INTERNATIONAL JOURNAL OF ADVANCED STRUCTURAL ENGINEERING (2024)

The effect of different arrangements of longitudinal reinforcements on the capacity of wide concrete beams

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Abstract:

A beam that has a width greater than the width of the column connected to it is called a wide beam. Due to the reduction in the height of the beams in this type of system, many advantages are created, including reducing the costs of molding and construction, increasing the execution speed, reducing the height of the floor and of course increasing the number of floors in high-rise buildings, as well as including Other advantages of these beams from the architectural point of view are the hiding of the beams in the roof of the structure. In concrete structure design, ductility is one of the important parameters. The ductile behavior of the structure has a significant effect in reducing the design forces caused by the earthquake due to its energy absorption and loss. The role of reinforcement in the ductility of concrete is very important. In this article, a concrete beam with six different types of longitudinal rebar arrangement has been selected for study and four-point loading has been applied to the models. All models have been analyzed in ABAQUS finite element software. The results indicate that; The pattern of placing the rebar crosswise and diagonally has less hardness, ductility and resistance than other models. The highest amount of energy absorption was related to the model with six bars in a trapezoidal arrangement.

Keywords: Concrete Structure, wide Beam, Ductility, Reinforcement Arrangement, Finite Element Method.

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1. Introduction

Beam is one of the main members in the set of elements used in building structures. In fact, the main task of the beams is to withstand the stresses resulting from the shear force and bending moment caused by the loads on it and the weight of the beam itself. In the design of structures, beams are usually designed based on the existing bending moment and the shear rule is controlled in them. The system of wide beams in concrete frames has been used in the construction of building structures since the past until today. In this system, the height of the beam is considered equal to the height of the ceiling beams. Therefore, the height of wide beams is shorter than the normal beam, and this low height causes the width of the beam to increase in order to create the hardness and resistance necessary to bear the loads on the frame. The result of this increase in the dimensions of the beam is that the width of the beam is larger than the width of the column, which causes a part of the beam reinforcements to be restrained outside the column. Such systems have long been prevalent in the Arab countries of the Middle East and some European countries [1]. A wide beam is a beam that is wider than the width of the column connected to it. Wide beam frame system can be considered as a system between flat slab and conventional frame system with normal beam, which is called strip slab system. Wide beam structural systems can be used in buildings in two ways: 1. Wide beam systems with slabs 2. Wide beam systems with beams. The wide beam system with a slab includes a one-way slab connected to a wide beam, and the advantages of using it are: reducing the height of the building, more flexibility in the placement of columns, simpler molding, and reducing steel in the slab and for spans up to 7 meters. It is suitable. The system of wide beams with beams includes beams with the same depth as the wide beams, which are supported by the wide beams. Wide beam structural systems are of particular importance in situations where floor height is limited, and their use reduces the cost of molding. Using the mentioned system, in addition to reducing the overall height of the building, will reduce the costs of building columns, walls, elevators and other materials. Also, because wide beams provide more viewing space than ordinary beams, they are in the focus of attention of architects and designers. For example, if the structural system is a building with a glass exterior, it can be used to provide greater viewing angles to the inhabitants using a wide beam, thereby enhancing the external view, which has become a feature for the construction of high-rise buildings in Japan [2]. It is worth noting that wide beam frames have shortcomings such as lateral stiffness and increased displacement under earthquake loads. This issue attracted the attention of researchers to solve them in such a way that the results of their studies led to the process of completing the ACI regulations, which previously did not allow their use in earthquake-prone areas, but today it is allowed [3]. An example of a wide beam system with a slab is shown in Figure (1).

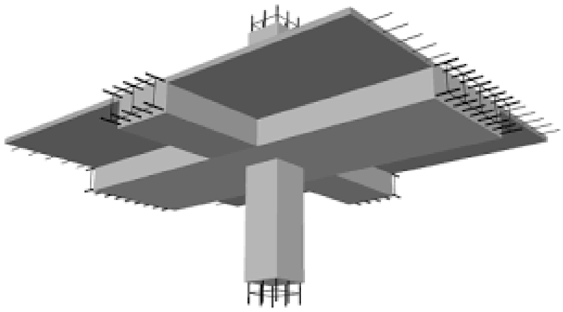

Fig. 1. Wide beam system with slab [4].

In general, when the reinforcement is used in the tensile zone of a concrete section, it practically bears all the tensile stresses in the final state.

Considering this issue, it is logical that the greater the amount of bending moment applied to the section, the more reinforcements we need in the tensile area. In areas with less anchorage, less reinforcement is used. But the problem is that steel reinforcements are tubular components with a constant cross-section, and the area of one reinforcement cannot be increased or decreased along the length of the beam, and as a result, to reduce the area of the reinforcements, the only solution is to use several reinforcements and increase the number of reinforcements. decrease in areas with less anchorage. But the problem is that steel reinforcements are tubular components with a constant cross-section, and the area of one reinforcement cannot be increased or decreased along the length of the beam, and as a result, to reduce the area of the reinforcements, the only solution is to use several reinforcements and increase the number of reinforcements. decrease in areas with less anchorage. In continuous concrete beams, steel reinforcements are used at the top and bottom of the section at all sections, while there is no need for reinforcement at the top of the section in the middle of a beam. This difference is caused by the difference of theoretical viewpoints in the process of concrete structure design, with regulatory and executive criteria. Concrete structure design regulations, such as the ninth topic of the National Building Regulations, consider it necessary to use at least reinforcements at the bottom and top of the section in order to ensure the ductility of the structure. Placement should be done based on the following two items:

1. In continuous concrete beams, the appropriate number of steel reinforcement is used all over the top and bottom of the section.
2. In certain places of the length of the beam, such as near the support or the middle of the beam, the bending capacity of the section may be increased with the help of reinforcing reinforcements.

