EFFECT OF FREEZING AND THAWING ON STRESS-STRAIN RELATIONSHIPS OF POLYMER MODIFIED CONCRETE (PMC)

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Abstract

The investigation includes the effect of freezing and thawing cycles on stress-strain relationships of polymer modified concrete (PMC). Cycles of freezing and thawing contains 12 hours at 100°C and 12 hours at -4°C. The process of cycles of freezing and thawing

Simple experimental technique is used to obtain the complete stress-strain curves up to strain of 0.006 (Both ascending and descending portions) sample subjected to freezing and thawing cycles (FTC), then subjected also to stress-strain tests.

Keyword : Polymer modified concrete, Compressive strength, Modulus of elasticity, Styrene Butadiene Rubber, Foil gages.

تأثير دورات الانجماد – الذوبان على علاقة الاجهاد – الانفعال للخرسانة المطورة بالبوليمر

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الخلاصـــــة

البحث يتضمن تأثير دورات الانجماد والذوبان على منحني الإجهاد–الانفعال للخرسانة المطورة بالبوليمر. دورات الانجمـــاد والذوبان تتكون من ١٢ ساعة بدرجة حرارة (١٠٠) درجة مئوية و١٢ ساعة بدرجة حـــرارة (–٤) درجـــة مئويـــة. دورات الانجماد والذوبان تستمر لمدة (٣٠) يوم لجميع النماذج، تم استخدام موديل عملي للحصول على علاقة الإجهـــاد – الانفعـــال الكاملة (الجزء الصاعد والنازل). النماذج أُخضعت لدورات الانجماد والذوبان ثم فحص الإجهاد – الانفعال.

Nomenclature

f_t **:** Splitting tensile strength (N/mm^2)

f_c **:** Compressive strength (N/mm^2)

P : The applied load of machine (N)

L : Height of cylinder specimens (mm)

Es : Modulus of elasticity of steel (N/mm^2)

fs : Stress in steel tube (N/mm^2)

Pconc : The load on concrete specimens (N)

Ac : Cross sectional area of concrete cylinder (mm^2)

P_{total} : Total load by machine (N)

ε_s : Average strain in steel tube (mm/mm)

σ_c **:** Stress in concrete specimens (N/mm2)

P_S **:** The load on steel tube (N)

Specimens and Materials

Specimens were (7.5 × 15 cm)cylinders, 36 specimen were made to obtain total stress-strain curves, a different mix proportions of cement: Fine Aggregates: Coarse Aggregates of (1:1.5:2) (1:1.5:3) and (1:1.5:4) using styrene Butadiene Rubber (SBR) as a percentage of cement weight of 15% to improve the properties of ordinary concrete and makes the concrete with high strength values.

The maximum size aggregate is (10 mm) of 2.8 specific gravity sieve analysis is shown in **(Table 1)** Ordinary portland cement was used in all mixes ordinary drinking water was used in all mixes.

Curing :

Ordinary mixes were cured in water, but polymer mixes cured 6 days in water and 22 days in air. This gives the perfect curing according to Radomir investigation (Radomir, 1998)

Experimental Program

Testing Method

A simple Technique was developed by ASTM C-469 (ASTM, C-469, 1981) to obtain the stress-strain curve of concrete (both ascending and descending portions) up to the strain of 0.006 (**Figure 1**) (Wang, 1978)

Concrete cylinders were loaded in parallel with a steel tube. The high strength steel tube was case hardened so that it's stress-strain curve was linearly elastic up to the strain of 0.006.

The specimens were capped in the testing machine to ensure that the load will be shared simultaneously by both the tube and concrete cylinder immediately on loading.

The strains in the steel tube were measured with two foil-type resistance strain gauges . These strains gave not only the amount of load taken by the steel tube, but were also used to obtain nominal strains in concrete. Thus knowing the total load and steel strain, the stress – strain relationship of each curve were made by three tested specimens and taking average of three readings of stress.

