Designing Composite Fabric for Strengthening Concrete Slabs

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Abstract:

The main objective of this study submit bases for the local textile uses in different scope in structural engineering and knowing the maximum load of the standard concrete element after adhesion to composed FRP with epoxy, and Put the scientific and the best style to use the FRP and its affecting on increasing the structural capacity for the various structural elements with consideration for cost and price. Reinforced concrete (RC) slabs can be divided into two main groups, namely beamless and beam supported slabs. Beamless slabs (flat slabs) are among the first types of reinforced concrete floor systems. Flat slabs have been used in different structural applications, such as floors and roofs of buildings, parking garages, walls of tanks, and offshore structures.

Keywords:
Fiber reinforced polymer

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1. Introduction

Many of the researches in the field of textile design technology focus on study and cover of the important properties which must be saved to produce textile fed with its purpose of use. Textile structures, in the form of woven, knitted, braided or nonwoven fabrics, are used in civil engineering in many applications due to their excellent properties provided by the type, orientation and architecture of the fibers used.

Worldwide ,a great deal of research is currently being conducted concerning the use of fiber reinforced plastic wraps ,laminates and sheets in the repair and strengthening of reinforced concrete members .Fiber –reinforced polymer (FRP) application is a very effective way to repair and strengthen structures that have become structurally weak over their life span .FRP repair systems provide an economically viable alternative to traditional repair systems and materials.

Rigid pavement face defect such as cracks in rigid, contraction and expansion. Owing to this ,it is very important to study the use of the mechanically fastened FRP technique as a new alternate strengthening method for concrete structures(RC slabs). From this point of view this field of study was chosen. "Designing composite fabric for strengthening concrete slabs"

This study submit bases for the local textile uses in different scope in structural engineering and knowing the ultimate Load of concrete element after addition of the materials composed of FRP and resin and put the scientific and the best style to use these FRP and the rang of its affecting on increasing the structural capacity for the RC slabs. This study attempts to investigate the behavior of RC slabs strengthened in flexure with the mechanically fastened FRP system. Two series of large-scale reinforced concrete slabs are tested.

1.1. Technical Textiles

The definition of technical textiles adopted by the authoritative textile terms and definitions, published by the Textile Institute, is ‘textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics’. Such a brief description clearly leaves considerable scope for interpretation, especially when an increasing number of textile products are combining both performance and decorative properties and functions in equal measure.

There is an extensive range of raw materials, processes, products and applications encompassed within the technical textile industry, making it an industry with a wide spread of capabilities. [1]

1.1.1. Technical Textiles for Concrete Reinforcement

There are different applications, including :

- strengthening, rehabilitation and retrofitting (slabs, beams, columns, shear, torsion);

- semi finished products (integrated formworks, formwork elements);
- new structural members/buildings (facades, slabs, structural elements);
- industrial products/consumer goods (design, concrete furniture, engineering);
- artwork (sculptures, repair, etc.) .

1.1.2. Classification of textile structures for technical uses:

There are various ways of classifying textile structures considering the different factors. The most commonly used classification considers the technique used to produce each structure, grouping textile structures into woven, knitted, braided or nonwoven fabrics if, respectively, weaving, knitting, braiding and nonwoven techniques are used. This classification is commonly used in conventional textiles ,However for technical uses the most suitable classification takes into consideration the orientation of the fibers in the structure, no matter what technique is used to produce it. In this way, textile structures can be classified as:

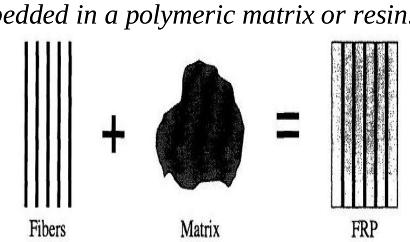
- **planar or conventional structures (2D)**
- **three-dimensional structures (3D)**
- **directionally oriented structures (DOS)**
- **hybrid structures.** [2]

1.2.Composite Materials

Composite materials are a macroscopic combination of two or more distinct materials having a finite interface between them. One of the constituents is the reinforcement, while the other is the matrix.

