Experimental Study on Flexural Performance of Reinforced Concrete Beams with Lap Splices and Threaded Coupler-type Mechanical Splice

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Abstract

This study aimed to assess the feasibility of mechanical splicing as an alternative to traditional lap splicing in reinforced concrete (RC) beams. Six RC beams, including a control beam, a lap-spliced beam, and a mechanically spliced beam using threaded couplers, were subjected to two-point load tests. While the lap-spliced beam exhibited the highest load-carrying capacity, the control beam demonstrated superior ductility, as indicated by higher deflection. The mechanically spliced beams, on the other hand, displayed inferior flexural performance compared to both the control and lap-spliced beams. This reduced performance was attributed to the decreased cross-sectional area of the rebars due to threading and the limited strain distribution caused by the short coupler sleeve. Consequently, this study concludes that lap splicing remains a more effective method for achieving desired levels of flexural strength and ductility in RC beams, and threaded coupler splicing, in its current form, is not a suitable replacement.

1. Introduction

Reinforced concrete is widely favored in various building constructions worldwide. By combining adequate concrete compressive strength with reinforcing bars that possess sufficient tensile strength, an ideal structural element known as reinforced concrete can be created. Reinforced concrete (RC) can be shaped into various desired sizes and shapes, increasing its flexibility and versatility [1]. In multi-story buildings, RC elements such as beams, columns, shear walls, and slabs are commonly utilized.

RC beams play a crucial role in transferring the load from the slabs to the columns. This load generates axial compression and bending forces in the columns, which are then distributed to the foundation. In a flexible beam structure like the one described, the strength is influenced by factors such as the compressive strength of the concrete, the yield stress of the reinforcement, the length of the beam, and the beam's stiffness. Another significant factor to consider is ductility. It is essential for buildings to be designed with high ductility, meaning they can undergo substantial deformations without experiencing sudden fractures due to applied loads [2]. RC beams are commonly categorized as tension-controlled elements, and thus they are designed under an under-reinforced condition where failure initially occurs at yielding of the steel [3].

In construction, the dimensions and lengths of RC beams can vary. However, the length of the rebar is often limited due to manufacturing [4] and transportation considerations [5]. Consequently, rebar splicing becomes necessary. Rebar splicing is vital in reinforced concrete structures as it facilitates the transfer of stress between separate bars, ensuring they function together as a continuous reinforcement system [6]. There are different

methods for rebar splicing, including welded splicing, mechanical splicing, and lap splicing [7]. Among these methods, lap splice is the most commonly used in construction. Lap splicing, also known as the conventional method, involves providing sufficient length of rebar at the spliced area [8]. It can be performed as either a contacted or non-contacted splice. However, there are drawbacks to lap splices, including reinforcement congestion in the spliced area [9], increased total weight of rebars affecting both environmental and economic aspects, and a reduction in strength or displacement capacity in areas allowing inelastic deformation [10].

An alternative to lap splicing is the use of mechanical splices. Mechanical splicing involves joining bars using couplers, which can be classified as grouted sleeve couplers, shear-screw couplers, swaged couplers, headed bar couplers, and threaded couplers [8]. The application of mechanical splices has the potential to address the drawbacks of lap splices. The primary benefit of couplers is to reduce splice length and minimize bar congestion at the connection [11]. Hence, mechanical splices offer an attractive time- and cost-effective advantages [12]. This study explores the opportunity to replace the lap splice method with mechanical splicing.

This research is motivated by the question of whether the use of mechanical splices in RC beams can offer improved performance and behavior compared to the commonly used lap splices in construction. Evaluations of the performance and behavior of RC beams with mechanical splices are rarely conducted by researchers. Previous studies on performance of RC beams with couplers were conducted by Nah [13] and Phuong & Mutsuyoshi [14], however, both of which used rebars with diameter of 19 mm and 22 mm. This study aims to evaluate the performance of couplers for smaller-diameter rebars, specifically 13 mm. A series of experimental studies were conducted on RC beam specimens with different splice variations, including lap splices and threaded coupler-type mechanical splices. The results were compared to a control beam specimen without any splice. The objective is to comprehend the performance comparison of reinforced beams with and without rebar splices. The observed performance includes flexural strength, ductility, and the occurrence of crack patterns (collapse).

Nomenclatures and Abbreviations

ℓ_d	= length of development (mm)
ℓ_{st}	= length of the lapped deformed rebars (mm)
f_y	= yeild strength of reinforcement (MPa)
f'_c	= compressive strength of concrete (MPa)
Ψ_t	= factor used to modify development length for casting location in tension
Ψ_e	= factor used to modify development length based on reinforcement coating
d_b	= diameter of longitudinal reinforcement (mm)
λ	= modification factor of lightweight concrete relative to normalweight concrete
a	= depth of equivalent rectangular stress block (mm)
b	= width of the beam (mm)
d	= effective depth of the beam (mm)
A'_s	= area of compression reinforcement (mm^2)
$A_{s,p}$	= provided area of rebars (mm^2)
$A_{s,r}$	= required area of rebars (mm^2)
f_s	= stress in compression reinforcement (MPa)
d'	= distance from extreme-compression fiber to centroid of compression reinforcement (mm)
Mnx	= Nominal flexural moment from laboratory experiment
Mn	= Nominal flexural moment from theoretical calculation
NS	= No Splicing (Control Beam)
CLS	= Contacted Lap Splice Beam
$MSTC$	= Mechanical Splice Threaded Coupler-Type Beam
P	= Plain rebar
D	= Deformed Rebar
RC	= Reinforced Concrete
$LVDT$	= Linear Variable Differential Transformer

2. Literature Reviews

2.1 Lap Splice

Lap splices are commonly utilized in construction because of their simplicity and efficiency [15]. They are categorized into two types: contact and non-contact splices. In a contact lap splice, the spliced rebars are positioned adjacent to each other and secured with wires, as illustrated in Fig. 1(a). To ensure adequate spacing, the distance between any two lap splices must be no less than the larger value of one inch, the bar diameter, or four-thirds the aggregate diameter. Alternatively, non-contact lap splices involve parallel placement of rebars with

a gap or spacing, as depicted in Fig. 1(b). The transverse spacing between the centers of spliced bars should not exceed the smaller value of one-fifth of the required lap length or six inches [16]. For this research, a contact lap splice configuration was employed in the RC beam specimens.

