# TENSILE STRENGTH OF HIGH STRENGTH POLYMER MODIFIED CONCRETE

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## Abstract

High strength concrete is widely used especially during the last century. High Strength concrete means concrete with max. Compressive strength ( $fc'$ )more than 50 N/mm$^2$ (Shetty, 1988). Polymer modified concrete was) used since 1970s by adding polymer monomers such as styrene Butadiene rubber (SBR) to ordinary concrete during casting as a percentage of weight of cement in order to improve the mechanical properties of concrete.

This research includes the study of the effect of styrene Butadiene Rubber on Tensile Strength of Polymer modified concrete PMC, also include the effect of the polymer on compressive strength and relationship between tensile and compressive strength (as a mathematical model). A different types of mixes (1: 1.5: 2, 1:1.5:3 and 1:2:4) were used in this research.

**Keywords: Polymer modified concrete, Compressive strength, Tensile strength, styrene Butadiene rubber, Cylinder splitting**

# مقاومة الشد للخرسانة المطورة بالبوليمر والعالية المقاومة

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## الخلاصة

إن الخرسانة المطورة بالبوليمرات أصبحت من المواد الشائعة الاستخدام في الصناعة الإنشائية والتي بدأت في السبعينات من القرن الماضي في اليابان والولايات المتحدة ثم شاعت الاستخدام على مستوى العالم.
الخرسانة العالية المقاومة مثل الخرسانة المطورة بالبوليمر أيضا استخدمت بصورة شائعة في القرن الماضي والخرسانة العالية المقاومة تعني الخرسانة التي مقاومة انضغاطها العظمى أكثر من (50) ميكا باسكال واستخدم هذا النوع من الخرسانة في بداية السبعينات عن طريق إضافة مستحلبات البوليمرات مثل مستحلب الستايرين بيوتادين للخرسانة الاعتيادية أثناء صب الخرسانة وإنتاجها كنسبة مئوية من وزن الاسمنت لتحسين الخواص الميكانيكية للخرسانة الاعتيادية .,
ويتضمن هذا البحث تأثير هذا المستحلب على مقاومة الشد للخرسانة المطورة بالبوليمر ويتضمن أيضا تأثير إضافة نسب مختلفة من ( الستايرين بيوتادين ) على مقاومة الانضغاط واستخراج موديلات رياضية لهذه العلاقات إضافة إلى استنباط موديل رياضي يربط مقاومة الانضغاط بمقاومة الشد وتم استخدام نسب خلط مختلفة من ( الاسمنت : الركام الناعم: الركام الخشن) في هذا البحث.

**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)

## Polymer Modified Concrete PMC

This type of concrete means a concrete composed of cement latex and aggregates with polymer added as a percentages by weight of cement.
This type of concrete can be used for high loaded structural members and also for both pre-cast and prestressed concrete (Vipulanandan, 1990)

## Tensile strength of " PMC "

The study of Tensile strength of concrete is very important .
For prestudies , the increase of compressive strength leads to increase tensile strength.
There is a different relationships between compressive and tensile strength; some researches, gives the tensile strength as a percentage form the compressive strength ranged between 1/8 to 1/12 (Neville, 1995). This investigation gives a better improvement in tensile strength, and also a better ( $ft / fc'$ ) ratio .Indirect Tension test is used in this study by splitting of cylinder using the following equation (Eq.1 )

$$f_t = \frac{2p}{\pi dL} \qquad \ldots(1)$$

The High value of tensile strength may lead to use less tension bars of Reinforcement and make the construction of Building more economic.

## Aim and Scope of Work

The aim of this investigation is to study the effect of (SBR) polymer on Tensile strength PMC and also the optimum P/C(polymer/cement) that gives the Higher values of Both compressive and tensile strength also anew mathematical model is suggested to relationship between: P/C with tensile strength, P/C with compressive strength and tensile strength with compressive strength.

## Materials

Ordinary Portland cement (Type I) was used in this work. Aggregates with specific gravity of 2.79.
The max: size Aggregate is 10mm with grading shown in this **Table 1** blow . SBR polymer with specifications shows in **Table 2** was used in this study.