1.2.1. Fiber Reinforced Polymer(FRP)

FRP composites consist of high strength fibres embedded in a polymeric matrix or resin.



Fig(1): Formation of Fiber Reinforced Polymer Composite[3]

1.2.1. 1. Advantages of FRP

There are several advantages of FRP composites as strengthening materials such as:

(1) FRPs offer a combination of low specific gravity and high strength-to-weight ratios that are remarkably superior to those of steel.

(2) a distinct property of FRPs is their non-corroding behaviour, which makes them extremely attractive for many applications.

(3)FRP composites can be formed on-site in any shape as flexible sheets.

(4) a significant advantage of using FRPs in many applications is their dimensional stability over a wide range of temperature.

1.2.1. 2. Fibers

Fibers are very effective and attractive reinforcement materials for civil engineering. The aspect ratio of length and diameter can be ranging from thousand to infinity in continuous fibers. According to their origin, textile fibres may be classified as natural fibres, when they occur in nature in fibre form, and man-made fibres, when they do not occur in nature in fibre form. The fibres in the FRP composites are the main load carrying elements, which exhibit a relatively high strength when pulled in tension. In the production of composite materials for concrete elements reinforcement, the most commonly used fibres are: Carbon fibers, Glass fibers , Aramid fibers ,Polypropylene and Polyester.

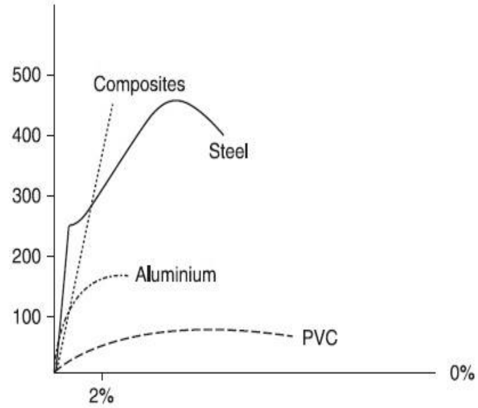
Table 1.Comparison between CFRP,Steel Plates[3]

Steel plates	CFRP strips	Criteria
High	Low	Own weight
High	Very high	Tensile strength
Small	Very thin	Overall thickness/
Yes	No	Corrosion
Limited	Unlimited	Length of strips
Difficult ,rigid	Flexible ,easy	Handling
In any direction	In the direction of the fibers only	Load –bearing
Complex	Easy	Laps
Adequate	Outstanding	Fatigue behavior
Low	High	Material costs
High	Low	Installation costs
Requires lifting equipment and clamping device	No tools necessary	Application

Note :CFRP→ Carbon reinforced polymer

1.2.1. 2. 1. Type of fibers

Composite rods are usually made of a single type of fibre such as carbon, glass or aramid. From the cost perspective, glass-fibre reinforcement rods are the most promising, since they are the least expensive and widely available. However, from the design and serviceability perspective, glass-fibre reinforcement rods do not have the stiffness and ductility require- ments of conventional steel reinforcement bars. In many cases, concrete elements using glass-fibre reinforcement rods underutilize the material strength properties and thereby increase the cost of the overall project. On the other hand, carbon-fibre reinforcement rods present high stiffness and strength, comparable to those of steel reinforcement bars. However, their cost is high, making them not commercially viable for conventional reinforced concrete structures.



Fig(2):Glass-Fiber Reinforced Composite Rod Stress–Strain Curve **(43)**

In reinforced concrete structures, ductility is provided by the yielding of the longitudinal steel reinforcement . The yielding of reinforcement is then translated into excessive deformation in the concrete element, providing a warning to the occupants that failure of the structure is imminent. With composite rods there is no yield point, since most fibres behave linearly elastic until failure. This brittle behaviour would give no early warning of structural failure. To overcome this major drawback of composite rods, ductile hybrid reinforcement rods were developed. The material ductility is obtained due to the selection of different fibres that would fail at different strains.

