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Effect Of Eggshell Powder On The Behavior Of Axially And Eccentrically Loaded Columns

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Abstract:
The content of Eggshell powder were similar as cement content. Eggshells from poultry farms are usually thrown away as a waste. Such a renewable waste is collected and used in this research to reduce environmental problems.This research work investigates the effect of using eggshell powder (ESP) as partial replacement for ordinary Portland cement in the concrete mix of Grade 25 and reinforced concrete columns. The eggshellpowder, sieved to 100 µm. The concrete mix proportion is 1:2:3.7 in which cement is partially replaced with egg- shell powder.The egg- shell powderare 5%, 10% and 15% by weight of cement. The main purpose of this study is to compare between the behaviors of using different ratios of Egg Shell Powder in concrete with normal concrete under different types of loading of reinforced concrete columns. Twelve reinforced concrete columns were cast in four groups, each group contains three columns . The first group was a control group and the other groups the percentage of ESP were varied as 5%, 10% and 15% .All specimens divided into three types of loading, axial load, eccentricity load with e/t=0.5 and 0.75. Based on the results of this research, it was observed that 5%ESP gives close results to the results of normal concrete at compressive strength, tensile strength, flexural strength and load of reinforced concrete columns. Finally, Egg Shell Powder (ESP) can be used by 5% as a replacement of cement in concrete.

Keywords:R*einforced concrete columns, Egg shell powder , eccentricity, flexural behavior.Cement, Axial compression*

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I. Introduction

Throughout today's building industry, waste materials such as glass powder, fly ash and slag are used to minimize environmental issues and increase benefit while eliminating waste. The waste from the Egg Shells is commonly dumped into landfills without any pre - treatment as it is generally useless. Scientifically known, The content of Eggshell powder and cement were found to be very close. Around 95% of the dry eggshell is calcium carbonate weighing 5.5 grams. The regular eggshell contains about 0.3% of magnesium, phosphorous, and traces of sodium, zinc, potassium, iron, copper and manganese. Since the chemical properties of the eggshell ash can influence the properties of concrete mix, the strength of the concrete affected by adding eggshell ash [1]. The chemical composition of egg shell powder is shown Table (1) [2] and table (2) shows the physical properties of Egg Shell Powder [3]. Micro structural analysis of the eggshell powder was carried out using a scanning electron microscope (SEM), the powder particles appeared to have a serrated edges, irregular shape and a variable particle size as shown in Fig. 1[4]. Simultaneous thermo gravimetric analysis (TGA) experiment was conducted on lime stone, white and brown powdered samples to estimate the weight change with the temperature valid from room temperature to 1000^{o}C. For white and brown eggshell powders the weight loss curves are the same in shape with lime stone as shown in Fig. 2 [4].

Table (1): Chemical composition of egg shell powder **Table (2):** physical properties of Egg Shell Powder

Chemical composition	Eggshell (%)
Calcium oxide (CaO)	61.71
Silicon dioxide (SiO_2)	0.61
Aluminium oxide (Al_2O_3)	0.07
Iron oxide (Fe_2O_3)	0.63
Magnesium oxide (MgO)	0.36
Potassium oxide (K_2O)	0.22
Sulphur trioxide (SO_3)	1.32

Name	Physical Properties
Specific Gravity	0.85
Moisture content	1.18
Bulk Density (g/m3)	0.8
Particle Density (g/m3)	1.012
Porosity (%)	22.4 BET
Surface area m2/g	21.2