**Concrete Mixing Procedure**

Aggregates were added to a mechanical mixer with max. capacity of $0.1m^3$ before adding the cement .

After adding the cement, the mixer turned on with adding water according to W/C ratio then the (SBR) polymer should be added to be the homogeneous mix and the mixing should be continued until all particles are fully coated with (polymer- cement paste) matrix.

Also, the total mix should have a uniform or homogeneous colour.

Ohama (Ohama, 1998) adopted this procedure under title "Modification with liquid polymers", also this mixing procedure was illustrated by Radomir (Radomir, 1998)

**Program layout**

The program layout is shown in **(1).**

**Curing**

Using air curing in all polymer mixes, specimens of dimensions (150 × 300mm) were cured in water for six days and 21 days in air with temp ( Average temp. $20^oC$)

This is the best method of curing. Radomir (Radomir, 1998) illustrate the best method for curing for polymer modified concrete see **Figure (2)**

**Specimens**

Using (3) specimens for each mix, the specimens of dimensions of (150×300 mm) where used for both compressive and indirect tension tests, capping were used only for compression tests .

The max. Size Aggregates for all mixes was 10mm. (W/C) ratio used in this study were: 0.30 for polymer mixes and 0.35 for reference mixes because of the action of polymers that's tend to reduce the W/C ratio for concrete and improve the Mechanical properties (Bentur, 1982)

**Specimens Tests**

**a.Compressive strength tests**

Using rate of loading according to ASTM (39/C 39M-2001), (ASTM, 2001) standard specifications for determination of static Modulus of elasticity and poisons ratio of concrete in compression. This test was done using ELE compression testing machine with max capacity (2000 kN).

Capping is done in this work for all cylinder specimens (for compression test ) in order to obtain uniformly distributed load under applied load, and also to obtain accurate readings, the capping was made by means of cement paste and by glass plate of about 7mm in thickness and of a length about (diameter of cylinder +30 mm) (Shetty, 1988). The capping was done after (4hrs) of casting so that the concrete in cylinder mould undergoes plastic shrinkage and subsides fully.

**b. Indirect Tensile Strength " Cylinder splitting "**

A three specimens for each mix were used and also the same rate of loading and same ELE testing machine is used.

**c. Development of tensile and compressive strength, and Mathematical models.**

Table 3, shows the effect of the increase in P/C ratio on compressive strength, P/C of 15% Gives the higher value of compressive strength (or optimum value ) for all mixes. (1:1.5:2) (cement :Fine Agg.: Coarse Agg ) mixes gives the Maximum Compressive strength of about (83.3) MPa. **Table (4)**, shows the effect of the increase in P/C on tensile strength, 15% P/C is the optimum P/C that gives the maximum tensile strength for all mixes;

Both tensile and compressive strength are improved by adding polymer, this improvement due to double influence of polymer caused by the polymer films formation of SBR polymer and a co-matrix phase is formed by both cement hydration and polymer film formation processes (Ohama, 1997). Also, another factors that causes improvement in the properties for this type of concrete; the first is that the voids in this type of concrete is fill up by polymers, and some polymer particles bond with cement hydrates and silicate surfaces of Aggregates. Also, Some chemical reactions may take place between the particles surfaces of polymers and calcium ions ($Ca^{+2}$), $Ca(OH)_2$ solid surfaces, or silicate surfaces of aggregates (Sujjavnith, 1998). **Figure (3)**, shows the effect of the increase in P/C up to 25% of weight of cement on the compressive strength for different mixes. The mathematical model shown in equations **2,3 and equation 4**.

$$Fc = -0.1757 * (P/C)^2 + 5.297 * (P/C) + 39.29 \quad \ldots(2)$$

$R^2 = 0.88$ [ For mix. Proportion =1:1.5:2]

$$Fc = -0.135 * (P/C)^2 + 4.945 * (P/C) + 28.92 \quad \ldots(3)$$

$R^2 = 0.98$ [ For mix. Proportion =1:1.5:3]

$$Fc = -0.093 * (P/C)^2 + 3.316 * (P/C) + 27.54 \quad \ldots(4)$$

$R^2 = 0.96$ [ For mix. Proportion =1:2:4]

