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STRENHTHENING OF REINFORCED CONCRETE SLABS WITH DIFFERENT TECHNIQUES

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ملخص البحث:

من خلال هذا البحث تم اختبار عدد (12) بلاطة خرسا نية مسلحة بابعاد (0.6 x0.6x0.05 م) تحت تاثير عزم الانحناء لتحديد مقاومة كل بلاطة لعزم الانحناء .تم تحميل كل بلاطة فى اتجاه واحد (بلاطة ذات اتجاه واحد). تم تدعيم البلاطات قبل الاختبار بعدة طرق مختلفة مثل اسياخ الحديد الاضافية-شرائح الصلب بابعاد مختلفة-الياف الكربون – الالياف الزجاجية حيث انه يوجد عدد كبير من الابحاث التى ركزت على استخدام البوليمرات المسلحة بالالياف فى تقوية وتدعيم العناصر الخرسانية المسلحة . من النتائج التى تم التوصل اليها فى هذا البحث ان العينات التى تم تدعيمها باستخدام شرائح الياف الكربون حققت اعلى قيمة من حمل الانهيار مقارنة بالبلاطات الاخرى . ايضا بزيادة المقاومة المميزة للخرسانة زاد حمل الانهيار للبلاطات. العينات التى تم تدعيمها بالالياف حققت مقاومة اعلى للتحميل مقارنة بالبلاطات التى تم تدعيمها باسياخ تسليح اضافية .

ABSTRACT

In this work (12) slabs of reinforced concrete and its dimensions (0.6x0.6x0.05m) were tested under bending moment to define the resistance of each one to bending moment. loading were done for each slab in one direction (one way slab). Slabs were strengthened before testing by many methods like, additional steel bars, Steel sheet, Carbon fiber and Glass fiber where a lot of thesis focused on using fiber reinforced polymers in strengthening reinforced concrete elements [1-5] From the results of this work, it was showed that specimen was strengthened by Sheets of carbon fiber have The beigest value of failure load and by increasing concrete compressive strength failure load increased.

Key words: Reinforced Concrete, Slab, Carbon Fiber, Polymers, Sheets

1.Introduction

Different strengthening techniques have been developed so far for the reinforced concrete slabs with or without cut-outs [6]. The strengthening of examined slabs with CFRP sheets improves the textural strength capacity [7-10] and Punching resistance [11-12].The use of CFRP sheets delays the appearance of the cracks by (14.75%-51.76%) compared with slabs without strengthening .[13-14] the ultimate loads and mid span deflection of strengthened reinforced concrete slabs were more effected by using the steel fiber on the ferro-cement mortar [15].

Many experimental studies on performance of reinforced concrete slab under a central point load with respect to yield load, flexural strength and deflection by using CFRP & GFRP sheets and test results strengthening elements are effective to increase the strength characteristics of reinforced concrete slab .[16-17]. Many existing concrete slabs require strengthening in punching shear due to increased loading, change in use, design defect and structural damage. of the different retrofitting techniques, the use of fiber reinforced polymer (FRP) reinforcements has proven to be an effective way to increase the punching shear capacity and ductility of flat slabs[18-19]. the ultimate loads and mid span deflection of strengthened reinforced concrete slabs were more effected by using the steel fiber on the ferro cement mortar, increasing the thickness of Ferro cement and the compressive strength of Ferro cement.

1.1 Parameter of this study :

1. Additional steel bars
2. Steel sheet with dimensions 1*150 mm
3. Steel sheet with dimensions 1*50 mm
4. Carbon fiber sheets with dimensions 0.129*50mm
5. Fiber glass sheets with dimensions 0.173*150 mm
6. Concrete with compressive strength 22 and 40 mpa

2-Experimental Work

2.1 Used Materials in this Study

1- Two types of concrete with characteristic compressive strength 22mpa and 40 mpa and concrete consists of (dolomite, sand, cement and water) by ratios calculated by design mix method of absolute volume.

