International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 4, Issue 2, pp: (82-100), Month: October 2016 - March 2017, Available at: www.researchpublish.com

EFFECT OF ADDING POLYMERS TO CONCRETE ON THE BEHAVIOR OF R.C. BEAMS EXPOSED TO FIRE

Magdy.M.M Genidi[1], Hany.R.M.Mahmoud[2]

[1]Associate Professor - Department of Structural Engineering. Faculty of Engineering - Helwan University
[2]Teaching assistant at Faculty of Engineering Egyptian Russian University (ERU)

***Abstract*: The main objective of this Thesis is study the effect of adding polymers to concrete on the behavior of R.C. beams exposed to fire under loading on the behavior of reinforced concrete (RC) beams under different fire and cooling conditions. Experimental Work includes eighteen beams were tested with rectangular section its dimensions (120 * 250 * 1650) mm, divided into six groups, using different polymer ratio (R_P) equal to (0%, 5%, and 10%) from cement weight. First and second groups were tested at room temperature. The third and fourth groups were loaded by 30% of the load measured at room temperature and then subjected to a temperature of 700° C for one hour then the load was increased up to failure. The fifth and sixth groups were loaded by 30% of the load measured at room temperature and then subjected to a temperature of 700 ° C for one hour then cooling by water then the load was increased up to failure. Analysis of test results shows clear improve in Flexural and shear Strength by adding polymer for the R.C beams not exposed to fire. But in the R.C beams exposed to fire the Flexural and shear Strength decreased by adding polymer.**

***Keywords:* RP; temperature; Flexural and shear Strength.**

---

1. INTRODUCTION

Fire remains one of the serious potential risks to most buildings and structures. The extensive use of concrete as a structural material has led to the need to fully understand the effects of fire on concrete. Generally concrete is thought to have good fire resistance .

Exposing concrete to high temperature causes strength deterioration, reduction in bond strength with reinforcement and increase in the risk of reinforcement corrosion due to high permeability and cracks. Previous studies indicate that the concrete the reduction of strength happened in concrete at high temperatures. This reduction depends on many factors such as: specimen dimensions, loading conditions, concrete strength, temperature level, heating duration and method of cooling.

Also previous studies indicate that concrete containing Styrene Butadiene Rubber (SBR) polymer had high tensile strength than that of plain concrete and using of polymer may lead to reduction in the amount of cracking under serviceability conditions.

Up till now, there are many studies about the mechanical properties of reinforcement concrete (RC) beam subjected to high temperature. Almost the investigations have been focused on the mechanical behaviors of RC beams during heating or after heated under an unloading state, only have a few studies been reported on the mechanical properties of RC beams after exposed to fire in a loading sate. So that the aim of this research is to study the effect of adding Styrene Butadiene Rubber (SBR) polymer on the behavior of R.C beams exposed to fire under loading.

1.1. Principles of Polymer Modification

Although polymer-based admixtures in any form such as polymer latexes, water-soluble polymers and liquid polymers are used in cementitious composites such are mortar and concrete. It is very important that both cement hydration and polymer film formation (coalescence of polymer particles and the polymerization of resins) proceeds well to yield a monolithic matrix phase with network structure in which the cement hydrate phase and polymer phase interpenetrate. In polymer-modified mortar and concrete structures, aggregates are bound by such co-matrix phase, resulting in superior properties compared with conventional cementitious composite [1].Polymer latex modification of cement mortar and concrete is governed by both cement hydration and polymer film formation. The cement hydration process generally precedes the polymer film formation process by the coalescence of polymer particles in polymer latexes [2 , 1]. In due course both cement hydration and polymer film formation processes form a co-matrix phase. The co–matrix phase is generally formed according to the simplified model given by Ohama [2], and integrated model by A.Beeldens, et al. [3] , shown in Fig (1) [2].

Some chemical reactions happen between polymers and cement hydration that lead to improve the bond between cement hydrates and aggregates [2].

1.2. Styrene Butadiene Rubber (SBR) Polymer Modified Concrete

SBR Polymer is the most widely used in concrete. Fig. (2), shows the chemical structure of Styrene butadiene Rubber latexes. Co-polymers of butadiene with styrene (styrene-butadiene rubber (SBR)), are a group of large-volume synthetic rubbers [4]. High adhesion occurs between the polymer films that form and cement hydrates. This action gives less strain compared to ordinary concrete and improves the properties of concrete such as flexural and compressive strength and gives also a higher durability. [2].

2. EXPERIMENTAL WORK

Eighteen R.C. beams with rectangular cross-section, sized 120 mm (width) x 250 mm (height) x 16500 mm length, were manufactured and tested as shown in Figure (3).

Two parameters were considered in this study; variable polymer ratio and variable treatment fire methods. Details of tested specimens with different parameters are shown in Table (1).

The behavior of reinforced concrete beams with different polymer ratio equal to 0%, 5%, and 10% by cement weight exposed to a fire is the main objective of studied. Therefore, a total of eighteen beams classified into six groups as shown in Table (1).

The first group have three tested specimens contained polymer ratio equal to0, 5%, and 10%, and flexural failure mode and the second group have tested specimens with polymer ratio equal to 0, 5%, and 10% have shear failure mode. And also, the group G3 and G5 have six tested specimens with the same content and dimension as control group G1 and G2 respectively. Finally, the groups G4 and G6 have six tested specimens with the same content and dimension as control groups G1, and G2 respectively.

In the groups G3, and G4, the beams were loaded first up to 0.30 of the ultimate load resulted from the control beams (without polymer ratio) in group G1, and G2. Under this load, the beams were exposed to fire to reach 700 C^o during one hour, and after that the loads increased immediately after the firing up to the failure.

In the groups G5, and G6, the beams were loaded first up to 0.30 of the ultimate load resulted from the control beams (without polymer ratio) in group G1, and G2. Under this load, the beams were exposed to fire to reach 700 C^o during one hour. And then the beams were cooled by using water and after that the loads increased immediately up to ultimate load.

Concrete mix used to cast the tested RC beams have concrete compressive strength 25MPa consisted of Portland cement, natural aggregates, SBR polymer, and natural water. The properties of SBR polymer in table (2).

Mixing is performed using a concrete drum mixer with maximum capacity 0.125 m3. Sand, dolomite and cement were dry mixed for about until a homogenous color.

