# EFFECT OF ADDITION THE CONDUCTIVE SCREWS ON THE BEHAVIOR OF REINFORCED CONCRETE BEAMS AND COLUMNS

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**Abstract**

In the present paper, experimental investigations were used to study the effect of the addition conductive screws on the behavior of reinforced concrete columns and beams. Screws with 25.4mm (1 inch) length were used. These screws were made of iron coated with Zinc-Aluminium alloy (called Al-Clad), which is resistant to corrosion and rust. The volume fractions of the conductive screws were 0%, 0.5%, 1%, and 1.5% by volume of concrete mix with water/cement ratio equal to 0.55. The results show that the use of the conductive screws enhanced the strength. The strength in tested beams was increased by 15.78%, 44.73%, and 76.31% for 0.5%, 1%, and 1.5% screws content respectively compared to the reference beam with no screws. The same trend was observed with the columns results, where the strength was increased by 12.44%, 26.79%, and 50.71% for 0.5%, 1%, and 1.5% screws content respectively compared to the reference column with no screws.

**Key words:** Screws, reinforced concrete columns, reinforced concrete beams.

# دراسة تأثير اضافة الصواميل الموصلة على تصرف العتبات الخرسانية المسلحة والاعمدة الخرسانية المسلحة

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**الخلاصة**

الهدف من هذا البحث هو دراسة تأثير اضافة الصواميل الموصلة على تصرف العتبات الخرسانية المسلحة والاعمدة الخرسانية المسلحة. وبنسب مختلفة ( ,0%, 0.5%, 1%, and 1.5% من حجم الخلطة الخرسانية). . تم استخدام صواميل موصلة بطول ٢٥.٤ ملم (١- انج). هذه الصواميل الموصلة مصنوعة من الحديد المطلي بسبيكة زنك-المنيوم والمسماة (Al-Clad) المقاومة للتآكل والصدأ والتي تعطي القوة والمرونة للصواميل. نسبة الماء الى سمنت التي استخدمت كانت (w/c=0.55) والنسبة الحجمية للصواميل الموصلة التي اضيفت للخرسانة كانت (0%, 0.5%, 1%, and 1.5% من حجم الخلطة الخرسانية). النتائج بينت ان وجود الصواميل زاد من مقاومة تحمل العتبات والاعمدة. حيث زاد تحمل العتبات بمقدار (15.78%, 44.73%, 76.31%) عن العتب المرجعي الخالي من الصواميل الموصلة وللنسب ( ,0.5% ,1.5% ,1%من حجم الخلطة الخرسانية) على التوالي. كما زاد تحمل الاعمدة بمقدار ( 50.71% , 12.44%,26.79%) عن العمود المرجعي الخالي من الصواميل وللنسب ( ,0.5%, 1% ,1.5% من حجم الخلطة الخرسانية) على التوالي.

**الكلمات المفتاحية: صواميل الموصلة، العتبات الخرسانية المسلحة، الاعمدة الخرسانية المسلحة.**

## 1. Introduction.

Concrete is relatively a brittle material and has poor toughness. Addition of randomly distributed fibres improves concrete structural characteristics such as, strength, ductility and flexural toughness etc., which depend upon fibre type, size, aspect ratio and volume fractions of the fibres used (Singh et al. 2010).

Steel fibre is one of the most commonly used fibres. The effect of using steel fibres on the behavior of concrete has been studied by many researchers. (Craig et al. 1984) reported that adding steel fibers to a reinforced concrete column improved its compressive strength, shear strength, and ductility. The study carried out by (Oh 1992) indicates that ductility and ultimate resistance of reinforced concrete beams are remarkably enhanced due to the addition of steel fibres. (Casanova et al. 1997) shown that steel fibers can be used to significantly reduce the amount of transverse shear reinforcement in beams while maintaining the required shear resistance. (Cohen 2012) show that if steel fibres added in sufficient quantity can be used to replace traditional shear reinforcement and promote flexural failure and ductility . ( Namdar et al. 2013) indicated that steel fiber improves flexural strength of beams and controlled crack morphology. (Aoude et al. 2014) Show that the addition of steel fibres in concrete columns enhances confinement and cover spalling. The results obtained by (Mosheer 2015) showed that the addition of conductive screws to plain concrete led to enhancement mechanical properties of concrete.

