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Finite Element Modeling of One-Way Recycled Aggregate Concrete Slabs Strengthened using Near-Surface Mounted CFRPs under Repeated Loading

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ABSTRACT

This study offers numerical simulation results using the ABAQUS/CAE version 2019 finite element computer application to examine the performance, and residual strength of eight recycle aggregate RC one-way slabs. Six strengthened by NSM CFRP plates were presented to study the impact of several parameters on their structural behavior. The experimental results of four selected slabs under monotonic load, plus one slab under repeated load, were validated numerically. Then the numerical analysis was extended to different parameters investigation, such as the impact of added CFRP length on ultimate load capacity and load-deflection response and the impact of concrete compressive strength value on the structural performance of slabs. This article aims to provide a numerical model for simulating the nonlinear behavior of such slabs, including a trustworthy finite element model approach and constitutive material models. In aspects of load-deflection and cracking patterns, comparisons between computational and experimental models are provided, and a reasonable fit is demonstrated. The average ratio of numerical model ultimate load and deflections to experimentally tested slabs were 0.992 and 0.913, respectively. As a result, finite element analysis may be regarded as a preferred and trustworthy approach for simulating the non-linear behavior of one-way slabs (strengthened or not) in terms of complexity, difficulty, time savings, human effort, and money.

Keywords: recycle aggregate, ABAQUS, repeated load, reinforced concrete one-way slabs, crack patterns, CFRP strips.

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النمذجة بطريقة العناصر المحددة للسقوف الخرسانية المعادة المسلحة والمقواة بواسطة اليااف الكربون البوليميرية قرب السطح تحت تأثير الاحمال التكرارية

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الخلاصة

تقدم هذه الدراسة نتائج المحاكاة العددية من استخدام تطبيق الكمبيوتر ذي العناصر المحدودة ABAQUS / CAE 2019 لفحص الأداء والقوة المتبقية لثمانية سقوف خرسانية (معادة) مسلحة أحادية الاتجاه (ستة منها مقواة بصفائح NSM CFRP) تم تقديمها للتحقق من تأثير العديد من المتغيرات على السلوك الإنشائي لها. تم التحقق من صحة النتائج التجريبية لأربع بلاطات مختارة تحت الحمل الرتيب بالإضافة إلى لوح واحد تحت الحمل المتكرر عددياً ثم تم توسيع التحليل العددي ليشمل معايير مختلفة مثل ؛ تأثير طول CFRP المضاف على سعة التحميل القصوى واستجابة انحراف الحمل ، وتأثير قيمة مقاومة الانضغاط للخرسانة على الأداء الإنشائي للألواح. تتمثل أهداف هذه المقالة في توفير نموذج عددي لمحاكاة السلوك غير الخطي لهذه الألواح ، والذي يتضمن نهجاً موثوقاً به لنموذج العناصر المحدودة ونماذج المواد التأسيسية. فيما يتعلق بأنماط انحراف الحمولة والتكسير ، يتم توفير مقارنات بين النماذج الحسابية والتجريبية ، ويتم توضيح التوافق المقبول. كان متوسط نسبة الحمل النهائي والانحراف للنموذج العددي إلى الألواح المختبرة تجريبياً 0.992 و 0.913 على التوالي. نتيجة لذلك ، يمكن اعتبار تحليل العناصر المحدودة نهجاً مفضلاً وجديراً بالثقة لمحاكاة السلوك غير الخطي للبلاطات أحادية الاتجاه (مقواة أو غير مقواة) من حيث التعقيد والصعوبة وتوفير الوقت والجهد البشري والمال.

الكلمات الرئيسية: الخرسانة المعادة , برنامج الاباكوس , الاحمال التكرارية , السقوف الخرسانية المسلحة ذات الاتجاه الواحد , نمط التشقق, الواح اليااف الكربون البوليميرية .

1. INTRODUCTION

Conventional concrete can be considered worldwide as primarily used building material constantly changing. Recycling concrete construction waste is one of the long-term alternative solutions to waste construction materials and the depletion of quasi-natural aggregate source materials (Ignjatović et al., 2013). The concrete aggregate is pre-used for this purpose, but its overall strength is less than that of the natural aggregate.