The performance of lap splices is affected by several factors, including the concrete cover, lap length, proportion and diameter of the reinforcing bars, transverse reinforcement in the splice region [17], as well as the properties of the concrete and the positioning of the poured concrete [18]. Both ACI 318-14 [19] and SNI 2847:2019 [16] stipulate that lap splices are restricted to rebars with diameters smaller than 36 mm, as there is insufficient experimental data for splices involving larger diameters. The calculation of the required lap length is governed by the formula provided in SNI 2847:2019, as presented in Equation (1).
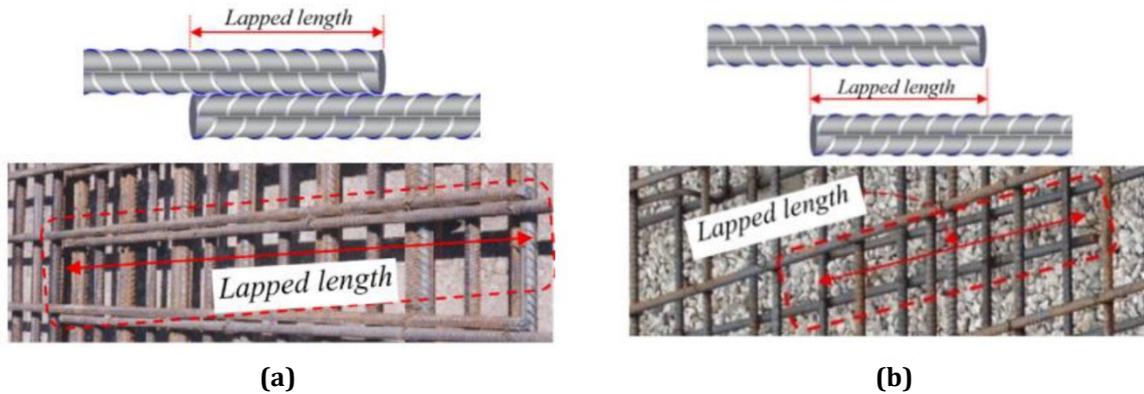

Fig. 1 *Lap splice (a) Contacted; (b) Non-contacted* [20]

$$\ell d = \left(\frac{f_y \, \Psi_t \, \Psi_e}{2,1 \, \lambda \, \sqrt{f'_c}}\right)d_b \tag{1}$$

In tension conditions, lap splices can be classified into two classes: Class A and Class B, as specified in the Indonesian Standard SNI 2847:2019 and the American Standard ACI 318-14. The length of the lapped deformed rebars (ℓ_{st}) should be determined based on the required development length of the rebars (ℓ_d). The lap splice lengths for deformed bars in each class are presented in Table 1.

Table 1 *The length of lapped rebars in tension condition as per SNI 2847:2019 and ACI 318-14*

$A_{s,p}/A_{s,r}$	Percentage of spliced rebars	Type of Splice	ℓ_{st}	
≥ 2.0	50	Type A	Greater of	1,0 ℓ_d and 300 mm
	100	Type B	Greater of	1,3 ℓ_d and 300 mm
< 2.0	All Cases	Type B		

2.2 Mechanical Splice

Reinforcement bars in this method are joined together using rigid elements commonly known as couplers. These couplers can be classified into five main groups based on their ability to transfer stress between the bars and the couplers: shear screw couplers, headed bar couplers, threaded couplers, grouted couplers, and swaged couplers [6]. The advantages of using mechanical splices include rapid installation, environmentally friendly application, and satisfactory performance under tension and compression forces. Specifically, mechanical splice used in this experiment is threaded couplers with yield strength of 530 MPa and tensile strength 705 MPa. Outer diameter of the coupler is 21 mm while the inner diameter is 11 mm. Threaded coupler used in this research can be seen in Fig. 2.

To prepare a threaded coupler for splicing rebar, first, both ends of the rebars should be cleanly cut and free from contaminants, such as rust or grease. Using a rebar threading machine, threads are then cut onto each rebar end, with thread depth and length sufficient for full engagement according to the coupler's specifications (see Fig. 2(a). For installation, the coupler is first screwed onto one end of the rebar and tightened securely. The second rebar is then aligned and screwed into the opposite end of the coupler until both rebar ends are fully engaged and securely connected.
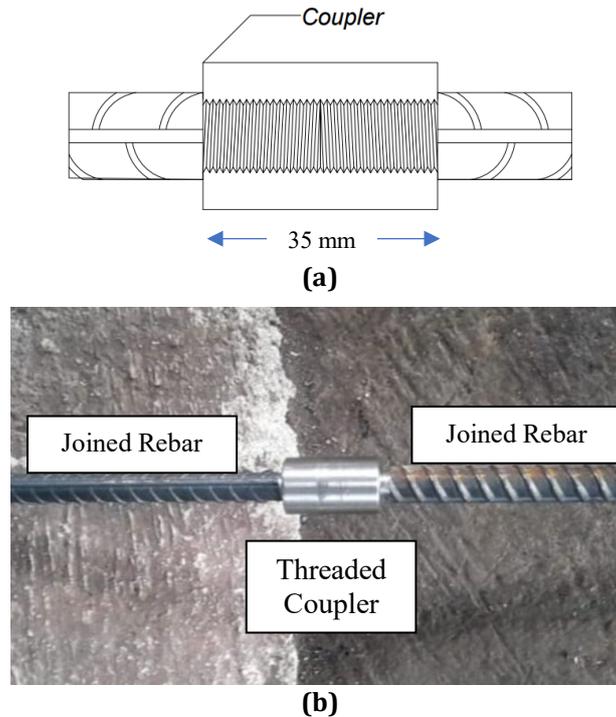
Fig. 2 *Threaded coupler mechanical splice (a) Illustration; (b) Real Setup*