Then the water with SBR polymer was gradually added while mixing was continued for two minutes. The concrete was cast in the molds and cured at about 95 percent relative humidity.

The testing frame was consisted of steel I-beams rested on four steel columns. All tested beam specimens were supported on the testing frame during firing and loading as shown in figure 4. The cantilever I-beam was rested in two supports. One of them is the tested beam to create load acting at the center of the tested beam and the anther support is hinged as shown in Figure 5. The acting reaction generated in the center of tested beam by the cubes load, this acting reaction considered as the working load (30% from ultimate load). During load process after this, the loading was increased using the tying of the loading nuts as displacement control.

Digital Load cell of capacity of 550 kN with accuracy of 0.1 kN was adopted to measure the applied loads. The values of the applied loads were recorded from the monitor connected to the load cell. The beams were tested using an incremental loading procedure. The vertical displacement of the tested beams was recorded using two electric dial gauges, one at the middle of beams and the other at distance equal to one fourth lengths from the support. During tests, after 30% from applied load, the displacement was kept constant at each load stage for measuring and observing.

3. TEST RESULTS AND ANALYSIS

In this part, the behavior RC beam containing SBR polymer exposed to fire under different conditions is analysis. Comparing between cracks patterns and load deflection curves are discussion. The values of ultimate loads are analysis.

3.1. Crack Patterns and Modes of Failure

The crack patterns and mode of failures shows in figure 6.for groups G1 and G2, as shown in figure 7 and 8, the failures are a flexural and shear type respectively and, by adding the SBR polymer, the cracks width decreased and the numbers of cracks at tension zone near the main reinforcement increased. When tested specimens exposed to fire in groups G3 and G4 the cracks pattern and mode of failures for tested specimens under fire, as shown in figure 8 and 9, concluded that the fire not change in the mode of failures And the failures were flexural- shear and flexural-bond failure because of decreasing the compressive strength of concrete and yield strength of main steel bars.

When tested specimens in groups G5 and G6 exposed to fires then cooling, as shown in figures 10 and 11, the deformation happened at the middle zone of tested specimens and the diagonal cracks decreased.

3.2. Load Deflection Curved

From groups G1and G2, find that the stiffness of tested specimens increased by adding polymer. But the tested specimens have polymer ratio equal to5% and 10% is more stiffness than that without polymer. In groups G3, G4, G5 and G6 the tested specimens exposed to fire, the adding polymer causing decreased stiffness after fire than that before fire and also more than the control specimens

3.3. Failure Load

For R.C tested beams with flexural failure mode that were not exposed to fire, by increasing the polymer ratio to 5% and 10%, the failure load increased by 11 % and 23 % respectively compared with the referential beam. And Also in case of fire then cooling by air, by increasing the polymer ratio to 5% and 10% the failure load decreased by 20% and 15 % respectively compared with the referential beam. Moreover, in case of fire then cooling by water, by increasing the polymer ratio to 5% and 10% the failure load decreased by 10 % and 10 % respectively compared with the referential beam.

These increases in strength capacity may be attributed to three. The first is that; PMC had less W/C ratios, which gave higher strengths. The second is that, the use of SBR polymer leads to form a continuous three-dimensional network of polymer molecules throughout concrete which increases the binder system due to good bond characteristics of the polymer SBR. The last is the partial filling of pores with polymer which reduces the porosity, and hence increases the strength Y. Ohama [5]. and also increases ductility may be attributed to the polymer concrete contain polymers (modulus of elasticity, 0.001-10 x $l0^4$kgf/cm^2) with considerably smaller modulus of elasticity compared to cement hydrates (modulus of elasticity, 10 _ 30 x 10^4kgf/cm^2). Consequently, their deformation behavior and ductility (or extensibility) can different to a great extent from those of ordinary cement concrete. [6]

For RC tested beam with shear failure mode not exposed to fire, by increasing the polymer ratio to 5% and 10%, the failure load increased by 4% and 10 % respectively compared with the referential beam. In addition, in case of fire then cooling by air, by increasing the polymer ratio to 5% and 10% the failure load decreased by 14 % and 11 % respectively compared with the referential beam. Also in case of fire then cooling by water, by increasing the polymer ratio to 5% and 10% the failure load decreased 19 % and 18 % respectively compared with the referential beam.

4. CONCLUSIONS

Based on the analysis of the experimental results of the tested RC beams contained polymer exposed to fires, the following conclusions can be drawn:-

1. By increasing polymer ratio the flexural and shear strength capacity of beams increased and the number of cracks decreased compared to control beam without fire.
2. The optimum ratio of polymer in concrete 10% by cement weight.
3. For flexural failure mode and shear failure mode, in the case of fire and cooling by air, the strength capacity of tested beam were decreased by adding polymer
4. The used of polymer Reduces the resistance of RC beam during by restrained the deformation during fire.

REFERENCES

[1] Fukuchi,T. and Ohama,Y.,"Manfacturing High-Strength Concrete". Int.Symposium, SP-58, ACI, Detriot, 1978:215-224.

[2] Ohama, Y., “Polymer-Based Admixtures.” Cement and Concrete Composites J., 1998, 20, pp. 189-212.

[3] Beeldens, A. ; Germert,D. V. ; Ohama,Y. and Czarnecki, L. ; "FromMicrostructure to Macrostructure: an Integrated Model of Structure Formation in Polymer Modified Concrete", 4th Asia Symposium of Polymers in Concrete, Korea, May 1-3, 2003. (Internet report).

