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# BEHAVIOR OF REINFORCED CONCRETE CONTINUOUS DEEP BEAMS WITH OPENINGS

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**Abstract**

In this research, after conducting experimental work, the behavior of reinforced concrete continuous deep beams with openings was studied. One model was also strengthened using NSM and using vertical reinforcement bars to apply the reinforcement. All beams were tested under two-point top loading. Seven continuous beams were tested, one as a reference without openings and three with openings, once and once after applying reinforcement to them. The results proved that the beam with four openings reduced the bearing capacity to 50%, while the beams with two external and internal openings decreased by (21.276%-14%), respectively. As for the results of the strengthening process, it increased the bearing capacity of the beams with four openings and those with two external and internal openings to 7.894%, 10.638% and 22%, respectively.

**Keywords:** Strengthening, Near Surface Mounted, Continuous Deep Beam, Mode Of Failer, Crack Pattern

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سلوك العتبات الخرسانية المسلحة المستمرة العميقة ذات الفتحات

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**المستخلص**

في هذا البحث، وبعد إجراء العمل التجريبي، تمت دراسة سلوك العتبات الخرسانية المسلحة المستمرة العميقة ذات الفتحات. كما تم تقوية أحد النماذج باستخدام NSM واستخدام قضبان التسليح العمودية لتطبيق التسليح. تم اختبار جميع العتبات تحت التحميل العلوي بنقطتين. تم اختبار سبع كمرات متواصلة، واحدة كمرجع بدون فتحات وثلاثة بفتحات، مرة ومرة بعد تطبيق التسليح عليها. أثبتت النتائج أن العتبات ذات الفتحات الأربعة قللت قدرة التحمل إلى 50%، بينما العتبات ذات الفتحتين الخارجية والداخلية انخفضت بنسبة (21.276%-14%) على التوالي. أما نتائج عملية التقوية فقد أدت إلى زيادة قدرة التحمل للعتبات ذات الأربع فتحات وتلك ذات الفتحتين الخارجية والداخلية إلى 7.894%، 10.638%، و22% على التوالي.

**الكلمات المفتاحية:** التقوية، التثبيت على السطح القريب، العتبة العميقة المستمرة، وضع الفشل، نمط التشقق

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**معلومات البحث**
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## 1 Introduction

The need for repair and strengthening of concrete structural elements of buildings and bridges around the world highlights the importance of these activities in the field of concrete construction. External bond reinforcement (EBR) and near surface reinforcement (NSM) are two reinforcement technologies. It is important to repair and strengthen concrete structural elements of buildings and bridges. Although external bond strengthening and surface area strengthening are widely used techniques, near surface strengthening (NSM) technology has been introduced to overcome their limitations. NSM provides greater safety, stiffness, and fatigue resistance, but has limitations such as beam specimen width and lateral stresses. More CFRP bars are needed to meet current service load requirements. More CFRP bars are needed for current service load requirements. The beam specimen to be reinforced must be wide enough to allow the required edge clearance and clearance between adjacent NSM groove. It should also be noted that two or more slots cut to a limited width may separate due to lateral pressures. However, in most cases, strengthening the design of structural members requires more carbon fiber reinforcement to meet the current service load requirements. [1] Deep reinforced concrete beams are often used as structural elements for load distribution, pile caps, building walls, supports, shear wall structures that resist lateral forces, soil diaphragms, foundations in strips or slabs and marine structures. [2] Since the deep beams are loaded on one face and supported on the opposite face, strut-like compression members can form between the load and the support, satisfying conditions (a) or (b). [3] :(a) The net span shall not exceed four times the total depth of member h.(b) The concentrated load is located at a distance of two hours from the supporting surface. Continuous, deep reinforced concrete beams are of great importance in structural engineering applications. Reinforced concrete continuous core beams (RCCDB) is a very interesting topic. Beams, pile caps, tanks, curved frames and foundation walls are some examples of RCCDBs that carry a large number of small loads and transmit them to a limited number of reaction points. [4]. Simply supported deep beams and continuous deep beams are different from continuous deep beams. High moment and shear zones occur at intermittent depths and are usually damaged at these locations. In deep reinforced concrete beams, regions of high shear forces and low bending moments coexist. Therefore, the failure mechanism of continuous deep reinforced concrete beams is significantly different from that of simply supported reinforced concrete beams. Shear forces occur in a uniform diagonal stress field in thin beams, while deep beams show a more pronounced extension or bending behavior. [5]

## 2 EXPERIMENTAL WORK

The experimental work consisted of testing seven concrete Continuous deep, one was the reference and the other three have openings and three have been strengthened using vertical reinforcement bars, all beams had a length of (2200 mm), with (150 mm) width and (500 mm) height as shown in Fig.1 A preliminary design using (strut and tie) model that described in (ACI-318.14) was conducted on control beam to find the main reinforcement. with shear span-to-overall depth ratio (a/h) equal to 1.0 and effective length to overall depth ratio (ln /h) equal 2.0, to ensure that the beams will behave as deep beams (ACI code). All beams were tested under two-point top loading. Four bars of Ø 16 mm were provided as bottom and top longitudinal reinforcement for each layer. The ends of all beams extended 100 mm beyond the support's centerlines and the steel bar had a 90º hook of length 180 mm at each end to provide sufficient anchorage. The concrete bottom cover of 25 mm and 50 mm as top cover were adopted to prevent splitting failure. All specimens were reinforced in bottom and top with two layers (4 Ø 16) bars for each as longitudinal reinforcement and three bars of (Ø 10) were used for linking longitudinal reinforcement see figure1. The tested beams were made without vertical horizontal shear reinforcement to ensure the shear failure mode for the control specimens. The designed concrete compressive strength was (fc'= 28 MPa).