2- Steel rebar of (fy =240 mpa)

3- (Adebond 65) as a paste material to connect new concrete by ancient one

4-Screws for supporting additional steel bars and steel sheets to slabs

5-Steel sheets with dimensions (1x50) and(1x150)mm

6- Fiber Glass sheets (0.173x50mm) and Carbon Fiber sheets (0.129x50mm)

7-(Sika dur-330-componnet A) as a paste material to connect fiber glass and carbon fiber sheets by ancient concrete.

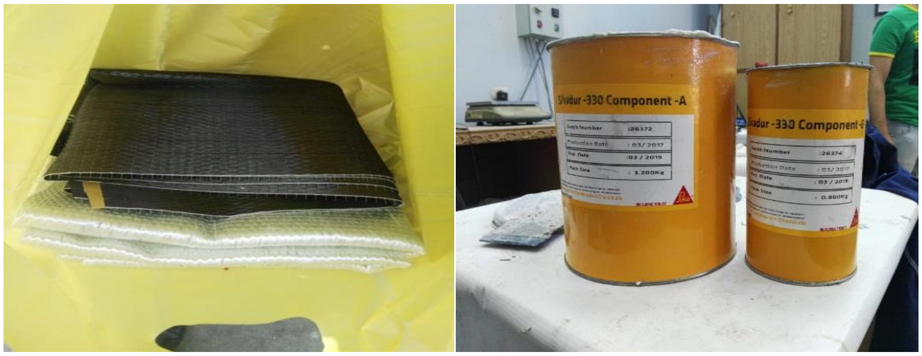

Fig. 1: Fiber Glass, Carbon Fiber And Sikadur-330-Componant A

2.2 Description of used Slabs

2.2.1 first : Reference Slabs

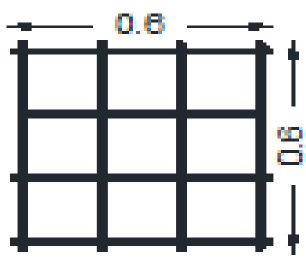

Fig. 2:Reference Slab with Reinforcement 4 ø 6 mm steel bars in both Directions

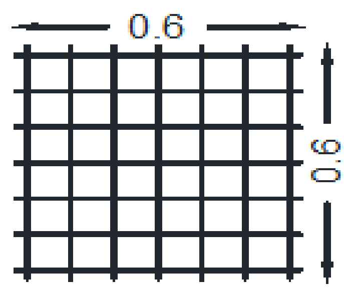

Fig.3:Reference Slab with Reinforcement 7 ø 6 mm steel bars in both Directions
Fcu = 220 kg/cm2

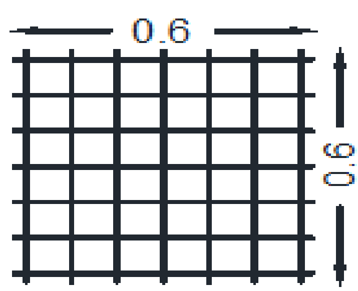

Fig. 4: Slab with Reinforcement 7 Ø 6 mm steel bars in both Directions
Fcu = 400 kg/cm2

2.2.2 Second : Strengthening Slabs with Additional Steel Bars

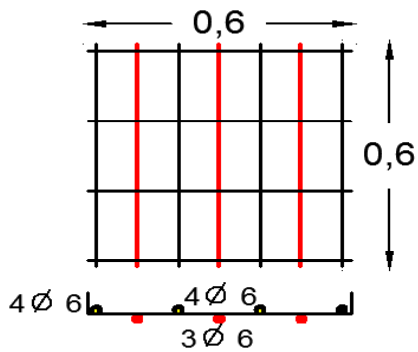

Fig. 5: Slab with Reinforcement 4Ø6 mm steel bars and strengthened with 3Ø6
Fcu = 200 kg/cm2