[4] McCrum, N.G., Buckley .C.P. and BucknaIi.C.B.."Principles of Polymer Engineering ".Oxford University Press. 2Ed. 1997.pp. 447.ZS1

[5] Yoshihiko Ohama, HANDBOOK OF POLYMER-MODIFIED CONCRETE AND MORTARS Properties and Process Technology

[6] Shiroishida, K., “Durability of Polymer-Modified Mortars (in Japanese),” pp. 136216,Master Thesis, College of Engineering,Nihon University, Koriyama, Japan (1983)

[7] Kobayashi, K., and Kimachi, Y., “Improvement of Ductility of Concrete through the Addition of Polymer Dispersion (in Japanese),”pp. 414-417, Semento-Gijutsu-Nempo 31 (Dec. 1977)

APPENDIX - A

List of Tables:

Table (1): The Experimental Program

Group	Specimen Code	SBR Content%	Heating Temp.	Cooling method
G1	B1-F-0%-C	0	Non	Non-Cooling
	B2-F-5%-C	5	Non	
	B3-F-10%-C	10	Non	
G2	B4-Sh-0%-C	0	Non	
	B5-Sh-5%-C	5	Non	
	B6-Sh-10%-C	10	Non	
G3	B7-F-0%-H	0	700 C°	Air
	B8-F-5%-H	5	700 C°	
	B9-F-10%-H	10	700 C°	
G4	B10-Sh-0%-H	0	700 C°	
	B11-Sh-5%-H	5	700 C°	
	B12-Sh-10%-H	10	700 C°	
G5	B13-F-0%-W	0	700 C°	Water jet
	B14-F-5%-W	5	700 C°	
	B15-F-10%-W	10	700 C°	
G6	B16-Sh-0%-W	0	700 C°	
	B17-Sh-5%-W	5	700 C°	
	B18-Sh-10%-W	10	700 C°	

Table (2): Properties of SBR Used in the Experimental Work

No	Properties	Description
1	Colour	White Emulsion
2	Less degree to form athin membrane of latex	4^{o}c
3	Percentage of solid material	47 ± 3%
4	PH Value	7.5±1.5
5	Density	1.02±0.02 kg/L

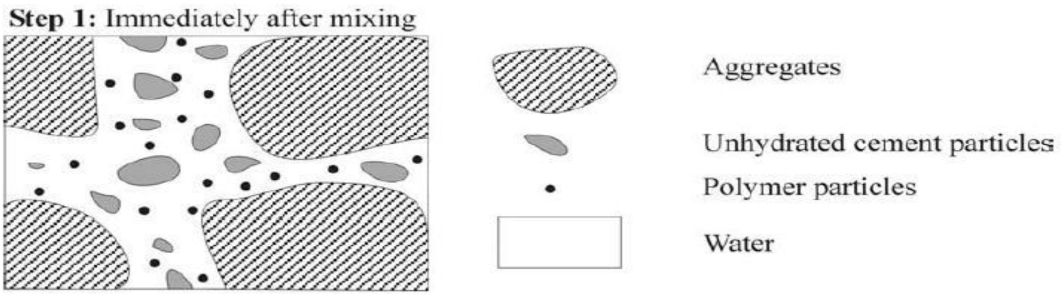
Table (3): Failure Load for Tested specimen'sFlexural failure mode

Group	Specimen	Polymer ratio(%)	Fire Condition	P_u(kN)	Pu/Pu^{1*}%	Pu/Pu^{2*} %
G1	B1-F-0%-C	0	No Fire	72	100	100
	B2-F-5%-C	5		80	100	111
	B3-F-10%-C	10		88.7	100	123
G3	B7-F-0%-H	0	Fire & Air Cooling	60	83	100
	B8-F-5%-H	5		47.6	59	79
	B9-F-10%-H	10		51	57	85
G5	B13-F-0%-W	0	Fire & Water Jet Cooling	55	76	100
	B14-F-5%-W	5		50	62	90
	B15-F-10%-W	10		50	56	90

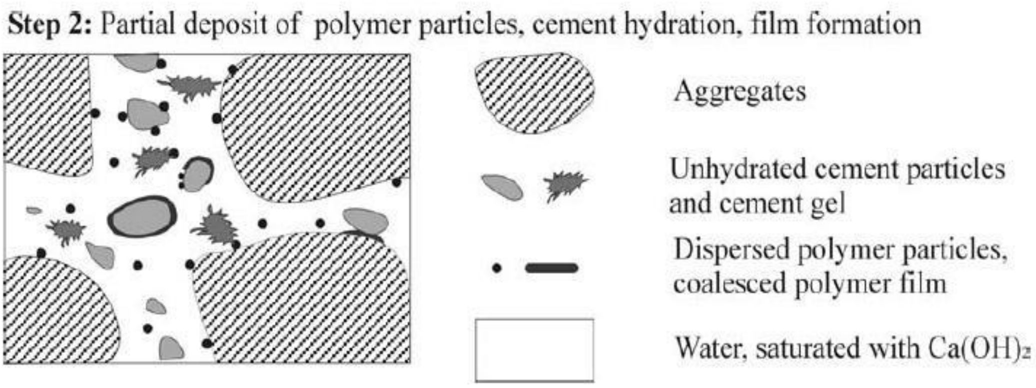
Table (4): Failure Load for Tested specimens shear failure mode

Group	Specimen	Polymer ratio(%)	Fire Condition	P_u(kN)	Pu/Pu^{1*}	Pu/Pu^{2*}
G2	B4-Sh-0%-C	0	No Fire	150	100	100
	B5-Sh-5%-C	5		156	100	104
	B6-Sh-10%-C	10		165	100	110
G4	B10-Sh-0%-H	0	Fire & Air Cooling	113	75	100
	B11-Sh-5%-H	5		97.2	62	86
	B12-Sh-10%-H	10		100	60	88
G6	B16-Sh-0%-W	0	Fire & Water Jet Cooling	107	71	100
	B17-Sh-5%-W	5		87	56	81
	B18-Sh-10%-W	10		88	53	82