1.2.1.3. Type of resin

The matrix is the binding material of the composite. The main function of the matrix is to transmit the load to the fibres in the composite. The matrix also supports and protects the fibres and ensures that the fibres remain aligned.The advantages of epoxy resins over other polymers as adhesive agents for civil engineering use can be summarised as follows :

- *High surface activity and good wetting properties for a variety of substrates.*
- *May be formulated to have a long open time (the time between mixing and closing of the joint).*
- Minimal shrinkage on curing, reducing bondline strain. [3]

1.2.1.4. The Main Forms of Strengthening Reinforced Concrete Structures (RC)

- **Flexible sheets** or fabrics that are made of fibers in one or at least two different directions that are sometimes pre-impregnated with resin.(A)
- **Thin unidirectional strips** (with thickness in the order of 1 mm) made by pultrusion**(B)**

A 

wet lay-up system

B 

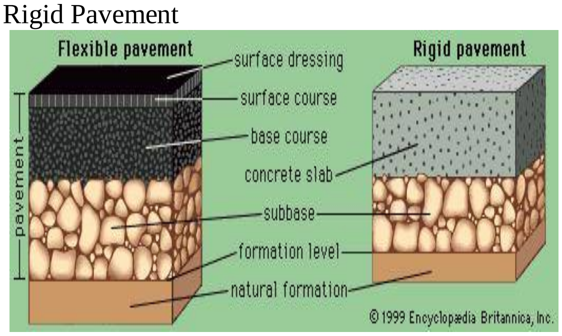
precured FRP system

Fig(3):The Manual Application EB-FRP Systems[4]

1.3.Textiles for Pavement

The definition of Pavement is the actual travel surface especially made durable and serviceable to withstand the traffic load commuting upon it. Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil .

All hard road pavements usually fall into two broad categories namely. Flexible Pavement, Rigid Pavement



Fig(4): Comparison of Flexible Pavement, Rigid Pavement[5]

1.3.1 .Rigid Pavement

The rigid characteristic of the pavement are associated with rigidity or flexural strength or slab action so the load is distributed over a wide area of subgrade soil. Rigid pavement is laid in slabs with steel reinforcement .

1.3.1.1. Advantages of Rigid Pavement

Rigid lasts much, much longer i.e 30+ years compared to 5-10 years of flexible pavements
-In the long run it is about half the cost to install and maintain. But the initial costs are somewhat high
-Rigid pavement has the ability to bridge small imperfections in the subgrade.
Less Maintenance cost and Continuous Traffic and Flow-
-High efficiency in terms of functionality

1.3.1.2.Disadvantages of Rigid Pavement

Rigid pavement face defects shown in figure (5) a


b


Fig(5): Disadvantages of Rigid Pavement (A)Cracks in Rigid, (B)Contraction and Expansion[6]

A new technique for strengthening reinforced concrete (RC) slabs using FRP composites is investigated ,FRP technique as a new alternate strengthening. [6]

2. Experimental work

This study submit bases for the local textile uses in different scope in structural engineering and knowing the ultimate load of concrete element after addition of the materials composed of FRP and resin and put the scientific and the best style to use these FRP and the rang of its affecting on increasing the structural capacity for the of RC slabs. through these different parameters.

1- Weft yarns material for produced fabrics.(Glass fiber/ Polypropylene).

2 Different dimensions of FRP on reinforced concrete slabs (full repair/ partial repair).

2.1. Yarn Specifications

Table 2.Warp specifications

No.	Property	Specification
1	Warp type	Polypropylene(A) from Masr El Nour company
3	Width of warp	2.2Mm
4	Count of warp yarns PP(A)	1800 denier

Table 3.Weft specification

No.	Property	Specification
1	Weft type	Glass, Polypropylene (B), from Oriental weavers company
2	Count of weft yarns (Glass)	1600×3 denier
3	Count of weft yarns PP(B)	2000 denier

2. 2.Concrete:

Concrete is a construction material composed of portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite.

2.2.1.Reinforcement

High strength steel-welded wire mesh of 6 mm diameter was used in the slab’s reinforcement. The steel reinforcements were obtained from Ezz - El Dekhala Iron & steel Company.

2.3. Resin used

2.3.1.Epoxy resin

Epoxy resins are found in many kinds with different specifications according to the end use. The epoxy resin used is Kemapoxy 150As in Figure (2.5) ; it is a two component solvent free non-pigmented liquid resin.