Considering the popularity of CFRP reinforcement in a wide range of structural implementations, tiny empirical information on their long-term effectiveness under repeated loads is obtainable. The fatigue behavior (i.e., adjustments in stiffnesses and strengths) of CFRP reinforcement has been hard to quantify due to issues associated with grabbing the strips in just such a way that their fatigue behavior is not impeded. The majority of available investigation on the fatigue behavior of composite materials has concentrated on aerospace and transportation applications and is, therefore, not broadly applicable to the construction field. Only a few studies



on the fatigue performance of CFRP reinforcement in concrete constructions for civil engineering applications are available (Adimi et al., 2000); (Brimah et al., 2006); (El-Ragaby et al., 2007a) and (El-Ragaby et al., 2007b). There are notable disparities in the intensity of the deformations involved and the environment where the materials are used. (Adimi et al., 2000). Repeated loads are forces applied to a structural element many times, causing strain in the material to vary continuously, usually within a defined range. If stresses are developed in a structural element and then released, the member is said to have been subjected to a cycle of stresses. Furthermore, if tensile stress is developed and released, and afterward compressive stress is developed and released, the element is said to have been exposed to a reversal of the stress cycle or, in a nutshell, a reversal of stresses. If the opposite stresses are of equal magnitude, the stress reversal is comprehensive. (Allawi and Jabir, 2016).

(Gawari and Murugan, 2008) conducted a comparison study on the structural performance of one-way concrete slabs strengthened with GFRP reinforcements versus traditional reinforcements when exposed to monotonic loading magnitudes. The experimental program consisted of 21 one-way slabs 240 cm long and 60 cm wide. A lower concrete cover of 20 mm was used for all the samples. The constructed slabs were divided into three categories, with seven slabs in every category. The specimens in the first category were simply supported and exposed to two-point monotonic loading. It was discovered that slabs reinforced with GFRP reinforcements exhibited greater deflections and stresses than those reinforced with traditional steel reinforcements due to the small modulus of elasticity and various bond properties of the GFRP reinforcements. (Soliman et al., 2010) investigated the flexural strengthening of 20 beams with near-surface mounted (NSM) fiber bars. The specimens' dimensions were (301 cm in length, 20.0 cm in width, and 30.0 cm in depth). The test variables were: reinforcement steel ratios, size of groove, and mode of failure. The test results showed that the presence of FRP increased the load-carrying of the beams. The results revealed that raising the reinforcement ratios from 0.40 to 1.60 percent reduced CFRP efficiency. Moreover, the failure load was enhanced by 71% (for a steel reinforcement ratio of 0.40%) and only 9.0% (for a reinforcement ratio of 1.60%) compared to the un-strengthened specimen.

Under cyclic loading, (Hong and Park, 2016) tested 4 RC beams strengthened with external CFRP using single and double strips. One specimen was used as a reference beam with no strengthening, while the remaining beams were strengthened externally and covered at both ends in CFRP strips. Four beams measured 270 cm in span length, 200 mm in width, and 30 cm in height, with carbon fiber installed along 89% of the clear span. The samples were tested using a 3-point load with a max load of 60% of the control beam's ultimate load at a 2.0-Hz cycle frequency. The results revealed that the performance of un-strengthened specimens changed from elastic to plastic over a certain number of loading cycles because of accumulated deformation, whereas strengthened beams withstand cycles without steel, yielding beyond many cycles.

(ELWakkad and Heiza, 2019) investigated failure analysis of concrete beams under repeated loading. An experimental test program was carried out to investigate the performance of strengthened continuous RC beams subjected to repeated loading Using NSM Techniques. The experimental test consists of nine test specimens that have a constant cross-section with dimensions of (3800×4000×300) mm. One specimen was subjected to concentrated load, and the other eight test specimens were subjected to repeated loading. The results concluded that the use of the NSM reinforcement system was used as an effective benefit in the enhancement of the flexural capacity of RC continuous beams subjected to cyclic loading. Cyclic loading increases deflection and rotation at intermediate support. Applying strengthening materials (steel or stainless steel) at both upper and lower surfaces in negative and positive moment zones by using the NSM technique increases cracking load values by about 20% up to 30%.

(Jabir et al., 2021) made a comparison between the bubble RC slabs to RC solid slabs under the impact of restricted repeated 4-point loads. As a result, six slab strips were produced in the same forms, except for the cross-section kind. Three were solid, and the others were void due to the inclusion of 7 cm-diameter balls. The span of shear to the effective depth ratios (a/d) was also investigated. As a result, one slab from each type was tested, with an a/d of 2.0, 3.5, or 5.0. The loads were repeated ten times at a load value of 25.0 kN, representing 70.0% of the ultimate load approximated by the ACI-19-code, and after that, lasted gradually till the slabs collapsed. The



results revealed that the presence of the balls caused slabs to fail immediately because of shear mode, in any case of the a/d . The strength, stiffness, and toughness of the same slab type decreased as the a/d increased; however, the ductility showed an opposite trend. The measured mechanical values of the bubble slabs, excluding the service stiffness, were significantly lower when compared to solid comparable. Nevertheless, the stiffness deterioration was minimal, falling below 15.0%. Furthermore, a sustainability analysis was carried out, and the voided slabs were discovered to become more eco-friendly than solid slabs, reduction in CO₂ emissions, and consume embodied energy that was approximately 14 percent and 10% lower, respectively, than the solid slabs.