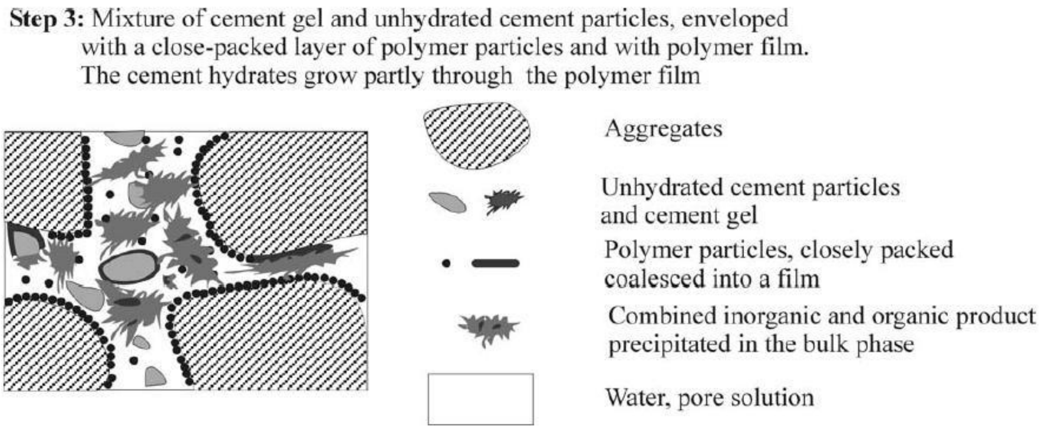
List of Figures



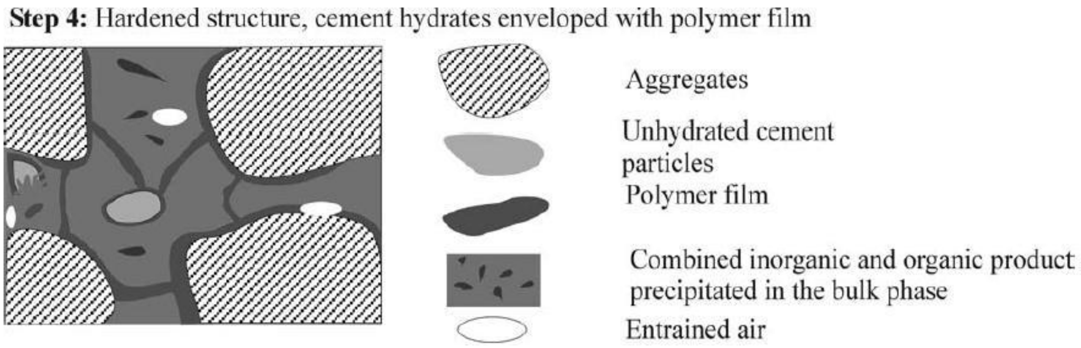
(a) Immediately after mixing



(b) Partial deposit of polymer particles, cement hydration, film formation



(c) Cement hydration proceeds, polymer film formation starts on specific spots.



(d) Cement hydration continuous, the polymer particles coalesce into aContinuous film.

Fig. (1): Integrated model of structure formation [2].

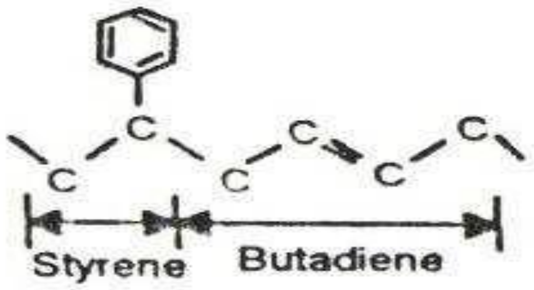
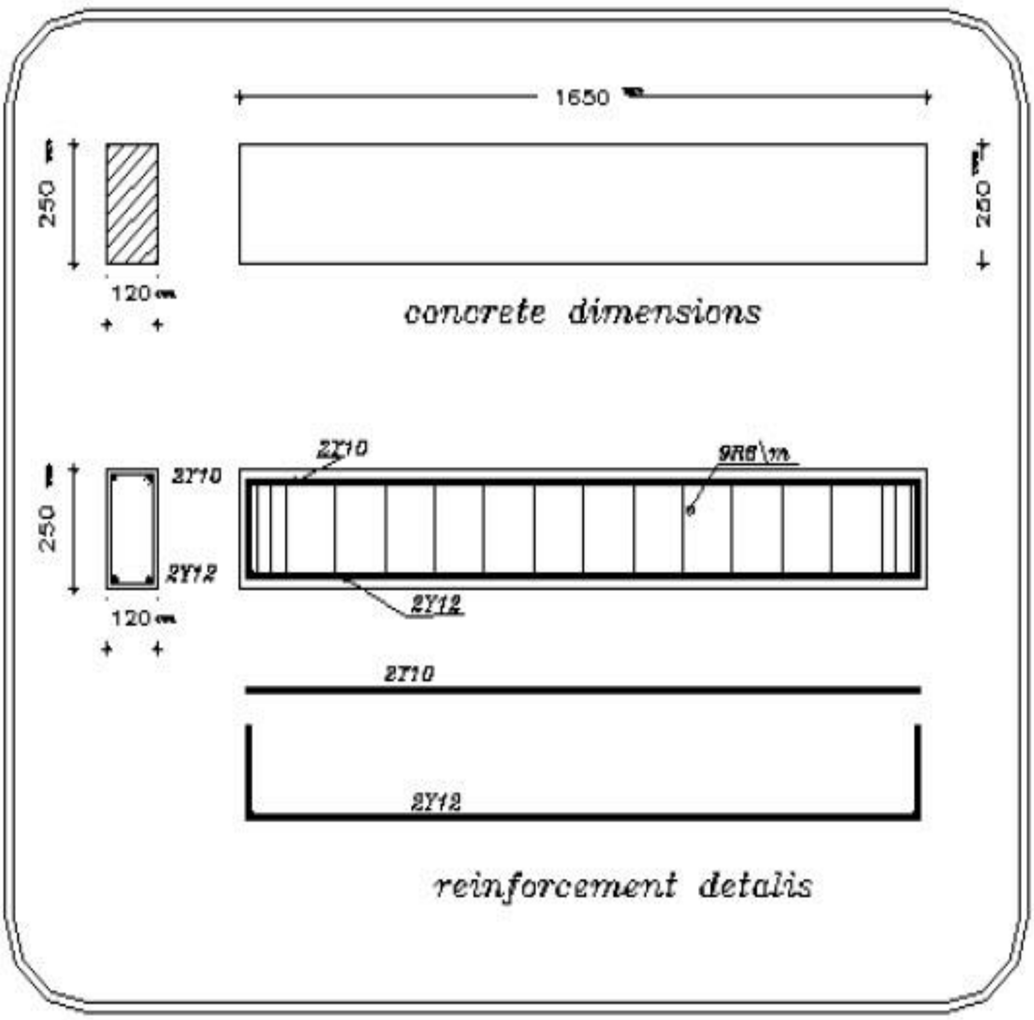


Fig. (2) Chemical structures of SBR polymer latexes [6]



All Dimentions In mm

Figure (3): Details of Typical Specimen.