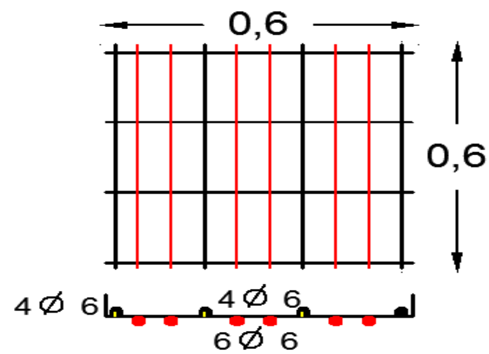

Fig. 6: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened wit 6 Ø 6
Fcu = 220 kg/cm2

2.2.3 Third : Strengthening Slabs with Steel Sheets

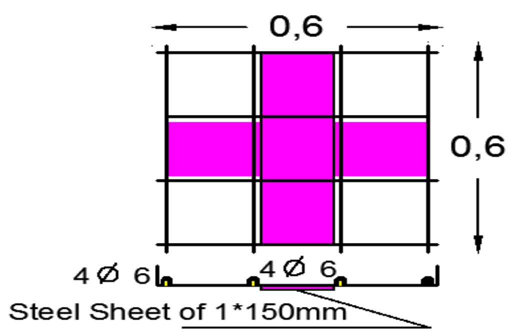

Fig. 7: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with two steel sheets of 1*150 mm Fcu = 220 kg/cm2

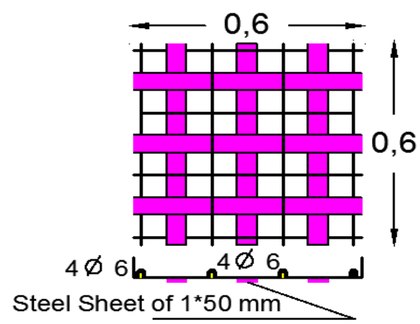

Fig. 8: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 6 steel Sheets 1*50 mm Fcu = 220 kg/cm2

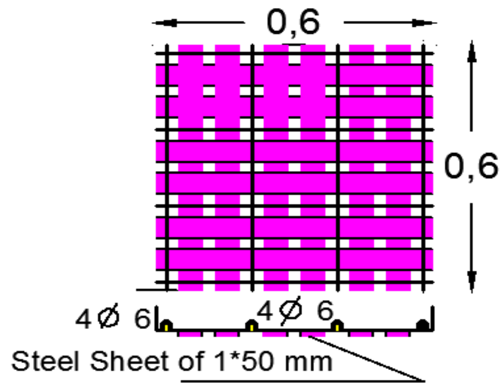

Fig. 9: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 6 Steel Sheet of 1*50mm Fcu = 220 kg/cm2

.2.4 Fourth : Strengthening Slabs with Carbon Fiber Sheetes

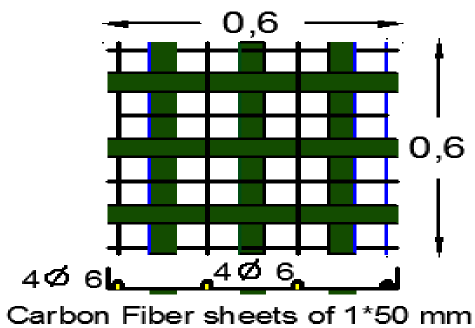

Fig. 10: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 3 Carbon Fiber Sheets of 0.129*50 mm in each Direction

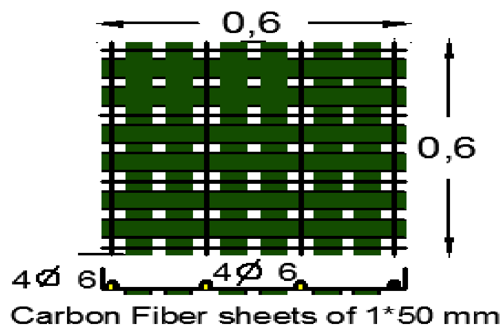

Fig. 11: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 6 Carbon Fiber Sheets of 0.129*50 mm in each Direction

