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THE IMPACT RESISTANCE OF CONCRETE BEAMS EXTERNALLY REINFORCED WITH NON -WOVEN FABRIC

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خلاصـــة : -

يشتمل هذا البحث على دراسة سلوك الكمرات الخرسانيه المسلحه خارجياً بالاقمشه الغير منسوجه تحت تأثير حمل الصدم . تم رصد الشروخ الحادثه من حيث بداية حدوثها وشكلها واتساعها وأطوالها والمسافات بينها في مراحل التحميل المختلفه . تم أيضاً دراسة سلوك تلك الكمرات تحت تأثير قوى عزم الانحناء الأستاتيكي حيث تم قياس الترخيم الحادث عند نقطة المنتصف في مراحل التحميل المختلفه . تم مقارنة النتائج بتلك المأخوذه على كمرات من الخرسانه العاديه وأخرى تم تسليحها بواسطة الألياف الزجاجيه التي وضعت على هيئة طبقات على مسافات مختلفه مقاسه من أسفل منطقة الشد . أوضحت النتائج أن قوة تحمل الكمرات ذات التسليح الخارجي بالاقمشه الغير منسوجه وصلت إلى خمسون ضعف الكمرات العاديه حتى حدوث الأنهيار الكلي .

ABSTRACT:

The object of the experimental work carried out in this investigation is to study the behaviour of concrete beams reinforced externally with non-woven fabric under impact loading. Crack initation and pattern, i.e. crack width, heights and spacing records at different stages of loading are reported and discussed.

Plain and glass fibre reinforced concrete beams were cast and tested under the same conditions and cases of loading as non-woven fabric reinforced concrete beams for comparison.

1. INTRODUCTION :

Non-woven Fabrics has been used in the building industry during the last three decades in different applications. Among the most wide applications are as protective layers for under ground structures subjected to ground water, lining of canals and water passes and in general as reinforcement for bituminous materials used as isolation materials.

Non-woven fabrics proved to be an excellent material to reinforce cement and concrete. Needle felted non-woven fabrics structure has been used as an impermeable material to cover the walls of the water station in Folorida in U.S.A. A million and half square maters of the non-woven fabric were used in this project . However, the total product of this material in the year 1976 was 3.3 million suquare meters which increased to be 330 million square meters in the year 1986 [1].

Glass fibres among other fibres like steel and plypropylene fibre were used to reinforce concrete and offered a convenient and practical means of achieving improvement in many of the engineering properties of the material [2-9].

A limited number of research were carried out on the impact resistanc of the different fibre reinforced concrete elements [6-7].

This research concerns mainly with the effect of using non-woven fabrics commercially available in the Egyptian market on the impact resistance of concrete beams. Glass fibre reinforced concrete beams were also tested under impact loading for comparison.

The non-woven fabric used in this research is of the chemical mechanical laminated fabric group. It consists of three layers which are; surface layer, intermidiate layer and a carrier layer. The surface layer is of polyester fibres [300 gm/m^2], the intermidiate layer is of waste of fibres with 5.78 mm thickness which weighs 858 gm/m^2 and the carrier layer is of plain weave 1/1 of Jute fibres with 1.5 mm thickness which weighs 122 gm/m^2. The three layers were fixed together using a loom punching machine with needling density 100 $needle/cm^2$, then the cloth was immersed in an a dhesive of Acralen fy Bayer. The cloth was then resined and dried so that the adhering material represented 20% of the cloth by weight. The fabrication process was carried out according to Graig et al., [10] . The mechanical properties of the non-woven fabric used are shown in Tabel[1].

2. EXPERIMENTAL ARRANGEMENT AND TECHNIQUE

Three sets of beams were cast and tested in this investigation as shown in Table [2] . The first set of beams was cast of plain concrete .

The second set of beams was cast of glass fibre reinforced concrete and the third set of beams was cast of plain concrete with non-woven fabrics glued to the hardened concrete beams at different positions.

The size of all tested beams were 100x100x500 M.M.