Table 4. Design of the Concrete Mixes

Constituents	Quantities of materials required for 1 m3 (kg)
	Mix (1) F cu = 25 N/mm2
Cement	325
Crushed Dolomite	1190
Sand	710
Total Water	174

Table 5. Mechanical Properties of Concrete Mix

Property(N/mm2)	Mix (1) Normal strength concrete
f 'c	21
f cu	26.0
Ec	2.24E+4

It is found in front of two components (A) the resin and (B) the hardener. Component (B) should be poured in component (A) and mixed together according to the ratio 2A:1B. The resin was brought from CMB Company .

2.4. Specifications of machine used in produced fabric samples

The experimental work was carried out by using World class circular weaving machine for PP /HDPE WOVEN FABRIC,GCL India Pvt. to produce the study samples.at MISR EL Nour Company in 10th of Ramdan city. The following table is to illustrate the technical specifications which used for producing the study samples.

Table 6. The technical specifications of machine(36)

Model	GCL-6A	
Number of shuttles	6 Nos	
Manufacturer Country	India	
Manufactured Date	2008	
Working width –tubular	48-71cms(19-28 inch)	
Machine speed	130-167RPM	
WEFT INSERTION	780-1000PPM#	
CREEL CAPACITY	576,tow creels ,boobin storage above the intake	
BOOBIN Package	Warp bobbin	Weft bobbin
Inside Diameter of the pipe	35mm	35mm
Length of the pipe	220mm	220mm
Traverse Length of the bobbin	190/200mm	190/200mm
Bobbin Diameter	100/120mm	115mm

Fig(6):GCL-6A machine

2.5.Type of Fabric

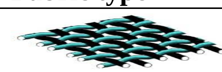
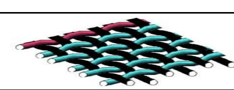
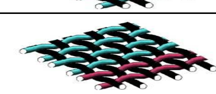
Achieve the first parameters by different Weft yarns material.(Glass fiber/ Polypropylene):

Machine produced 7 different type of fabric named as the percentage of glass weft per unit.

Table 7. Basic Specifications of the Produced Samples Represent the Substrate

7	5 picks per cm	**Picks /Cm**
8	5 end per cm	**Warp sett (end per cm)**
9	Plain weave 1/1	**Weave structure**

Table8.Details of Fabric

Fabric ID	**Fiber Percentage**		**Fabric type**
	Glass	**PP%**	
F (0)	0 %	100%	
F (1)	32.43%	67.56	
F (2)	54.54%	45.45%	
F (3)	70.58%	29.41%	

F (4)	82.75%	17.25%	
F (5)	90.56%	9.43%	
F (6)	100 %	0 %	

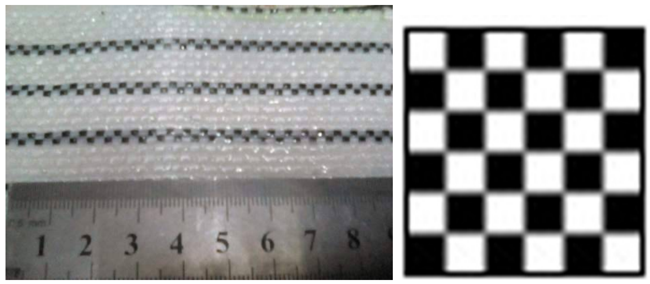


Fig.(7): Fabric Structure

2.6.Fabrics tests

2.6.1. Tensile strength:

Measurement of tensile stress–strain properties is the most common mechanical measurement on fabrics. It is used to determine the behavior of a sample while under an axial stretching load. From this, the breaking load and elongation can be obtained

2.6.2.Mass per unit area (Weight test)

This test was carried out according to the American Standard Specification of (ASTM,D3776).

2.7.Design(7)slabs,reinforcing-steel.(400*100*1000)mm..

The sequence of work as identify the perfect sample by testing ,then laminate the RC slabs with the perfect sample and achive the second perimeter of reinforced concrete slabs (full repair/ central repair).