Increasing the amount of CFRP strips does not necessarily result in a proportional increase in the flexural capacity of the RC member, especially if debonding of CFRP strips controls the failure (Khalifa et al., 2016); (Godat et al., 2010); (Mostofinejad et al., 2016) and (Leung et al., 2007). According to the literature study that has been given, and to the author's knowledge, no research was found studying the finite element modeling of one-way recycled aggregate concrete slabs strengthened using near-surface mounted CFRPs under repeated loading.

2. RESEARCH SIGNIFICANCE

To determine the efficiency of the CFRP strip reinforcement on the performance of the one-way slab. The repeated response of a recycled aggregate reinforced concrete one-way slab to a 4-point bending test was investigated experimentally. The tests concentrated on the effects of thickness and the number of strips of CFRP by using the NSM technique.

3. TEST SPECIMENS

The experimental study included eight simply supported one-way slabs of 1200 x 600 x 140 mm in dimensions. The experimental study was planned to study several parameters and their effects on the flexural performance of strengthened slabs, including the thickness of the CFRP layer, flexural strengthening effects, and the effect of recycled aggregate used in the concrete mix. **Table 1** presents the details of the test program for the specimens group.

Table 1: Details of testing slabs

Group number	Specimens	Dimension of CFRP plate (t×w) mm	No. of strips
1 (Monotonic load)	RGC	---	---
	RG1.2	1.2×25	2
	RG2.4	2.4×25	2
	RG1.2.3	1.2×25	3
2 (Repeated load)	RGC	---	---
	RG1.2	1.2×25	2
	RG2.4	2.4×25	2
	RG1.2.3	1.2×25	3



*where RG= recycle aggregate, C= control slab, 250= width of CFRP plate.

Recycled concrete was used for pouring the RC slabs. The properties of concrete (e.g., modulus of elasticity, compressive strength, and tensile strength) were measured using steel cylindrical molds with 30 cm height and 15 cm diameter. The reinforcing steel bars had a diameter of 12 mm, and Standard tests on steel bars were used to determine the average yield, ultimate strength, and elongation. **Table 2** shows the properties of the concrete and steel reinforcements used in this work. **Table 3** shows the properties of the CFRP strip.

Table 2: Materials properties

Material	splitting tensile strength (MPa)	Compressive strength f'_c (MPa)	Yield stress (MPa)	Ultimate tensile strength (MPa)	Modulus of elasticity (GPa)
Concrete	3.01	28.56	--	--	25.1
Steel Ø10mm	---	---	591	690	200

Table 3: Properties of CFRP strip.

Properties	Sikadur carbondur S1012
Tensile strength (KN)	336
E-modulus (GPa)	165
Strain at break (min.) %	1.69%
Width (mm)	100
Thickness (mm)	1.2

4. Modeling and analysis of tested rafters in ABAQUS

For the one-way slabs, only one step was used for the structural analysis (static analysis step). Slabs were modeled using (C3D8R) the isoperimetric eight-node brick element to represent concrete. Every node has three-dimensional movements in x, y, and z directions. While the effective method for modeling the reinforcement modeling is by a truss element in which the only necessity is to input the cross-sectional area of bars, for reinforced steel bars, the three-dimensional

two-node bar element with three-dimensional movements in x, y, and z directions, truss element (T3D2) was used. To represent the CFRP laminates, 2D shell elements were selected. Linear three-dimensional 4-node was used with CFRP plate with reduced integration and hourglass control (S4R5). For each slab, a two-line load was subjected at the top of the slab as uniform pressure with the same area and position of the experimental test. Displacement boundary conditions were used for modeling end supports of model slabs to simulate the analytical model similar to the tested slabs properly. The boundary conditions required to be utilized at the points used to support the specimens in the experiments test. Since the specimens were simply supported over the two shorter edges, all the nodes along one of the supporting lines were fixed translated in y and z-direction, and one of the other supported lines was fixed translated in x, y, and z-direction. **Fig. 1** shows the creating parts in ABAQUS. The damaged plasticity model (CDP) was adopted in this study, which can draw concrete behavior in compression and tension. The model will adopt two failure mods, tensile cracking and compression fractures.