## 2.1 Details of Specimens

All specimens were reinforced as shown in Figure (1).

S: square opening, v: vertical strengthening, C= control, B=beam, O= opening, E: Exterior, I: Interior.

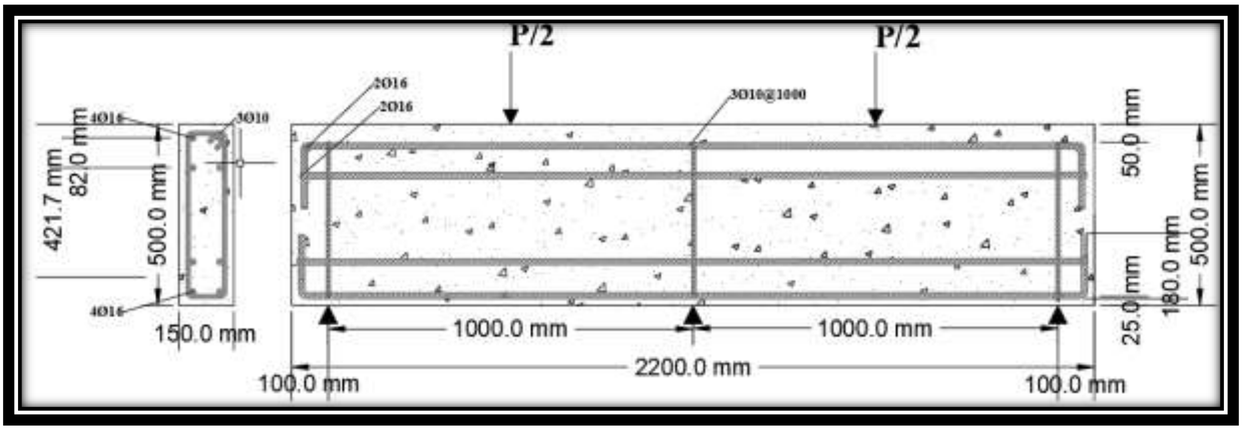


**Figure (1): Dimensions and Reinforcement Details of control beam**

The details of the controlling specimen for the first group are also shown in Figure (2).

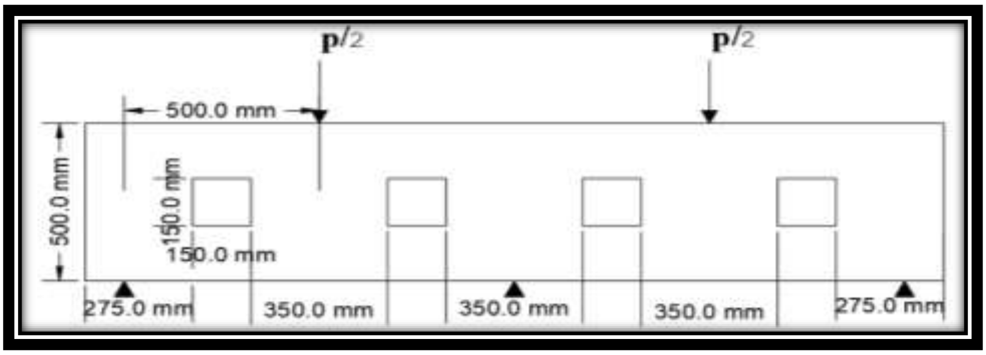


**Figure (2): Geometrical dimensions of the beam CBSO4**

The details of the controlling specimen for the second group are also shown in Figure (3).

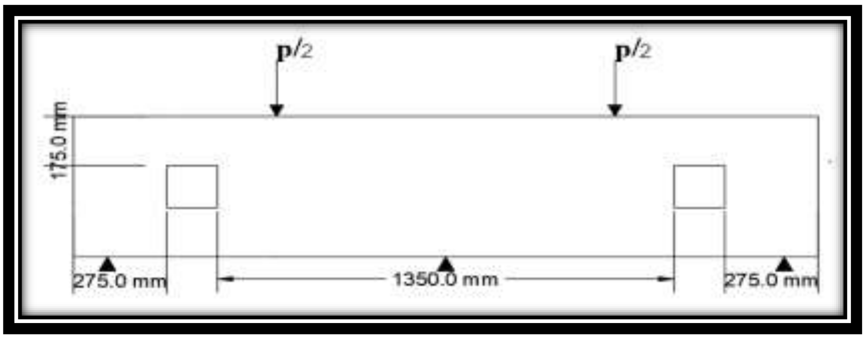


**Figure (3): Geometrical dimensions of the beam CBSEO2**

The details of the controlling specimen for the third group are also shown in Figure (4).

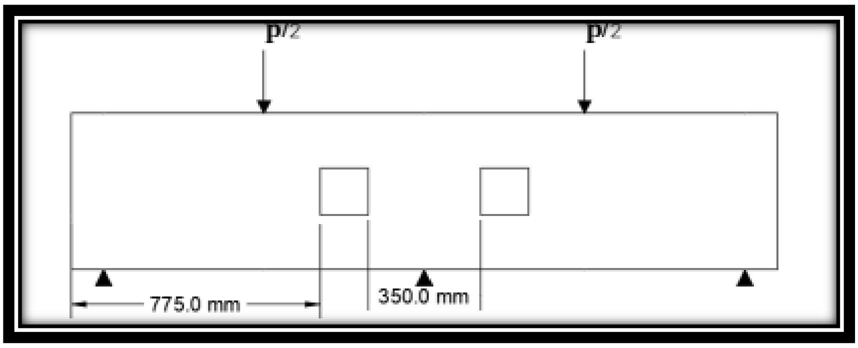


**Figure (4): Geometrical dimensions of the beam CBSIO2**

Details of the vertical reinforcement of the first group are shown in the figure (5).