2.2.5 Fifth : Strengthening Slabs with Glass Fiber

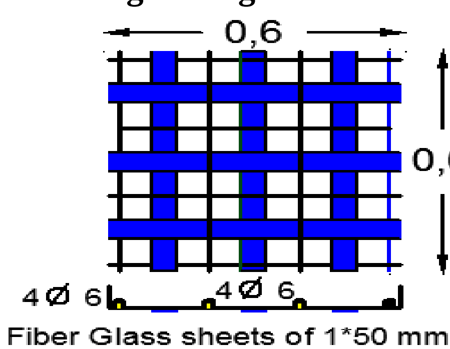

Fig. 12: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 3 Glass Fiber Sheets of 0.173*50 mm in each Direction

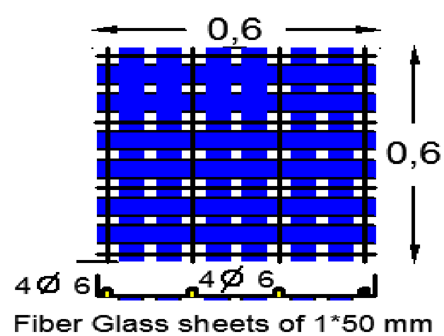

Fig. 13: Slab with Reinforcement 4 Ø 6 mm steel bars and strengthened with 6 Glass Fiber Sheets of 0.173*50 mm in each Direction

3.Concrete mix Design

Concrete mix for each type of Concrete were done by using absolute volume method and the contents of each type of concrete were:

3.1.Concrete 22 mpa volume for 1 cubic meter

Water	Dolomite	Sand	Cement
200 kg	1060 kg	848 kg	250 kg

3.2- Concrete 40 mpa volume for 1 cubic meter

Water	Dolomite	Sand	Cement
175 kg	1135 kg	756 kg	350 kg

From each type of concrete mix design, six cubes of dimensions 15*15*15 cm were taken and half of them were tested after 7 days and other half were tested after 28 dayes and test results for each type of concrete were as following: -

Table 1: At age 7 days -

Concrete of Compressive Strength 40 mpa			Concrete of Compressive Strength 22 mpa			Cube number
Compressive Strength (mpa)	Failure Load(kn)	Cube Weight(kg)	Compressive Strength (mpa)	Failure Load(kn)	Cube Weight(kg)	
23.6	235.9	2.425	13.8	138.3	2.46	1
25.6	256.7	2.465	21.2	212.8	2.39	2
26.2	261.9	2.45	16.09	160.9	2.36	3

Table 2: At age 28days

Concrete of Compressive Strength 40 mpa			Concrete of Compressive Strength 22 mpa			Cube number
Compressive Strength (mpa)	Failure Load(kn)	Cube Weight(kg)	Compressive Strength (mpa)	Failure Load(kn)	Cube Weight(kg)	
37.8	378	2.465	19.3	192.9	2.445	1
41.07	410.7	2.515	28.8	288.4	2.42	2
43.36	433.6	2.49	22.9	229.1	2.375	3

4. Discussion of experimental work results

1-Reference Slab (S7) with reinforcement 4x6 mm in both directions and tested from concrete with compressive strength 22 mpa , it has failure load = 12.2 kn

2- Reference Slab (S11) with reinforcement 7x6 mm in both directions and tested from concrete with compressive strength 22 mpa , it has failure load = 22.3 kn

From the above results it is showed that, failure load increased from 12.2 to 22.3 kn (increasing percent =82%) by increasing reinforcement ratio

3- Slab (S12) with reinforcement 7x6 mm in both directions and tested from concrete with compressive strength 40 mpa , it has failure load = 26 kn

From the results of 2 and3, it is showed that, failure load increased from 22.3to 26 kn (increasing percent =16%) by increasing compressive strength from 22 to 40map for slabs with same reinforcement

4-Slab (S9) with reinforcement 4x6 in both directions and strengthened by 3 Ø6, failure load increased from 12.2kn to 21.5 kn compared with slab (S7) reference without strengthening

5-Slab (S10) strengthened by 6 x6, failure load increased from 12.2kn to 30.5 kn compared with slab (S7) reference without strengthening.