The glass fibre reinforced concrete set consisted of three groups of beams which differed in the number of glass fibre layers. The first group of glass fibre reinforced concrete beams [G.F.C.1] was cast with glass fibre layer at a height of 25 mm measured from the bottom of the beam. The second group of beams [G.F.C.2] was cast with two layers of glass fibres at heights of 25 mm and 50 mm, respectively. The third group of beams (G.F.C.3) was cast with tree glass fibre layers at heights of 25 , 50and 75 mms successively.

The fresh concrete was cast with different heights in the forms and then the glass fibre layers were laied at choosen positions as longitudinal reinforcement and then concrete casting was continued. Compaction was carried out using both a steel rod and mechanical vibration. The optimum amount of glass fibres used in one layer of a beam without causing separation between the surrounding concrete layers were taken according to the previous investigation results[8].

Three percentages of glass fibres of 0,15%, 0.3% and 0.45%(by volume of concrete)were used with the three groups of glass fibre reinforced concrete beams G.F.C.1 to G.F.C.3, used in this invetigation, successively. Alkali-resistance glass fibres commercially available were used. The properties of the glass fibres used are shown in Table [3].

The non-woven fabric [N.W.F] reinforced concrete set consisted of three groups of beams all of them were cast of plain concrete and differed in the position in which [N.W.F] was glued. Non-woven fabric was glued at the bottom of the concrete beams for the first group. For the second group the non-woven fabrics were glued to the bottom side and the top side of the hardened concrete beams. For the third group the non-woven fabrics were glued to the bottom and to the sides of the concrete beams as shown in Tabel[2] and Figure[1].

The concrete mix used was made from Ordinary Portland cement, sand and gravel . The nominal maximum size of coarse aggregate was 19mm. The mix proportions by weight were 1cement : 2 sand : 4 gravel and the water cement rati used was 0.5. Properties of the concrete mix used in this investigation are shown in Table [3] .

The concrete beams were cured in the laboratory atmosphere for 28 days after casting as shown in Figure (2) . All tests were carried out at - age of four weeks after casting.

To carry out the impact test , the beams were laid on two support with an effective span of 400 mm, under the apparatus shown in Figure (3). The beam was adjusted such that the mid-span point laied vertically under the load . THe falling weight (16 N) consists of a machined block which gives a line load welded to a rolled bar(13mm) devided into distances of 50 mm each. The weight was left to fall free from different heights starting from 85 mm with 50 mm intervals which increased continuosly up till beam failure.

Crack Widths , heights and spacing were recorded as they appeared and up till the end of the test. Impact resistance was calulated as the multiplication of the falling weight P with the sum of the different hights h till failure i.e. :

$$\text{Impact resistance} = P\,(h_1+h_2.......h_n) \quad \text{N. mm}$$

For crack width measurements an Ultra lens instrument which is provided with small lamp and a battary to give clear vision of cracks was used .

Out of the six beams casted for each group in this investigation, three were tested under impact loading and the other three were tested under point bending test .The deflection at mid span point of the beam was recorded under loading up till failure as shown in Figure (4).

3. ANALYSIS AND DISCUSSION OF TEST RESULTS

3.1 Crack Initiation and Pattern Under Impact Loading

The use of glass fibres as main reinforcement for concrete beams retarded the crack initiation which increased with the increase of the glass fibre content as shown in Fig. (5) . The rate of increase of crack widths decreased with the increase of the glass fibre layers. The improvement in beam resistance to cracking under impact loading is mainly affected by the existence of glass fibre layers in the tension side.

Using non-woven fabrics as external reinforcement at the bottom of concrete beams at the tension side caused significent retardation in the crack initiation which was increased when an additional layer of the non-woven fabric was used at the top of the beam . The non-woven fabric layer used at the top of the concrete beam has mainly absorbed the impact energy of the falling load while the bottom layer helped in resisting the tensile stresses created at the bottom of the beam. Gluing non-woven fabric to the sides of concrete beams beside the bottom layer has shown the highest resistance among all the tested beams to crack initiation which was observed in this case as a sign on the fabrics surface but could not be measured in width .

However ,reinforcing the concrete beams with three non-woven fabric layers one at the bottom and one at each side of the beam increased the initial cracking resistance and the ultimate impact resistance 12 times and 50 times , respectiviely .