Table9. lamination of slabs

No.	Slab ID	Strengthened with FRP	FRP Width (mm.)
1	S(R)	Un-strengthened	0
2	SF4F	F (4)	400
3	SF4P	F (4)	250
4	SF5F	F (5)	400
5	SF5P	F (5)	250
6	SF6F	F (6)	400

Note: SF4F→ slab Strengthened with F4(82.75%%glass: 17.25%PP,full repair (400mm),etc.

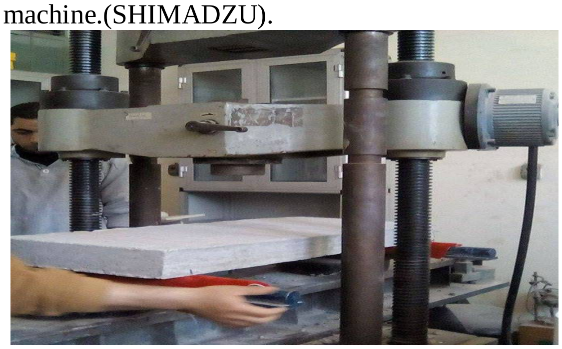
Note: SF4P→ slab Strengthened with F4(82.75%%glass: 17.25%PP, partial repair,(250 mm),etc.

Fig(8):FRP Wraping around Concrete Elements

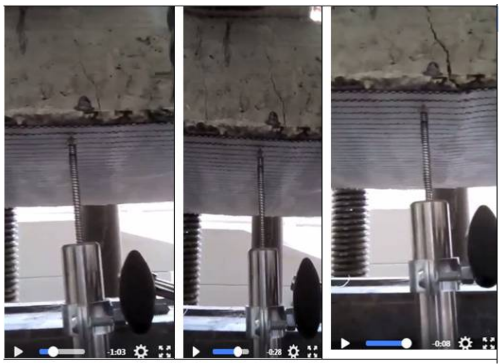
It is also important that the strengthening work is carried out with skilled workers with experience from these types of works.

2.8. Concrete Test Set up

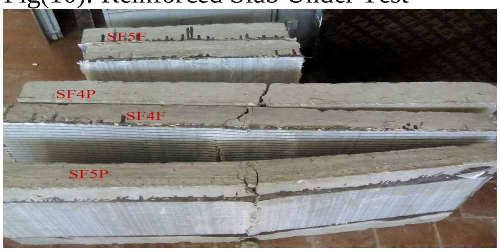
All test specimens were tested under4-points loading using a 500 kN hydraulic machine.(SHIMADZU).



Fig(9): Preparing the Slab for Test



Fig(10): Reinforced Slab Under Test



Fig(11):Behavior of Reinforced Slab after Test

Fig(12): SF6F after Test

This test was carried out by using Martindale Pilling and Abrasion Tester. The pilling test was achieved according to ISO standard no. 12945-2 in year 2000. The evaluation of the pilling of tested samples was assessed subjectively by comparing them with a standard samples, and tested samples was rated from 1 to 5, as 5 is the best with less pilling and 1 is the worse with more pilling.

3. Results and Discussion

Part 1: Testing Fabrics.

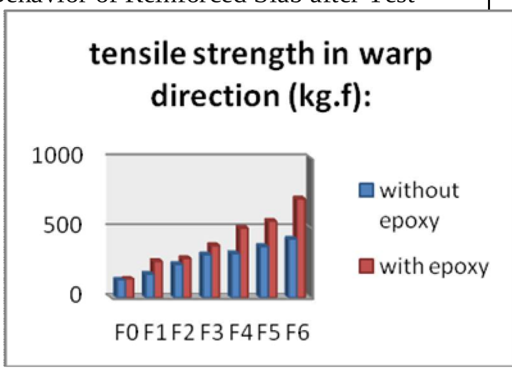
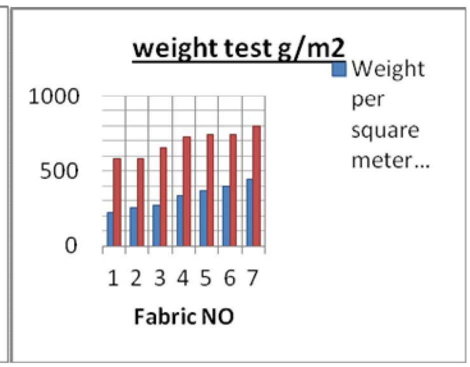