3. Literature Reviews

This study employs a laboratory experimental method. A series of systematic laboratory tests are conducted on prepared specimens to measure various parameters, including concrete compressive strength, rebar yield and tensile strength, maximum load and deflection of RC beam, and crack pattern.

3.1 Concrete Compression Test and Rebar Tension Test

Compressive and tension testing of concrete provides insights into how the material behaves under compression and tension by measuring key variables such as strain, stress, and deformation [21]. In this study, a compression test is conducted on cylinder-shaped concrete specimens to determine their compressive strength (f'_c) in accordance with SNI 1974:2011. The specimens have a diameter of 150 mm and a height of 300 mm. Prior to testing them in the compression machine, the specimens are cured in the laboratory by applying saturated wet coverings. These coverings are consistently kept wet throughout the curing period. This process is crucial for maintaining optimal temperature and moisture conditions in the concrete for an extended period, ensuring sufficient hydration. Meanwhile, tensile strength test in this study was conducted to record the yield and tensile strength of the rebars in accordance with SNI 8389:2017. The mechanical properties of concrete and rebars are needed to estimate the nominal flexural moment of RC beam specimens.

3.2 Test Specimens

This study utilized reinforced concrete (RC) beams with dimensions of 200 mm x 300 mm x 2000 mm (width x depth x length). A total of six specimens were prepared, with two beams per variant across three variants: (i) RC beams without splicing (control specimens), (ii) RC beams with lap-spliced rebars, and (iii) RC beams with threaded coupler-type mechanical splices. The RC beam in this study utilized deformed rebars with yield strength of 420 MPa as tension rebars and plain rebars with yield strength of 280 MPa as compression rebars and stirrups. The compressive strength of the concrete is 25 MPa. Splices were located at the mid-span to assess their performance under maximum flexural moments. Details of the variations and reinforcement arrangements are illustrated in Fig. 3–5 and summarized in Table 2. The reinforcement design adhered to SNI 2052:2017 and SNI 2847:2019 standards.

Concrete cylinder tests were conducted to determine the actual compressive strength (f'_c), while tensile strength tests provided the actual yield and tensile strength (f_y) of the reinforcing bars. These properties were essential for calculating the theoretical nominal moment (Mn) of the beams using analytical formulas.

The lap splice length was initially calculated as 346.667 mm using Equation (1), based on the following assumptions: normal-weight concrete with a target f'c of 25 MPa, non-epoxy-coated reinforcing bars, a rebar

diameter of 13 mm, and an assumed fy of 280 MPa. This value was rounded and adjusted to 430 mm for practical installation. However, subsequent tensile tests revealed that the actual fy of the reinforcing steel was 464.646 MPa, classifying the bars as TS420 under SNI 2052:2017 rather than the assumed TS280. Consequently, the required lap splice length should have been 520 mm. Unfortunately, this discrepancy was discovered only after the specimens had been assembled and cast, as tensile testing and rebar installation occurred simultaneously.

Recognizing this oversight, the shorter lap splice length was noted as a research limitation. It was acknowledged that an inadequate lap length could compromise the bond strength between the rebars and concrete, potentially leading to slippage or separation under loading. This issue could reduce load transfer efficiency and the structural stability of the elements under flexural stress. Despite this limitation, the study proceeded, with the implications of the shortened lap length incorporated into the research findings.

Table 2 *RC beam specimens*

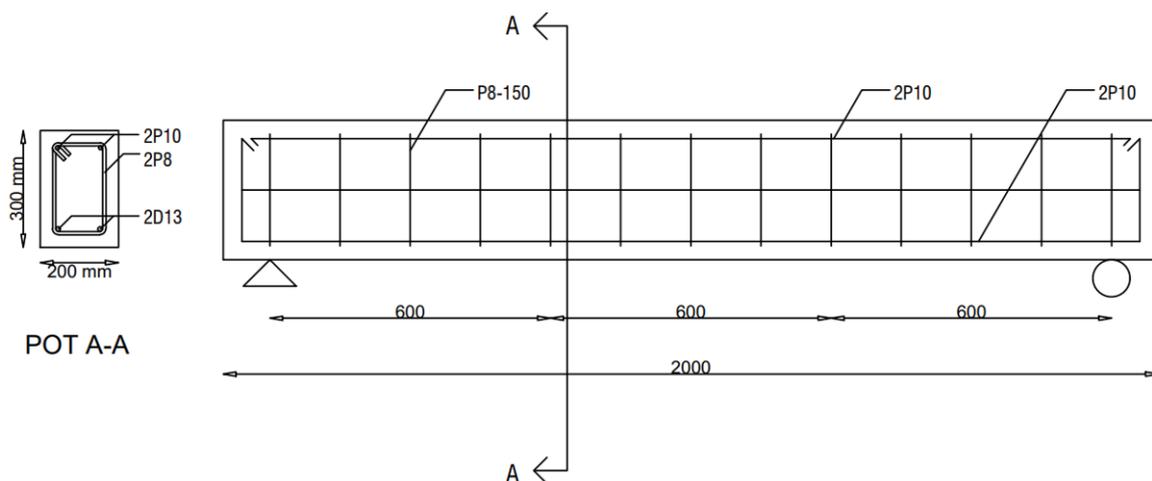| RC Beam | Rebars Detail | | Type of Splicing |
	Longitudinal	Transversal	
NS-1	Top 2P10	P8-150	No Splicing (Control Beam)
	Bottom 2D13		
NS-2	Top 2P10	P8-150	
	Bottom 2D13		
CLS-1	Top 2P10	P8-150	Contacted Lap Splice
	Bottom 2D13		
CLS-2	Top 2P10	P8-150	
	Bottom 2D13		
MSTC-1	Top 2P10	P8-150	Mechanical Splice Threaded Coupler
	Bottom 2D13		
MSTC-2	Top 2P10	P8-150	
	Bottom 2D13		