The above mentioned results show that existing of non-woven fabric layer in the tension side of the beam resists the tensile stresses, while the top layer absorbs and minimise the impact energy transfered to the concrete beam . The non-woven fabrics glued to the sides of the concrete beams helped in resisting the shear stresses. The rate of increase in the crack width decreased with the increase of either the glass fibre layers or the non-woven fabric layers as shown in Fig.[6].

3.2 Mode of Failure :

The failure of plain concrete beams occured with complete separation into two parts . However , no complete separation was observed with concrete beams reinforced with multi layers of glass fibres or those reinforced externally with non-woven fabrics Fig.[7]. It deserves to be mentioned that complete collapse of those beams reinforced with non-woven fabrics at the bottom and the top of the beams or at the bottom and the sides of the beam did not occur.

Although the non-woven fabric reinforced beams reached their ultimate impact load, however , the two parts of the beams were linked together by means of the non-woven fabrics as shown in Fig. (7), (8).

3.3 Flexural Tests

The behaviour of plain concrete beams , glass fibre reinforced concrete beams and those reinforced with non-woven fabric under flexure testing was more or less the same behaviour as under impact loading . The flexural rigidity of reinforced beams has greatly improved Fig.[9]. Values of recorded deflection at mid span point of the tested beams at the different stages of loading are shown in Fig. [9] . All reinforced beams showed deflection at ultimat moment less than that of plain concrete beams . The value of maximum deflection at ultimate moment decreased with the increase of glass fibre content . While the deflection value at ultimate momente increased with the increase of the number of non-woven fabric layers .

The ultimate moment increased with the increase in glass fibre content or with the increase of number of non-woven fabrics . Non-woven fabric reinforced concrete beams showed higher values of ultimte moment than that obtained with those reinforced with glass fibre layers as shown in Fig.[9] and Table [5]. Those beams reinforced with non-woven fabrics either in the bottom tension side of the beams or at the bottom and the top showed very close results which proves that the non-woven fabric contributes mainly in resisting the tensile stresses. Beams reinforced with non-woven fabrics at the bottom and the sides of the concrete beams showed the highest values of ultimate moment as shown in Fig. [5].

CONCLUSIONS

1. Good bond was achieved between concrete and the non-woven fabric layers glued to the beams . The bond was still existed up till the beams failure under either the static bending test or the impact test. Good bond also occured between concrete and glass fibre layers and no separation was observed after casting or during flexure or impact testing up till beam failure.

2. Using glass fibre layers as internal reinforcement for concrete beams increased their flexure rigidity , initial cracking load and ultimate strength under static or impact loading. Comparatively tremendously higher results were obtained when non-woven fabric layers were used as external reinforcement for concrete beams.

3. Initial cracking load and ultimate impact load of non-woven fabric reinforced concrete beams reached 12 times and 50 times respectively of that of plain concrete beams.

4. The two parts of the non-woven fabric reinforced concrete beams were linked together even at the ultimate impact load and complete collapse did not occured .

5. Among the many applications of fibre reinforced concrete are industrial floors , concrete in earth-quake areas and military structures

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Table (1) Properties of Nonwoven Fabrics

Mass / unit area	Qs=1600 $g.m^{-2}$
Laminated fabric thickness	t=10.4 mm,
Mass / unit volume	Q=153.9 $Kg.mm^{-3}$
Laminated fabric packing coefficient	Ø=0.107
Laminated fabric hardness	H=105.9 gf. $cm^{-2}mm^{-1}$
Energy absorbed index	b=4.108 (gf. cm^{-2}.mm)
Compressibility index	C.I=1.485×10^{-3}(cm^{2}- g^{-1})
Air permeability	=2.012 (CC-Sec^{-1}. cm^{-2})

Table (2) Schedule of Investigated Beams

Set No.	No. of Spec.	Type of Concrete	Type of Fibres	Symbol of Concrete	Tested Property	Beam Cross-Section
I	6	Plain Concrete	—	P.C.	.Flexure Test	100 100
II	6	Glass Fibre Reinforced Concrete	Glass Fibres	G.F.C.1	-Deflection -Cracking -Ult.Ld.	G.F
	6			G.F.C.2	-Impact Test -Cracking Initiation	G.F
	6			G.F.C.3	-Crack Pattern	G.F
III	6	Non-woven Fabric Reinforced Concrete	Non-woven Fabrics	N.W.F.1	-Ultimate Impact Resistance	N.W.F.
	6			N.W.F.2		N.W.F.
	6			N.W.F.3		N.W.F.