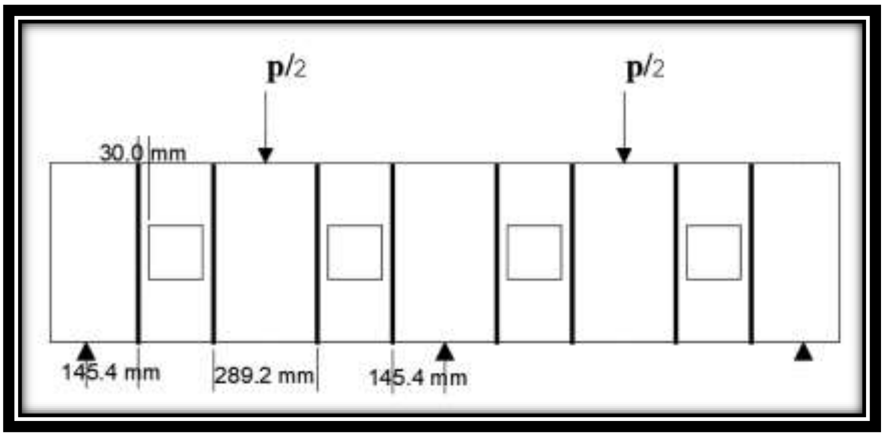


**Figure (5): vertical strengthening of BSO4V**

Details of the vertical reinforcement of the second group are shown in the figure (6).

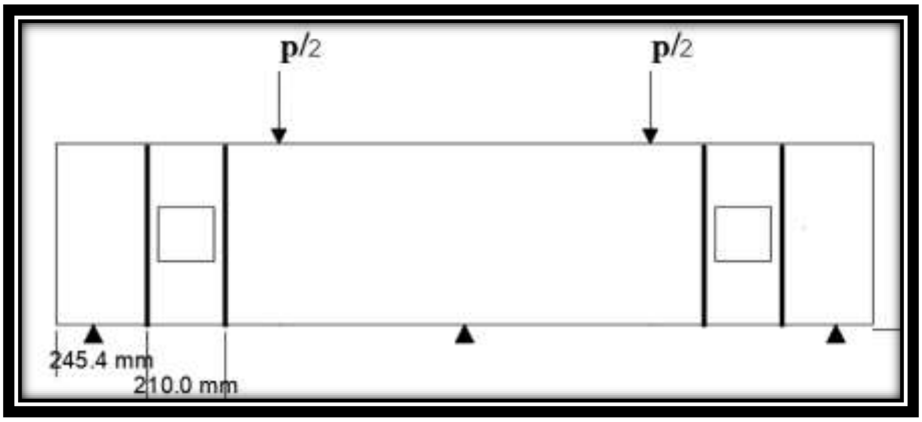


**Figure (6): vertical strengthening of BSEO2V**

Details of the vertical reinforcement of the third group are shown in the figure (7).

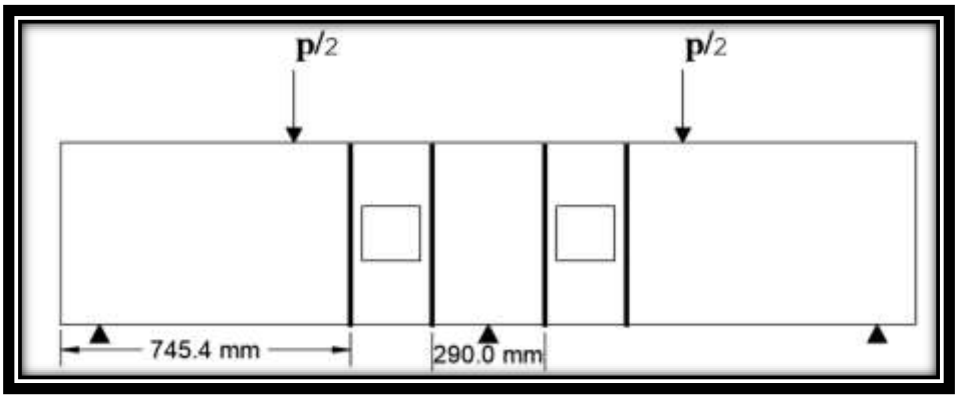


**Figure (7): vertical strengthening of BSIO2V**

All specimens were casted with normal weight concrete. The designed mix were 1:1.5:3 (by weight) cement, sand, gravel respectively and 0.4 water cement ratio (w/c). lists the quantities of the final mix per cub meter as shown in table (1).

**Table (1): Proportions of Concrete Mix**

| Material | Cement ($kg/m^3$) | Coarse Aggregate ($kg/m^3$) | Fine Aggregate ($kg/m^3$) | Water ($l/m^3$) | w/c |
|---|---|---|---|---|---|
| Amount | 336 | 1130 | 683 | 155 | .4 |

The frameworks were washed and oiled after that Reinforcing steel were put in the frameworks carefully, the concrete was casted into the frameworks in three layers. Each layer was compacted by using mechanical vibrators, six cubes and three cylinders were casted. The cubes were casted in three layers and each layer was compacted using 36 blows by steel bar. The cubes and cylinders were used to determine compressive and tensile strength respectively. Three days later, the frameworks were removed and the samples were covered with wet burlap and the curing period continued up to 28days. The casted specimens and Curing process as shown in Figure (8).

**Figure (8): Casting and Curing Process**

## 2.2 Strengthening Process by NSM Bar Technique

A sketch was drawn to fix the boundaries of the desired grooves that needed for embedding the strengthening bars, Then, the grooves have been drilled in the both side of the beam (both front faces of the beam) by utilizing special concrete saw with a diamond blade, A layer of epoxy paste was added which filled to the half depth of the groove. After that, the samples were dyed, as they were painted white, and the reinforcement areas were painted red.

