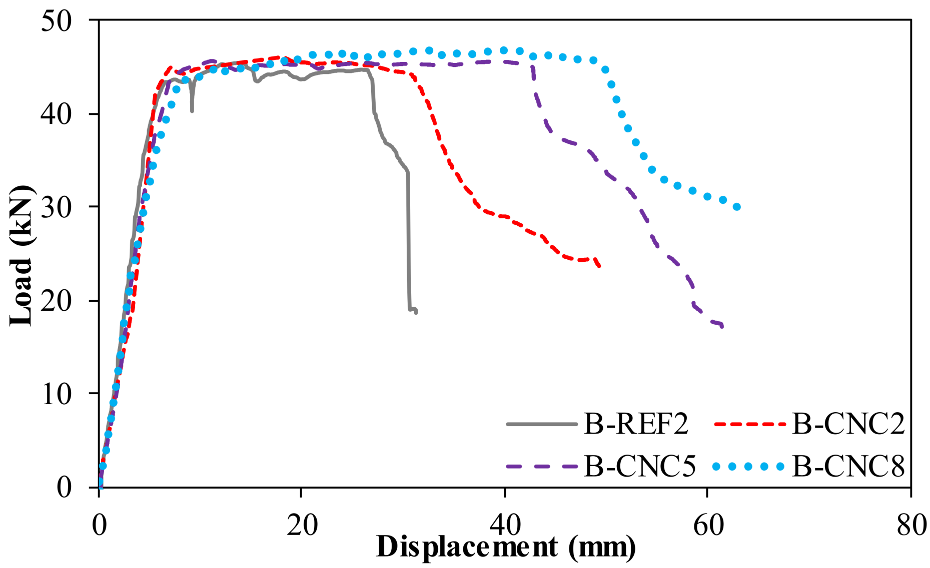

Figure 15. Load-Bending attitude of reference RCB for BREF-2, BCNC-2, BCNC-5 and BCNC-8.

4.2.3. Case 3: Failure and Load-Bending Attitude of Proportion of Waste Lathe Scraps for 2ϕ8 Tension Reinforcement

In this part of the investigation, while tension reinforcement in the RCB is used constant as 2ϕ8, proportions of waste lathe scraps are used as 0%, 1%, 2%, and 3%. As detailed by empirical results for BREF-3, BCNC-3, BCNC-6 and BCNC-9, it is noticed that there were remarkable shear and bending failure in the RCB depending on the vertical load as shown in Figure 16. According to Figure 17, bendings escalated as a rectilinear line until an accurate stage and the ultimate of this rectilinear line relates to 35.44 kN, 36.85 kN, 37.20 kN, and 38.47 kN for BREF-3, BCNC-3, BCNC-6 and BCNC-9. Then, 15.61 cm, 8.71 cm, 43.99 cm, and 45.76 cm bending is detected at maximum vertical load for BREF-3, BCNC-3, BCNC-6 and BCNC-9. After these loads, although the load diminished, the bending is slightly escalated. Hence, 70.94 cm, 69.78 cm, 72.97 cm, and 74.66 cm maximum bending for BREF-3, BCNC-3, BCNC-6 and BCNC-9 was detected at the ultimate of the test and RCB lost its load carrying ability at this bending values. As detected from the empirical results shown in Figure 17 and Table 3, as all proportions of waste lathe scraps are used in the RCB, it is detected that bending type failure occurs in all RCBs. Furthermore, as detected from the empirical test results, it is detected that the load–displacement ability of RCB is increase as the proportion of waste lathe scraps is increased for all proportions except for 1% waste lathe scraps.

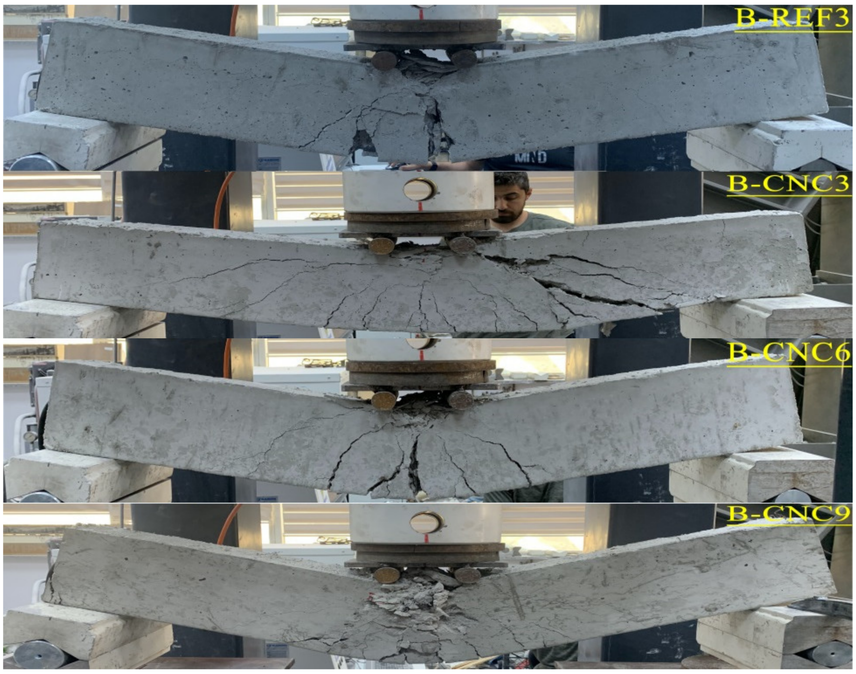

Figure 16. Failure and bending attitude of RCB for BREF-3, BCNC-3, BCNC-6, BCNC-9.