In concrete structure design, ductility is one of the important parameters. The malleable behavior of the structure has a significant effect in reducing the design forces caused by the earthquake due to its energy absorption and loss. It should be noted that this issue is taken into account with the help of the behavior factor Ru in the fourth edition of the 2800 standard. The malleable structure will undergo a lot of significant deformations before its destruction, which will make its residents face warning signs before the structure collapses completely and reduce the possibility of casualties. The malleable structure can better adapt itself to unexpected forces caused by earthquakes, as well as forces such as impact, explosion, etc. It should be noted that many of these unexpected factors are ignored in loading and conventional designs of structures. In the formable structure, the final load of the structure is achieved when a sufficient number of plastic joints are formed in the structure. This ultimately causes us to fully use the capacity of many structural members against the force of an earthquake during an earthquake. But the important thing you should know is that although it is necessary to provide ductility for structures that are exposed to earthquake forces, excessive ductility can also cause problems in the seismic performance of the structure. Therefore, when designing earthquake-resistant structures, a specific range of ductility must be considered by the designer, which of course is automatically included in the design if the regulations are taken into account. The role of reinforcement in the ductility of concrete is very important. According to the above explanations, it can be pointed out that the effect of different arrangement of rebar on the bending behavior of concrete beam is very important. This importance will be doubled when this beam is made in a high cost structure. In this article, we study different arrangements of longitudinal bars and the effect of this arrangement on the behavior of wide concrete beams. Recently, some researchers have conducted studies on the shear behavior of wide beams. Lubell et al investigated the effect of shear reinforcement spacing on the shear capacity of wide concrete beams. 13 concrete samples with normal strength were tested. In this study, they concluded that by increasing the distance of the shear reinforcements in the shallow beam, the cross-sectional capacity decreases and also the use of several shear reinforcements at a distance of 2d reduces the fragility of the failure mode compared to a geometrically similar member without shear reinforcement [5]. Sherwood et al conducted a laboratory study to investigate the shear behavior of wide beams and thick slabs as well as the effect of member width. They tested five samples of normal strength concrete with a nominal thickness of 470 mm and member widths ranging from 250 to 3005 mm. This study showed that the breaking shear stress of narrow beams, wide beams and slabs are all very similar [6]. In 2020, the numerical analysis of wide beams is presented by Hosseini et al. The proposed models were loaded with a static seismic load. Various models of wide reinforced concrete beams were analyzed numerically by ANSYS platform and a parametric study was carried out. The studied parameters included percentage of life reinforcement, percentage of tensile reinforcement and percentage of compression reinforcement. The percentage values of tensile reinforcement (1.5%, 1%, 0.7%, 0.3%) of the cross section, percentage of compression reinforcement (0.8, 0.6, 0.5, 0.4) from the tensile reinforcement ratio and the percentage of life reinforcement (0.13%, 0.067%). The effect of these parameters on ductility, loss, strength, hardness and excessive resistance was investigated. The results showed that the studied parameters affect all these characteristics and the lowest formability is observed in the wide beam (B7) whose value is 1.1 [7]. Ranjian et al. has studied the time-varying reliability evaluation of reinforced concrete beams designed under the provisions of ACI. A wide range of practical design conditions are considered. Beams are subjected to bending, shearing and twisting. The interaction between shear and torsion is considered through an elliptic failure surface defined in torsional shear stress space. No interaction between flexural strength and strength in both shear and torsion is assumed. Representative statistics and appropriate probability distributions of basic resistances and load variables are selected from related works. Reliability analysis is performed using modern reliability methods, where the formulation of limit state functions is consistent with basic design criteria. Reliability indices for different failure modes are compared and system reliability analysis including all failure modes is performed. It is found that reliability indices are more sensitive to live load, model uncertainty and material strength. For the failure modes considered, the reliability indices are not very sensitive to the values of the design parameters, indicating that the ACI Building Code achieves its intended goal of uniform reliability over a wide range of design conditions [8]. In 2013, Skarzynski and Tejchman conducted a study on the failure of deep concrete beams. The failure behavior of concrete and reinforced concrete beams under quasi-static three-point bending was comprehensively investigated with laboratory scale experiments. Eight different concrete mixes were tested. The effect of shape, volume and size of aggregate particles and reinforcement on concrete fracture under bending was investigated. Displacements on the surface of concrete beams were measured using the Digital Image Correlation (DIC) method. Attention was paid to the formation of a local area and its characteristics. In order to avoid the influence of the search patch size and cutoff value on displacement and strain profiles, a consistent method is presented to uniformly and accurately determine the width of a local region. The surface displacements measured from DIC were fitted by the ERF error function, while the surface strains calculated from the displacements were fitted with the usual normal (Gaussian) distribution function. The width of a local region before macro-rifting grew strongly with increasing maximum grain size and slightly with decreasing grain volume. It does not depend on the roughness and presence of total reinforcement [9]. The first reported tests on wide beam-to-column connection specimens were performed by Hatamoto et al. in 1991. 9 samples of internal connection of wide beam to column were tested under lateral load. Generally, the tested samples have experienced a significant slippage in the armatures as well as a drop in resistance. Observations showed that the absorption of low energy due to the weakening of the force in the reinforcements restrained outside the column creates torsion in the transverse beam (perpendicular to the direction of the main wide beam) and if the cross section of the transverse beam has the necessary torsional resistance does not have it, severe torsional cracks and resistance drop occur [10]. Popov and his colleagues studied a wide beam-to-middle column connection example. Torsional failure and loss of resistance were not observed in the tested substructure. However, by emphasizing the ambiguity in the seismic requirements of wide beam detailing, they found it necessary to conduct more tests to provide more accurate details for the wide beam (including the transverse reinforcement of the wide beam, especially at the connection to the column) [11]. Fadwa and his colleagues tested two side samples and two middle samples. Half of the samples had a wide beam and the rest had a normal beam. In the wide samples and to simulate the effect of the presence of the transverse beam in the connection, two steel sheets were placed on the sides of the wide beam and welded to the longitudinal reinforcements of the transverse beam. Under the effect of the presence of these plates and due to the relatively high volume of the longitudinal reinforcement of the transverse beams, the wide samples performed better in terms of ductility and energy consumption than the samples containing ordinary beams and the complete formation of the plastic joint in the wide beams without torsional failures. or an incision was made [12]. Numerous experimental studies have proven the efficiency of externally bonded fiber-reinforced polymer (FRP) systems on structural concrete elements, such as reinforced concrete (RC) beams. The current paper presents an analytical formulation of mechanical constants based on the results of experimental data, which were acquired from fatigue testing of intact and CFRP retrofitted RC beams. A total of six scaled RC beams were prepared for the test, three of which were strengthened with carbon fiber-reinforced polymers (CFRPs). A specific finite element model coupled with experimental results from the proposed RC beams made it possible to compare the theoretical and experimental fatigue behavior of RC beams with and without composite reinforcement. The developed numerical model was then extended to evaluate a higher number of fatigue load cycles, as recommended by bridge codes. This was carried out to monitor the performance of CFRP-retrofitted RC beams in terms of flexural stiffness deterioration and damage propagation. The relationships presented in this paper were calibrated to the tested specimens. Moreover, they were useful for the design of RC and CFRP-retrofitted RC beams and for predicting fatigue performance, including the damage behavior of constituent materials [13]. In the article of HojjatKashani et al investigates bending and compressive strengths as mechanical characteristics of cement-based repair mortar containing nano-silica (NS) and micro-silica (SF) as cement replacements particles and polyvinyl alcohol (PVA) fibers. The mentioned materials were added to the mortar in three different conditions, including single (just one material), binary (mixture of two admixtures), and ternary (mixture of all three admixtures) modes. The use of PVA fibers, nano-silica and micro-silica in the triple combination of a cement-based mortar is the primary objective of the current research. In total, 28 mix designs with various percentages of particles and fiber were employed in the current study, and 112 different specimens were prepared to conduct the experimental research. The compressive and flexural strength results have been selected as the criteria for obtaining the optimum mix design for each condition. In order to specify the mechanical characteristics of specimens, a compressive test was carried out according to ACI 318, and the three-point bending test was utilized according to BS EN 1015-11. The results obtained from this study show that the mixture containing 10% silica fume (SF10) can be considered the optimum mix design for the single-mode condition. For such a mix design, a flexural strength increase of 27% and a compressive strength improvement of 48% were determined in comparison to the reference mixture design. The mixture containing nano-silica at 2% and silica fume at 8% (NS2SF8) was the optimum mix design in the binary mode condition. With the current mix design, a flexural strength improvement of 24% and a compressive strength increase of 49% in a 28-day specimen were recorded. Finally, under the ternary mode condition, a flexural strength enhancement of 3.5% and a compressive strength improvement of 4.6%