## 2.3 Materials Properties

The concrete mix components were supplied by (Asad Al-Najaf Ready Mix Concrete Company), Ordinary Portland cement was used, which was manufactured from the production of the Karbala Factory (Karbala / Iraq). The clean water was used in mixing and curing the specimens. Fine aggregates were taken from the natural sand available in Bahr Al-Najaf. The crushed gravel taken from the Nabaie area was used as coarse aggregate in the concrete mix. Sikadur-30 manufactured by Sika company used to bond the strengthening bars with concrete in the grooves drilled with (NSM) technique. In this study, deformed steel reinforcement bars of Ukrainian origin were used.

# 3 RESULTS AND DISCUSSION

## 3.1 Cracks Patterns and failure mode

The paragraphs below explain the failure mode, path, and crack pattern.

### 3.1.1 Control Beam (CB)

The first flexural crack was showed at the load (60 kn) After that, the bending cracks increased, and when the load reached 44% of the maximum load (280kn), shear cracks began to appear. Then, the bending cracks continued with the diagonal shear cracks with increasing load until the sample reached failure when the load reached the maximum load (570 kn). The failure type was diagonal shear failure. The figure 9 shows the load-deformation curve, as it appears from its solution that at the beginning of the load it shows how strong the beam is, then it will begin to weaken to the point of failure. as shown in Figure (9) and (10).

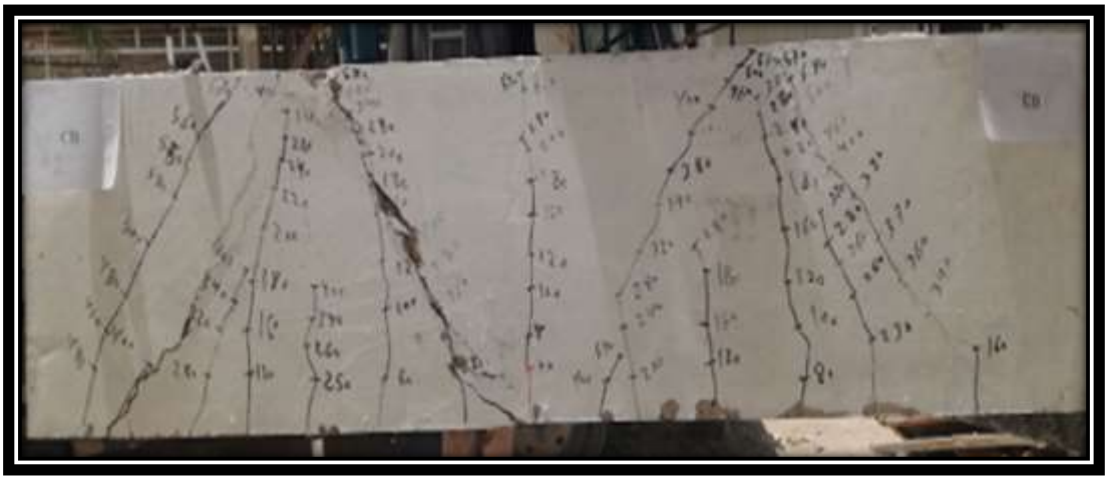

**Figure (9): Cracks Patterns and failure mode for Control Specimen (CB Specimen)**

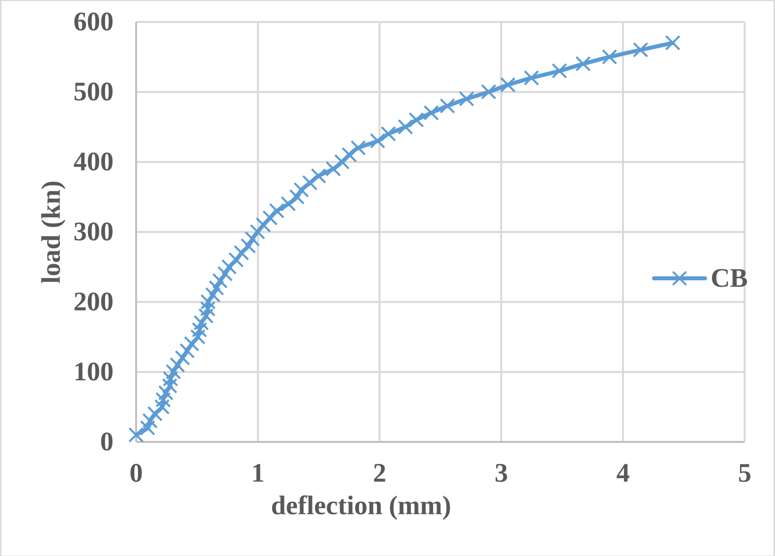


**Figure (10): Load-displacement curves at midspan for (CB beam)**

### 3.1.2 The Beam (CBSO4)

Presence the openings in the beam caused the stresses to be concentrated in their four sharp corners. That led to the appearance of first shear crack at the corner of the openings. The flexural cracks started to appear at a load of 70 kn and continued to extend vertically until the mid-height of the beam and stopped extending at a load of 300 kn, at the same time shear cracks began to appear from the bottom of the beam in areas close to the supports, when loading reached 380 kn the beam failed and the type of failure was diagonal shear failure and bending failure. The figure 11 shows the failure mode of the continuous beam, while the figure12 shows the load-deformation curve, as it shows that it fell below the reference because it is weaker than it, and this weakness is attributed to the presence of the four openings. as shown in Figure (11) and (12).