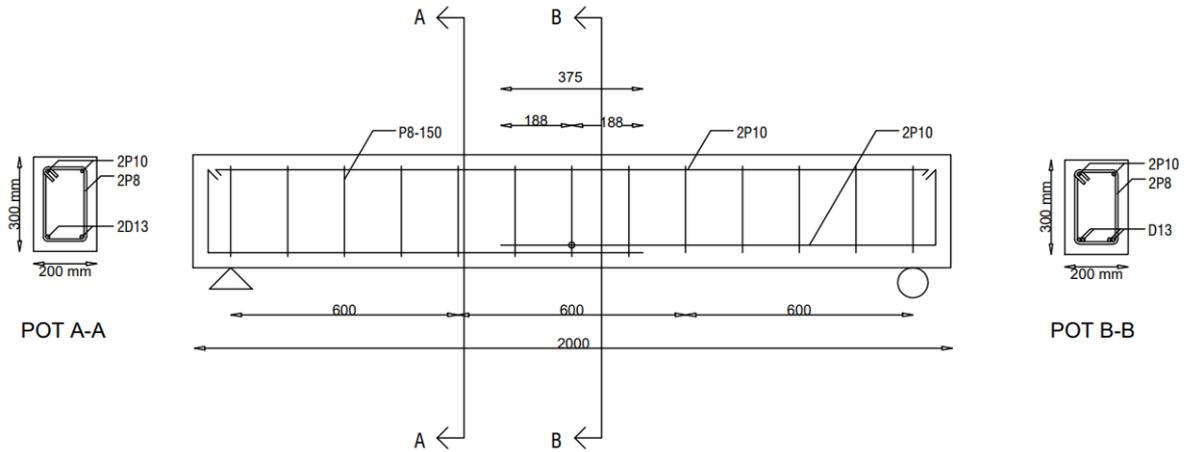**Fig. 3** *Reinforcement detail of NS beams*

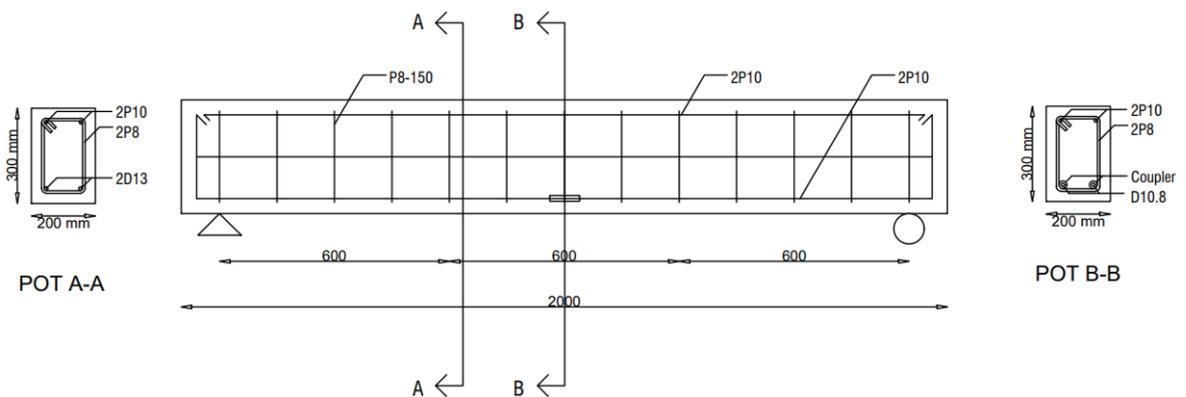**Fig. 4** *Reinforcement detail of CLS beams*

Fig. 5 *Reinforcement detail of MSTC beams*

3.3 Experiment Setup

The RC beam specimens were designed as simply supported beams with an effective span of 1.8 meters. The beams were supported by a pin support at one end and a roller support at the other end. Laboratory tests were conducted using a two-point loading configuration, with the loads applied 60 cm apart. Using a hydraulic pump, the load was incrementally increased at a rate of 0.252 kN until the beam reached its ultimate load and failed. A Linear Variable Differential Transformer (LVDT) was installed at three locations between the two loading points to measure deflections during the testing process, with all data recorded via a data logger. Illustrations of the testing setup and actual test configurations are provided in Fig. 6 and 7.