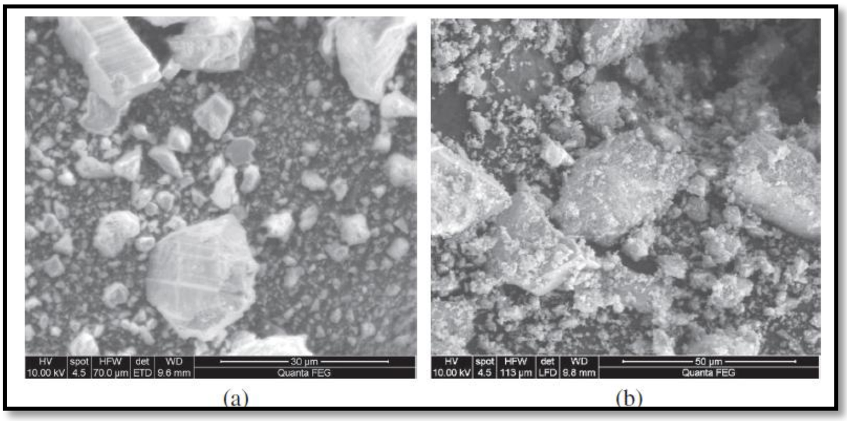


Fig. (1): SEM image appears powder morphology, (a) white and (b) brown eggshells

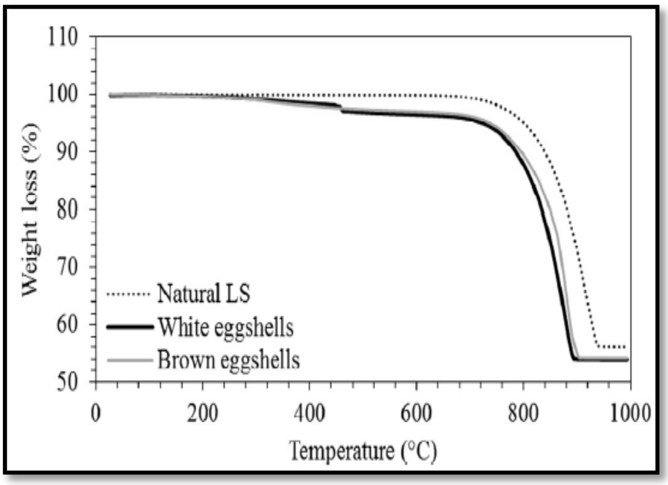


Fig. (2):TGA analysis for limestone, white and brown powders [4]

II. Background

S.Raj and A.Samelin [5] had investigated the use of egg shell as a 100% fine concrete aggregate compared to that of traditional concrete with sand as fine aggregate. The concrete was designed using aggregate (granite &egg shell powder), ordinary Portland cement and water. The results recommended that the egg shell should not be used as fine aggregate in concrete production at 100% replacement amount. J.Karthik and others [6] prepared a concrete mix M25 grade design. Egg Shell was being used as a partial replacement of sand. Replacement of the ESP up to 10%, 20%, 30%, 40% and 50% for every proportion, split tensile Strength, compression strength and flexural strength tests werestudied. From the results, the tensile strength, flexural strength was decreased with increasing the ratio of egg shell powder.

Fazera Ujn and others [7] researched on the effect of (ESP) on cement setting time, cement-egg shell powder (CESP) paste was formed using 0%, 0.1%, 0.5%, 1%, 1.5%, 2.0% and 2.5% of ESP by weight of cement. Consistency test was carried out, the amount of water needed to make standard cement past of normal consistency is amounting to 148ml. This decoded to 0.37 water/cement ratio, which was utilized in consisting the CESP paste on which was conducted the setting time test. From the results of the setting time test it can concluded that: i. Egg shells powder (ESP) is an accelerator. ii. The higher the ratio of the ESP, the greater the accelerating effect. iii. For all the ESP ratios used in this study, the requirements of BS 12: 1991 are obtained for both the initial and final setting times of the OPC.

N. Baloch and others [8] performed slump tests and compacting factor tests to estimate the workability of ESP fresh concretes. Five different percentages with 5, 10, 15 and 20% replacement of cement by eggshell powder (ESP). Based on the investigation they concluded that workability of concrete is reduced as the percentage of egg shell powder (ESP) increased.

Divya.B and Yeramala [9,10] studied the compressive strength of concrete with eggshell powder (ESP) as cement replacement. M20 grade concrete was designed for this mix proportion . The concrete mix proportion is 1:1.5:3 in which cement is partially replaced with ESP as 5%, 10%, 15% and 20% by weight of cement.The compressive strength of 7days and 28days strength was determined. From the results that replacement of 5% and 10% of ESP in increased by around 4% in 28days compressive strength and the optimal replacement is 15%.

Siew Cho and others [11] studied the Flexural Strength of concrete using eggshell powder as a partial cement replacement at volumes of 5%, 10%, 15% and 20%. According to the resut 15% of ESP is the desirable percentage to use as partial cement replacement for the flexural strength.

III. Experimental work

A. Materials

1. Aggregates

The coarse and fine aggregates were tested according to ECP 203; List of tests presented as follows:
Sieve Analysis, specific gravity, absorption of aggregate and unit weight of aggregate. Table (3) shows the characteristics of the coarse and fine aggregate used.

Table (3): Characteristics of the Coarse and fine aggregate

Property	Coarse aggregate	Fine aggregate
Type used	Basalt	Sand
Specific Gravity	2.77	2.56
Bulk density (t/m3)	1.62	1.73
Max aggregate size (mm)	16	2.43
Absorption %	0.76	1.01

2. Cement

The cement used for this study was cement CM I (42.5N) provided from AL- Masry Cement Company, Egypt, which met the specifications of ECP [12]. After bringing the cement into the laboratory, it was stored in an airtight plastic container and sealed. This was done to avoid any likely reaction of air moisture with cement. The physical properties of the cement are shown in Table (4).