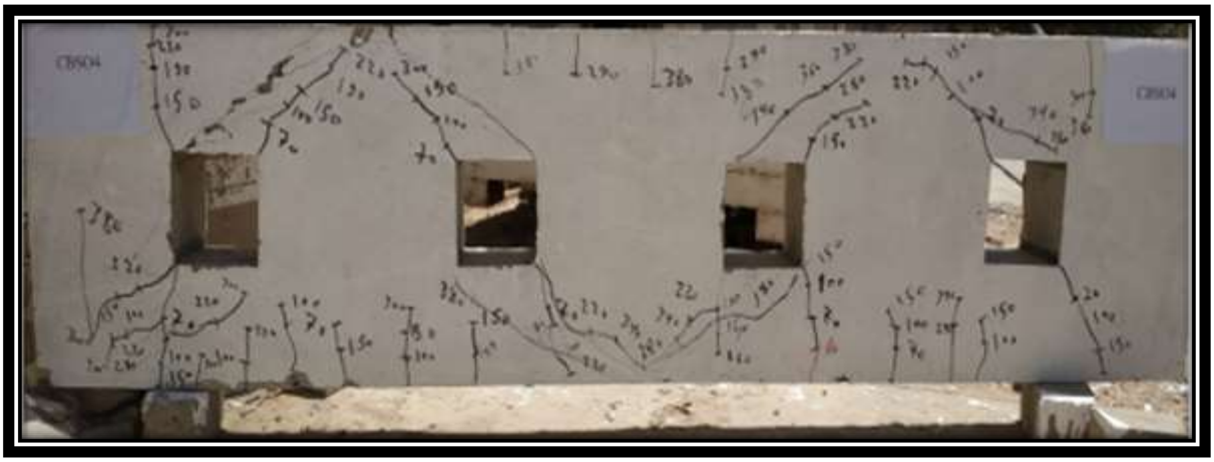

**Figure (11): Crack patterns and failure mode for specimen (CBSO4)**

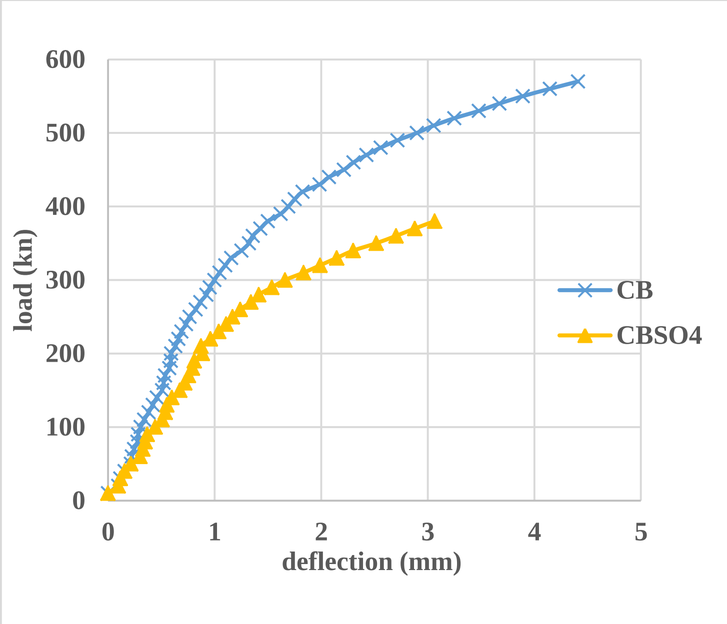


**Figure (12): Load-displacement curves at midspan for (CBSO4 beam)**

### 3.1.3 The Beam (CBSEO2)

In this deep continuous beam, the openings are located near to the end supports. The results showed that the bending failure started at the loading (70 kn), while the diagonal shear failure started at loading (90 kn) and continued to develop gradually with increasing device loading until it failed at loading (470 kn). The figure 13 shows the failure mode of the continuous beam, while the figure14 shows the load-deformation curve, as it shows that it has fallen below the reference beam because it is weaker than it, but higher than the previous beam meaning that it is stronger to bear than it. as shown in Figure (13) and (14)

**Figure (13): Crack patterns and failure mode for specimen (CBSEO2)**

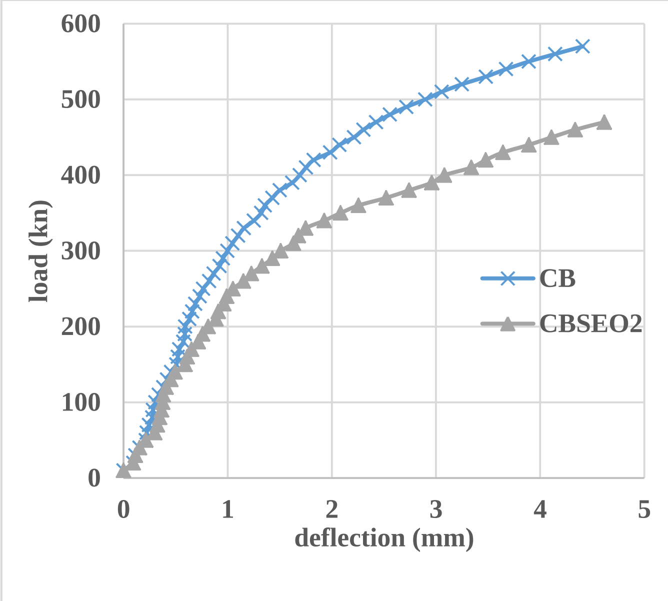


**Figure (14): Load-displacement curves at midspan for (CBSEO2 beam)**

### 3.1.4 The Beam (CBSIO2)

the results showed that the beginning of the appearance of cracks was of the type bending cracks at the loading point 70 (kn) and these cracks continued and gradually increased After that, diagonal shear cracks, then continued to increase gradually until the continuous beam failed at (500 kn) loading. The figure 15 shows the load-deformation curve, as it shows that it has fallen below the reference threshold because it is weaker than it, but higher than the previous threshold, meaning that it is stronger to bear than it. as shown in Figure (15) and (16).