Figure (4): Test Setup

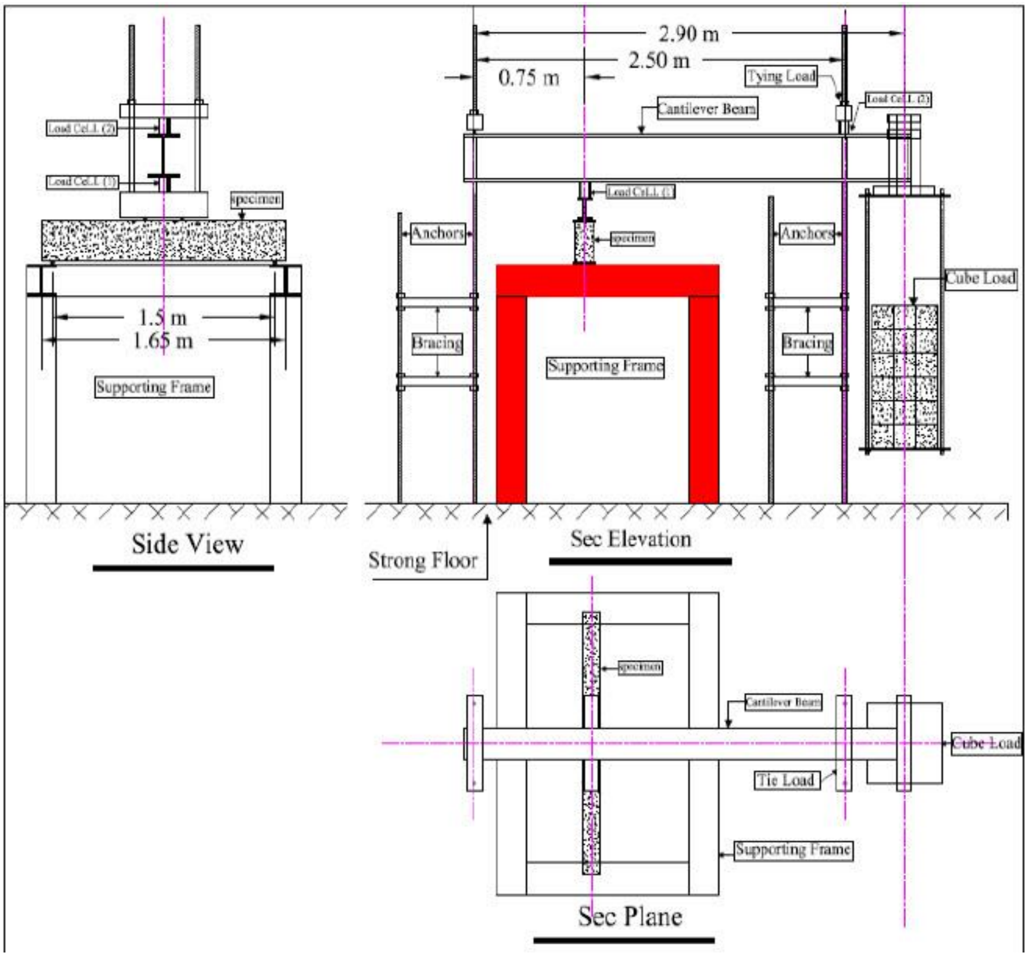


Figure (5): Sketch Test Setup

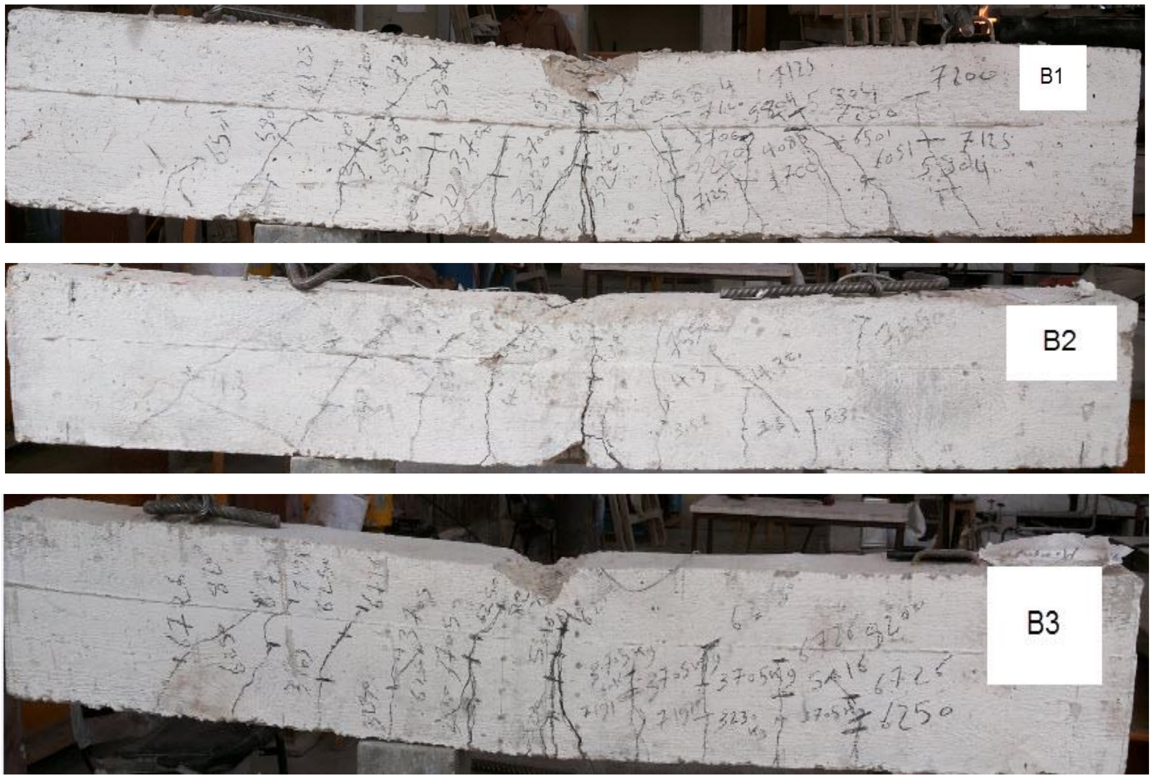


Fig (6): The Crack Patterns for Group1