Table (4): Physical Properties of Cement

Property		Cement
Surface area of particles(cm2/gm)		2950
Water standard		28%
Volume change		1
Specific gravity		3.15
Setting time	initial	46 min
	final	1.6 hr

3. Egg Shells Powder

The eggshell wastes were supplied from poultry farms located at EL Azab, Fayoum, Egypt. The eggshell wastes were cleaned with tap water and then dried under the sun for several days. The eggshells were crushed and ground to a powder, then passed through 100 μm sieves. The physical Properties of Egg Shells powder (ESP) are shown in Table (5). The chemical compositions of the eggshell and cement are shown in Table 6). Fig. 3 shows the shape of ESP.

Table (5):Physical Properties of Egg Shells Powder

Name	Physical Properties
Specific Gravity	2.14
Moisture content	1.18
Bulk Density (gm/m3)	0.8
Particle Density (gm/m3)	1.012
Porosity (%)	22.4 BET
Surface area m2/gm	21.2

Table (6):Chemical Properties of Cement and Egg Shells Powder

Composition	Cement	ESP
CaO	63.80%	47.49%
SiO2	21.40%	0.11%
Al2O3	5.10%	Nil
Fe2O3	2.60%	Traces
MgO	0.36%	Nil
SO3	3.38%	0.38%
K2O	1.88%	Nil
Na2O	0.14%	0.14%

A-Before grinding b- After grinding
Fig. (3):Shape of ESP

4. Super Plasticizers (Sikament NN)

Super plasticizer is manufactured to conform to ASTM C-494 [13] specification type F and BS 5075 part 3 [14]. Sikament NN is used as super plasticizer in the production of free flowing concrete such as walls, columns and pipes. It is also used as water reducing agent leading to high early strength concrete. The physical and chemical properties of Sikament NN are shown in Table (7). The advantages of using Sikament NN as a super plasticizer are : improving workability, reduse water improved strength by 40 % after 28 days and increase water tightness.

Table (7): The Physical and Chemical Properties of Sikament NN

Property	Sikament NN
Chemical base	Poly-naphthalene condensate
Color /appearance	Brown Liquid
Density	1.20 ± 0.005 kg/Lt
Chloride content	Nil
pH value	8
Dosage recommended	0.6 – 3.0% by weight of cement

5. Concrete mix design

This research compares between four mixes, normal concrete mix and Different percentages of Eggshell Powder (ESP) (5%, 10%and 15%) concrete mix. The mix design and testing program were conducted in accordance with ECP [12]. The different mixes are conveniently designated as M1, M2, M3 and M4 respectively. The proportions used in preparing concrete for one cubic meter for mix of the four mixes are shown in Table (8). Fig (4) shows the percent of the constituent materials for cubic meter of N.C by weight.

Table (8): Mix Proportions of Concrete Mixes

Mix	Mix ID	W/C	Water (L/m3)	Cement (kg/m3)	ESP Weight (kg/m3)	Fine Agg (kg/m3)	Coarse Agg (kg/m3)	Super Plasticizer (L/m3)
M1	Normal concrete	0.4	140	350	0	716	1290	3.5
M2	5% ESP concrete	0.4	140	332.5	17.5	716	1290	3.5
M3	10% ESP concrete	0.4	140	315	35	716	1290	3.5
M4	15% ESP concrete	0.4	140	297.5	52.5	716	1290	3.5