6- slab (S2) strengthened by 2 steel sheets (of size 1x150mm), failure load increased from 12.2kn to 40 kn compared with slab (S7) reference without strengthening

7- slab (S1) strengthened by 3 steel sheets (of size 1x150mm), failure load increased from 12.2kn to 40.3 kn compared with slab (S7) reference without strengthening

8- slab (S3) strengthened by 6 steel sheets (of size 1x150mm), failure load increased from 12.2kn to 50.5 kn compared with slab (S7) reference without strengthening

From the results of 6 and 7, it is showed that, failure load increased from 22.3to 40 and 43 kn respectively for slabs strengthened by 2 and 3 steel sheets it seen that, by adding steel sheets as a strengthening material, failure load increases proportional with amount of steel sheets

9- slab (S5) strengthened by 3 Carbon Fiber sheets (of size 0.129 x50mm), failure load increased from 12.2kn to 44 kn compared with slab (S7) reference without strengthening

10- slab (S8) strengthened by 6 Carbon Fiber sheets (of size 0.129 x50mm), failure load increased from 12.2kn to 36 kn compared with slab (S7) reference without strengthening.

It an be seen that, failure load increased by increasing quantity of Carbon Fiber sheets as a strengthening material.

11- slab (S4) strengthened by 6 Fiber Glass sheets (of size 0.173x50mm), failure load increased from 12.2kn to 51 kn compared with slab (S7) reference without strengthening

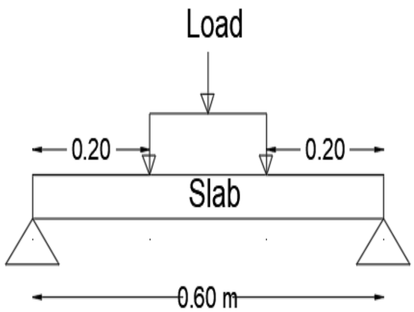

Fig. 14: System of loading for different slabs

Fig. 15: shape of Reference slab (S7)

Fig. 16: Strengthening of slabs with steel bars

Fig. 17: Strengthening of slabs with fiber glass and carbon fiber sheets

Fig. 18: Reference Slab (S7) with Reinforcement 4Ø6 mm in both Directions (Fcu =22 mpa Pu=12.2kn

Fig. 18: Reference Slab (S7) with Reinforcement 4Ø6 mm in both Directions (Fcu =22 mpa Pu=12.2kn)

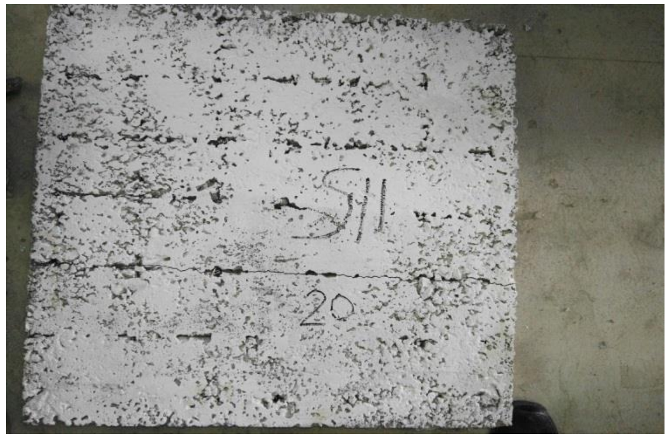

Fig. 19: Reference Slab (S11) with Reinforcement 7x6 mm in both Directions (Fcu =22 mpa Pu=23.32kn)

Fig. 20: Slab (S12) with Reinforcement 7x6 mm in both Directions(Fcu =40mpa Pu=26.5kn)