* Dimensions of test specimens = 100 x 100 x 500 mm

Table (3) : Properties of glass fibres

Filament length (cm)	23.9
Specific gravity (g/cm^2)	2.54
Breaking elongation (%)	4.8
Elastic Recovery (%)	100
Average toughness (gpd).	0.37
Effect of moisture	None
Effect of sunlight	None
Cross - section	circular
Surface toughness	smooth
Effect of acids and alkalis :	Resist most acids and lkalis

Table (4) : Concrete Properties

Mix Proportions C.S.G	Cement Content Kg/m^3	Cube Compressive Strength (N/mm^2) 28 days age	Flexural Strength (N/mm^2) 28 days age	Modulus of Elasticity) (KN/mm^2) 28 days age
1:2:4 w/c = 0.5	350	35	6.5	27

Table (5) Test Results of Reinforced Concrete Beams Under Bending Test

Set No	Type of Beam	Beam Symbol	Defl. of R.C. beam * / Defl. of Ref. beam ** %	Crack Ld. of R.C. beam / Crack Ld. of Ref. beam %	Ult.Ld. of R.C. beam / Ult.Ld. of Ref. beam %
II	Glass Fibre reinforced Concrete	G.F.C.1	64 %	120 %	124 %
		G.F.C.2	50 %	125 %	129 %
		G.F.C.3	45 %	130 %	131 %
III	Non-woven fabric reinforced Concrete	N.W.F.1	45 %	130 %	150 %
		N.W.F.2	36 %	143 %	155 %
		N.W.F.3	33 %	160 %	198 %