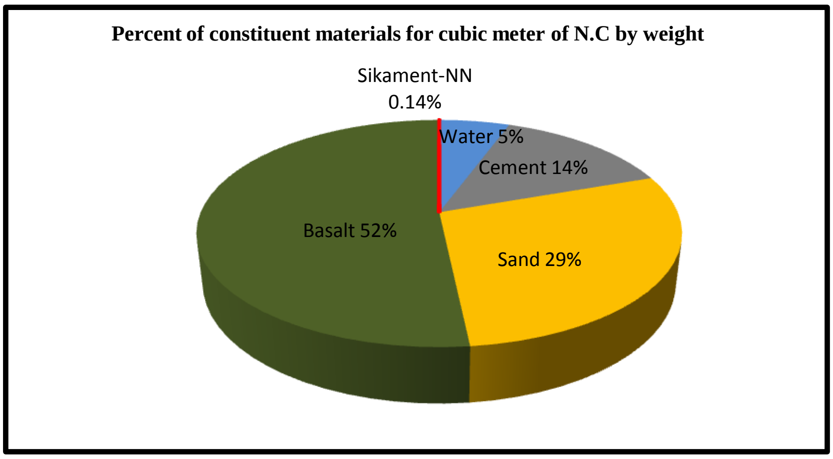


Fig. (5): Percent of Constituent Materials for Cubic Meter of N.C by Weight

B. Design of Specimens

Twelve reinforced concrete columns were cast. Each mix of the four mixes contains 3 columns, one of them its dimensions was 12 cm x 12cm x90 cm and the other two columns of the same dimensions with a top and a bottom flange with dimensions 30 cm. Table (9) shows a cross section for columns.

Table (9): Cross Section For Testing Columns

Column Name	Mix	Cross Section
C5	M1	$(12*12)cm^2$ (with 2 cm concrete cover from each side)
C6	M2	
C7	M3	
C8	M4	
C1 &C2	M1	$(12*12)cm^2$ (with 2 cm concrete cover from each side) With two flanges $(30*12)cm^2$ (with 2 cm concrete cover from each side)
C3 & C4	M2	
C9 &C10	M3	
C11 &C12	M4	

All columns had identical internal steel reinforcement which designed according to minimum required. Four 10mm deformed bars with nominal tensile strength 3600kg /cm^2 were provided as longitudinal reinforcement. 8 mm bars with nominal tensile strength 2800kg /cm^2 were provided as transversal reinforcement with 10cm and 15 cm spacing. Fig.6 and Fig.7 show dimensions and reinforcement details of testing columns.

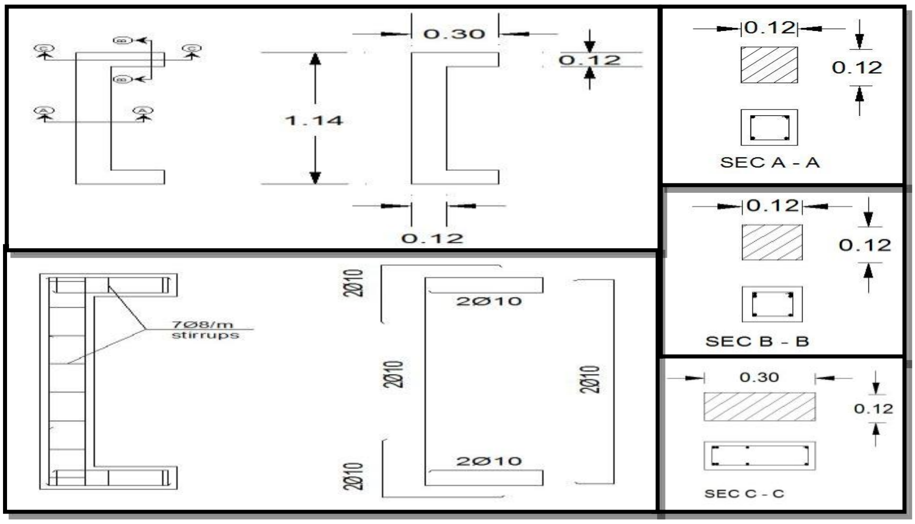


Fig. (6): Concrete Dimensions And Reinforcement Details For Columns (**C1, C2, C3, C4, C9, C10, C11andC12)**

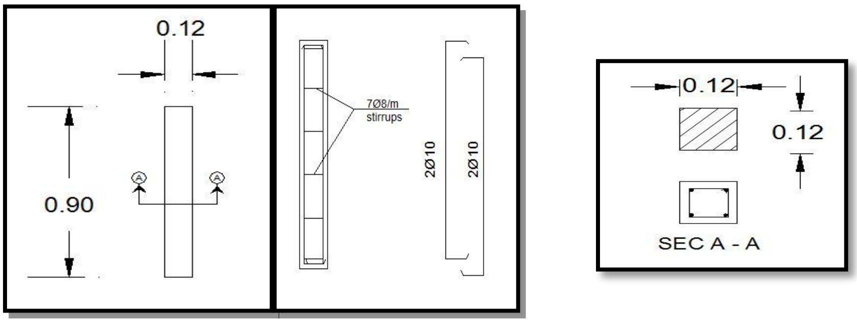


Fig.(7): Concrete DimensionsAnd Reinforcement Details For Columns (**C5, C6, C7 and C8**)

1. Casting, curing and testing of specimens

All twelve reinforced concrete columns were cast and cure in concrete research and material properties lap facilities-faculty of engineering – Fayoum university. All specimens were cast in the same way, according to Egyptian specifications[12]. All fresh concrete tests were applied as, initial & final setting time and slump test. Hardened concrete tests were also applied as compressive strength , splitting tensile strength and flexural strength. All tests were applied according to ESC [12]. Table (1) shows all results of fresh and hardened concrete tests for the four concrete mixes.