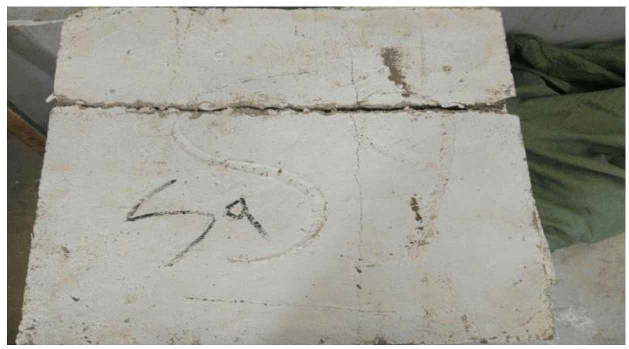

Fig. 21: Slab (S9) with additional Reinforcement 3Ø6 mm in both Directions (Fcu =22 mpa Pu=21.5kn)

Fig. 22: Slab(S10) with additional reinforcement 6Ø 6 mm in both Directions (Fcu =22 mpa Pu=30.52kn)

Fig. 23: Slab (S2) with additional steel sheet 1*150 mm in both Directions (Fcu =22 mpa Pu=40kn)

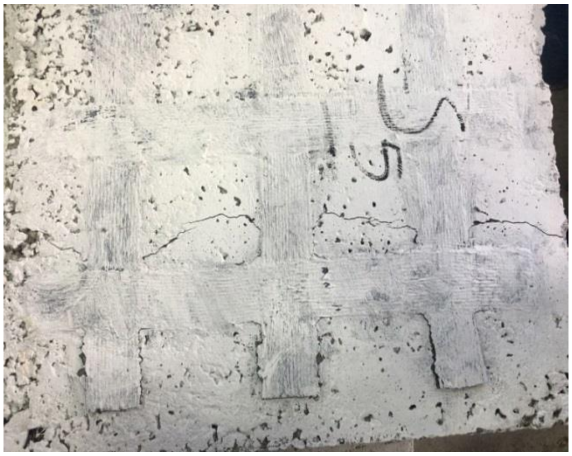

Fig. 24: Slab (S5) with additional 3 Carbn Fiber sheest 1*150 mm in both Directions (Fcu =22 mpa Pu=44.3kn)

Fig. 25: Slab (S8)with additional 6 Carbn Fiber sheest1*150 mm in both Directions (Fcu =22 mpa Pu=56kn)

Table 3: Comparison between different types of slabs due to strengthening materials and failure load

Slab number	Slab Dimensions	Compressive Strength	Reinforcement	Strengthening Material	Failure Load	Failure Load increasing percent
S7	60*60 cm	22 mpa	4 ø 6	------	1.22 t	0
S11	60*60 cm	22 mpa	7ø 6	-----	2.33 t	90 %
S12	60*60 cm	40 mpa	7ø 6	-----	2.6 t	113 %

S9	60*60 cm	22 mpa	4 ø 6	3 ø 6 additional steel	2.15 t	76%
S2	60*60 cm	22 mpa	4 ø 6	One Steel sheet of 1*150 mm on both directions	4 t	227 %
S1	60*60 cm	22 mpa	4 ø 6	3 Steel sheets of 1*50 mm both directions	4.3 t	252 %
S3	60*60 cm	22 mpa	4 ø 6	6 Steel sheets of 1*50 mm both directions	5.5 t	350 %
S5	60*60 cm	22 mpa	4 ø 6	3 Sheet of carbon fiber of 0.13*50 mm	4.4 t	260 %
S8	60*60 cm	22 mpa	4 ø 6	6 Sheet of carbon fiber of 0.13*50 mm	5.6 t	350 %
S6	60*60 cm	22 mpa	4 ø 6	3 Sheet of fiber glass of 0.17*50 mm	3.6 t	195 %
S4	60*60 cm	22 mpa	4 ø 6C	6 Sheet of fiber glass of 0.17*50 mm	5.1 t	318 %

Calculation of theoretical failure load and actual load for specimens

$A_s = M / Jd\ F_y$

$M = A_s\ Jd\ F_y$ m.t

$M = (P_u/2) * 0.2$ m.t

$P_{u\ =}\ M / 0.1 = A_s\ Jd\ F_y / .\ 1$

Compression between Theoretical failure load and Theoretical failure load of each specimen