In this study, conductive screws made from iron coated with Zinc-Aluminium alloy (called Al-Clad), which is resistant to corrosion and rust, were used as a short fibre to reinforce conventional concrete. The screws were used in different volume fractions. Experimental investigations were conducted to study the effect of addition conductive screws on columns and beams.

## 2. Experimental Program

Experimental program was mainly designed to examine the effect of addition conductive screws with different volumetric ratios on the behavior of reinforced concrete beams and columns.

### 2.1 Specimen details

The experimental work involved testing of four beams and four columns. The dimensions of beams and columns are 1200 × 150 × 150 mm. Geometry and reinforcement detail for beams and column are shown in **Fig**1.

### 2.2 Materials Properties

*2.2.1 Concrete*

Sulphate-resistant Portland cement (Type V) was used, coarse aggregate have a (5-19) mm size crushed gravel and the fine aggregate was natural river sand, zone 2 according to IQS:45 1984 with 2.85 fineness modulus.

*2.2.2 steel reinforcement*

Arrangement of steel bar used in tested beams and columns are indicted in **Fig**1. Sample of steel bars was tested by tensile testing machine to product some properties of them, results of test were listed in Table 1.

2.2.3 Screws

The conductive screws were used throughout the experimental program, made from iron coated with Zinc-Aluminium alloy, which is resistant to corrosion and rust. The screws were used with length 25.4 mm (1 inch) as shown in **Fig** 2. Some properties of the screws are listed in Table 2.

**2.3 Mix proportions**

Volumetric mixing ratio of (1:2:4) was used, with water/cement ratio (w/c) = 0.55. Cylinders and prisms for each mix were cast and stored with each beam and column. Average results of cylinder strength $f'_c$ and modulus of rupture $f_r$ are given in Table 3.

The screws were added in volume fractions of 0%, 0.5%, 1%, and 1.5% by volume of the total mix for the beams (B0, B1, B2,and B3) respectively, and for columns (C0, C1, C2,and C3) respectively as indicted in Table 4. The beam and column with no screws were considered as a reference sample. After a 28 day of curing, a tests were conducted for the reinforced concrete members.

**3. Testing Procedure**

**3.1 Reinforced concrete beams test**

All the tested beams were simply supported under one point load at mid span which incrementally loaded up to maximum load capacity by means of a hydraulic jack with maximum capacity of 200 kN. Dial–gage placed vertically at mid span of beams to measure the deflection at each increment of the load.

**3.2 Reinforced concrete columns test**

All columns were tested for concentric axial loads by an universal testing machine with capacity of (200) ton. The ends supports of all tested columns simulate the simply support conditions with no sideways movement (braced columns) because the top and bottom ends of the columns are not capable to move laterally. To ensure a uniform distribution of the axial compressive load, a square steel bearing plate with dimensions of (200×200×5) mm (width ×length× thickness) was fixed at the top end of each column during the test. The load was applied through a bearing plate in small increments up to failure. A dial-gage placed vertically at the top face of column to recorded the axial deformation, while the lateral deflection was measured using dial-gages placed horizontally at the mid height of column in each side. After each increment, the load was kept constant until the required measurements were recorded.

**4. Discussion of the results**

**4.1 Reinforced concrete beams**

From the test results shown in Table 5 and **Fig** 3 and 5, it can be seen that ultimate axial load increases with increasing the screws content. The ultimate axial load increased by 15.78%, 44.73%, and 76.31% for B1, B2, and B3 respectively from reference beam with no screws B0. The increase in ultimate axial load appears more clearly with screws contents of 1.5% for beam B3 compared to the reference beam B0. From **Fig** 5 it can be observed that cracks width decreases and number of cracks increase with increasing the volume fraction of the screws compared with the reference beam B0 (0.0% added ratio). This is due to the fact that the load path is intercepted by the conductive screws, which leads to a change in its direction.

**4.2 Reinforced concrete columns**

The reinforced concrete columns test results are illustrated in Table 5 and **Fig** 6 to 8. The ultimate axial load increased by 12.44%, 26.79%, and 50.71% for C1, C2, and C3 respectively from reference beam with no screws C0. **Fig** 9 show the reinforced concrete column specimens shapes after failure. As can be seen from this **Fig**, all tested columns have experienced similar failure pattern represented by concrete crushing at the top of the column followed by generating of cracks and splitting of the concrete cover.