Calculations

Simple calculations to obtain the stress-strain curve are given below

The strain in steel tube multiply by the modulus of elasticity of steel (Es) gives the stress in steel tube:

$$\epsilon_s * E_s = f_s \qquad ...(1)$$

where

ϵ_s : The strain (AVG. Strain in steel by two foil gages)

E_s : The modulus of elasticity of steel 207000 MPa

f_s : The stress in steel tube

1. The load on concrete

$$P_{conc} = P_{total} - P_s \qquad ...(2)$$

where

P_{conc} : The load on concrete specimen

P_{total} : Total load by machine

P_s : The load on steel tube

$$P_s = f_s \times A_s \qquad ...(3)$$

A_s : area loaded (steel tube)

2. The stress in concrete (σ_c) is calculated from Eq.4 below

$$\sigma_c = \frac{P_{conc}}{A_c} \qquad ...(4)$$

where

σ_c : The stress in concrete

A_c : Area (loaded) by concrete

$A_c = \frac{\pi}{4}(75)^2$ (in mm^2)

Thus, executing the calculations above gives the total stress – strain relationship of concrete.

Analysis of results

Figures (2-7) show the effect of cycles of freezing and thawing on stress – strain relationships for different mixes of concrete with or without polymers , the mixes with 15% p/c shows the higher values of maximum compressive strength with respect to the reference mix after FTC (Ohama, 2003)

Figure (2) shows the effect of FTC on stress-strain relationship of concrete mix (1:2:4) with 0% p/c (reference mix) .

The reduction in max. Compressive strength of the reference mix due to FTC is about (66%), but with using SBR polymer, the reduction is very little see **(Figure 3)** and its about (2.2%) .

Table 3 Shows the reduction in the value of the chord modulus of elasticity for the mixes. The reduction after FTC cycles is about 68% for (1:2:4) mix, but after using SBR polymer , the reduction is very less and about (9.8%).

Figure 4 also shows the effect of FTC on stress-strain relationship of concrete with mix proportions of (1:1.5:3) without adding polymers , the reduction in compressive strength is about (47%), but after using polymers, the reduction after FTC is about (1.2%), (see fig. 5).

The reduction in modulus of elasticity for the reference mix with mix prop. of (1:1.5:3), is about 57.7 , but the reduction in mixes with p/c=15% is about 0.4% and this is perfect, see **(Table 3).**

Figure 6 shows the effect of FTC on (1:1.5:2) mixes (p/c=0%) , the reduction in compressive strength is about (48.2 %). With using 15% p/c , the reduction is a bout (4.2%) see **(Figure 7).**

The reduction in modulus of elasticity for (1:1.5:2) reference mix is about (57.7), while in 15% p/c mix , is about (3.8%) see **(Table 3)**

Discussion

The improvement in properties of concrete with adding styrene butadiene rubber seen in previous **Figures (2-7)**, is very excellent, because of the action of styrene butadiene rubber (Watanable, 2005)

Polymer latex modification of concrete is governed by both cement hydration and polymer film formation processes (wang, 1978), some chemical reactions may take place between the surface of polymer particles and calcium ions (Ca^{+2}) , $Ca(OH)_2$ solid surfaces , or silicate surfaces over the aggregates (Kaempfer, 2006, Ye, 2005)

Moreover, there are other reasons that cause this improvement in the properties of these mixes ; the first is that the voids in the reference mixes are filled up by polymer particles when using the polymer with 15% , (p/c=15%) , also , it appears that the microcracks in latex - modified mortar and concrete under stress are bridged by the polymer films or membranes formed , which can prevent cracks propagation , and that a simultaneously strong cement hydrate- aggregate bond is developed (Ohama, 1998)

Therefore, these reasons cause the prefect reduction in compressive strength and modulus of elasticity after FTC

Conclusion

1. The action of FTC on concrete with different mix proportions without using polymer is very high with respect to polymer modified concrete (PMC) .
2. (PMC) with 15% p/c gives perfect results in both compressive strength and static modulus of elasticity .
3. PMC gives a perfect durability against cycles of freezing and thawing, because of the action of polymer – film formation and less voids inside the concrete.

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Table 1: Sieve Analysis of Aggregates

I.S. Sieve Designation	% Passing by weight	Indian standard (I.S.) for grading zone II
10 mm	100	100
4.75 mm	93	90-100
2.36 mm	85	85-100
1.18 mm	77	75-100
600 micron	62	60-79
300 micron	20	12-40
150 micron	1.0	0-10

Table 2: Chemical Composition of Styrene Butadiene Rubber (SBR)

Infra-Red (I.R) Test	PH	Humidity Content	Solid Particle content %
Styrene Butadiene Rubber with small percentage of admixtures	8.2	42.4	57.42