Fig (13):Fabrics' Weight Test



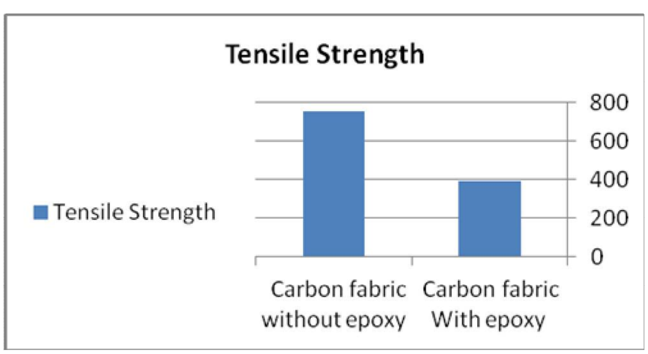
Fig(14) :Fabrics' Tensile Strength

By revising of the values in figure (13) it can be shown that sample F6 gave the highest tensile strength followed by F5 then F4, F3,F2, F1, F0 owing to glass yarn percentage on samples,

By revising of the values in figure(14), it can be shown that sample F6 gave the highest weight per square meter followed by F5,then F4,F3,F2,F1,F0 and the same arrange values when adhesion samples.

Table10. Tensile Strength of common carbon sample

Fabric ID	Tensile Strength	Elongation
Carbon fabric without epoxy	389	2.4%
Carbon fabric with epoxy	752.2	1.6%

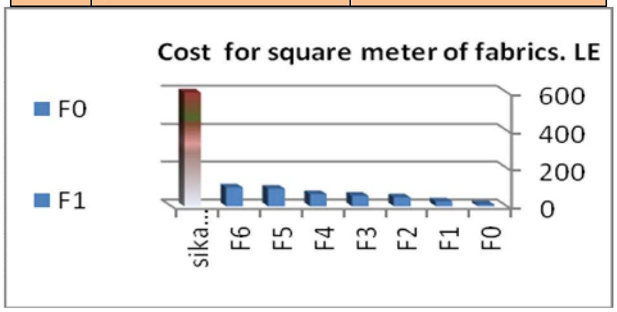


Fig(15):Tensile Strength for Carbon Fibers

By revising of the values in Table (10), it can be shown that sample F6 gave the higher tensile strength than Carbon fabric without epoxy.

Table11. Cost for Square Meter of Fabrics L.E

No.	FabricID	Cost for square meter of fabrics. LE
1	F0	9.4
2	F1	24
3	**F2**	**46.1**
4	**F3**	**54.4**
5	**F4**	**63.2**
6	**F5**	**92.2**
7	**F6**	**98.5**
8	**Sika carbon sheet**	**600**



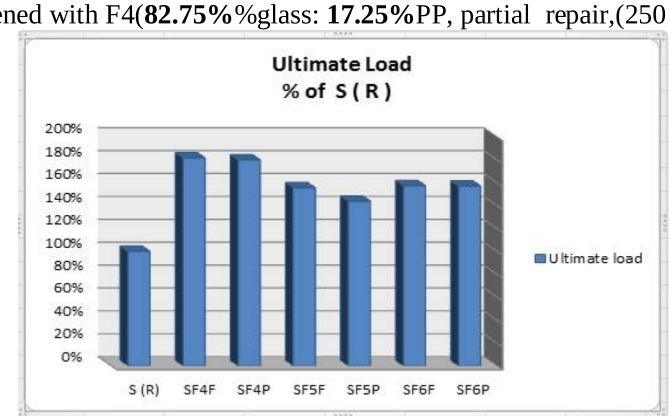
Fig(16) :Cost For Square Meter of Fabrics L.E