To accommodate the research timeline, an additive was included in the concrete mix to accelerate the hardening process, allowing the tests to be conducted at 14 days of concrete age. The additive used was Damdex, which contains calcium chloride agents. These compounds facilitate faster hydration of cement, expediting the curing and hardening of the concrete.
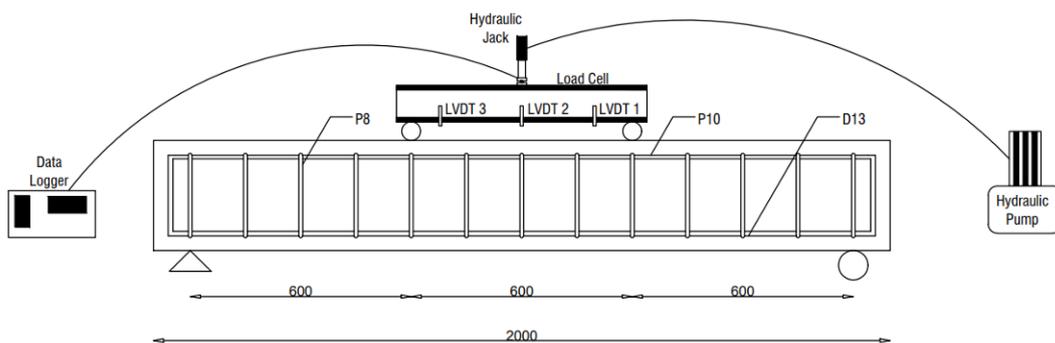

Fig. 6 *The illustration of experiment setup*

Fig. 7 *Experiment setup*

4. Result and Discussion

4.1 Rebar Tensile Strength Test Result

Tensile tests were performed on rebars to determine the yield and tensile strengths of both spliced and unspliced rebars. The results indicated that unspliced rebars had a yield strength (f_y) of 464.65 MPa and a tensile strength (f_u) of 646.63 MPa. In contrast, rebars spliced with threaded couplers exhibited a yield strength (f_y) of 471.18 MPa and a tensile strength (f_u) of 556.85 MPa. Based on the test results, it can be observed that the f_y and f_u values of the rebars spliced using a threaded coupler are greater than those without splicing.

Additionally, the laboratory tests revealed that damage to the rebars spliced using a threaded coupler occurred at the threaded region. This can be attributed to the reduction in the cross-sectional area of the threaded end, resulting in a smaller effective area compared to the non-threaded end. Consequently, tensile stress accumulated at the threaded end, leading to damage in that region. The summary of the test results can be found in Table 3. The damage to the D13 rebars with and without a threaded coupler can be observed in Fig. 8.

Table 3 *The records of rebar tensile test on deformed bars*

Specimens	Targeted f_y (MPa)	Recorded f_y (MPa)	Recorded f_u (MPa)
Rebars without splicing	420	464.65	646,63
Rebars Spliced using a Threaded Coupler	420	471.18	556.85

(a) Rebar without splicing

(b) Rebar spliced using a threaded coupler

Fig. 8 *Tensile test*

Penerbit
UTHM

4.2 Concrete Compression Strength Test Result

Concrete cylinders were prepared and tested alongside each RC beam specimen to determine the compressive strength (f'_c) of the concrete. Compression tests were conducted on these cylinders at 14 days of age using a compression testing machine. While concrete is typically tested at 28 days, the research timeline necessitated the use of a specific additive in the mix to accelerate the concrete's hardening process, allowing for testing at an earlier age. The results of concrete compressive strength tests are shown in Table 4. The results confirm that all compressive strength values (f'_c) met the minimum targeted value of 25 MPa, indicating that the mix design, including the proportions of PC, coarse and fine aggregates, and water, was appropriate.

**Table 4** *The dimensions and compressive strength of concrete cylinders*

Cylinders	Diameter (mm)	Height (mm)	Section Area (mm²)	Ultimate Load (kN)	f'_c (MPa)
C-NS-1	150.8	299.6	17860.46	595	33.31
C-NS-2	150.8	299.6	17860.46	540	30.23
C-CLS-1	149.3	289.3	17506.91	455	25.99
C-CLS-2	149.7	299.4	17600.84	555	31.53
C-MSTC-1	149.7	299.4	17600.84	575	32.67
C-MSTC-2	149.3	289.3	17506.91	540	30.85

## 4.3 The Flexural Strength Test on RC Beams

Flexural strength tests were performed on RC beam specimens to evaluate their flexural behavior, including flexural moment capacity, deformation, and crack development. The results of these tests provided key data, such as the maximum load (in kN) and the corresponding deflection (in mm), which were measured using an LVDT. The tests also allowed for observation of the crack development that formed as the hydraulic jack applied the load. Details of the maximum load and deflection values are presented in Table 5, while the load-deflection relationships are illustrated in Fig. 9, 10, and 11.