were obtained. Additionally, the mixture design containing a PVA content of 0.75% and an SF content of 10% (PVA0.75SF10) was considered optimum [14].

Improving the bending and shear performance of reinforced concrete (RC) beams plays a vital role in controlling the seismic behavior of concrete structures. In this research, the bending behavior of RC beams made with recycled coarse aggregate (RCA), steel fibers (SF) and polypropylene fibers (PPF) has been studied. A total of 54 beams (RC) with a cross section of 150 mm width, 200 mm height and 1500 mm length, with different transverse reinforcement spacing, are fabricated and tested. (RCA) from building demolition is used as a substitute for natural coarse aggregate (NCA) with 0%, 50% and 100% (by mass). In addition, (SF) and (PPF) are added at 0%, 1% and 2% (by volume) to improve the bending behavior of the beams. The specimens are tested under four-point bending settings. In these tests, the maximum bending capacity, the maximum deformation in the middle of the span of the beams, the ductility and hardness of the samples are measured. It was found that the effect of (PPF) in improving the flexural capacity of (RC) beams is greater than that made by (SF). However, the effect of (SF) on deformation is significant [15]. In 2023, Chira et al evaluated the full deformation response of prestressed wide beams numerically and experimentally. The parameters examined in this study included the size of the section, the amount of reinforcements without prestressing and with prestressing, concrete strengths, and member openings. The modeling methods were able to predict well the overall deformation and failure modes, with the 3D approach providing more detailed insight into the internal strain distribution. They showed in parametric studies that the reinforcement ratio has the greatest effect on the overall behavior compared to other parameters that govern the post-cracking response [16].