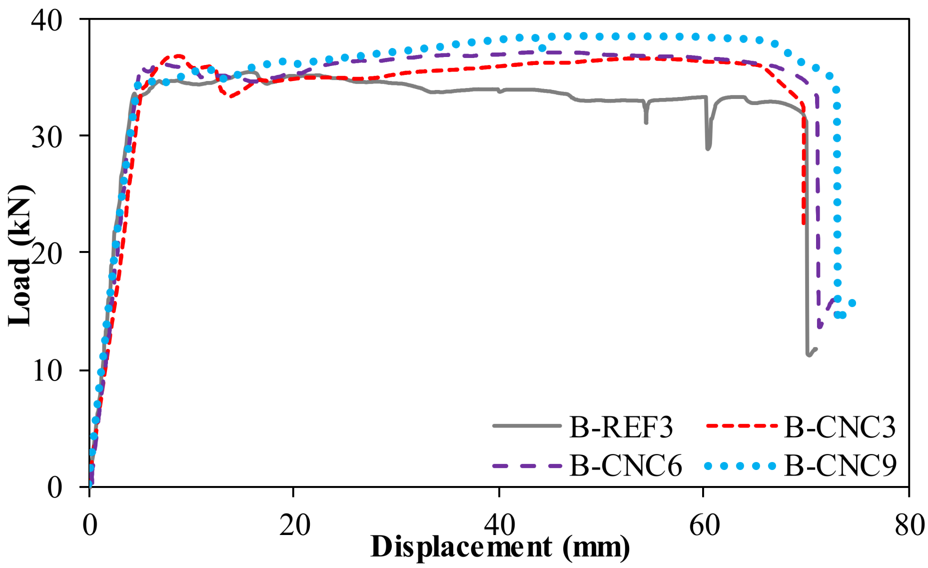

Figure 17. Load-Bending attitude of reference RCB for BREF-3, BCNC-3, BCNC-6 andBCNC-9.

5. Conclusions

Examining the bending behavior of reinforced concrete structures under external loads plays a vital role for the safety of these structures. For this aim, in this investigation, both the material behavior of concrete and failure behavior of various RCBs procreated with waste lathe scraps were investigated using empirical tests. Three of these specimens were reference specimens without any lathe scraps while the other ones consisted of V_f

proportion of 1%, 2% and 3% lathe scraps. After RCBs are organized in the laboratory, these special RCBs are exposed to failure tests using special gadgets. A vertical load is applied to the RCBs with various lathe scraps proportions and bendings in the RCBs are measured. Failure and bending behaviors of the RCBs are estimated according to the empirical tests in detail. These important results are assessed as below:

- According to slump test results, it was noticed that the workability of concrete reduced on increasing of the steel scrap content. In the other words, the concrete consistency diminishes depending on waste lathe scraps proportion.
- According to empirical test results, it can be obviously indicated that the maximum load carrying value in the RCB increases when the proportion of waste turned scrap in the concrete mix increases. Once reinforcement RCBs with different waste turned scrap proportions are compared with each other, maximum bending in the middle of the RCB is detected for 2% waste turned scrap RCB, and its numerical value is 74.66 mm.
- It is apparently realized that waste turned scrap proportion considerably affects failure attitude of the RCBs. Significant vertical and bending failures are detected in the RCBs depending on waste turned scrap. As waste turned scrap proportion in the concrete mixture is escalated from 0% to 3%, failures in the RCBs clearly grow and the widths of these failures rises depending on the waste turned scrap proportions.
- In this investigation, the impact of different proportions of tension reinforcement on the failure and bending attitude of RCBs is clearly investigated in detail. As detected from the empirical results, for all proportions of waste lathe scraps used in the RCB, it is detected that shear type bending occurs in RCBs using 2ϕ12 tension reinforcement. For other sections, bending type failure occurs in RCBs.
- The use of recyclable materials in conventional concrete has become widespread in recent years. Waste lathe scraps are one of these wastes. The study showed that when this waste material is used in concrete, it has a positive effect on the ductility and strength of the reinforced concrete element.
- It is recommended to use V_f of 2% lathe steel scraps in order to get optimum strength and workability for the practical applications.
- However, most of the structural system members in a reinforced concrete building are also affected by other cross-sectional internal forces besides bending moment. For example, a column under the effect of shear force + bending moment + axial force, a beam under the effect of torsion moment, a slab under the effect of punching force, high shear force on shear walls are examples of these. For this reason, a single type of reinforced concrete element sample often cannot go beyond a recommendation for a global structural design. It is clear that the global behavior of the structure should be better understood with the use of this type of material in concrete.

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