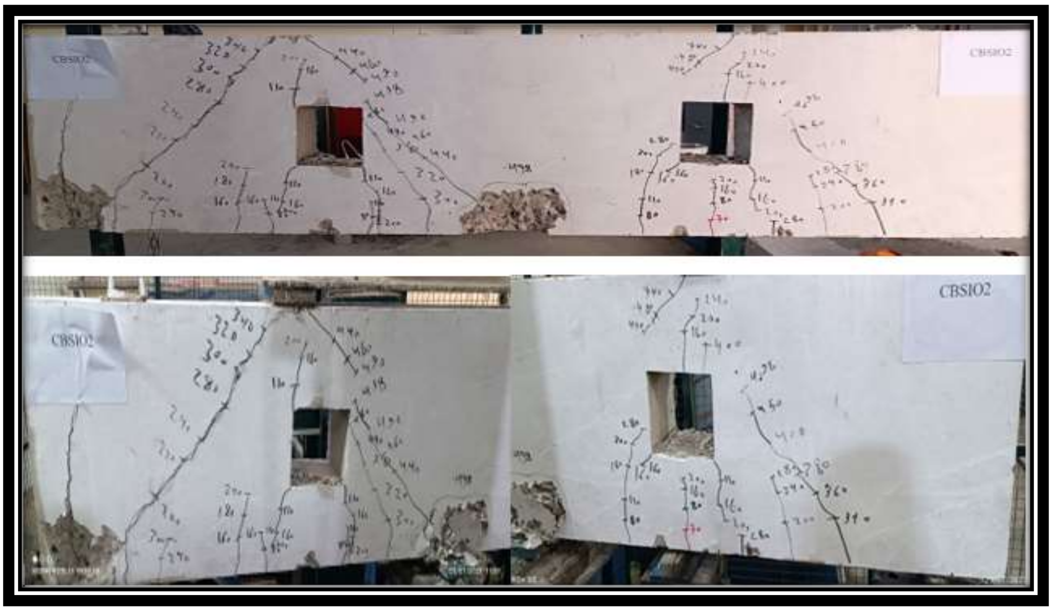


**Figure (15): Crack patterns and failure mode for specimen (CBSIO2)**

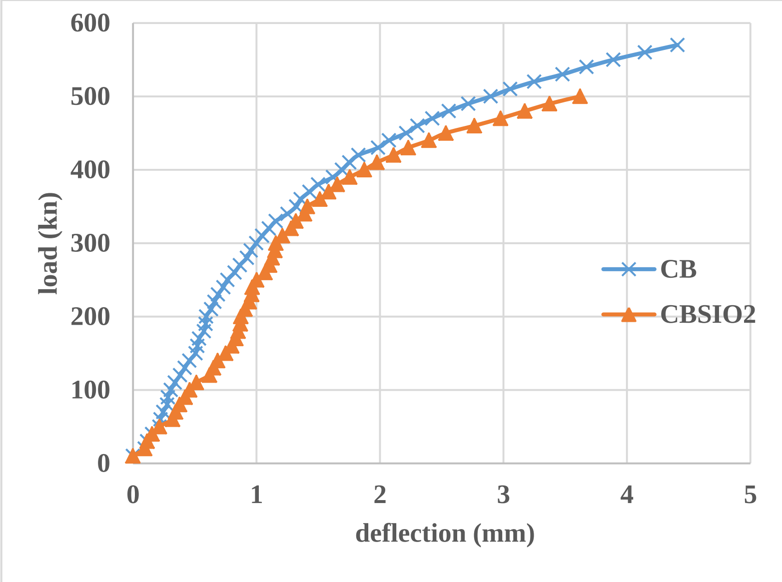


**Figure (16): Load-displacement curves at midspan for (CBSIO2 beam)**

### 3.1.5 The Beam (BSO4V)

The first crack initiated near the beam face at a load of 70 kn More cracks propagated and spread within the shear span. Due to the high shear resistance provided by the NSM steel bars, the tendency to diagonal shear failure is restricted. This strengthening scheme contributed for increasing ultimate load about 7.894 %. more cracks have appeared and the cracks propagated in the two opposite corners of the opening towards loading and supporting points until occurring shear failure at a load equal 410 kn. The figure 17 shows the load-deformation curve for the reinforced beam and shows that after strengthening it rose to the top, that is, it became more loading. as shown in Figure (17) and (18).