2. Concrete beam failure modes

2-1- bending failure

This failure mode mostly occurs for thin beams under concentrated load or under extensive load. In this situation, first, almost vertical cracks are created in the middle third of the beam. These types of cracks appear under the effect of very small shear stress and significant bending stress. In this condition of the beam, first under almost 50% load, several hairline cracks are formed in the middle of the opening, and then, with the increase of the load, new cracks are added in the central area of the opening, and the initial cracks become wider and towards the upper neutral web are drawn. At this stage, there is a significant increase in the rise of the beam. In this part, if the beam is reinforced concrete (having less steel than the balance state), a significant deformation occurs in the beam, which is referred to as ductility. This transformation will be useful because with this transformation, a warning will be provided to the residents and people who are there. Flexural strength of concrete is done using a simple beam with concentrated loading in the middle of the span. But it is usually used to determine the bending strength by using a simple beam with concentrated loading at the points of one third of the span. Figure (2) shows the location of the load in the reinforced concrete beam to determine the bending strength.

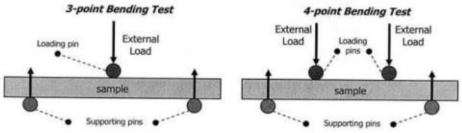

Fig. 2. Place of application of load in reinforced concrete beam to determine bending strength [17].

2-2- bending failure

This type of failure occurs in ordinary and common concrete beams. In this case, failure usually occurs under concentrated or extensive loads. In these beams, the first cracks are the vertical bending cracks in the middle of the opening, after which the connection and adhesion between the tensile steel and the surrounding concrete in the support is gradually lost. Then, without significant warning of premature failure, two or three diagonal cracks occur at distances close to the support. At the same time as these cracks are stabilized, one of the diagonal cracks becomes wider and extends towards the compression strands above the section. This situation will immediately be accompanied by tensile diagonal failure of the section. It is worth noting that usually in this type of failure, the bending cracks usually do not rise up to the neutral axis, and as a result, a little rise is created in the beam and basically a brittle failure occurs.

2-3- Compressive shear failure and tensile shear failure

The brittle and sudden nature of shear failure has made it one of the most important requirements in earthquake-resistant structures to use measures to avoid shear failure. Since the shear failure of the beam and column will be accompanied by the creation of diagonal cracks in the entire height of the beam or column, therefore, in strengthening reinforced concrete beams and columns against shear, it is necessary to strengthen their entire height. Shear failures are brittle and lead to a rapid decrease in the lateral strength of the foundation. Short beams with old transverse reinforcement details are particularly vulnerable to shear failure, while for a given lateral load the available flexural strength is usually much greater than the shear strength. Reinforced concrete beams of buildings may be vulnerable to cutting due to various reasons, the most important of these reasons are:

Inadequacy of silences

The height of the beams is short

The lower initial shear capacity of the cross-section is caused by the shear force applied to it during an earthquake and ultimately the reduction of the shear capacity of the cross-section during an earthquake. In this case of failure, several fine bending cracks are first created in the middle of the opening, and with the loss of adhesion between the rebars and the concrete around them in the support area, it is cut in front of the bending cracks. Then, suddenly, a diagonal crack with a steeper slope than what happens in tensile diagonal failure is created and moves towards the neutral axis. Simultaneously with the crushing of concrete in the compression strands above the cross-section, the redistribution of stress in the compression area takes place and it slows down in front of the diagonal crack. Finally, when the diagonal crack connects to the crushed concrete area, compressive shear failure occurs suddenly. It should be mentioned that compressive shear fracture, although it is considered a brittle fracture, but due to the limited redistribution of stress in the compressive region, it is considered less brittle than tensile diagonal fracture. This failure is to a limited extent associated with the previous warning. Usually, to evaluate this type of failure in the laboratory, the ratio of the shear opening to the effective depth of about 3 is used for the place of application of force to the sample (the place of application of force is not one third of the opening, unlike the case of bending).

2-4- Other failures (in I-shaped beams)

In I-shaped beams with a thin web, beam failure may occur due to crushing of concrete in the web, between diagonal cracks and under diagonal compressive forces, which is called web crushing. In I-shaped beams with a thin web, beam failure may occur due to the crushing of concrete in the web, between the diagonal cracks and under diagonal compressive forces, and this failure is called web crushing. This example of failure in Fig (3) is displayed.