* Deflection at initial crack load

**Ref- beam is the plain conrote beam

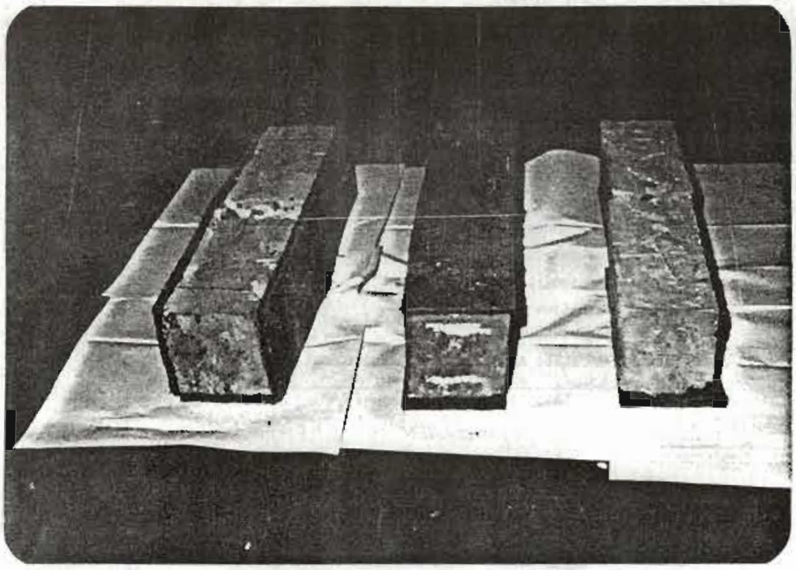


Fig. [1] Concrete beams externally
reinforced with non-woven fabrics

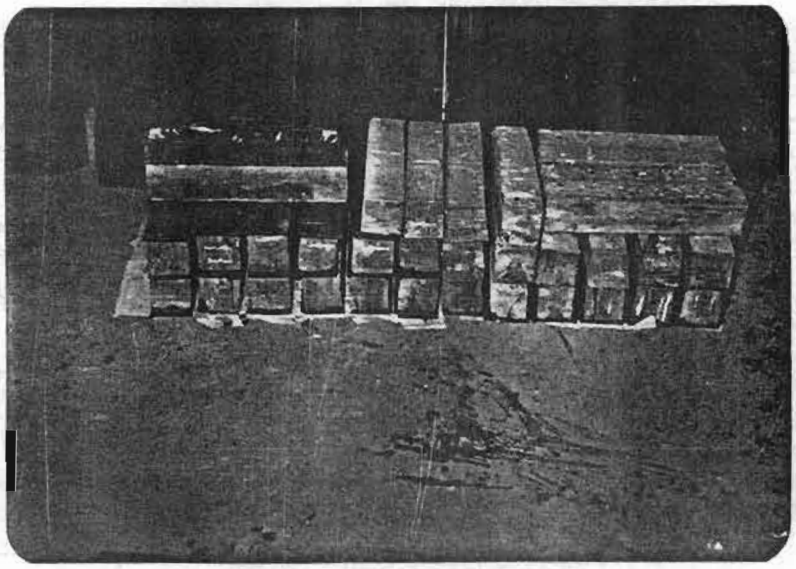
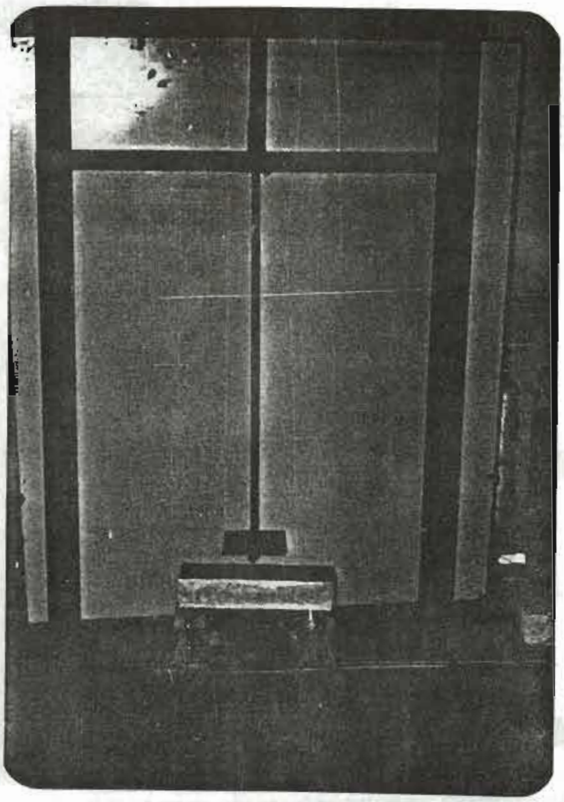


Fig. [2] Curing of test specimens
in laboratory atmosphere

[a]



[b]