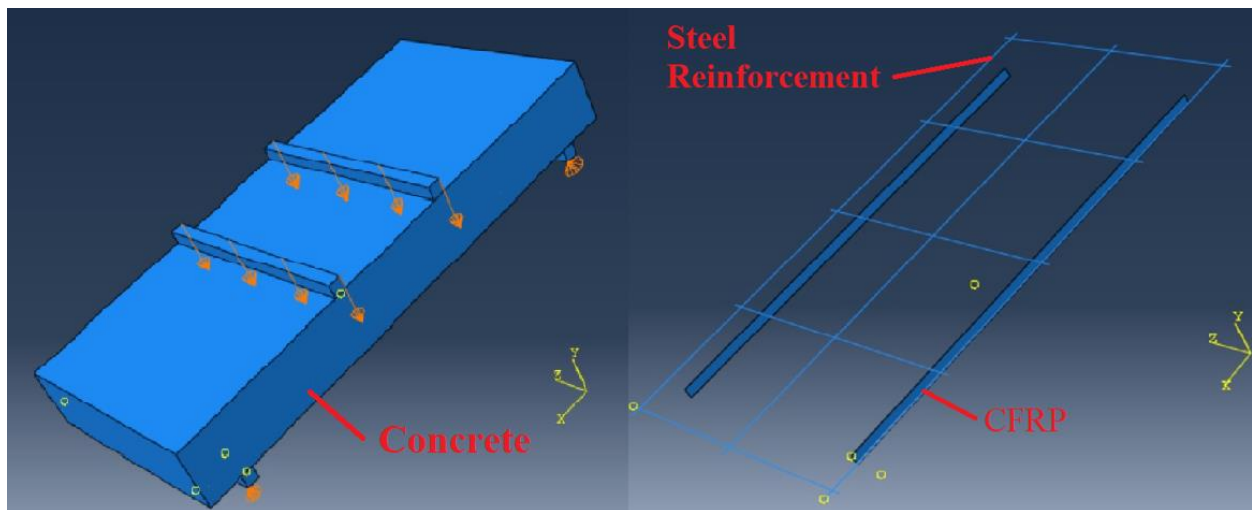
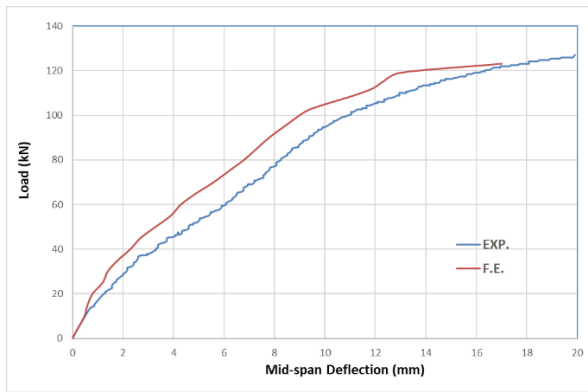


Figure (1): Creating parts in ABAQUS.

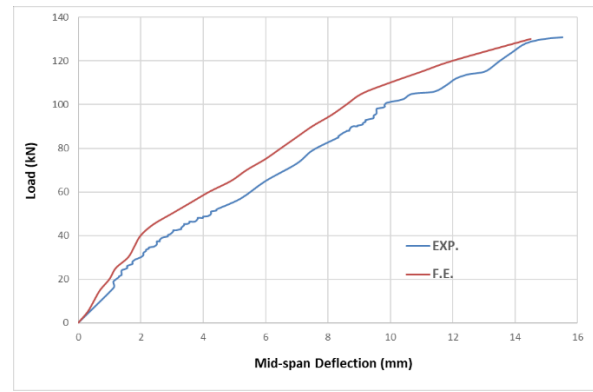
5. Results of analysis of tested rafters in ABAQUS

The models are stiffer than that of the experimental samples, according to the results of the FE analysis (loads-deflection relations under the applied stresses). Greater stiffness in FEM analysis results could be due to various factors. During the experiment, microcracks in the concrete were discovered due to drying, shrinkage, and curing. Therefore, the overall stiffness of the real specimen can be lower than that expected during FE analysis (**Abdulkareem and Izzet, 2022**); (**Mohammed and Fawzi, 2016**) and (**Izzat, 2015**).