Table 3: The Reduction in Elastic Modulus of Elasticity Due to FTC

Mix. Proportion	W/C	% P/C	Chord Modulus of Elasticity Before FTC(GPa)	Chord Modulus of Elasticity After FTC (GPa)	Reduction in Elastic Modulus Due to FTC%
1:2:4	0.35	15	47.0	42.4	9.8
1:2:4	0.4	0	24.4	7.8	68
1:1.5:3	0.35	15	67.8	67.5	0.4
1:1.5:3	0.4	0	29.3	12.6	57
1:1.5:2	0.35	15	71.3	68.6	3.8
1:1.5:2	0.4	0	37.1	15.7	57.7

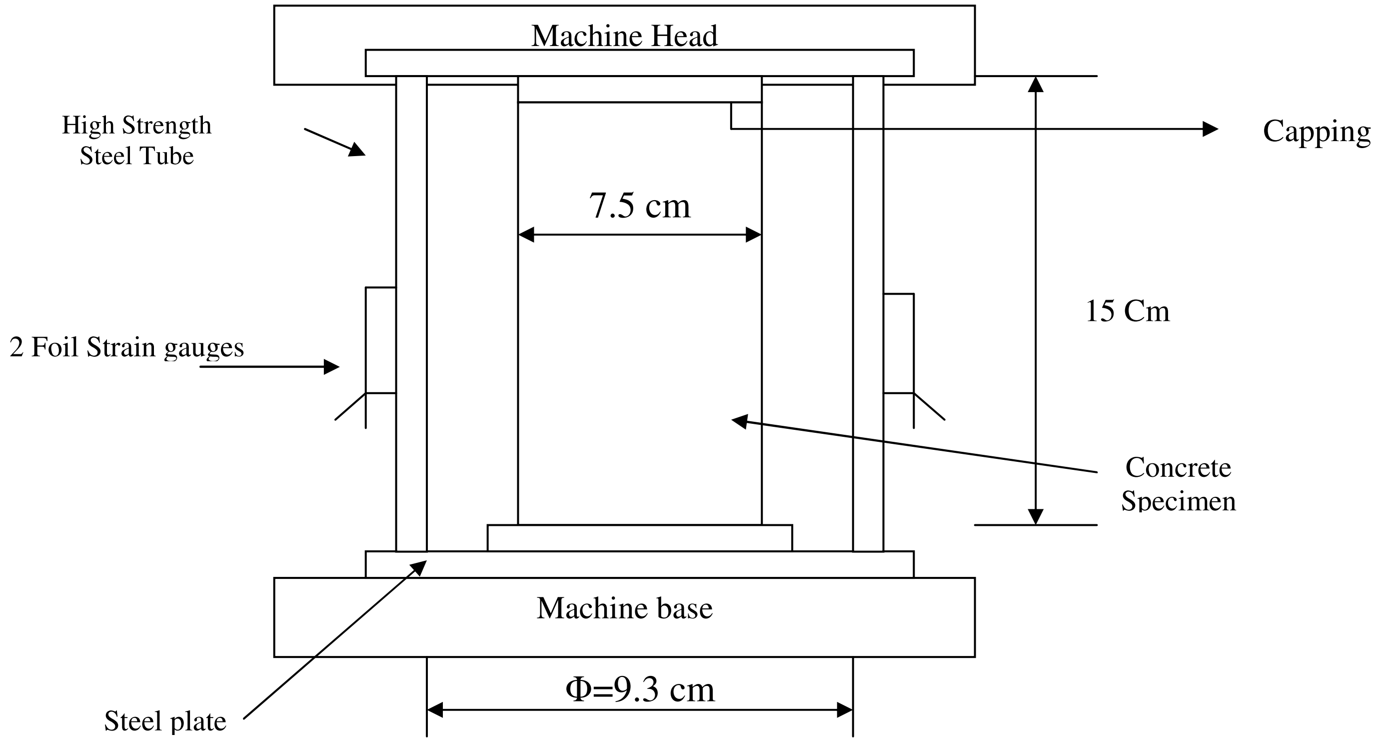

Figure1- Test Set up

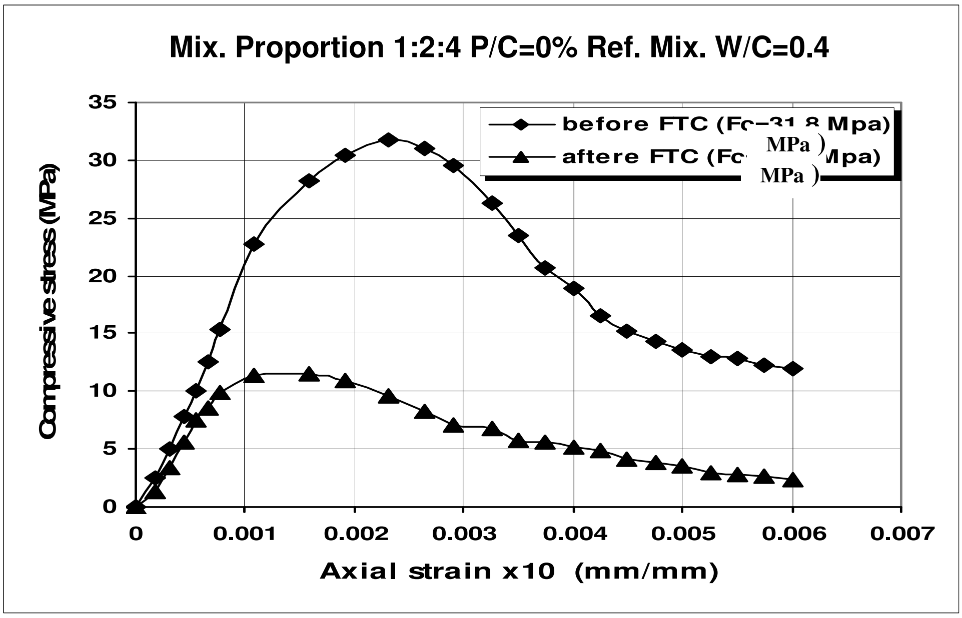

Figure (2) The effect of FTC on stress-strain behaviour for ordinary concrete (without polymers) with (1:2:4) mix proportion

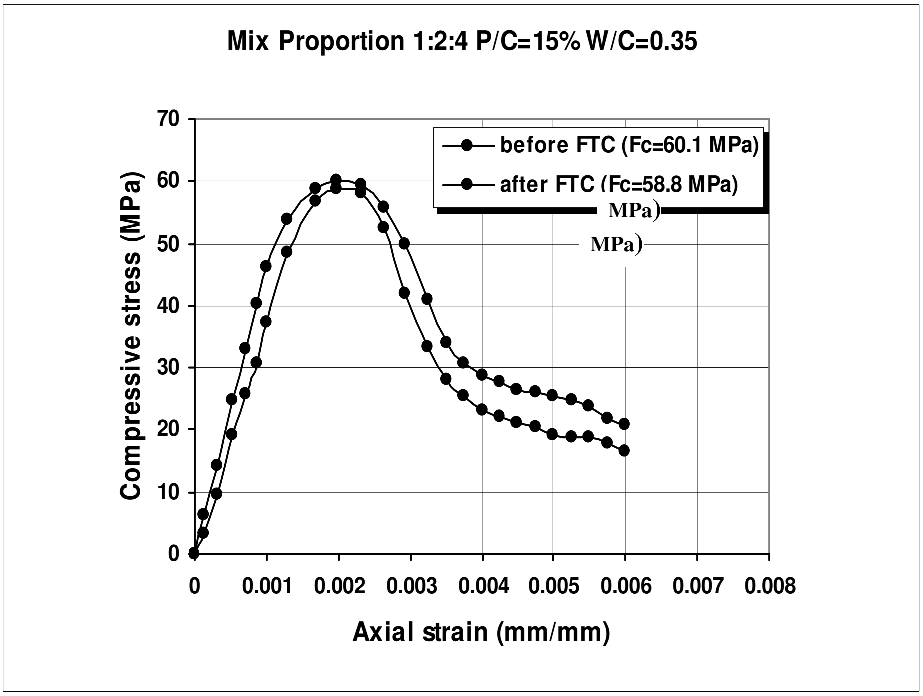

Figure (3) The effect of FTC on stress-strain behaviour for PMC with mix proportion of (1:2:4).