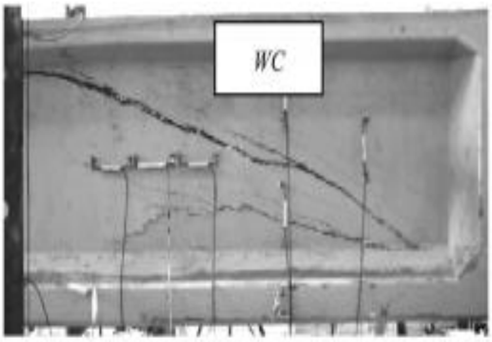

Fig. 3. Concrete beam with cracks created in John [4].

3. Rules of regulations regarding seismic design of wide beam

In table (1), the rules of regulations of America, Europe and New Zealand [18-21] regarding the seismic design of wide beam are given. According to these rules, the width of the wide beam (b_w) should not exceed the maximum allowed value. This allowed value is determined according to the width of the column (b_c), the height of the column in the direction perpendicular to the width of the wide beam (h_c) or the height of the beam (h_b). These restrictions are applied to the width of the concrete beam connected to the column to ensure the transfer of the force of the wide beam to the column.

Table 1. Rules of design regulations regarding wide beams.

Regulations	Wide beam limitations
ACI 318-19	$b_w \le \min\{3b_c ; b_c + 1.h_c\}$
EN 1998-1	$b_w \le \min\{2b_c ; b_c + h_b\}$
NZS 3101	$b_w \le \min\{2b_c ; b_c + 0.5h_c\}$

ACI 318-19 requires that in a wide beam, the total outside width of the column should not exceed twice the width of the column or one and a half times the height of the column. This code, similar to the European and New Zealand codes, does not have a calculation approach in relation to the design of the connection of the wide beam to the column. However, refer to ACI 352R-02 Design Guide for more detailed design details of wide concrete joints. In this instruction, the necessary recommendations for wide beam design are detailed [21]. According to ACI 352R-02, the transverse beam should be designed for torsion due to flexural yielding in the wide beam (T_u) along with other forces present in the transverse beam. This twist can be calculated from the following equation.

$$T_u = \frac{A_{s.out}}{A_s} M_{pr} \qquad (1)$$

where (A_{s}) is the total area of the longitudinal tensile reinforcements of the wide beam, ($A_{s.out}$) is the area of the restrained longitudinal tensile reinforcements in the transverse beam and (M_{pr}) is the possible anchor in the wide beam (assuming a 25% increase It is calculated in the nominal tensile strength of the reinforcements. According to ACI 352, the transverse beam must have sufficient lateral and longitudinal torsional reinforcement to withstand the torsion (T_u). Most of the regulations do not provide detailed rules regarding the details of the transverse reinforcement of the wide beam, especially in the connection area. Figure (4) shows the details of wide beam reinforcement according to ACI 318 in the connection area. According to ACI standards, in addition to the implementation of transverse reinforcements all around the wide beam cross-section in the entire length of the beam span, the reinforcements restrained outside the column in the connection area and the reinforcements restrained inside the column outside the connection area should be Separate transverse reinforcement. The use of these transverse silencers, especially in the connection area, due to the presence of the longitudinal reinforcements of the transverse beam as well as the transverse reinforcements of the transverse beam, is very difficult and complicated in terms of implementation. Also, the ACI regulation does not have a specific rule regarding the distance of these reinforcements. Therefore, the exact detailing of wide beams in the connection area according to the design regulations seems vague. This issue becomes more complicated when the beams are wide in both directions (wide bending frame system in both directions).

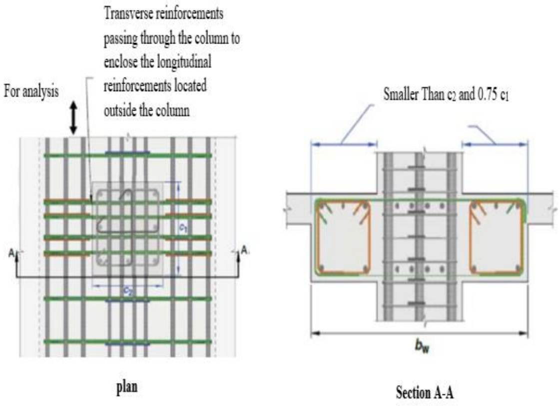

Fig. 4. ACI 318-19 Reinforcement Details for Wide Beam to Concrete Column Connections [18].

4. verification

In order to validate the article by M. Said and T.M. Elrakib is used. In this article, nine wide beams have been subjected to a four-point test by changing the size and spacing of the spacers, and their shear capacity and ductility have been investigated. In figure (5) the general representation of the model is presented [22]. SB7 model is selected for construction and comparison. This model has been in the form of laboratory studies, which is presented in Figure (6). In this article, displacement load curves for different conditions of beams with different sizes and distances of silencers are given, and each sample is compared with the control sample that does not have silencers. Figure (7) shows the sample made in Abaqus software.