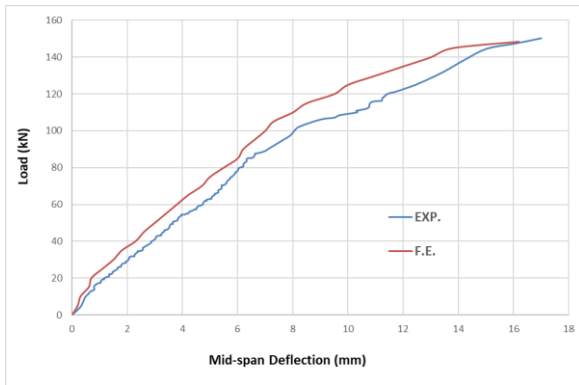
The mean ratio of numerical model ultimate loads capacity and deflections to experimentally tested rafters were 1.033 and 0.96, respectively. As a result, finite element analysis may be regarded as a preferred and trustworthy approach for simulating the non-linear behavior of RC one-way slabs (under monotonic or repeated load). **Fig. 2** shows a comparison between both experimental and numerical load deflection for the slabs.



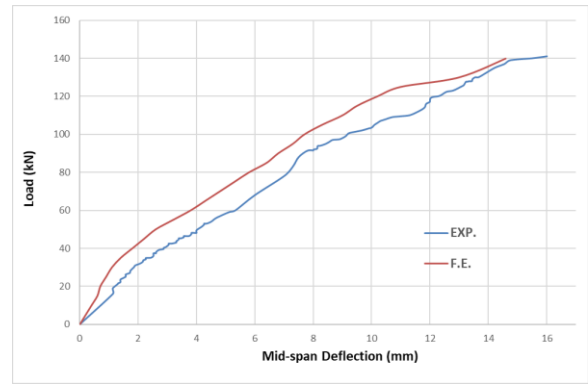
a-RGC



b-RGC1.2



c-RGC2.4



d-RGC1.2.3

Figure 2: Experimental and numerical load-deflection for the slabs.

Table 4 compares the failure load and mid-span deflection extracted from the finite element model and the experimental test at the failure stage (nearby failure load) for all slabs under the monotonic test. Good agreement was acquired between ultimate loads and deflections of FEM models, and that was found experimentally where the value of the average and coefficient of variation for $(P_u)_{FE}/(P_u)_{Exp}$ were 0.992 and 0.245 %, respectively, for ultimate loads, whilst, for the deflection $(\delta_{FE} / \delta_{Exp})$ they were 0.913 and 4.26 %, respectively. While **Table 5** illustrates a comparison between experimental and numerical results of slab RG1.2 under repeated load

**Table 4:** Experimental and numerical failure load and mid span deflection under monotonic load test.

slab's labeling	Failure, Load kN		$(P_u)_{FE}/(P_u)_{Exp}$	Mid span deflection (mm)		δ_{FE}/δ_{Exp}
	$(P_u)_{Exp}$	$(P_u)_{FE}$		δ_{Exp}	δ_{FE}	
RGC	124.025	123	0.992	19.896	17	0.854
RGC1.2	130.999	130.3	0.995	15.523	14.5	0.934
RGC2.4	150.12	148.5	0.989	17.01	16.2	0.952
RGC1.2.3	141.035	139.9	0.992	16.01	14.6	0.912
Mean			0.992	Mean		0.913
c.o.v			0.245	c.o.v		4.26
$COV=(SD/m)*100 \text{ , } SD = \sqrt{\frac{\sum(x-m)^2}{n-1}} \text{ , where } m=\text{mean}$						

Table 5: Experimental and numerical failure load and mid span deflection under repeated load test.

slab's labeling	Failure Load kN		$(P_u)_{FE}/(P_u)_{Exp}$	Mid span deflection (mm)		δ_{FE}/δ_{Exp}
	$(P_u)_{Exp}$	$(P_u)_{FE}$		δ_{Exp}	δ_{FE}	
RG1.2	120	128	1.07	14.6	15	1.02

6. Numerical Parametric Study

6.1 Effect of added CFRP length on the structural performance of slabs under repeated load test

The effect of added CFRP length on ultimate load capacity was studied for RGC1.2 and RGC2.4. Three lengths were chosen (600, 800, and 1000mm). **Fig. 3** shows the effect of added CFRP length on ultimate load capacity. It is clear that when the added CFRP length increases, the ultimate load capacity will increase.

Table 6 shows that the percent of the decrease in ultimate load capacity is 10.2 and 16.4% for slab RGC1.2 of CFRP length 800 and 600mm, respectively, related to slab RGC1.2 of CFRP



length 1000, while the percent of the decrease in ultimate load capacity is 15.2, and 17.9% for slab RGC2.4 of CFRP length 800, and 600mm respectively related to slab RGC2.4 of CFRP length 1000.