Table (10): Results Of Fresh And Hardened Concrete Tests

MIX	Slump(mm)	Initial Setting Time (min)	Final Setting Time (min)	Average Compressive Strength for 3 Cube at 7 Days (kg/cm^2)	Average Compressive Strength for 3 Cube at 28 Days (kg/cm^2)	Average Tensile Strength for 3Cylinders at 28 Days (kg/cm^2)	Average Flexural Strength for 3 Beams at 28 Days (kg/cm^2)
M1 (Normal concrete)	26	46	94	363.5	412.7	36.4	60.3
M2 (5%ESP concrete)	19	48	96	358.7	403.2	32.8	57.6
M3 (10%ESP concrete)	14	80	112	271.6	374.4	31.1	55.2
M4 (15%ESP concrete)	10	123	160	262.0	274.6	27.6	48.9

C. Test Configuration

1. Test groups

The specimens were divided into three groups depending on case of loading. The first group (group (A)) was set as a reference group with axial loading it includes columns C5, C6, C7 and C8. The second group (group (B)) simulated the conventional method of strengthening square concrete columns with eccentricity equal (e=0.5b) for each column this group contains columns C2, C4 , C10 and C12. The third group (group C) was loaded with a large eccentricity (e=0.75b) for each section of columns C1, C3, C9 and C11. All specimens were tested by loading frame machine. Fig.8 shows groups of specimens.

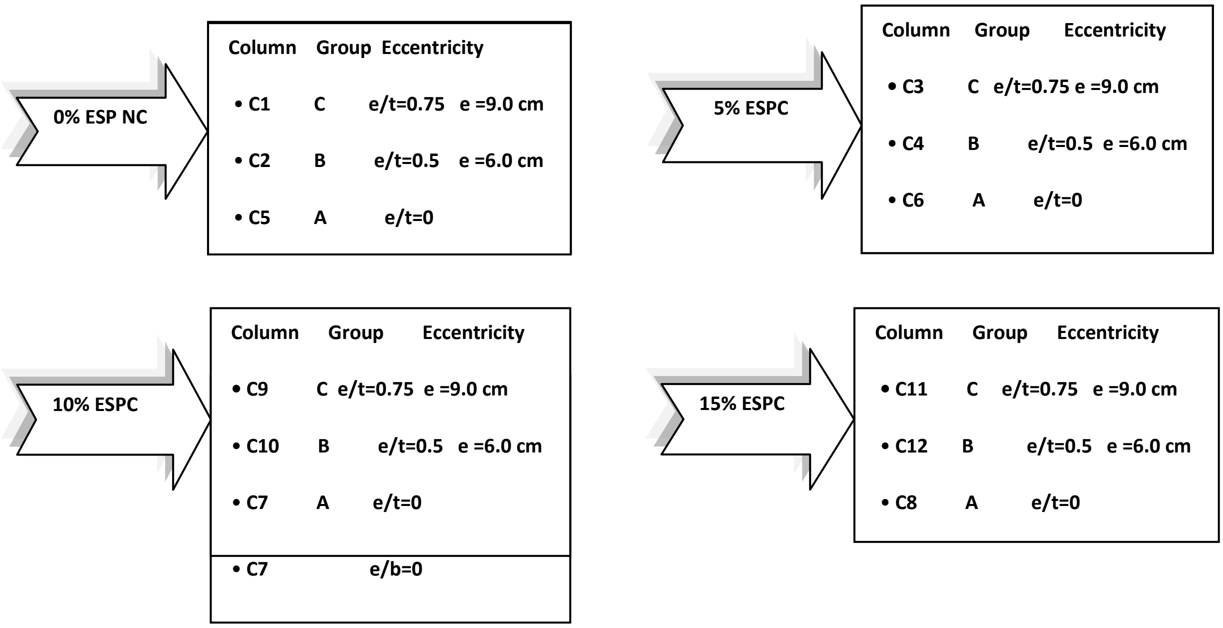


Fig.(8): Groups Of Specimens

2. Loading Frame

To determine the failure load of columns it is necessary to use loading frame .it consists of three major parts .firstly,the main loading frame ,which is created from two built- up welded steel section as loading section s as loading frame supports . at the top the- built up loading girder with three loading jacks, which used in loading test .the used loading jack with capacity 120 ton. All main loading frame components are fixed to reinforced concrete raft with eight rigid anchors. Secondly, the control machine, which linked with loading frame by oil pipe and with computer by loading sensor .Thirdly, the computer part which used to obtain the output data. Fig.9shows loading frames while from fig. 10 and fig.12 show the position of columns under loading jack.