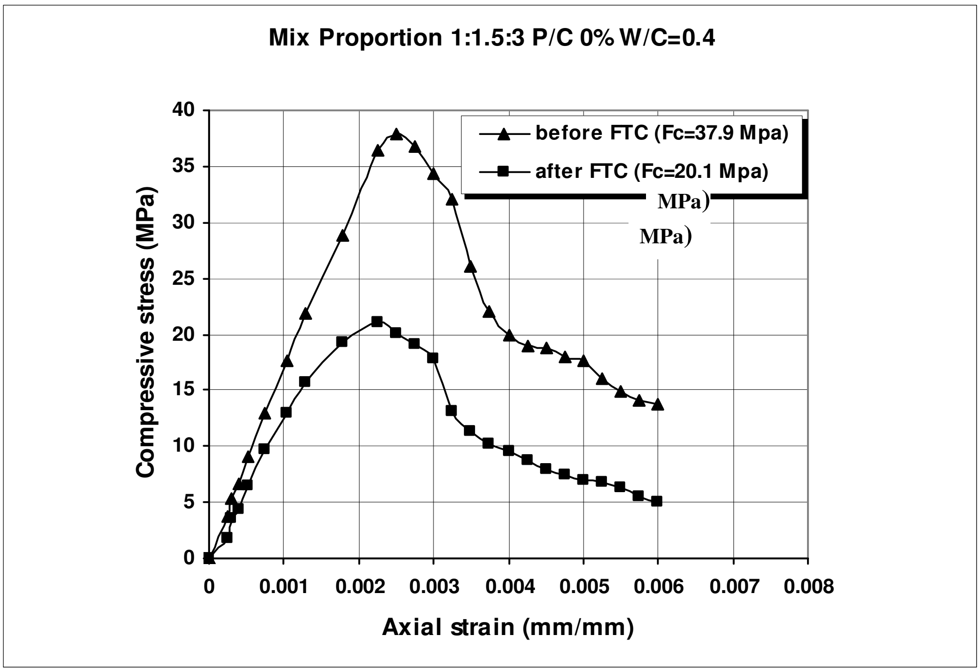

Figure (4) The effect of FTC on stress-strain behaviour for (1:1.5:3) mixes Without polymers

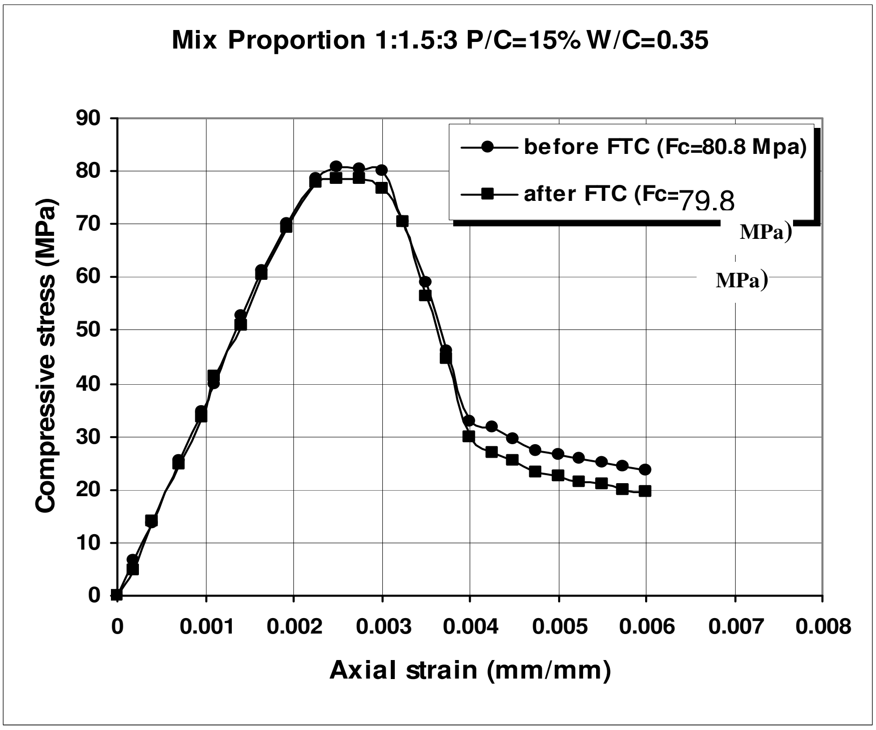

Figure (5) The effect of FTC on stress-strain behaviour for PMC of (1:1.5:3) mixes.