**5. Conclusions**

From the experimental results, the following conclusions can be stated:

1. The use of conductive screws works to increasing the strength capacity for reinforced concrete columns and beams. This is due to the ability of screws to control and redistribute the stresses after cracking.
2. The strength of beams and columns increased with increasing the screws content.
3. The cracks width in reinforced concrete beams decreases with increasing the screws content, instead, there was an increase in the number of cracks.

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**Table 1:** Test results of steel bars (MPa)

| **Material type** | $f_y$ **MPa** | $f_u$ **MPa** |
|---|---|---|
| bar Ø 12 | 447 | 731 |
| bar Ø 10 | 452 | 729 |

**Table 2** : Properties of conductive screws

| Material type | Average Diameter (mm) | Head Diameter (mm) | Length mm | Density kg/m$^3$ | Modulus of Elasticity GPa |
|---|---|---|---|---|---|
| **Screw** | 3 | 6.5 | 25.4 | 7500 | 200 |

**Table 3 :** Test results of Concrete (Mixing ratio=1:2:4)

| Fibre content % | $f\acute{c}$ MPa | | $fr$ MPa |
|---|---|---|---|
| | 7 days | 28 days | |
| 0.0 | 14.91 | 19.4 | 2.75 |
| 0.5 | 15.32 | 21.37 | 2.84 |
| 1.0 | 15.72 | 22.41 | 2.90 |
| 1.5 | 17.69 | 23.82 | 2.94 |

**Table 4:** Details of reinforced concrete beams and columns

| Member Type | Member No. | Screws content % | $f\acute{c}$ MPa |
|---|---|---|---|
| Beam | B0 | 0.0 | 19.4 |
| | B1 | 0.5 | 21.37 |
| | B2 | 1.0 | 22.41 |
| | B3 | 1.5 | 22.92 |
| Column | C0 | 0.0 | 19.4 |
| | C1 | 0.5 | 21.37 |
| | C2 | 1.0 | 22.41 |
| | C3 | 1.5 | 23.82 |

**Table 5**: Test result of beams and columns

| Member Type | Member No. | Screws content % | $f\acute{c}$ MPa | Ultimate load Pu (kN) | Increasing rate in ultimate load % |
|---|---|---|---|---|---|
| Beam | B0 | 0.0 | 19.4 | 38 | -- |
| | B1 | 0.5 | 21.37 | 44 | 15.78 |
| | B2 | 1.0 | 22.41 | 55 | 44.73 |
| | B3 | 1.5 | 22.92 | 67 | 76.31 |
| Column | C0 | 0.0 | 19.4 | 418 | - |
| | C1 | 0.5 | 21.37 | 470 | 12.44 |
| | C2 | 1.0 | 22.41 | 530 | 26.79 |
| | C3 | 1.5 | 22.92 | 630 | 50.71 |