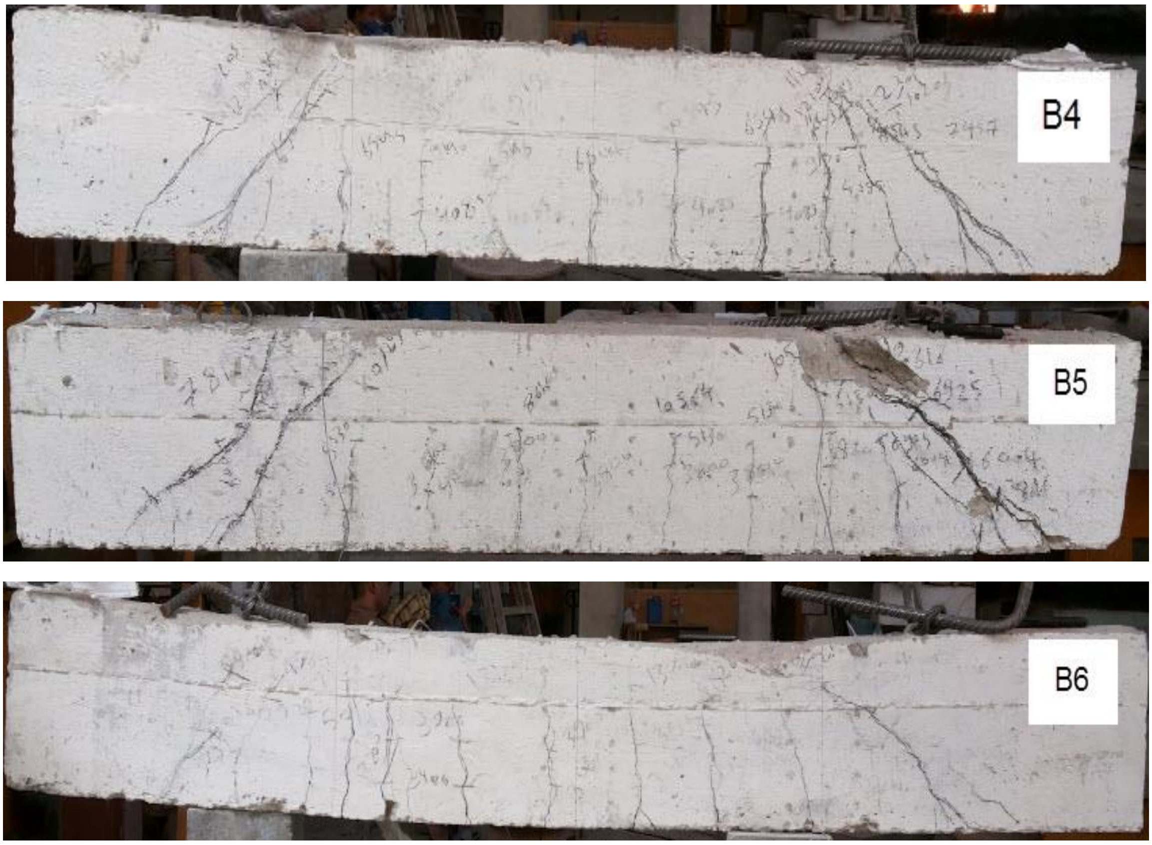


Fig (7): The Crack Patterns for Group 2

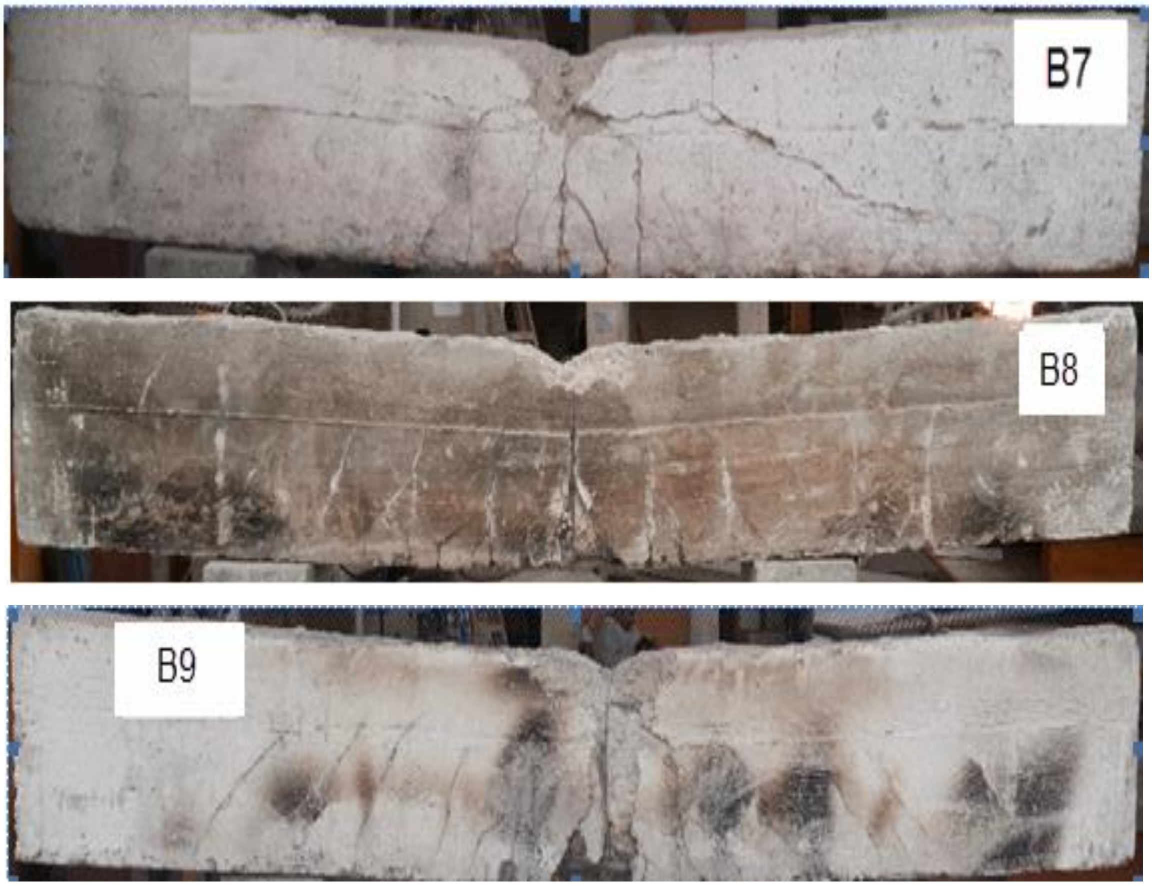


Fig (8): The Crack Patterns for Group 3

Fig (9): The Crack Patterns for Group 4