Specimen	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
Theoretical failure load (ton)	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	2.38	3.35	2.4	2.46
Actual failure load (ton)	4.3	4	5.5	5.1	4.4	3.6	1.22	5.6	2.15	3.05	2.15	2.15
Strengthening material	1Steel sheets	3Steel sheets	3Steel sheets	6Fiber glass	3carbon fiber	3Fiber glass	--	3carbon fiber	--	--	--	--

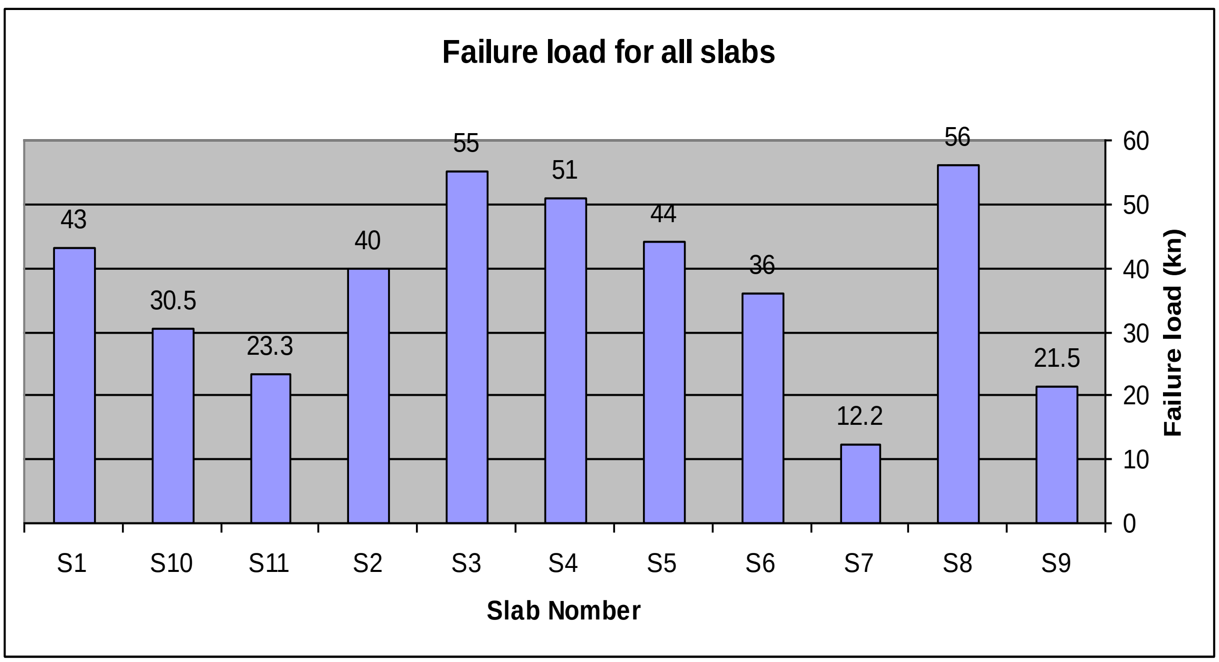

Fig. 26: value of failure load for different slabs

5.Conclusions

1- The beigest value of failure load was for specimen (S8) which was strengthened by 6 Sheets of carbon fiber of 0.13*50 mm

2- The lower value of failure was to specimen (S7) reference.

3-by increasing concrete compressive strength from 22 mpa to 40 mpa, failure load increased from 23.3kn to 26 kn which happened for specimens (S11) and (s12) respectively.

4-Failure load of specimen (S9) was the least one of specimens have been strengthened where it has been strengthened by 3 ø 6 additional steel reinforcement.

5- Specimens which has been strengthened by steel bars showed less failure load as a group compared by other specimens strengthened by other materials in this study.

6- Additional reinforcement by ratio 75% of main reinforcement increases failure load by rate 80% with noticing that, putting the same number of steel bars and casting concrete one time this increases failure load by rate 94% and in case of using concrete (Fcu=40mpa) instead of concrete (Fcu=22 mpa), failure load increases by rate 117%

8-Additional reinforcement by rate 150% of main reinforcement, increases failure load by ratio154%.

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