Where : $R^2$ Correlation Coefficient

**Figure (3)**, it can be seen that optimum P/C ratio is found as 15% , this optimum P/C Was also found 15% for maximum tensile strength. **Figure (4)**, shows the effect of P/C on Tensile strength of (PMC), the mathematical model also given in equation **(5), (6)** and equation **(7)** as follows:

$$Ft = -0.0277\,(P/C)^2 + 0.989\,(P/C) + 4.79 \qquad \ldots(5)$$

$R^2 = 0.96$ [ For 1:1.5:2 mixes]

$$Ft = -0.0126\,(P/C)^2 + 0.62\,(P/C) + 3.246 \qquad \ldots(6)$$

$R^2 = 0.98$ [ For 1:1.5:3 mixes]

$$Ft = -0.0133\,(P/C)^2 + 0.607\,(P/C) + 2.739 \qquad \ldots(7)$$

$R^2 = 0.96$ [ For 1:2:4 mixes]

A straight line related the data in **Figure 5** with equation illustrated as Equation **(8)**. This equation is a perfect equation shows that the increase in compressive strength due to the increase of (P/C); leads to increase in tensile strength,

In this research the increase in tensile strength is more than (1/8) of $fc'$ [as in the previous investigations]. Now we can see from **Table (3)**, if $Fc'$=83.3 gives indirect tensile strength $Fc'$=13.9, the $ft/fc'$ ratio equals to 1/6, and also for some other mixes the ratio becomes more than 1/6 , this due to the action of (SBR), while the ratio of *ft/fc* for ordinary concrete of the same mixes without (P/C) gives ($ft/fc'$) ratio of about (4.4/36.1)=(1/8.2). **Figure (5)** shows a relationship between tensile and compressive strength of (PMC).

$$Fc = 4.538(Ft) + 18.004 \qquad \ldots.(8)$$

**<u>Conclusions</u>**

1- Concrete specimens with different mix proportions developed with adding polymers. P/C of (15%) gives maximum values of both tensile and compressive strength.
2- The proposed model for polymer modified concrete (PMC) has a general form for all mixes. The constants change from mix to fit the shape of (P/C- compressive and tensile ) relations; and it is found from the second degree.
3- The proposed model for compressive – tensile strengths is found as a straight line (first degree) Equation and if we derive the equation then we can find $\frac{dy}{dx} = \frac{fc}{ft} = 4.54$ in general
4- The improved mixes in this study did not submit to previous relations that gives the value of tension as a percentage from compressive strength. *(ft/fc)* [As we seen in paragraph(3)].

In this research the value *(ft/fc)* is found as (1/4.54), this ratio is bigger than the previous ratio (1/8 – 1/10) that indicate the *(ft/fc)* for ordinary concrete in previous studies. This perfect improvement in Tensile strength make this type of (PMC) more useful and more economic for structural design and may lead to use less tension steel bars and make the construction more economic.

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**Table 1: Grading of Coarse and fine aggregates**

| I.S Sieve Designation | Percentage passing by weight (%) | Indian Standard (I.S) for grading(Zone III) |
|---|---|---|
| 10mm | 100 | 100 |
| 4.75mm | 90 | 90-100 |
| 2.36mm | 88 | 85-100 |
| 1.18mm | 83 | 75-100 |
| 600micron | 74 | 60-79 |
| 300micron | 18 | 12-40 |
| 150 micron | 2 | 0-10 |

**Table 2: Chemical composition of SBR**

| Infra-Red(I.R.)test | PH% | Humidity content | Solid Particles content % |
|---|---|---|---|
| Styrene Butadiene rubber with small percentage of admixtures | 8.2 | 42.4 | 57.42 |