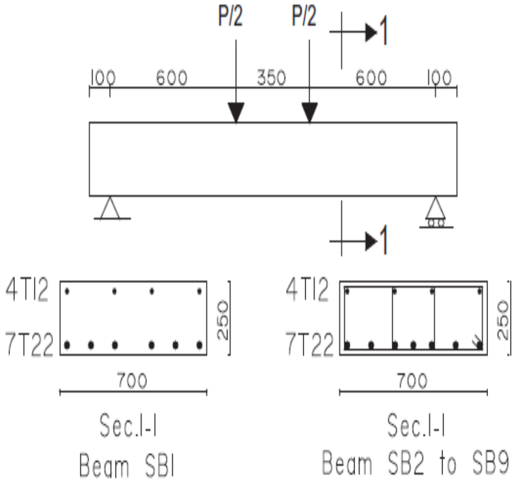

Fig. 5. General view of Verification model.

Fig. 6. Sample crack pattern SB7 [22].

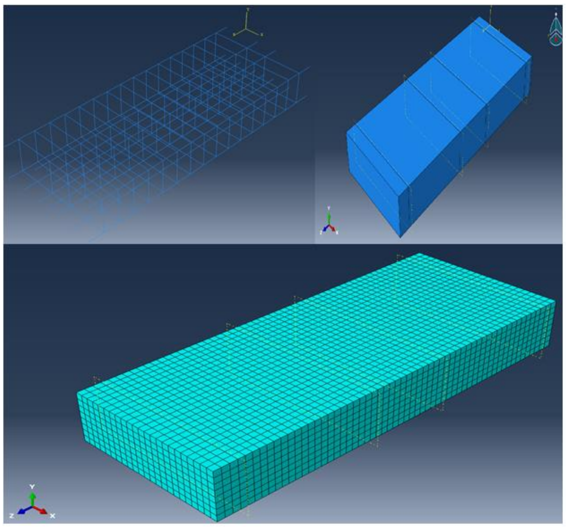

Fig. 7. Model made in Abaqus software.

The graph of displacement changes against force changes is shown in Figure (8) for SB7 sample. This model has 8 mm transverse reinforcements and 100 mm apart. After analyzing and drawing the diagram resulting from modeling in Abaqus, the results are compared and presented in Figure (9).

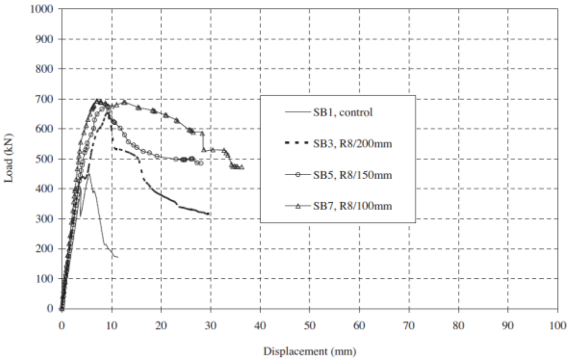

Fig. 8. Diagram of force-displacement of laboratory model reference article [22].

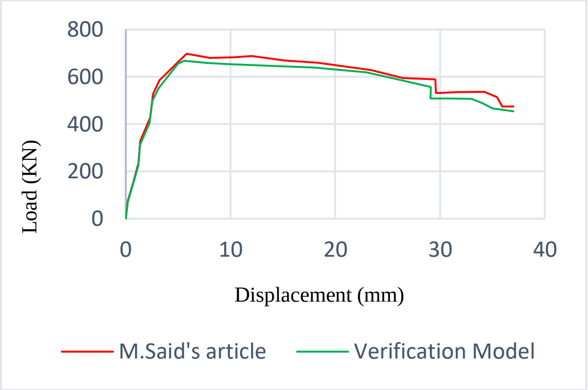

Fig. 9. Comparison of the load-displacement curve of the built model for verification with the model of the reference article.

5. Description of modeling and research results

In this article, a concrete beam is selected for study. Then, six different types of longitudinal rebar arrangements have been considered for this beam and four-point loading has been applied to the models. The models have been compared and evaluated in Abaqus finite element software. Tables (2-5) show the specifications of steel and concrete used in the models.

Table 2. Elastic properties of Steel.

Properties	value
Density (kg/m^3)	7850
Modulus of Elasticity (Pa)	200E9
Poisson's Ratio	0.3

Table 3. Plastic properties of Steel.

Yield Stress (Pa)	Plastic Strain
28E6	0
37E6	0.09

Table 4. Plastic properties of Steel.

Properties	value
Density (kg/m^3)	2400
Modulus of Elasticity (MPa)	25000
Poisson's Ratio	0.18
Compressive (kg/m^2) Strength	250

Concrete Damage Plasticity model is used in modeling the plastic behavior of concrete. The required parameters are as follows.

Table 5. Concrete Plastic Model Coefficients.

Dilation Angle	Eccentricity	fb0/fc0	k	Viscosity Parameter
30.5	0.1	1.16	0.5	0.0001

The transverse reinforcements of the models have a diameter of 12 mm and a distance of 10 mm, and the displacement control method has been used for loading. The complete specifications of the models are shown in table (6).

Table 6. properties of the studied models.

Sample Name	Rebar Above (mm	Lower Rebar (mm)	Diagonal Rebar (mm)	Beam Dimensions (mm)
S1	4φ12	6φ16	3φ12	700×250×1750
S2	4φ12	6φ16	6φ12	700×250×1750
S3	4φ12	6φ16	6φ12	700×250×1750
S4	4φ12	6φ16	6φ12	700×250×1750
S5	4φ12	6φ16	3φ12	700×250×1750
S6	4φ12	6φ16	6φ12	700×250×1750

Next, the arrangement of the longitudinal reinforcements of the studied models is shown in Figure (10). Also, the results of the analysis are shown in figures (11-14).