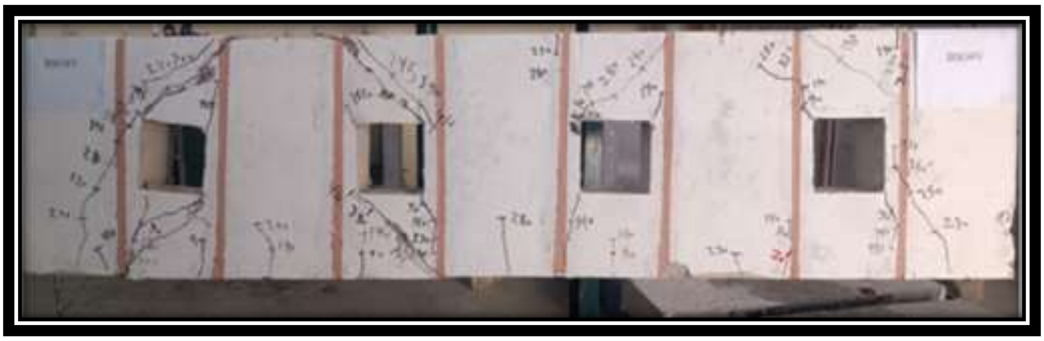

**Figure (17): Crack patterns and failure mode for specimen (BSO4V)**

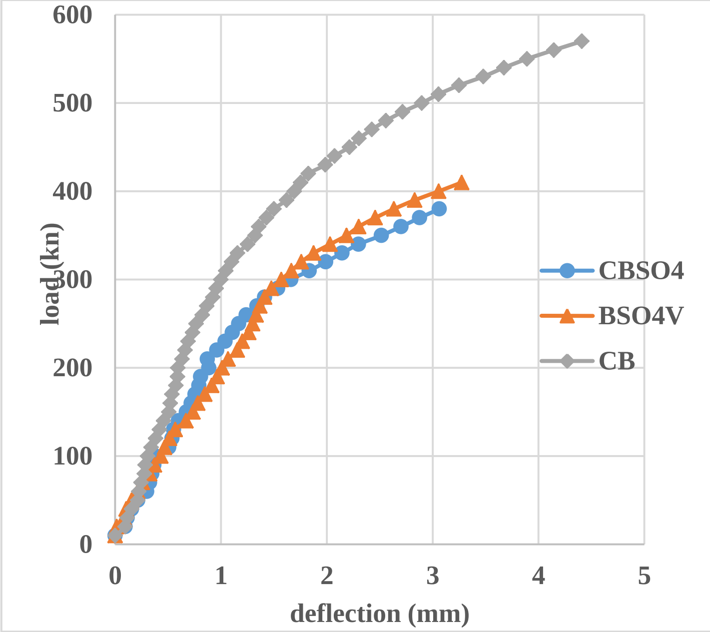


**Figure (18): Load-displacement curves at midspan for (BSO4V beam)**

### 3.1.6 The beam (BSEO2V)

The results showed that the percentage of increased failure load than the reference was about 10.638%. Bending failure began to appear at the loading point (90 kn), then gradually increased. As for the diagonal shear failure, it began at loading (110 kn. the failure path changed and deviated to a new path. This means that the vertical reinforcing bars changed the failure path. the continuous beam failed when loading (520 kn). The figure 19 shows the load-deformation curve for the reinforced beam and shows that after strengthening it rose to the top, that is, it became more loading. as shown in Figure (19) and (20).

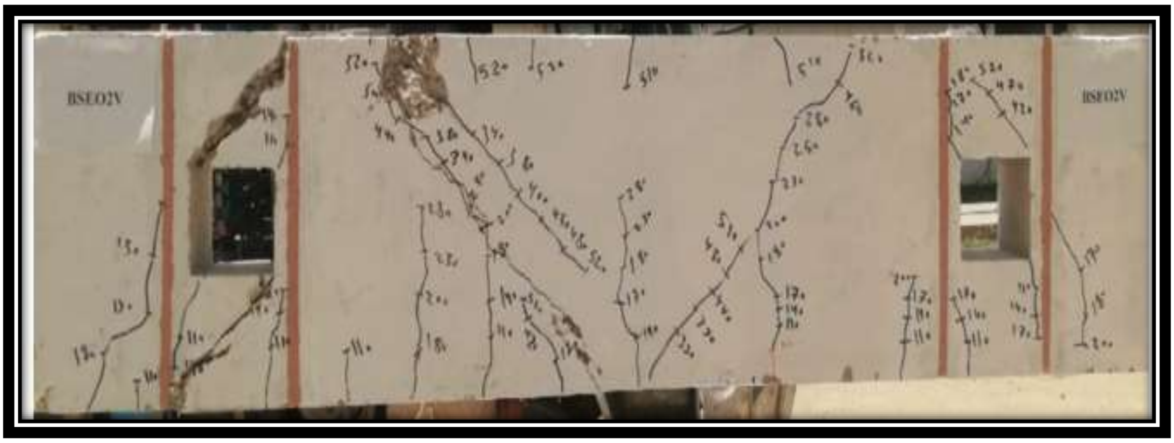

**Figure (19): Crack patterns and failure mode for specimen (BSEO2V)**

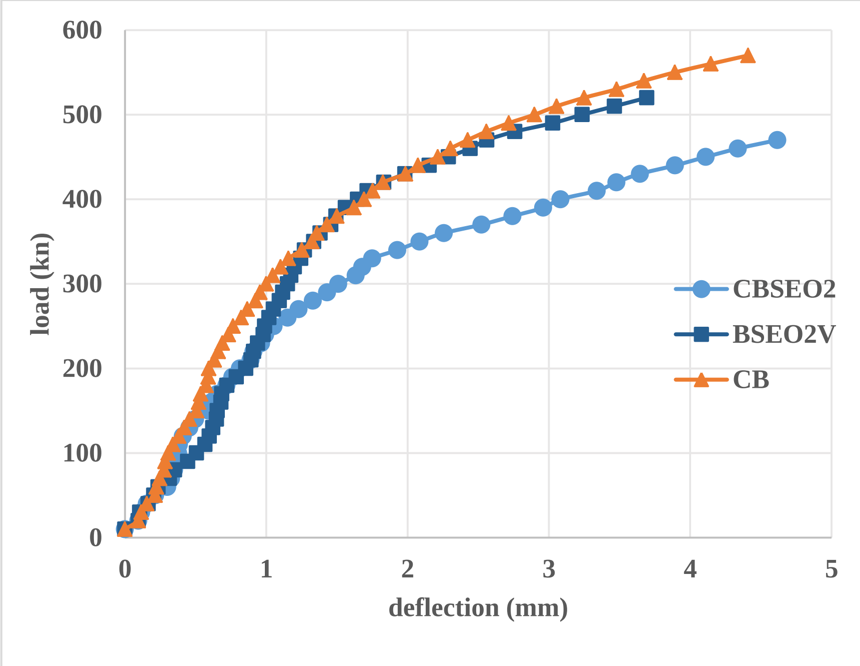


**Figure (20): Load-displacement curves at midspan for (BSEO2V beam)**

### 3.1.7 The beam (BSIO2V)

This specimen gave an increase in the maximum failure load of about 22% over the. because the openings here are farther from the area of greatest stresses, and this causes a delay in the appearance of cracks, which gives more load Where the bending stresses started here when loading (150 kn), and then when loading (180 kn), the diagonal shear stresses began and began to gradually increase, it failed at load (610 kn). The figure 21 shows the load-deformation curve for the reinforced beam and shows that after strengthening it rose to the top, that is, it became more durable. as shown in Figure (21) and (22), and Table(2).