Table 5 *Maximum loads and deflections*

RC Beam	Ultimate Load (kN)	Deflection (mm)		
		LVDT 1	LVDT 2	LVDT 3
NS-1	132.55	66.28	72.60	63.76
NS-2	130.79	100.75	75.58	65.02
CLS-1	137.84	78.44	61.98	49.58
CLS-2	138.85	38.84	44.08	63.76
MSTC-1	100.84	14.69	27.90	13.44
MSTC-2	95.004	16.75	19.07	14.89
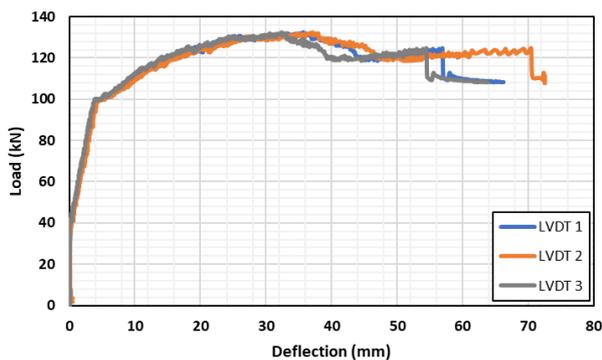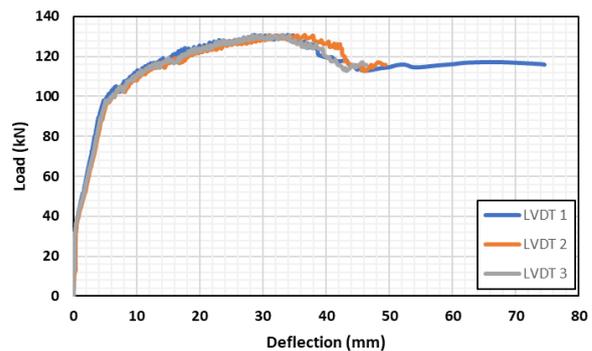
(a) NS-1   **(b) NS-2**

Fig. 9 *Load-deflection graphs for NS beams*

(a) CLS-1   **(b) CLS-2**
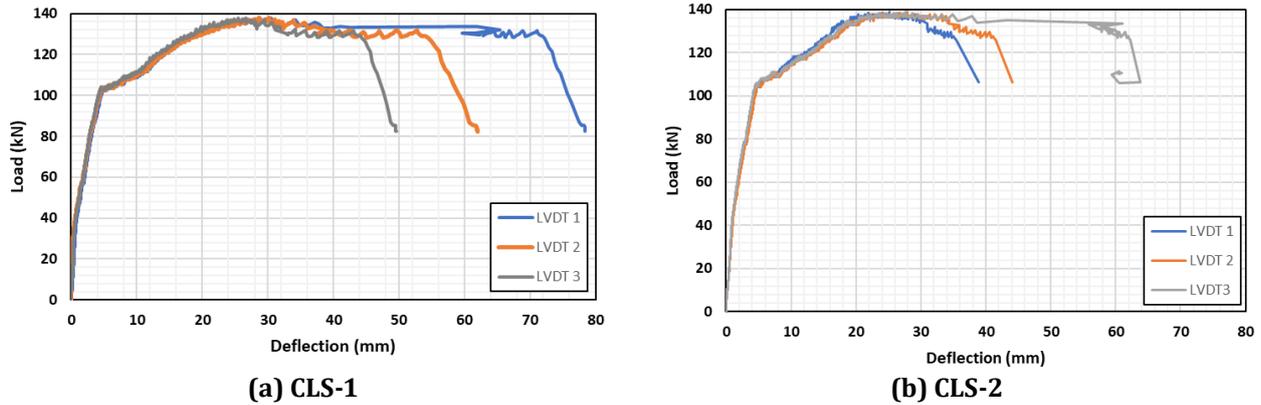
Fig. 10 *Load-deflection graphs for CLS beams*

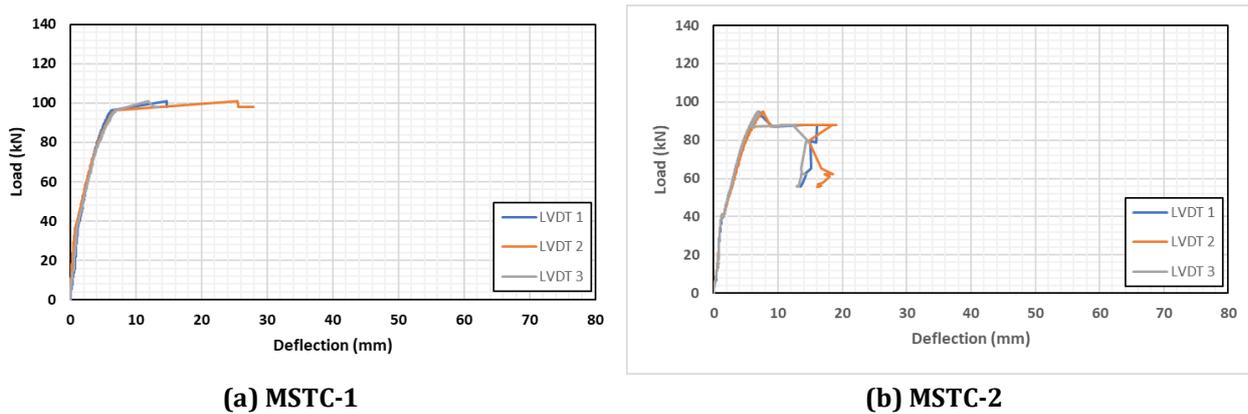**(a) MSTC-1**   **(b) MSTC-2**

Fig. 11 *Load-deflection graphs for MSTC beams*

Based on Table 5, beams with lap splice, LS-1 and LS-2, achieved the highest maximum load of 137. 844 and 138.852 kN, while beams with threaded coupler, MS-1 and MS-2, exhibited the lowest maximum load of 100.836 kN and 95.004 kN. This suggests that reinforced concrete beams with lap splice perform better compared to the other beams in terms of load capacity. However, when considering deflection, it is observed that the beam without any rebar splice (CB-1 and CB-2) generally experienced the greatest deflection, while the beam with threaded coupler splice had the smallest deflection. This indicates that beams with no rebar splice demonstrate superior ductility. Ductility refers to the ability of structural elements to undergo significant deformation without sudden collapse [2], and it can be measured as the ratio of ultimate deformation to yield deformation [9]. Ductility plays a crucial role in preventing structural failure, as a ductile structure provides early warning signs before failure occurs [22]. Based on the results of laboratory tests, it can be concluded that although beams with lap splice can withstand greater loads, beams without any rebar splice exhibit better ductility. On the other hand, beams with coupler connections demonstrate inferior performance in terms of both maximum load capacity and ductility compared to the other two variations. Furthermore, beams with coupler connections tend to exhibit greater brittleness, as evident from the deflection values. This is due to the very limited length of the threaded coupler. As shown in Fig. 2, the coupler length is only 35 mm, which restricts its strain capacity. Moreover, this 35 mm length must accommodate both rebar ends, leaving only 17.5 mm for each rebar to distribute strain as seen in Fig. 8. According to Dahal & Tazarv [8], strain distribution improves with a longer coupler, allowing for greater deformation.