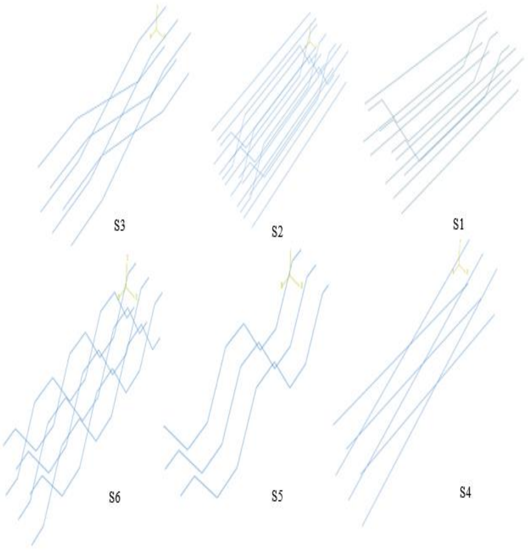

Fig. 10. Different arrangements of longitudinal bars of the studied models.

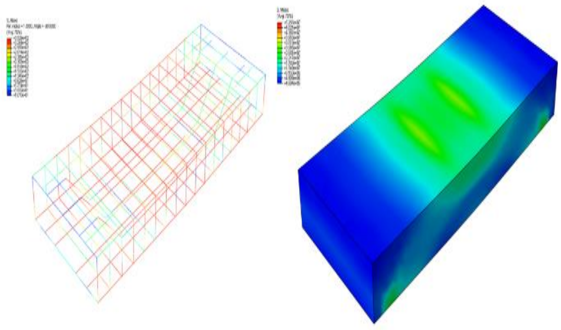

Fig. 11. Von Mises stress in concrete beam and steel rebar model S1

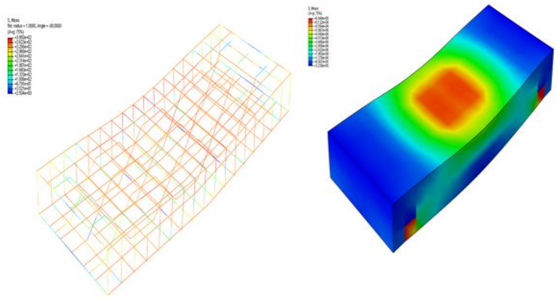

Fig. 12. Von Mises stress in concrete beam and steel rebar model S6.

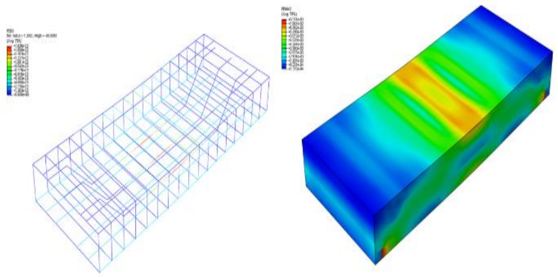

Fig. 13. Failure index in concrete and plastic strain in rebar model S1.

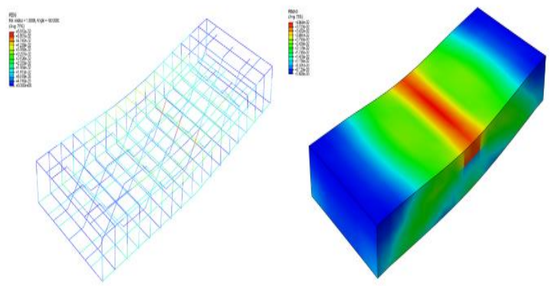

Fig. 14. Failure index in concrete and plastic strain in rebar model S6.

As can be seen from the above figures, in the place where the highest amount of stress was applied to the rebar and concrete, plastic strain also occurred in the same places. Therefore, the highest amount of compressive stress occurred at the upper point, and the concrete was crushed and broken in the upper area, and the upper rebars were also damaged. This issue is also observed in the lower area of the beam that is under tension. In the following, the general results obtained from the models are compared and evaluated. For a better comparison, all load-displacement diagrams are shown in Figure (15).

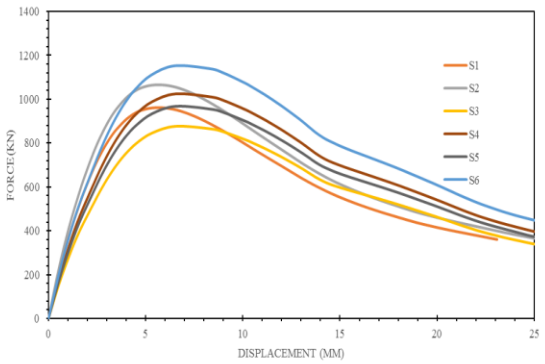

Fig. 15. Load-Displacement diagram in models.