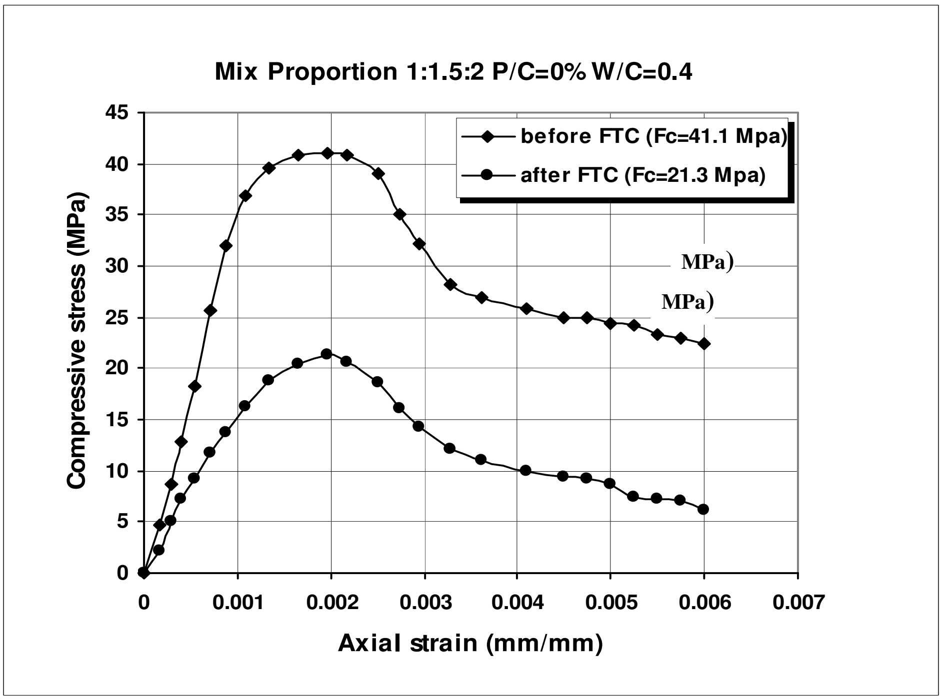

Figure (6) the effect of FTC on stress-strain behaviour for (1:1.5:2) mixes
Without polymers

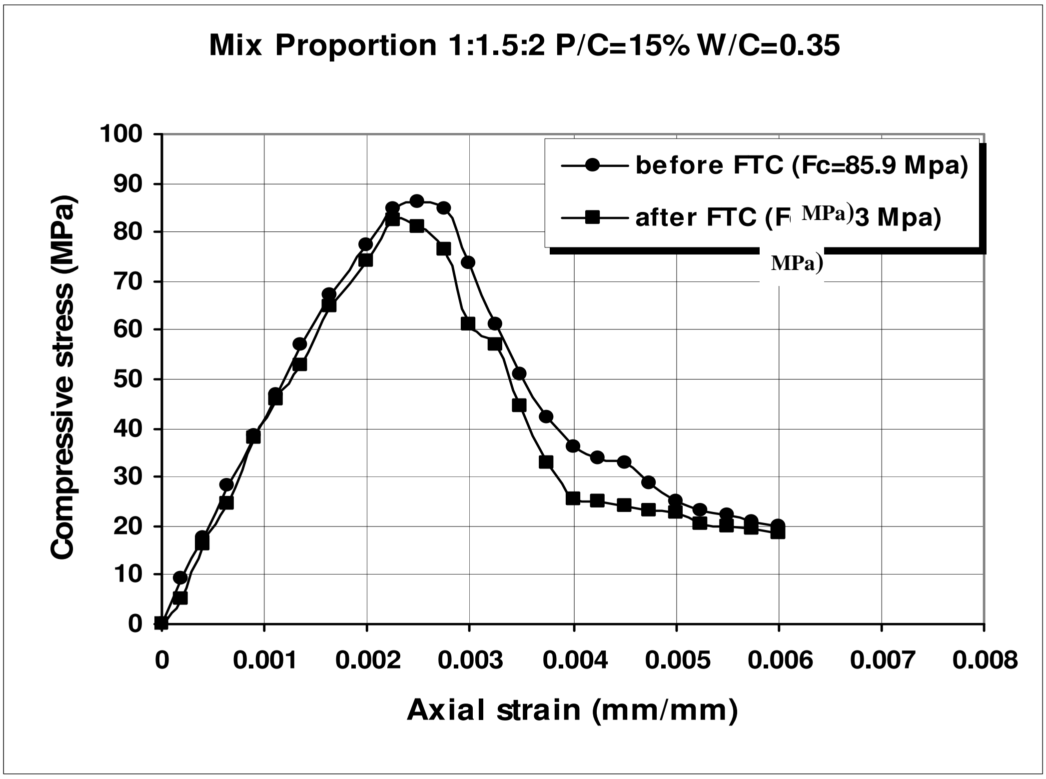

Figure (7) The effect of FTC on stress-strain behaviour for PMC
of (1:1.5:2) mixes.