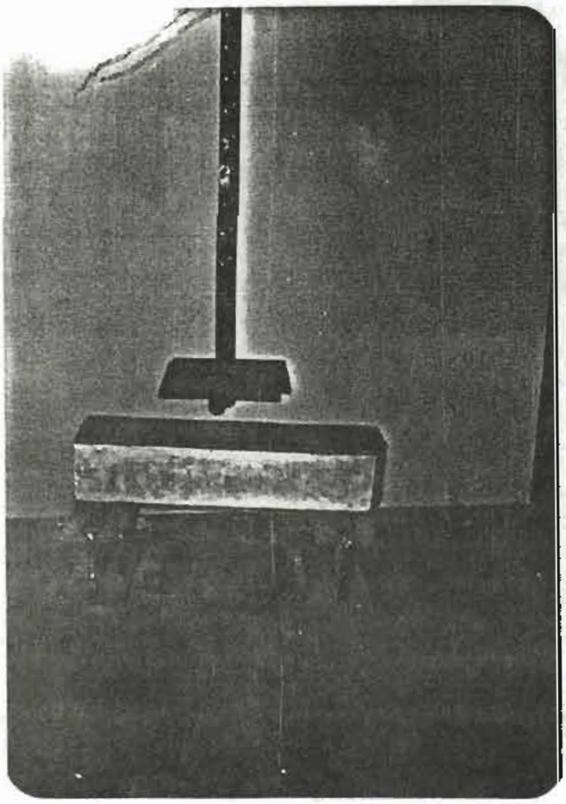
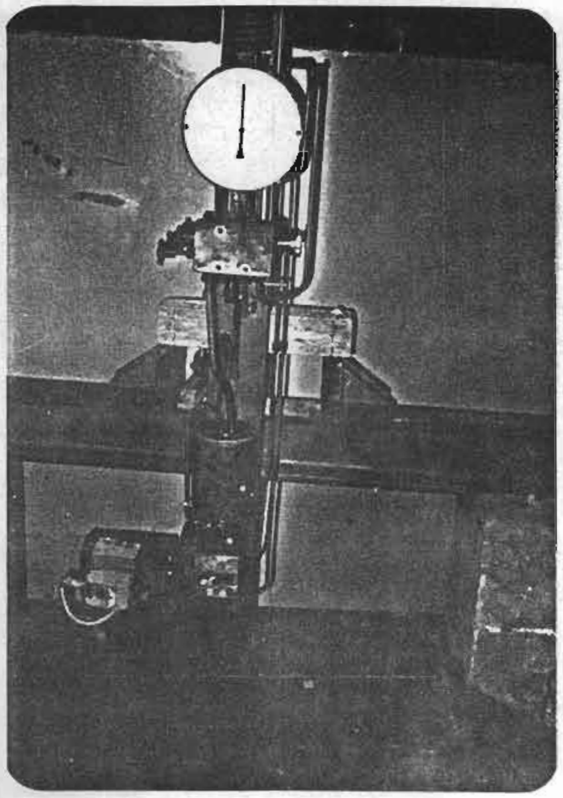
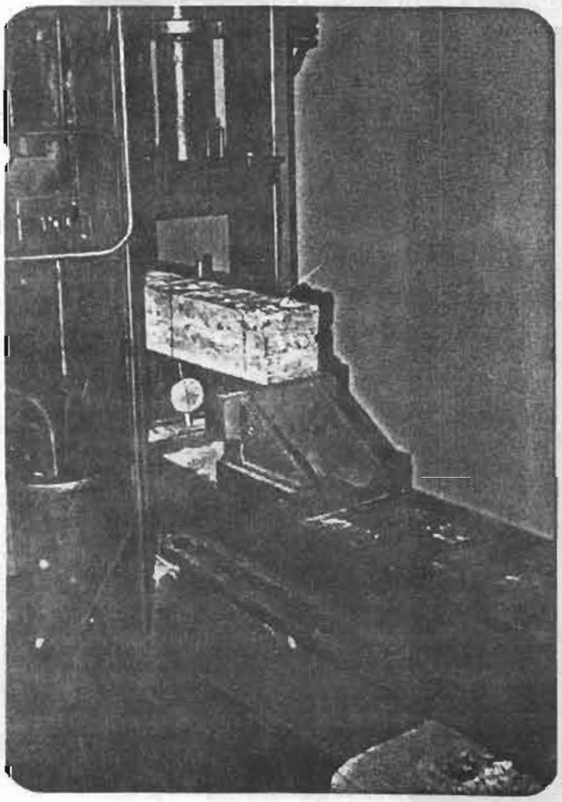


Fig. [3] Impact test apparatus

[a]





[b]