**Figure (21): Crack patterns and failure mode for specimen (BSIO2V)**

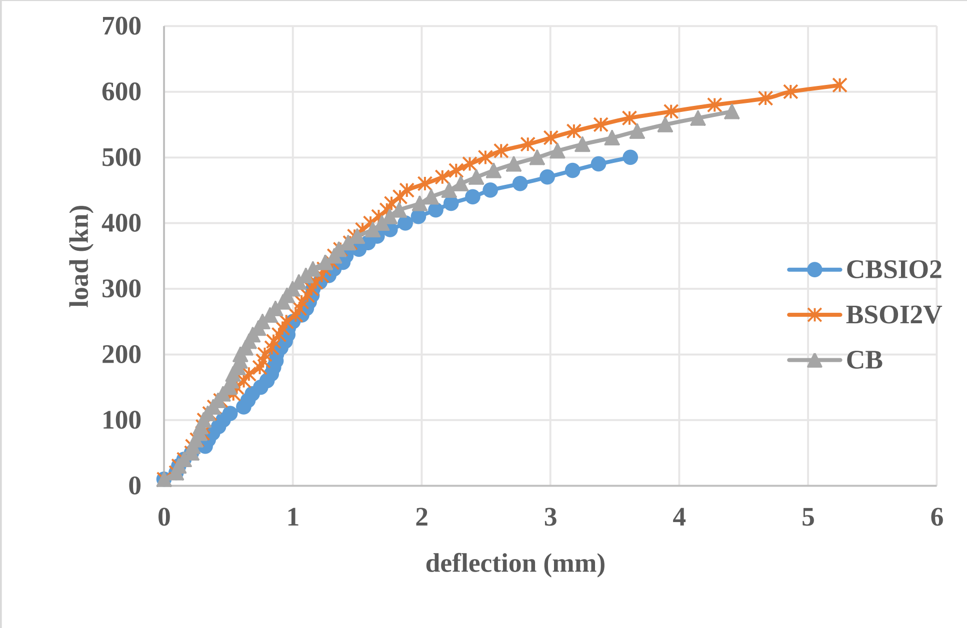


**Figure (22): Load-displacement curves at midspan for (BSIO2V beam)**

The table (2) shows the results tested for beams.

**Table 1 Test Result of all specimens**

| Beam name | Ultimate load (kn) | Increased ultimate load (%) | Deflection At failure (mm) | Failure modes |
|---|---|---|---|---|
| CB | 570 | ------------ | 4.41 | Shear |
| CBSO4 | 380 | 50 | 3.1 | Shear |
| BSO4V | 410 | 7.894 | 3.27 | Shear |
| CBSEO2 | 470 | 21.276 | 4.62 | Shear&Flexural |
| BSEO2V | 520 | 10.638 | 3.23 | Shear&Flexural |
| CBSIO2 | 500 | 14 | 3.62 | Shear&Flexural |
| BSIO2V | 610 | 22 | 2.49 | Shear |

## 4. CONCLUSION

### 4.1 Specimens without strengthening

1- The presence of four-square openings (150 * 150) mm led to reducing the maximum failure load to a certain percentage of about 50%. While the external and internal two openings to (21.276%-14%) Respectively.

2- The load-deformation curve at the middle shows the smoothness of the curves. At the beginning of the load, they were smooth and then gradually decreased.

### 4.2 Specimens with strengthening

1- After conducting experimental work, NSM technology increased the bearing capacity of reinforced beams by rates ranging between (7.894-%22%).

2- After applying the NSM technology using steel bars with a diameter of 10 mm, the bearing capacity increased in the beam with four openings to 7.694%, while with two external and internal openings to about (10.638%-22%) respectively.

3- After applying the NSM technique, it was found that the load-deformation curve improved greatly and became higher than the curve of unstrengthen specimens, and the ductility and stiffness also improved.

## REFERENCES

[1] M. A. Hosen, M. Z. Jumaat and A. S. Islam, "Side Near Surface Mounted (SNSM) technique for flexural enhancement of RC beams," Materials & Design, vol. 83, pp. 587-597, Jun 3 2015.

[2] Lafta, Y J; Ye, Kun, "Specification of Deep Beams Affect the Shear Strength Capacity," Civil and Environmental Research, vol. 8, no. 2, pp. 56-68, 2016.

[3] 318, ACI Committee, Building Code Requirements for Structural Concrete (ACI 318-19), Farmington Hills: American Concrete Institute, 2019.

[4] M. R. Khalaf, A. H. Al-Ahmed, A. A. Allawi and A. El-Zohairy, "Strengthening of Continuous Reinforced Concrete Deep Beams with Large Openings Using CFRP Strips," Materials, vol. 14, no. 11, 6 June 2021.

[5] Beshara, Fouad B.A.; Shaaban, Ibrahim G.; Mustafa, Tarek S., "Behavior of Reinforced Concrete Continuous Deep Beams in Shear," Engineering Research Journal, vol. 17, 10 Jul 2012.