**Table (3): The effect of (P/C) on compressive strength of (PMC).**

| P/C / Mix proportion | P/C 0% | P/C 5% | P/C 10% | P/C 15% | P/C 20% | P/C 25% |
|---|---|---|---|---|---|---|
| 1:1.5:2 | 36.1* | 67.8* | 71.1* | 83.3* | 67.7* | 65.3* |
| 1:1.5:3 | 30.1* | 48.3* | 63.7* | 76.1* | 72.3* | 68.0* |
| 1:2:4 | 28.9* | 40.2* | 48.8* | 60.3* | 56.4* | 51.7* |

*** Compressive strength in $N/mm^2$(MPa)**

**Table (4): The effect of (P/C) on tensile strength of (PMC).**

| Splitting Tensile Strength (MPa) | | | | | | |
|---|---|---|---|---|---|---|
| P/C / Mix proportion | P/C 0% | P/C 5% | P/C 10% | P/C 15% | P/C 20% | P/C 25% |
| 1:1.5:2 | 4.4 | 9.9 | 11.3 | 13.9 | 12.7 | 12.5 |
| 1:1.5:3 | 3.5 | 5.8 | 7.6 | 10.3 | 10.8 | 10.6 |
| 1:2:4 | 3.0 | 5.2 | 6.8 | 9.7 | 9.5 | 9.4 |

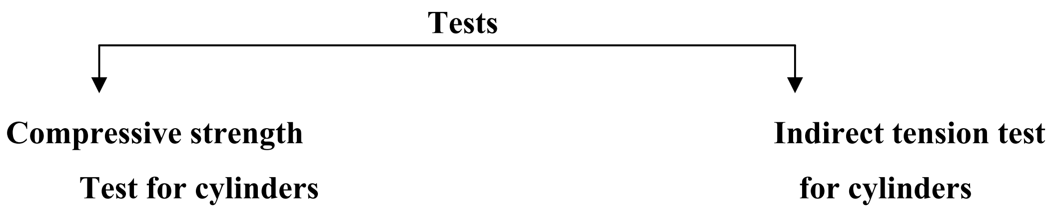


Figure **(1)** Experimental program of this work

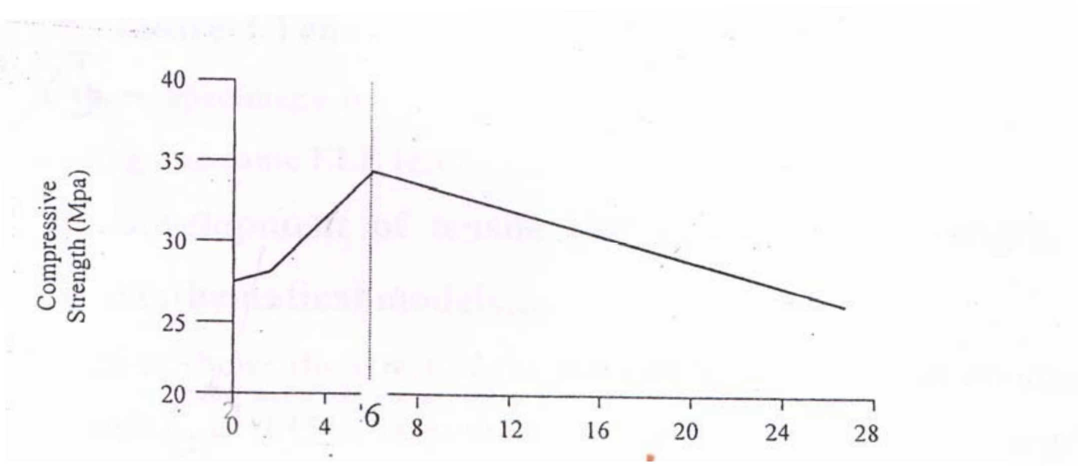


Figure **(2)** Effect of curing conditions on compressive strength for modified polymer concrete (5)

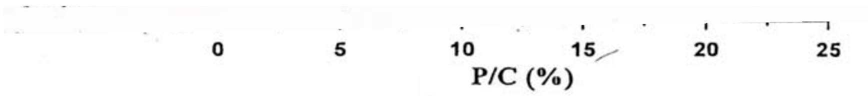


Figure **(3)** The effect of the increase in (P/C) on compressive strength of (PMC)