In reinforced concrete beams with threaded coupler connections, the deflection observed at the maximum load is smaller compared to the deflection in reinforced concrete beams with lap joints. This finding contrasts with the results of a previous study conducted by Cho et al. [23], where the deflection of the beam with coupler connections was greater than the deflection value of lap joints. This difference in findings could be attributed to the absence of stirrups in the lapped area, resulting in smaller deflection values. This current research builds upon the work of Cho et al. [23] by incorporating transverse stirrups 8in the reinforcement connection zone. Consequently, in beams with lap splices, the deflection values obtained are greater than those in beams with threaded coupler splices.

4.4 The Flexural Moment of RC Beams

The maximum flexural moment can be determined by analyzing the maximum load obtained from laboratory tests. This experimentally derived flexural moment is then compared to the theoretical flexural moment calculated using analytical formulas. The testing setup for reinforced concrete beams followed the procedure outlined in the research methodology. Each beam was simply supported at both ends and subjected to a two-point load applied along its mid-span. Under this configuration, the maximum bending moment is expected to occur at the beam's mid-span, making this region critical for analysis. Consequently, the calculated flexural moment corresponds to the bending moment at the mid-span. The nominal flexural moment values for all test specimens, as calculated, are presented in Table 6. Among the tested beams, those with lap-spliced rebars exhibited the highest nominal flexural moment, while beams with coupler-connected reinforcements displayed the lowest values. This discrepancy can be attributed to the reduction in the tensile reinforcement's cross-sectional area when couplers are used. Coupler connections require threading at the ends of the reinforcement bars, which decreases their net cross-sectional area. In contrast, lap joints allow reinforcement bars to overlap side by side without diminishing their cross-sectional dimensions.

Theoretical flexural moments were computed using material property data and beam dimensions. Key parameters included the beam cross-section dimensions, reinforcement types, concrete compressive strength (f'_c), and rebar yield strength (f_y). The beam cross-section was designed as 200 x 300 mm, with 2D13 bars used for tension reinforcement, 2P10 bars for compression reinforcement, and P8 stirrups spaced at 150 mm intervals. Material properties, including f'_c and f_y, were determined through concrete compressive and tensile strength tests, as detailed in Tables 3 and 4. The theoretical nominal flexural moments were calculated using Equation (2) and are summarized in Table 6. These values provide a benchmark for evaluating the performance of the tested beams.

$$Mn = \left[(0.85\, f'_c\, a\, b)\left(d - \frac{a}{2}\right)\right] + \left[(A'_s\, fs)\,(d - d')\right] \tag{2}$$

The data presented in Table 6 reveal that the experimental flexural moment (Mnx) consistently exceeds the theoretical Mn. This discrepancy arises due to simplifications inherent in the theoretical calculations. For instance, these calculations idealize the behavior of reinforced concrete beams by assuming a linear strain distribution in the concrete, as per Bernoulli's principle, and neglecting any slip between the concrete and reinforcing steel. However, such idealized assumptions may not accurately represent the actual behavior of the beam under load. Real-world conditions often introduce complexities and nonlinearities that deviate from theoretical models. Additionally, the actual material properties and behavior of the beam play a significant role in influencing the experimental results, leading to the observed differences between the theoretical and experimental flexural moments.

Table 6 *Experimental and theoretical nominal flexural moment*

RC Beams	Experimental, *Mnx* (kNm)	Theoretical, *Mn* (kNm)	Ratio
NS-1	38.73	37.86	1.02
NS-2	38.20	36.50	1.05
CLS-1	40.32	34.13	1.18
CLS-2	40.62	37.09	1.10
MSTC-1	29.21	33.73	0.87
MSTC-2	27.46	32.94	0.83

Based on Table 6, it can be concluded that beams with lap splice reinforcement exhibit higher flexural moment values (*Mnx*) compared to other beam specimens. Specifically, LS-1 and LS-2 have *Mnx* values of 40.316 kNm and 40.619 kNm, respectively. On the other hand, beams with threaded coupler splices show the lowest *Mnx* values, with MSTC-1 and MSTC-2 recording 29.214 kNm and 27.464 kNm, respectively. The difference in *Mnx* values can be attributed to the presence of a threaded section in the rebar, which reduces the cross-sectional area and subsequently results in smaller *Mnx* values. In contrast, lap splices maintain the full cross-sectional area of the bars by arranging two bars parallel to the lapped length, thus avoiding any reduction in their cross-sectional area.
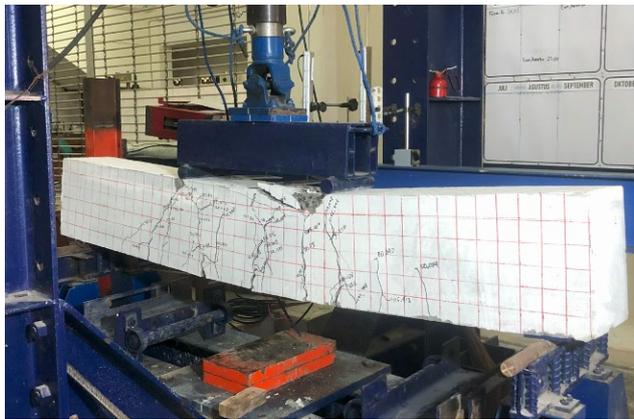
4.5 Crack Pattern of RC Beams