Fig. [4] Three point bending test

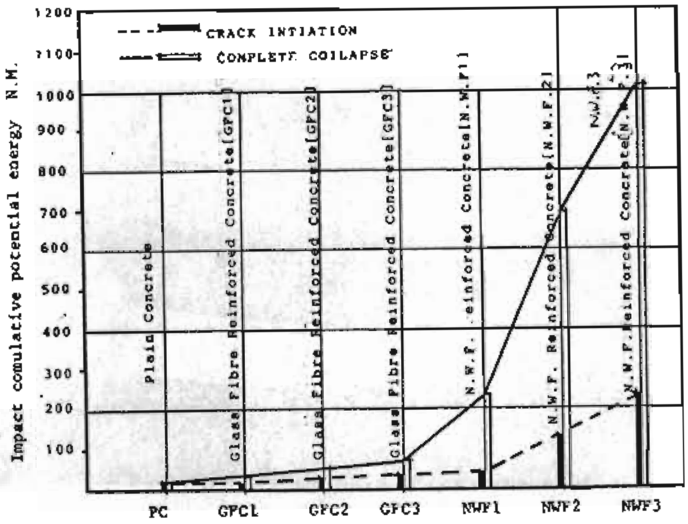


Fig.(5) Effect of the reinforcement of concrete beams with glass fibre layers or Non-woven fabric on their impact resistance

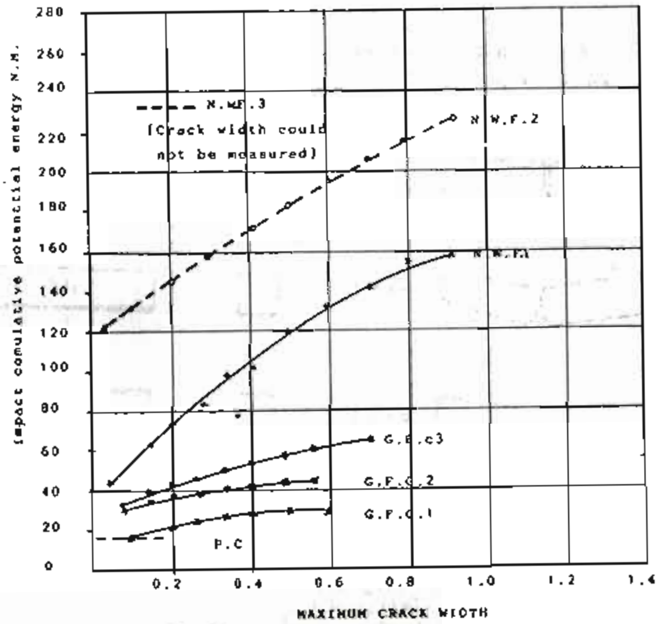


Fig.(6) Impact comulative potential energy Vs. maximum crack width.

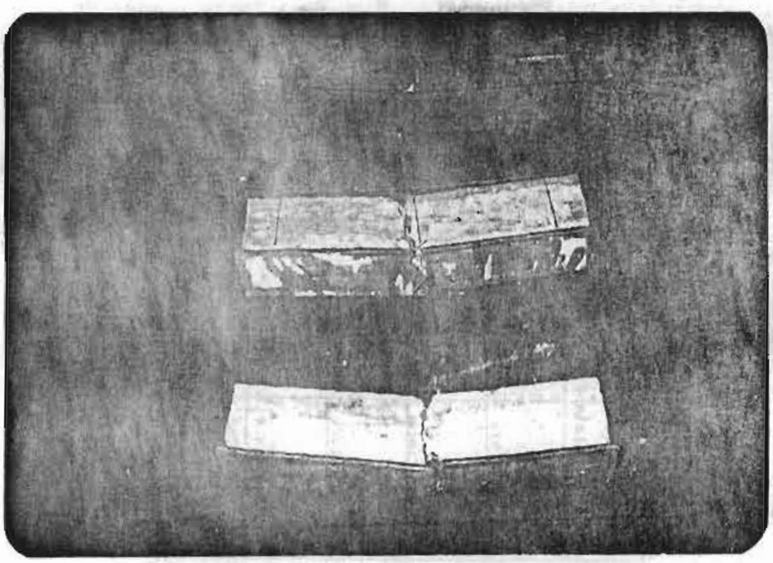


Fig. (7) Failure of concrete beams reinforced externally with non-woven fabrics -- under impact loading.