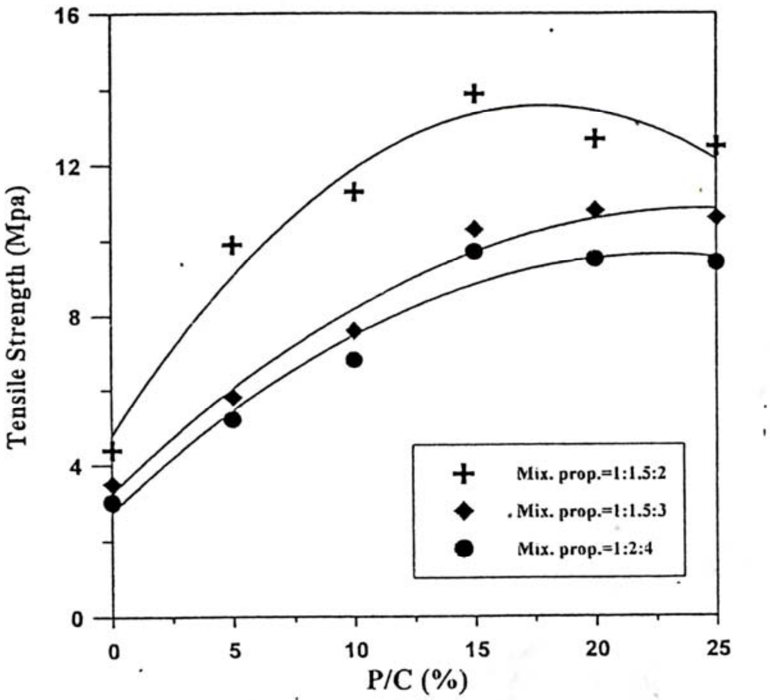


Figure **(4)** The effect of the increase in (P/C) on tensile strength of (PMC)

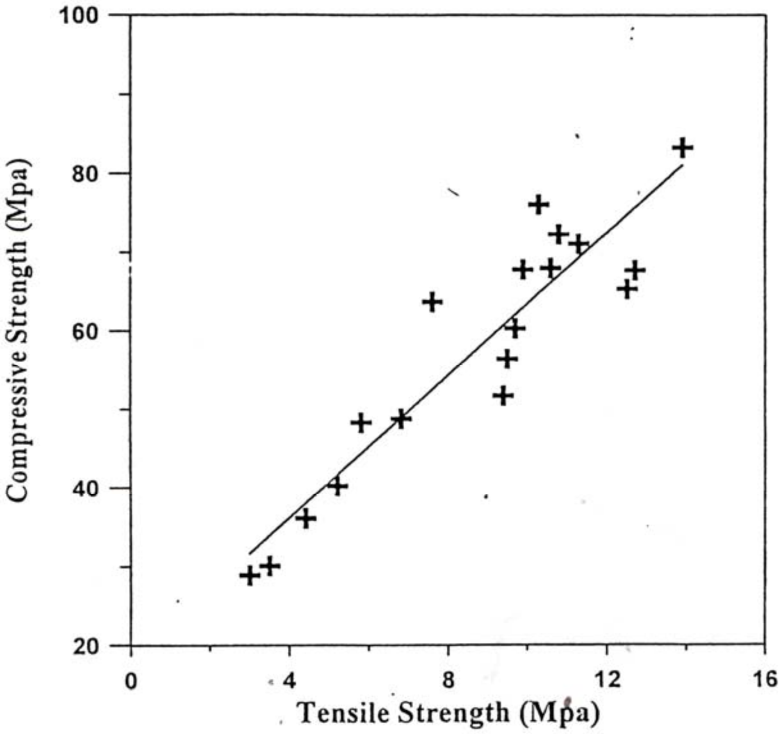


Figure **(5)** Shows a mathematical model for the relationship between tensile strength and compressive strength for different mixes of PMC.