The maximum flexural moments in the beam specimens occurred at their mid-span, resulting to the development of cracks. As shown in Fig. 12, flexural cracks propagated along the length of the beam up to the yield point. These cracks developed vertically, originating from the bottom of the beam and extending upward due to the tension in

the lower section of the RC beam. While concrete provides compressive strength, the embedded steel reinforcement resists tensile forces, preventing sudden collapse.

The images reveal that multiple cracks formed prior to reaching the maximum load. A single dominant crack at the location of maximum curvature was responsible for the structural failure. Notably, no shear cracks were observed, as indicated in Fig. 12, confirming that the failure mode was governed by flexural moments.

For RC beams without splices (CB) and with mechanical splices (MSTC), the primary cracks causing failure were located in the mid-span region, consistent with findings by Phuong & Mutsuyoshi [14]. In contrast, for RC beams with lap splices (LS), the major cracks occurred slightly to the left or right of the mid-span, with only minor cracks appearing in the central region. This behavior may be attributed to the greater cross-sectional area in the lapped zone, where two bars overlap. Consequently, the primary failure cracks formed outside this lapped region. These findings align with the results reported by Yoo et al. [24].
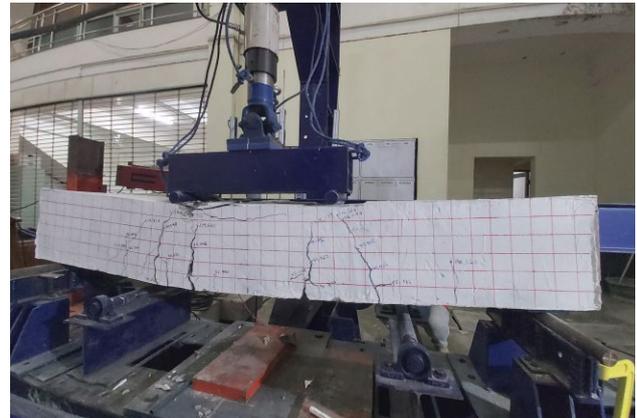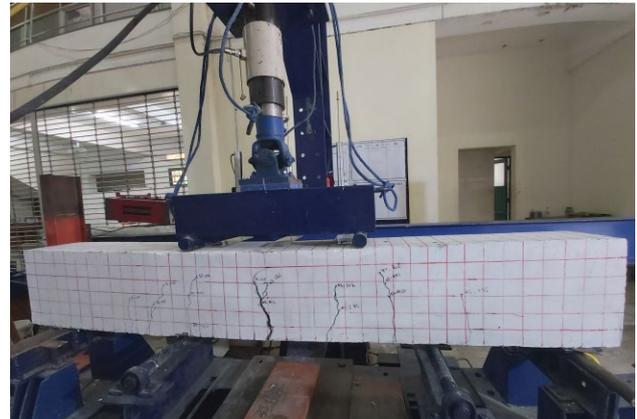

(a) CB-1   **(b) CB-2**
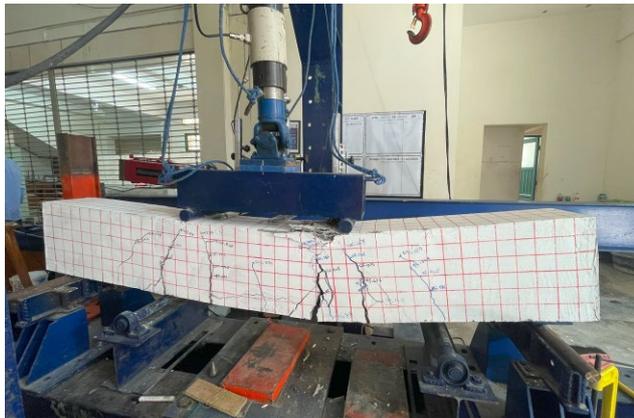
(c) LS-1   **(d) LS-2**

(e) MSTC-1   **(f) MSTC-2**

Fig. 12 *Flexural crack pattern on beam specimens*

5. Conclusion

In this study, a series of experimental tests were conducted to evaluate the flexural performance of reinforced concrete (RC) beams with lap splices, mechanical splices, and no splices. The results indicate that RC beams with lap splices outperform the other specimens in terms of maximum load capacity. However, when considering deflection measurements, RC beams without splices exhibit better performance, indicating higher ductility. On the other hand, RC beams with threaded coupler splices demonstrate inferior performance in both aspects compared to the other specimens. The failure of the threaded coupler mechanical splice occurred at the threaded region of the rebar. Based on these findings, it can be concluded that the threaded coupler mechanical splice is unable to match the superior flexural performance provided by lap splices. Therefore, when splicing is required in tension conditions, lap splices remain the preferred option. Based on the findings of this study, future research will aim to evaluate couplers with longer sleeves. Additionally, future studies will include a cost analysis comparing lap splices and mechanical splices.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Jafar, Hariadi Yulianto; **data collection:** Zaneta Ambarwati, M Firzaki Musyaffa; **analysis and interpretation of results:** Hariadi Yulianto, Jafar; **draft manuscript preparation:** Jafar. All authors reviewed the results and approved the final version of the manuscript.*

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