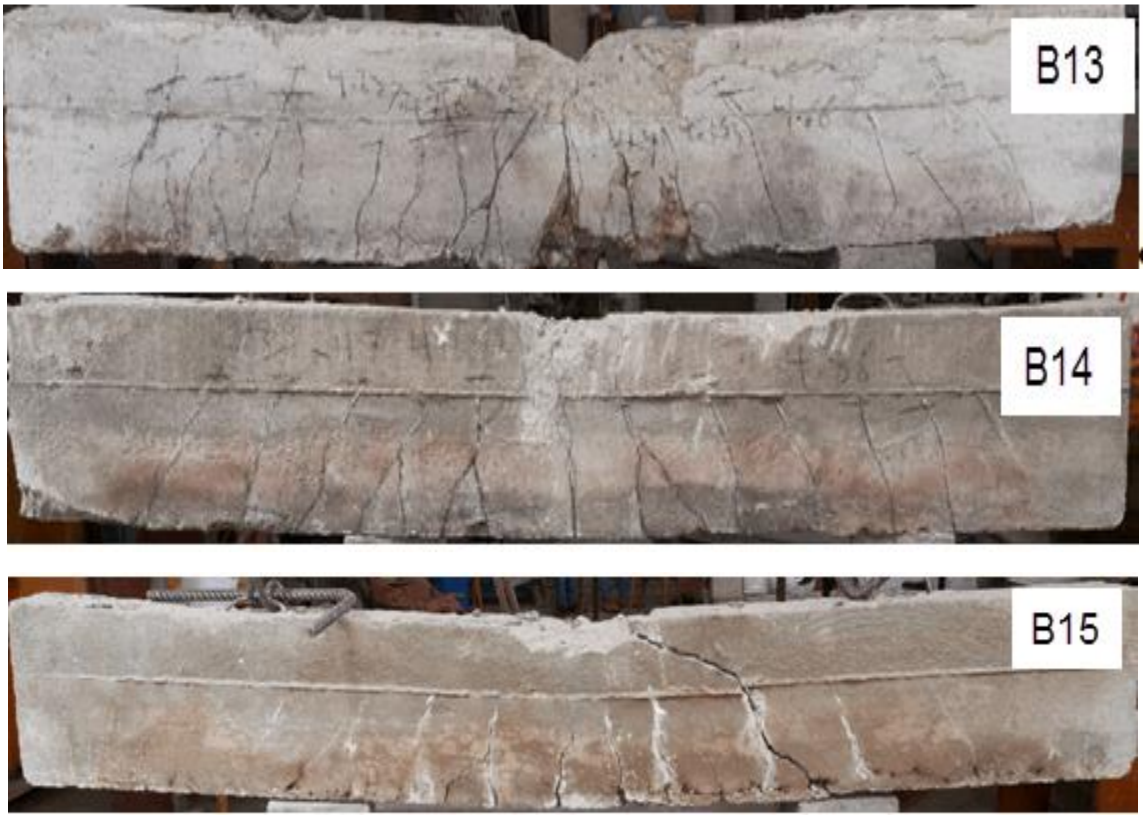


Fig (10): The Crack Patterns for Group 5

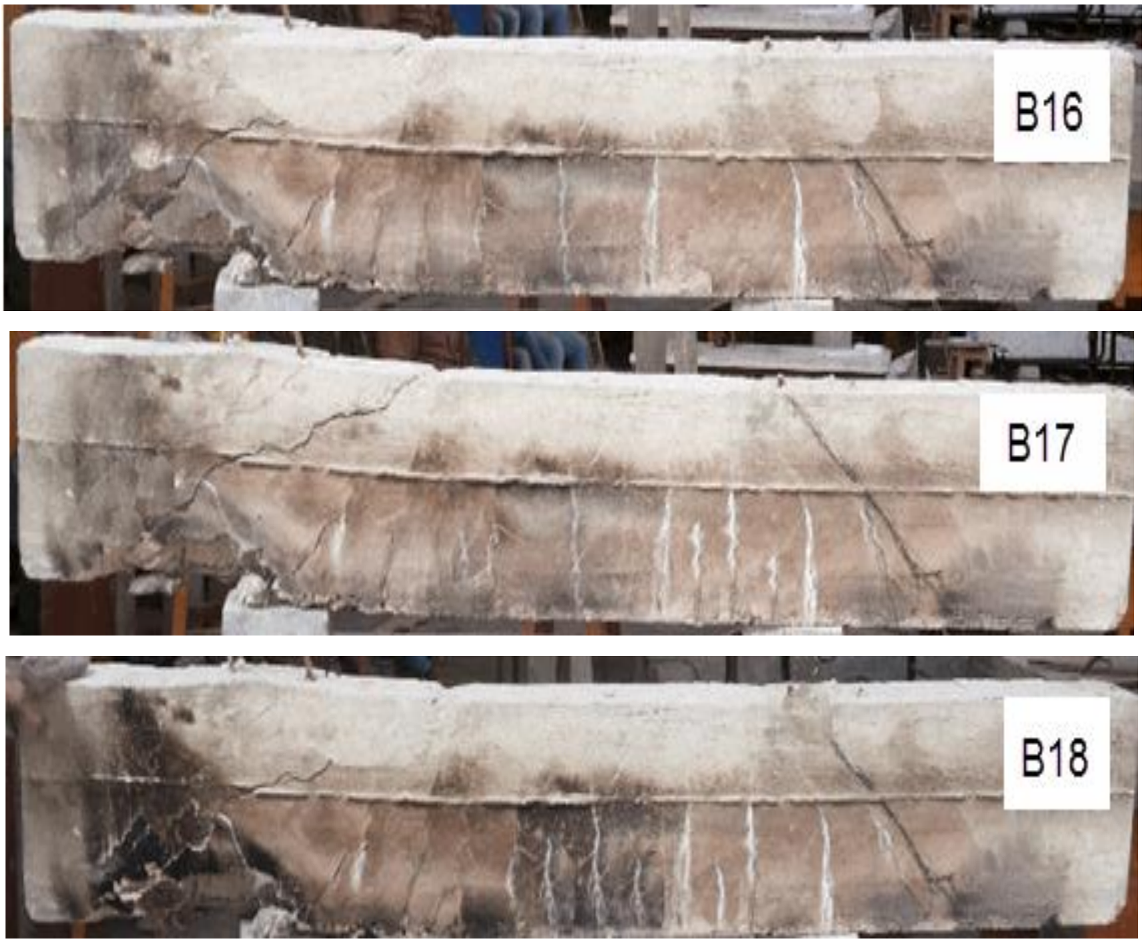


Fig (11): The Crack Patterns for Group 6