Fig (9): Loading Frame

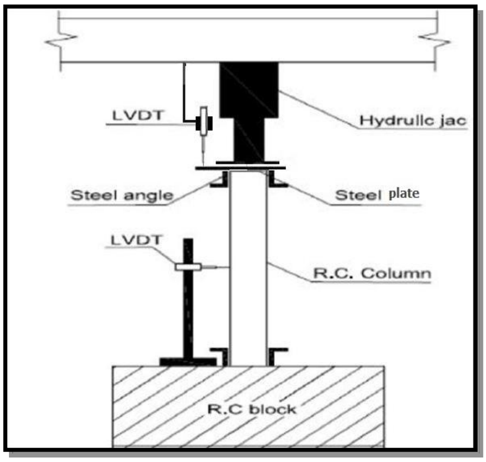


Fig. (10): Position of Group (A) Columns under Loading Jack

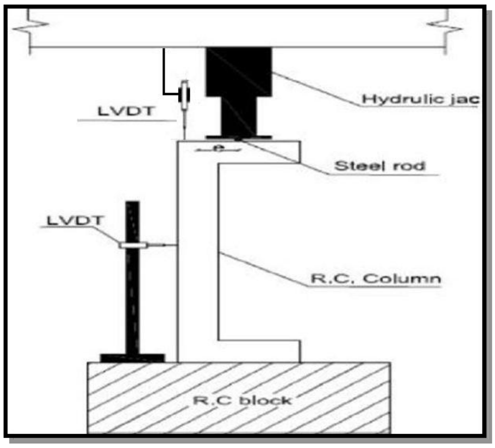


Fig. (11): Position of Group (B& C) Columns under Loading Jack

3. Linear Variable Displacement Transformer (LVDT)

Two linear variable displacement transformers (LVDT) were used to measure lateral deflection and axial displacement due to loading. Horizontal and vertical (LVTD) were placed in the mid–height of column and top of column during loading by loading jack (60 ton capacity) to determine the actual lateral deflection and axial displacement which occurs during and after loading of column. Relation between loading and corresponding lateral deflection and axial displacement will be seen in details in the next chapter. Fig. 13 shows LVDT in lap.

Fig.(13): LVDT Used in Lap

IV. Results Of Experimental Tests

A. Group (A)(e=9cm - e/t=0.75)

Group (A) consists of columns which eccentrically loaded. This group was loaded with a medium eccentricity equal (0.75b). The comparison between the columns of the group (A) was presented in Table (11). The relation between load and vertical displacement of the tested columns shown in fig. 14, while fig. 15 shows the relation between load and horizontal displacement of the tested columns.Fig.16 shows the mode failure of the tested columns C1,C3, C9 and C11. The results show increasing in ESP ratio from 5% to 15% in the NC column leads to decrease in normalized load capacity from 94.67% to 67.37% and slightly increase in stiffness from 72.58% to 103.31%.

Table (11): Results of Group (A) Eccentricity (e=9cm – e/t=0.75)

Column Name	ESP	Failure load (KN)	Lateral deflection (mm)	Axial deflection (mm)	Stiffness (KN/mm)
C1	0%	144.54	13.75	2.3	62.84
C3	5%	136.83	16.5	3	45.61
C9	10%	99.61	22.5	1.5	66.10
C11	15%	97.38	16.25	1.5	64.92