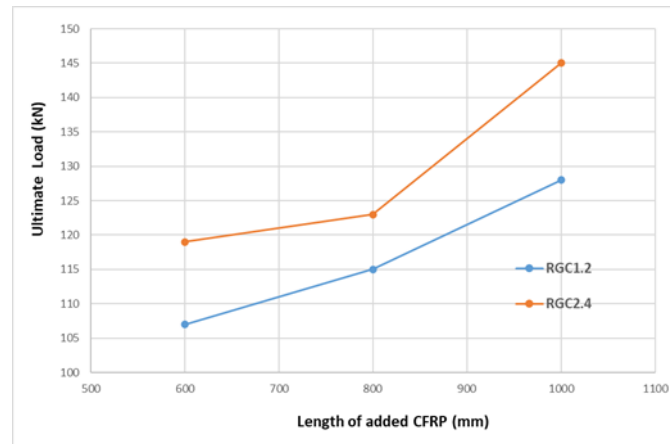


Figure 3: Effect of added CFRP length on ultimate load.

Table 6: Effect of added CFRP length on ultimate load.

Beam ID	CFRP length (mm)	$P_u = P_{ultimate}$ (kN)	Decrease percent of P_u related to P_u of (1000mm) (%)
RGC1.2	1000	128	Ref.
RGC1.2	800	115	10.2
RGC1.2	600	107	16.4
RGC2.4	1000	145	Ref.
RGC2.4	800	123	15.2
RGC2.4	600	119	17.9

The effect of added CFRP length on the deflection at the ultimate load was studied for RGC1.2 and RGC2.4. Three lengths were chosen (600, 800, and 1000mm). **Fig. 4** shows the effect of added CFRP length on the deflection at the ultimate load, it is clear that when the added CFRP length increases the deflection at the ultimate load will decrease.

Table 7 shows that the percent of the increase in the deflection at the ultimate load is 5.3, and 8.7% for slab RGC1.2 of CFRP length 800, and 600mm respectively related to slab RGC1.2 of CFRP length 1000. While the percent of the increase in the deflection at the ultimate load is 2.6, and 5.8% for slab RGC2.4 of CFRP length 800, and 600mm respectively related to slab RGC2.4 of CFRP length 1000.

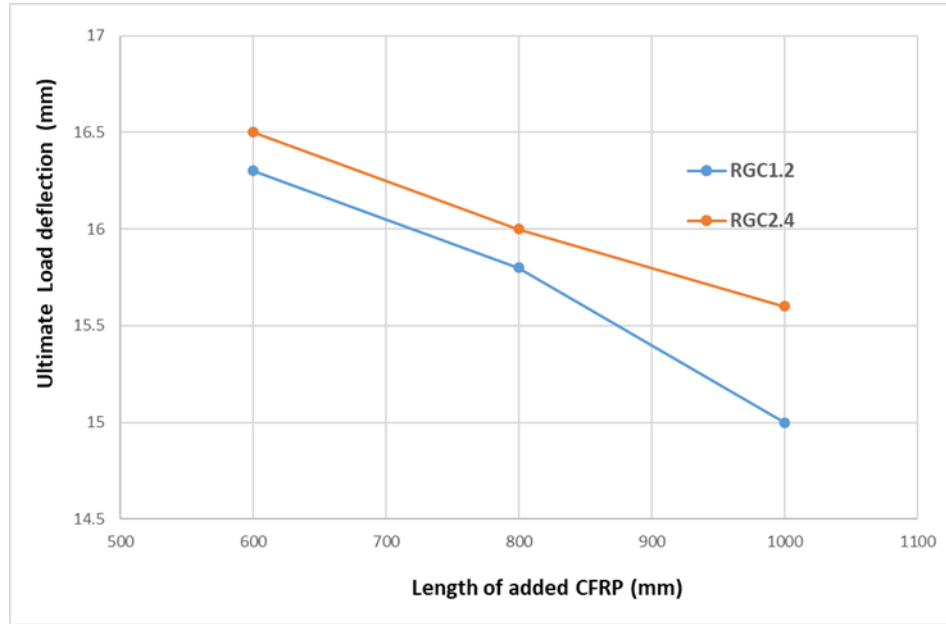


Figure 4: Effect of added CFRP length on the deflection at the ultimate load.

Table 7: Effect of added CFRP length on the deflection at the ultimate load.

Beam ID	CFRP length (mm)	δu =deflection at $P_{ultimate}$ (mm)	Increase in percent of δu related to δu of (1000mm) (%)
RGC1.2	1000	15	Ref.
RGC1.2	800	15.8	5.3
RGC1.2	600	16.3	8.7
RGC2.4	1000	15.6	Ref.
RGC2.4	800	16	2.6
RGC2.4	600	16.5	5.8

6.2 Effect of concrete compressive strength value on the structural performance of slabs under repeated load test

The effect of concrete compressive strength (f_c') on the ultimate load capacity was studied for RGC1.2 and RGC2.4. Three values of f_c' were chosen (25, 35, and 55 MPa). **Fig. 5** illustrates the impact of concrete compressive strength (f_c') on the ultimate load capacity. It is clear that



when the concrete compressive strength (f_c') increases, the ultimate load capacity will increase.