Note :-Cracks of the N.W.F.3 set could not be measured as the non-woven fabric covered the sides and the bottom

-X,y and. y' are variables

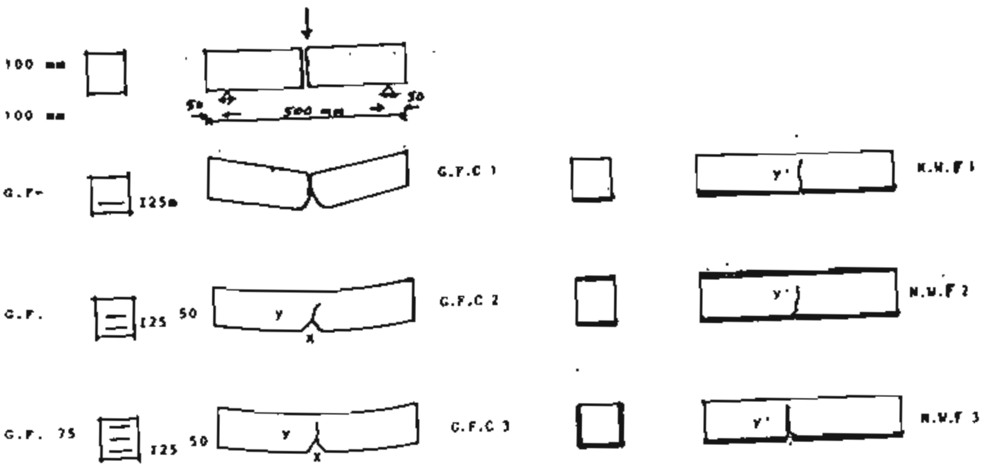


Fig. (8) .Different Pttern Of Beams Failure

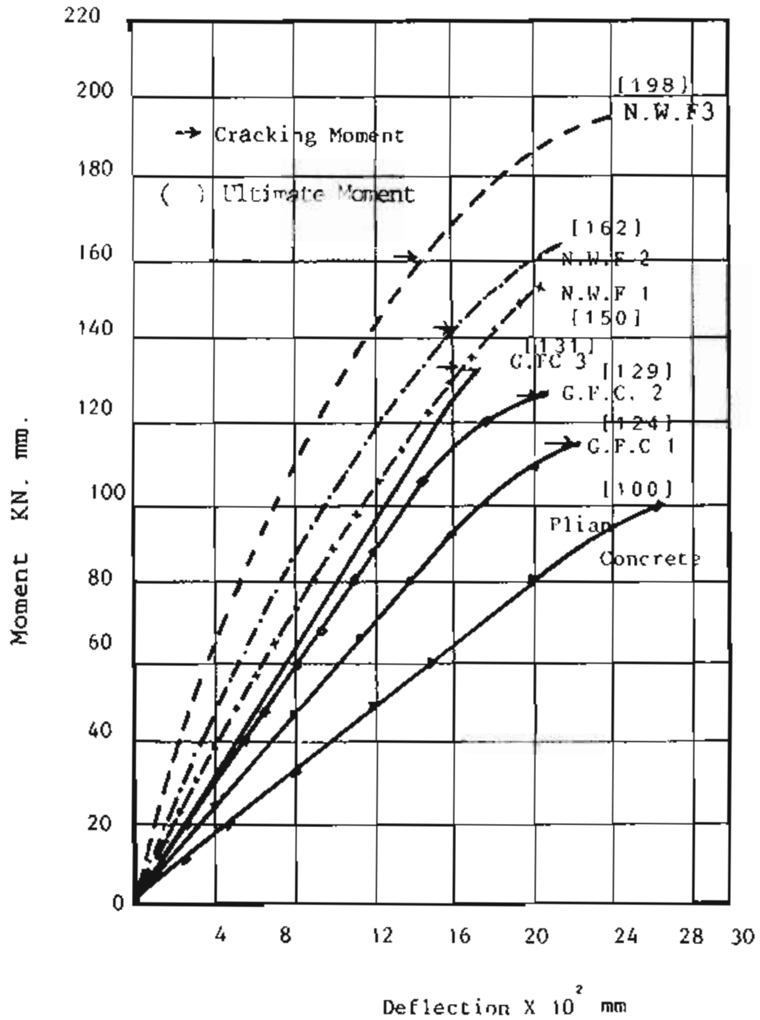


Fig. (9) Comparison between deflections of different tested concrete sets