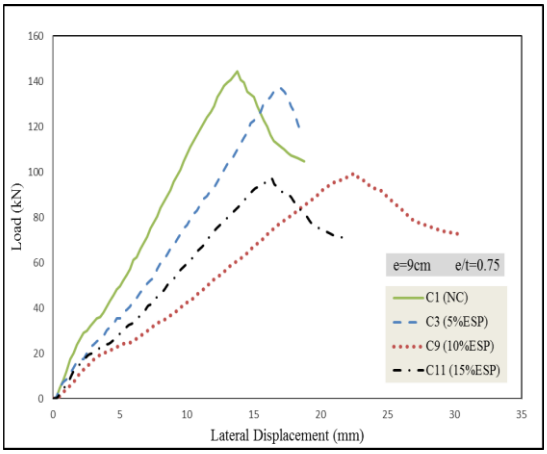


Fig.(14): Relation between Load and Lateral Deflection

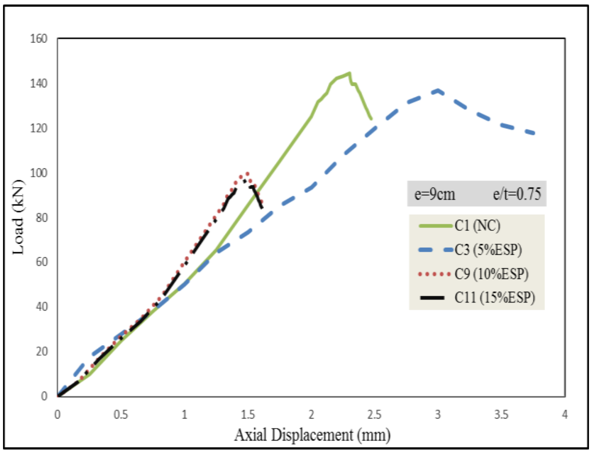


Fig. (15): Relation between Load and Axial Deflection

Fig. (16): Mode Failure Of The Tested Columns Of Group A

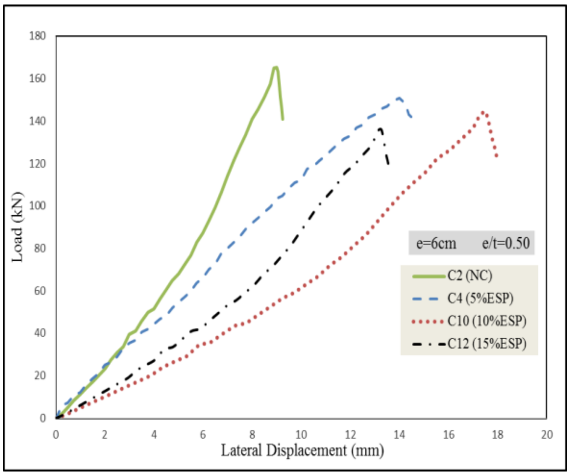
B. Group (B) (e=6cm – e/t=0.5)

Group (B)consists of columns which eccentrically loaded .This group was loaded with a medium eccentricity equal (0.5b). Group (B) contains columns (C2, C4, C10andC12).The comparison between the columns of the group (B) was presented in Table (12). The relation between load and vertical displacement of the tested columns shown in fig. 17, while fig. 18 shows the relation between load and horizontal displacement of the tested columns.Fig.19 shows the mode failure of the tested columns C2,C4, C10 and C12.The results show increasing in ESP ratio from 5% to 15% in the NC column leads to decrease in normalized load capacity from 91.24% to 82.37% and also decrease in stiffness from 84.21% to 24.12%.

Table (12): Results of Group (B) Eccentricity (e=6cm – e/t=0.5)

Column Name	ESP	Failure Load (KN)	Lateral deflection (mm)	Axial deflection (mm)	Stiffness (KN/mm)
C2	0%	165.45	9	3	55.15
C4	5%	150.96	14	3.25	46.44
C10	10%	144.54	17.5	11.5	12.57
C12	15%	136.28	13.25	10.25	13.30

Fig. (17): Relation between Load and Lateral Deflection Fig. (18): Relation between Load and Axial Deflection



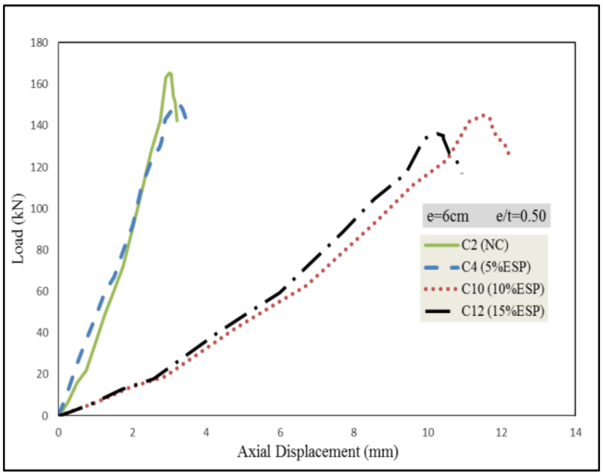


Fig. (19):mode failure of the tested columns of group B

C. Group (C) (e=0cm)

Group (C) consists of columns which axial loaded. Group (C) contains columns (C5, C6, C7and C8).The comparison between the columns of the group (C) was presented in Table (13). The relation between load and vertical displacement of the tested columns shown in fig. 20, while fig. 21 shows the relation between load and horizontal displacement of the tested columns.Fig.22 shows the mode failure of the tested columns C5,C6, C7 and C8.The results show increasing in ESP ratio from 5% to 15% in the NC column leads to decrease in normalized load capacity from 95.24% to 68.08% and also decrease in stiffness from 95.23% to 69.24%.