Part 2: Testing Slabs

Table 12.Details of Tested R. C. Slabs

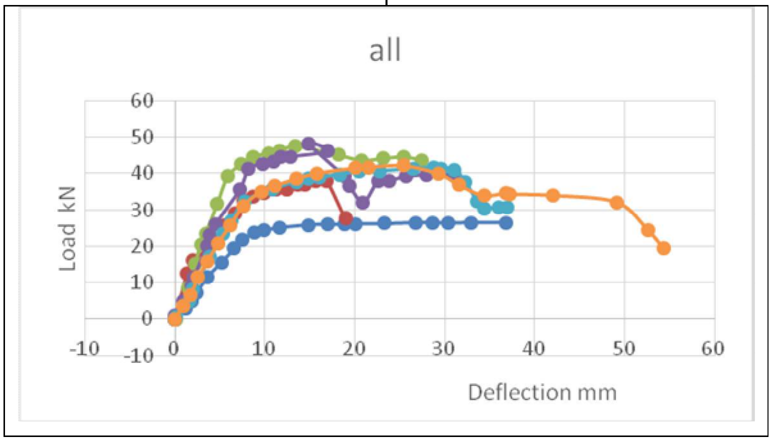
No	Slab ID	Slabs Dimensions (mm.)			strengthened with FRP	FRP Width (mm.)	Ultimate Load		Cross section
		width	Height	Length			kN.	% of S (R)	
1	S (R)	400	100	1000	Un-strengthened	0	26.49	100%	
2	SF4F	400	100	1000	Strengthened with FRP F (4)	400	48.1	181.57%	
3	SF4P	400	100	1000	Strengthened with FRP P (4)	250	47.64	179.84%	
4	SF5F	400	100	1000	Strengthened with FRP F (5)	400	41.2 (NA)	155.53%	
5	SF5P	400	100	1000	Strengthened with FRP P (5)	250	38.1	143.82%	
6	SF6F	400	100	1000	Strengthened with FRP F (6)	400	41.7	157.41%	
7	SF6P	400	100	1000	Strengthened with FRP P(6)	250	41.6	157.04%	

Note: SF4F→ slab Strengthened with F4(**82.75%**%glass: **17.25%**PP,full repair (400mm),etc.
SF4P→ slab Strengthened with F4(**82.75%**%glass: **17.25%**PP, partial repair,(250 mm),etc



Fig(17):Ultimate Load as A Ratio to Control for Tested Slabs

From figure (17) it can clear that the ultimate load of the R.C slabs was greater than the ultimate load of the control slab range from 143.82%to 181.57%. Ultimate load of SF4F which strengthened with F4(82.75%glass fibers) recorded the highest results followed by SF4P,then SF6F, SF6P, SF5F, SF5P.



Fig(18):The Relation Between Load and Mid-Span Deflection for The Tested Slabs SF(4),SF(5),SF(6) and S (R)

According to the second perimeter of reinforced concrete slabs (full repair/ partial repair).
figure(18) indicate that the difference on width surface reinforced(full repair/ partial repair) almost gave the same ultimate load on SF6 ,SF4.

4. Conclusion

1-The innovative local composite fabric can be successfully used for strengthening of R.C slabs. The use of woven structures allowed the utilization of different types of weft with specific functions. 2- The conclusions have been reached that point out the benefits of incorporating polypropylene fiber (F5) 9.43% slightly decreases the compressive strengths, but, appreciably increased the flexural strength on tested beams samples (plain concrete).
3-The study proved the superiority of **specific density**: is the relationship between the mass of the substance and how much space it takes up (volume) .
4- The study proved the maximum load of the R.C slabs was increased by the produced samples owing to ultimate load of the R.C slabs was greater than the ultimate load of the control slab range from 143.82%to 181.57%. Ultimate load of SF4F which strengthened with F4(82.75%glass fibers) recorded the highest results followed by SF4P,then SF6F, SF6P, SF5F, SF5P.
5- The ultimate load of reinforced concrete slabs whether full repair or partial repair of width surface slabs, is almost gave the same results on strengthening slabs . Subsequently ,a reduction in amount of fabric is an economical idea.
6-The failure mode of R.C. slabs was gradual and ductile with polypropylene fiber .

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