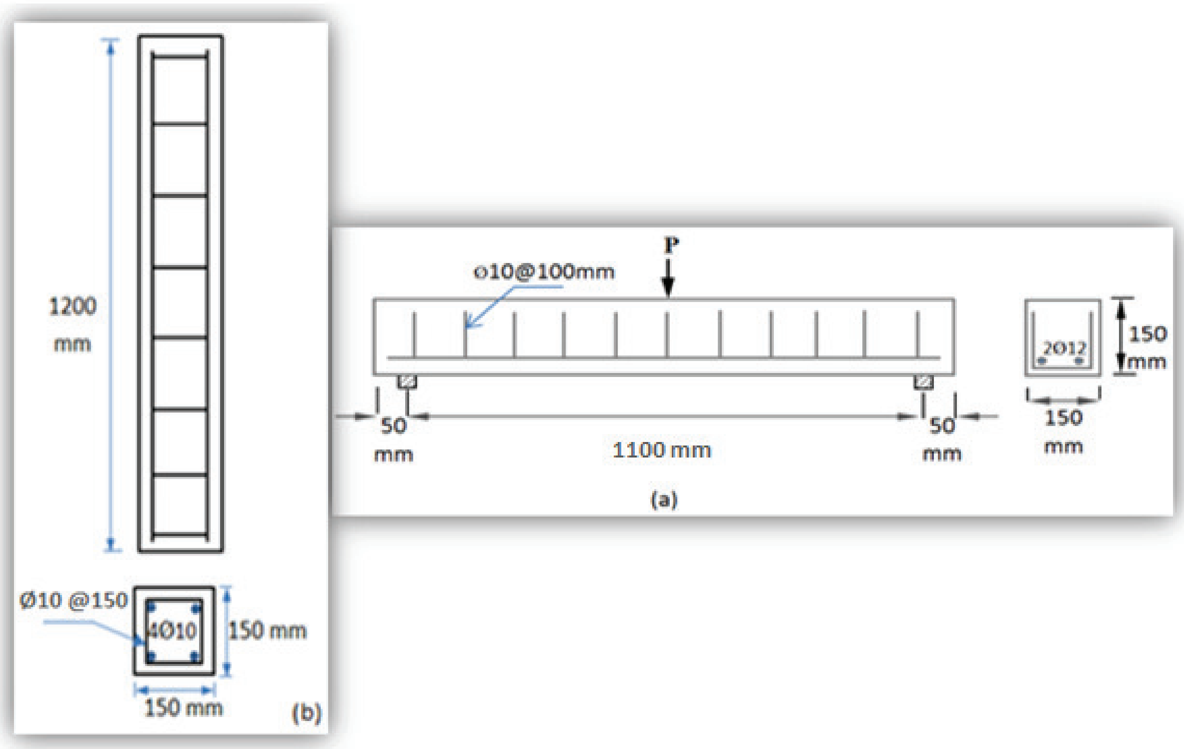


**Figure 1: Geometry and reinforcement detail for (a): Beams, (b): Columns**

**Figure 2: Screws used**

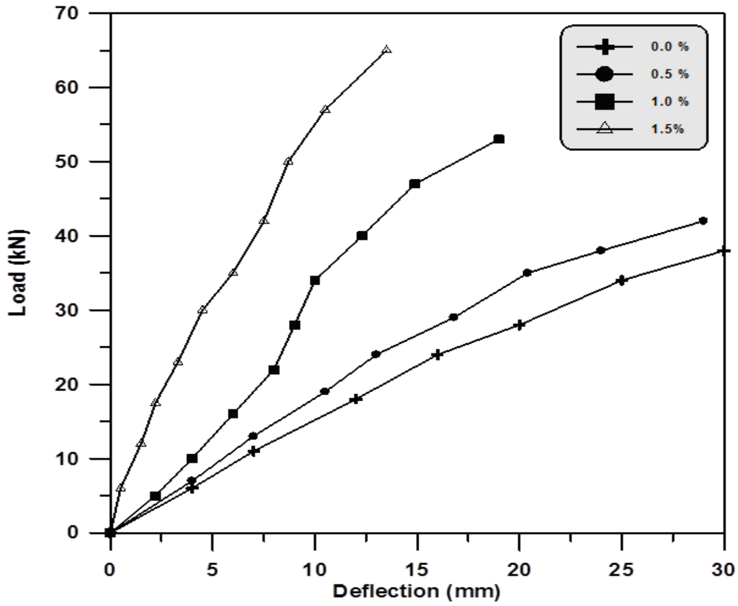


**Figure 3: Load-deflection curve for beams B0(0%) ,B1 (0.5%), B2 (1%), and B3 (1.5%)**

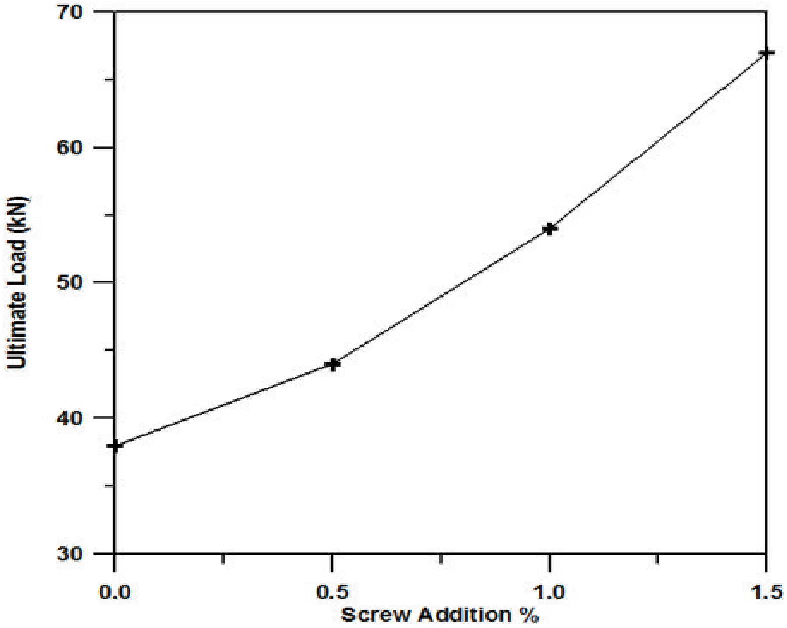


**Figure 4: The relationship between ultimate load in beams and the screws content**


**Figure 5: Failure mode of reinforced concrete tested beams**

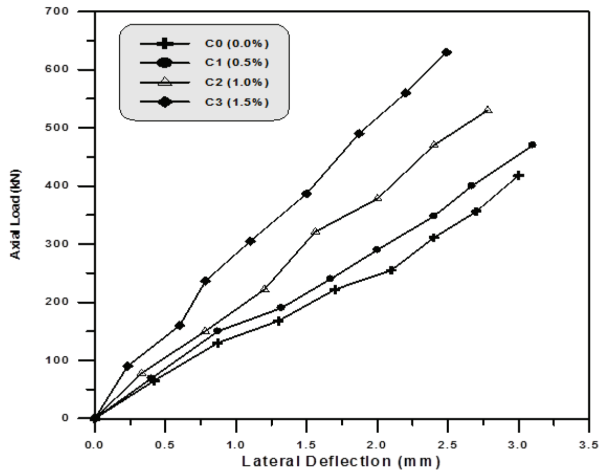