Table (13): Results of Group (C) Eccentricity (e=0)

Column Name	ESP	Failre load (KN)	Lateral deflection (mm)	Axial deflection (mm)	Stiffness (KN/mm)
C5	0%	742.16	1.25	15	49.48
C6	5%	706.82	1.25	15	47.12
C7	10%	653.79	3	10.25	63.78
C8	15%	505.27	3	14.75	34.26

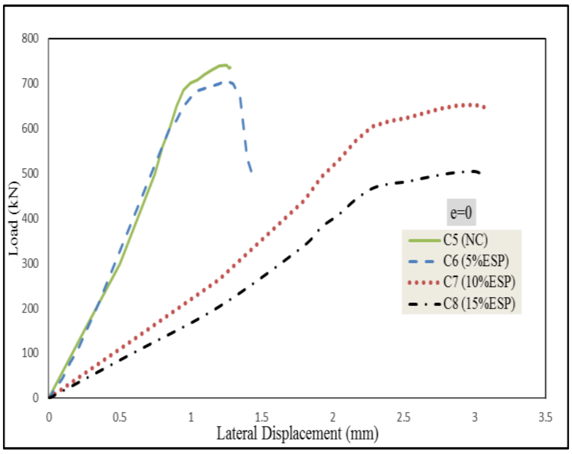


Fig. (20): Relation between Load and Lateral Deflection

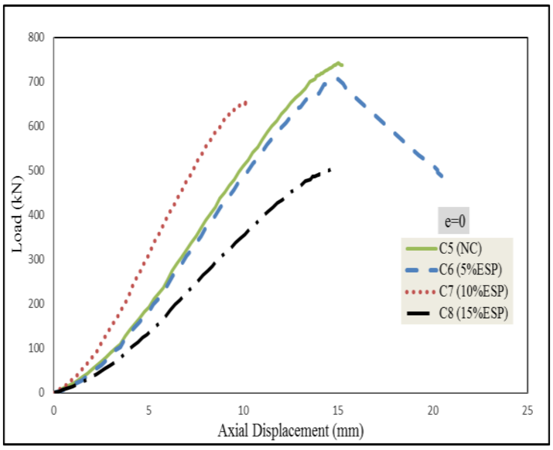


Fig. (21): Relation between Load and Axial Deflection

Fig. (19): Mode Failure Of The Tested Columns Of Group C

V. Conclusion

- Increasing of the percentage of ESP decreases the workability of concrete mix.
- Comparing with normal concrete, increasing the percentage of ESP by 5% ,10 and 15% increase the setting time of the concrete mix by 102.12%, 119.1% and 170.2% respectively.
- Using 5%ESP in concrete mix thecompressive strength slightly decreases by 2.3% compared with normal concrete. The decreasing on the other mixes were 9.3% and 33.46% to 10%ESP and 15%ESP respectively.
- Comparing with normal concrete, Tensile strength decrease of 9.8 %, 14.5% and 24.07% for using 5%, 10% and 15% of ESP in concrete mix.
- Flexural strength values decrease by 4.5%, 8.46% and 18.9% to 5%, 10% and 15 % ESP in concrete mix respectively, compared with normal concrete
- For the three cases of loading, it was observed that increasing in ESP ratio from 5% to 15% in the reinforced concrete column leads to decrease in normalized load capacity. In group (A) the normalized load capacity decreasesfrom 94.67% to 67.37%, while in group (B) the normalized load capacity decrease from 91.24% to 82.37% and in group (C) the decreasing in normalized load capacity will be from 95.24% to 68.08%.
- It was observed that the increase in ESP ratio from 5% to 15% in the reinforced concrete column leads to slightly increase in stiffness from 72.58% to 103.31% in the group (A), while for group (B) the stiffness decrease from 84.21% to 24.12% and for group (C) stiffness decreases also from 95.23% to 69.24%.
- All the twelve Columns exhibited a gradual ductile failure mode. Micro cracks appeared during loading which increased by increasing the load till reached to its ultimate failure, then load started to decrease while concrete has to maintain consistency during failure. Columns with eccentricity equal (e=0.5b) had shown warning signs before failure clearer than that of columns with eccentricity equal (e=0.75b).

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