Table 8 shows that the percent of the decrease in ultimate load capacity is 6.7 for slab RGC1.2 of f_c' =25 MPa related to slab RGC1.2 of f_c' =35 MPa, and the percent of the increase in ultimate load capacity is 19.5 for slab RGC1.2 of f_c' =55 MPa related to slab RGC1.2 of f_c' =35 MPa. While the percent of the decrease in ultimate load capacity is 10.3 for slab RGC2.4 of f_c' =25 MPa related to slab RGC2.4 of f_c' =35 MPa, and the percent of the increase in ultimate load capacity is 21.4 for slab RGC2.4 of f_c' =55 MPa related to slab RGC2.4 of f_c' =35 MPa.

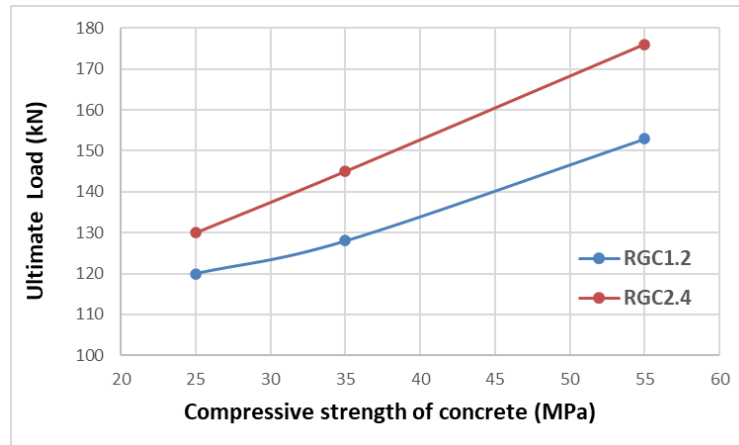


Figure 5: Impact of compressive strength of concrete on ultimate load capacity.

Table 8: Impact of compressive strength of concrete on ultimate load capacity.

Beam ID	f_c' (MPa)	$P_u=P_{ultimate}$ (kN)	Changing percent of P_u related to P_u of (35Mpa) (%)
RGC1.2	35	128	Ref.
RGC1.2	25	120	6.7%(decrease)
RGC1.2	55	153	19.5%(increase)
RGC2.4	35	145	Ref.
RGC2.4	25	130	10.3%(decrease)
RGC2.4	55	176	21.4%(increase)

The impact of concrete compressive strength (f_c') on the deflection at the ultimate load was studied for RGC1.2 and RGC2.4. Three values of f_c' were chosen (25, 35, and 55 MPa). **Fig. 6** illustrates the impact of concrete compressive strength (f_c') on the deflection at the ultimate load, it is clear that when the concrete compressive strength (f_c') increases, the deflection at the ultimate load will decrease.



Table 9 shows that the percent of the increase in the deflection at the ultimate load is 3.3 for slab RGC1.2 of $f_c'=25$ MPa related to slab RGC1.2 of $f_c'=35$ MPa, and the percent of the decrease in the deflection at the ultimate load is 6.7 for slab RGC1.2 of $f_c'=55$ MPa related to slab RGC1.2 of $f_c'=35$ MPa. While the percent of the increase in the deflection at the ultimate load is 3.8 for slab RGC2.4 of $f_c'=25$ MPa related to slab RGC2.4 of $f_c'=35$ MPa, and the percent of the decrease in the deflection at the ultimate load is 5.1 for slab RGC2.4 of $f_c'=55$ MPa related to slab RGC2.4 of $f_c'=35$ MPa. Because the effect of CFRP was noticeable in load while its effect was less in deflection, it was noticeable in the effect of ductility.