As can be seen from Figure (15), the area under the curve of model S3, which has six rebars placed in a diagonal arrangement, was the lowest, which shows that this type of arrangement does not have a proper distribution of stress. The surface under the curve of the S1 model, which has three bars in the Utka arrangement, ranks fifth in terms of energy. The surface under the curve of the S5 model, which has three bars in a trapezoidal arrangement, ranks fourth in terms of energy. The largest area under the curve is related to the S6 model, which has six bars in a trapezoidal arrangement. Table (7) shows the general results of the models.

Table 7. General results of the models.

Model	Maximum Force (KN)	Stiffness (KN/mm)	Ductility	Area under the curve (kN.mm)
S1	960.40	240.10	5.56	25349.39
S2	1067.11	266.78	5.56	28098.11
S3	876.10	159.29	4.55	23822.31
S4	1024.68	186.30	4.55	29014.36
S5	968.31	193.66	4.55	27487.29
S6	1151.40	287.85	6.25	30541.43

As can be seen from table (7), the hardness of the S3 model, which has six rebars placed in a diagonal arrangement, was the lowest, which shows that this type of arrangement does not have a proper distribution of stress. The hardness under the curve of the S1 model, which has three rods in an Otka arrangement, ranks fifth. The hardness of the curve of the S5 model, which has three rods in a trapezoidal arrangement, ranks fourth. The highest hardness is related to the S6 model, which has six bars in a trapezoidal arrangement. The following charts are displayed for a better comparison of the models.

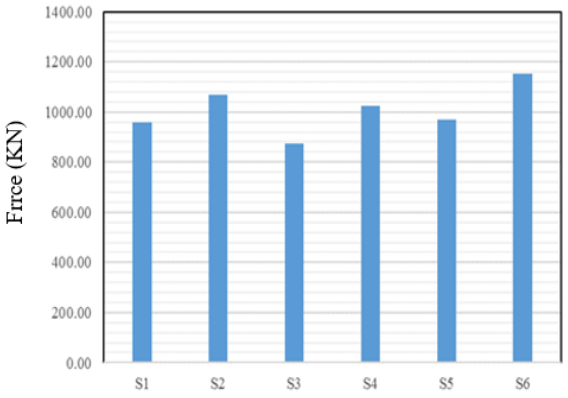

Fig. 16. Maximum force comparison chart.

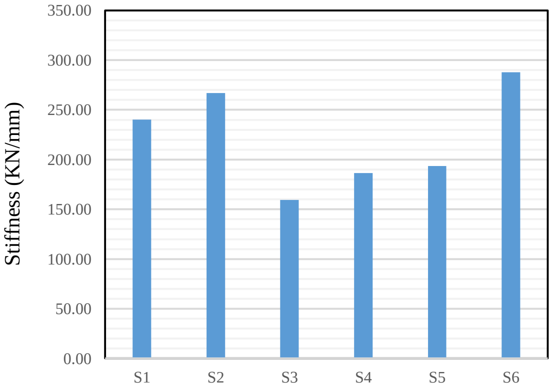

Fig. 17. Stiffness comparison chart.

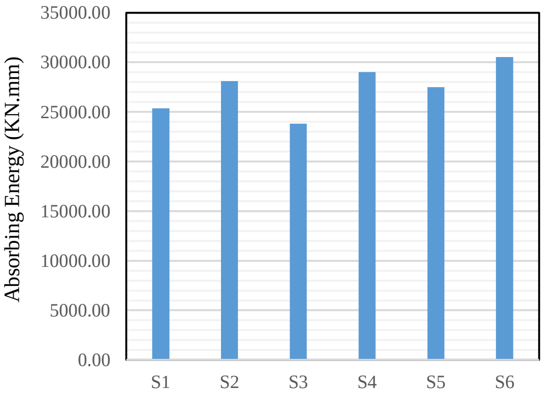

Fig. 18. Energy absorption comparison chart.

6. conclusion

In this study, deep concrete beam is selected for study. Then the pattern and arrangement of rebars have been selected and compared and evaluated. Six different types of makeup have been selected. This arrangement is made up of Utka, trapezoid, diagonal pattern. Four-point loading is applied to the model. All modeling has been done in Abaqus finite element software. The results of the analysis of the models are as follows.

By examining the studied models, the following results are observed:

1- The area under the curve of model S3, which has six rebars placed in a diagonal arrangement, was the lowest, which shows that this type of arrangement does not have a proper distribution of stress. The pattern of placing the rebar crosswise and diagonally has less hardness, malleability and resistance than other models.

2- The surface under the curve of the S1 model, which has three bars in the Otka arrangement, ranks fifth in terms of energy. Considering that this arrangement has fewer rebars than the S3 model, the amount of energy absorption is almost 7% higher than the S3 model, which was the lowest.

3- The largest area under the curve is related to the S6 model, which has six bars in a trapezoidal arrangement. In this arrangement, the amount of energy absorption is almost 30% higher than that of the s3 model, which was the lowest.

4- By examining the stress distribution, it can be seen that model S6, model S2, and model S4, the stress distribution among the rebars is almost uniform, and in tension and compression rebars, this distribution is almost uniform.

5- In all models, concrete behaved almost the same and no significant difference was observed in concrete.

6- The strength, hardness, and ductility of the S6 model, which has six trapezoidal rebars placed together, is almost 30% higher than the weaker model, the S3 model.

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