**Figure 6: Load- Lateral deflection curve for columns C0 , C1, C2, and C3**

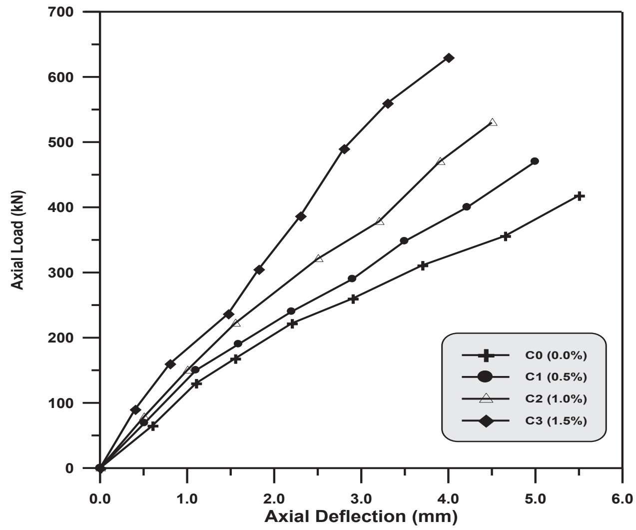


**Figure 7: Load-Axial deflection curve for columns C0 ,C1, C2, and C3**

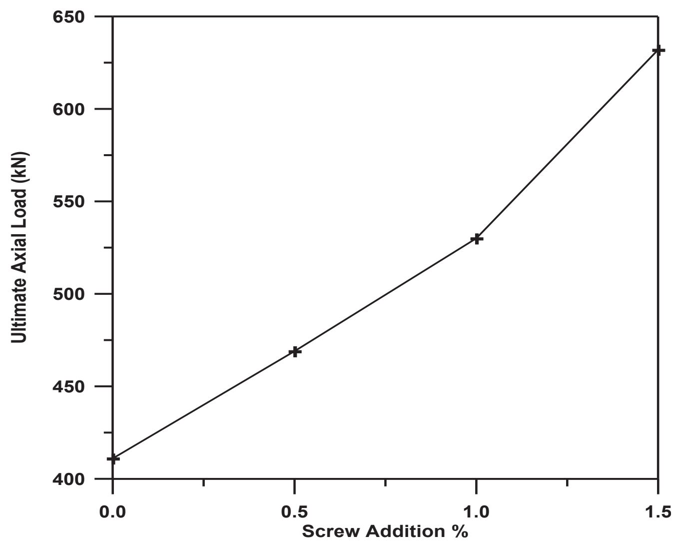


**Figure 8: The relationship between ultimate load in columns and the screws content**


| C0 (0.0%) | C1 (0.5%) | C2 (1.0%) | C3 (1.5%) |
|---|---|---|---|

**Figure 9: Failure modes of reinforced concrete columns**