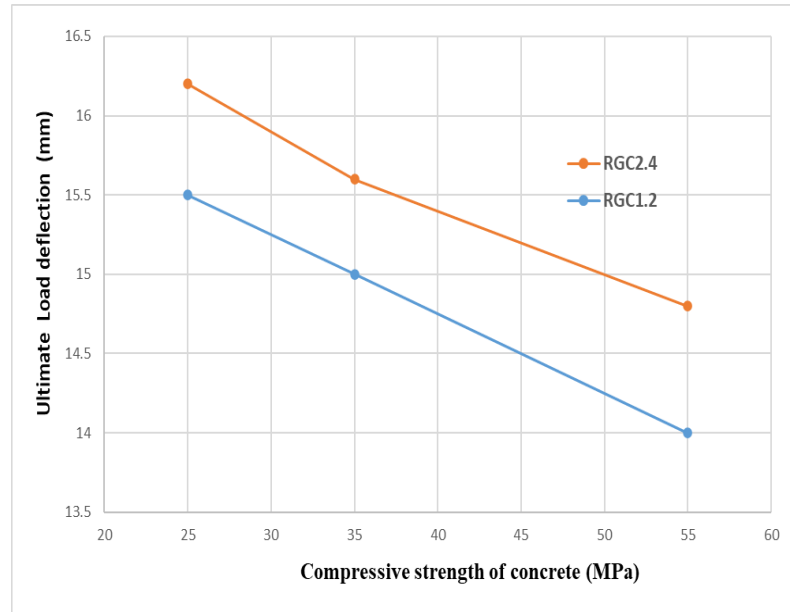


Figure 6: Effect of compressive strength of concrete on the deflection at the ultimate load.

Table 9: Effect of compressive strength of concrete on the deflection at the ultimate load.

Beam ID	f_c' (MPa)	δ_u = Deflection at $P_{ultimate}$ (mm)	Changing percent of δ_u related to δ_u of (35Mpa) (%)
RGC1.2	35	15	Ref.
RGC1.2	25	15.5	3.3%(increase)
RGC1.2	55	14	6.7%(decrease)
RGC2.4	35	15.6	Ref.
RGC2.4	25	16.2	3.8%(increase)
RGC2.4	55	14.8	5.1%(decrease)



7. CONCLUSIONS

- 1- Strong agreement existed between the numerical models' ultimate loads and deflections and those measured experimentally, where the value of the average and coefficient of variations for $(P_u)_{FE}/(P_u)_{Exp}$ were 0.992 and 0.245 %, respectively, for ultimate loads, while, for the deflection $(\delta_{FE} / \delta_{Exp})$ the value of the average and coefficient of variation was 0.913 and 4.26 %, respectively.
- 2- The effect of added CFRP length on ultimate load capacity was studied numerically. For specimens under repeated loads, the percent of the decrease in ultimate load capacity is 10.2, and 16.4% for slab RGC1.2 of CFRP length 800 and 600mm, respectively related to slab RGC1.2 of CFRP length 1000, while the percent of the decrease in ultimate load capacity is 15.2, and 17.9% for slab RGC2.4 of CFRP length 800, and 600mm respectively related to slab RGC2.4 of CFRP length 1000.
- 3- The percent of the increase in the deflection at the ultimate load is 5.3 and 8.7% for slab RGC1.2 of CFRP length 800 and 600mm, respectively, related to slab RGC1.2 of CFRP length 1000. While the percent of the increase in the deflection at the ultimate load is 2.6, and 5.8% for slab RGC2.4 of CFRP length 800 and 600mm, respectively, related to slab RGC2.4 of CFRP length 1000.
- 4- The effect of concrete compressive strength (f_c') on the ultimate load capacity was studied numerically, for specimens under repeated loads the percent of the decrease in ultimate load capacity is 6.7 for slab RGC1.2 of $f_c'=25$ MPa related to slab RGC1.2 of $f_c'=35$ MPa, and the percent of the increase in ultimate load capacity is 19.5 for slab RGC1.2 of $f_c'=55$ MPa related to slab RGC1.2 of $f_c'=35$ MPa. While the percent of the decrease in ultimate load capacity is 10.3 for slab RGC2.4 of $f_c'=25$ MPa related to slab RGC2.4 of $f_c'=35$ MPa, and the percent of the increase in ultimate load capacity is 21.4 for slab RGC2.4 of $f_c'=55$ MPa related to slab RGC2.4 of $f_c'=35$ MPa.
- 5- The percent of the increase in the deflection at the ultimate load is 3.3 for slab RGC1.2 of $f_c'=25$ MPa related to slab RGC1.2 of $f_c'=35$ MPa, and the percent of the decrease in the deflection at the ultimate load is 6.7 for slab RGC1.2 of $f_c'=55$ MPa related to slab RGC1.2 of $f_c'=35$ MPa. While the percent of the increase in the deflection at the ultimate load is 3.8 for slab RGC2.4 of $f_c'=25$ MPa related to slab RGC2.4 of $f_c'=35$ MPa, and the percent of the decrease in the deflection at the ultimate load is 5.1 for slab RGC2.4 of $f_c'=55$ MPa related to slab RGC2.4 of $f_c'=35$ MPa.

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