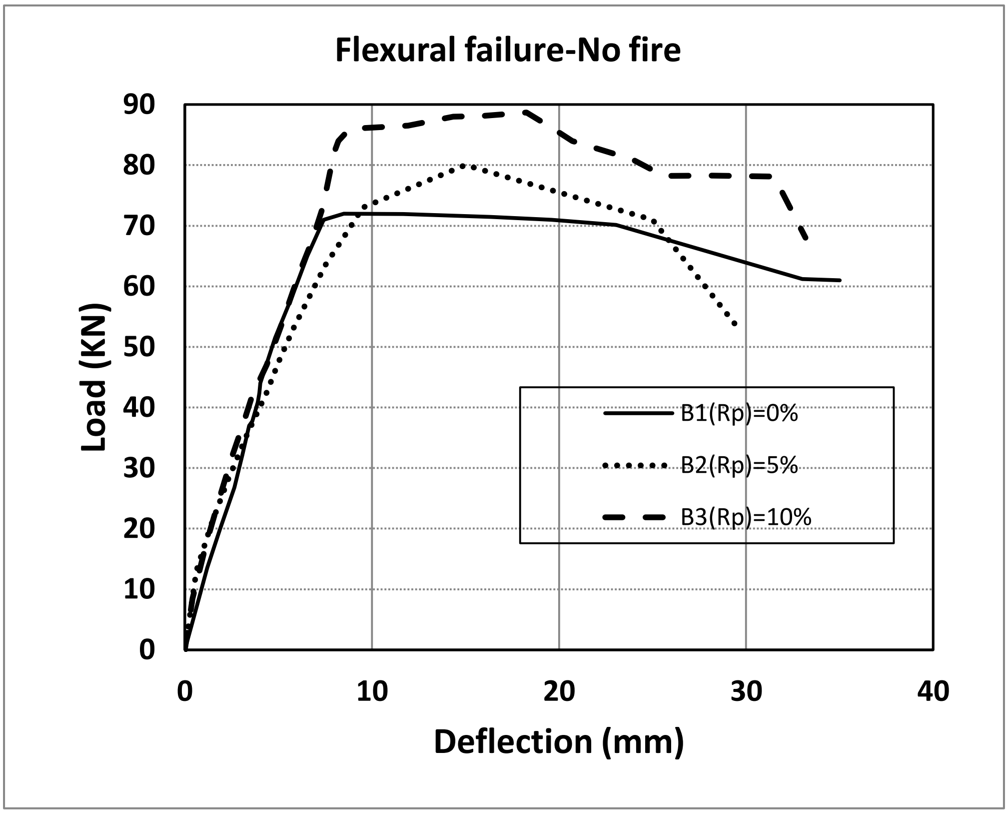


Fig (12): Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With flexural failure mode, No Fire

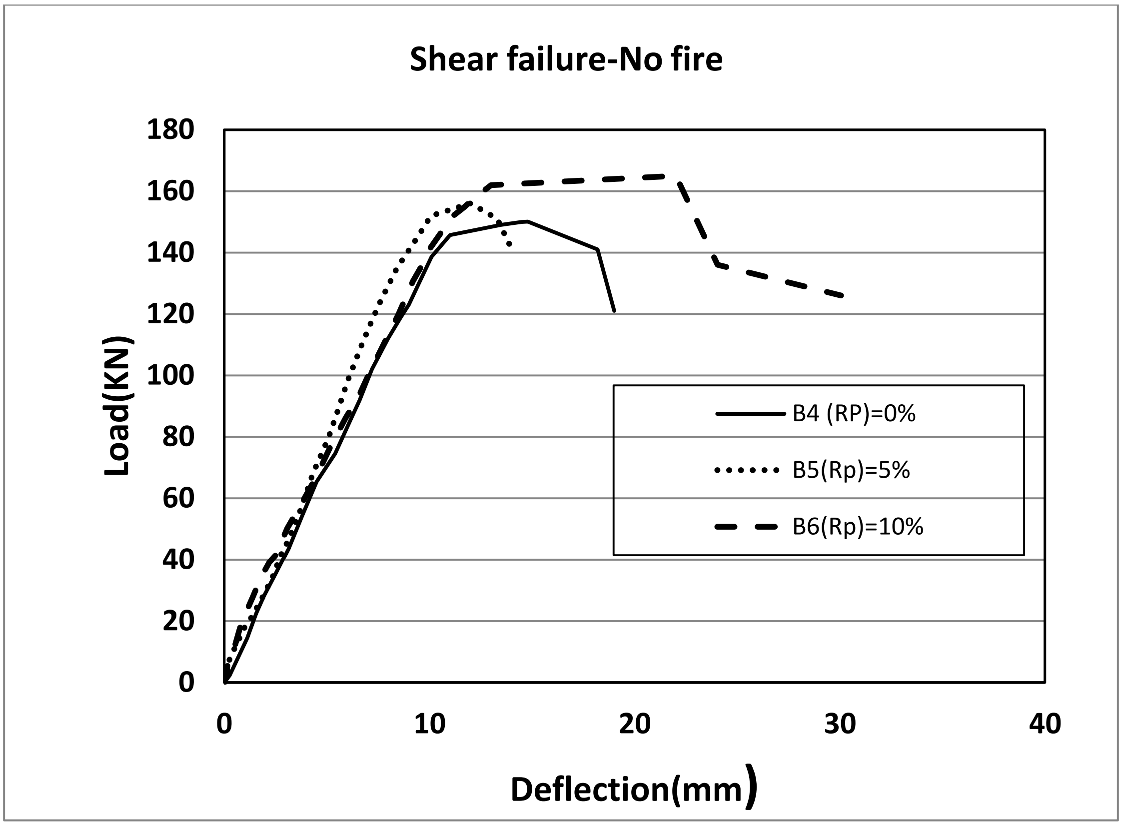


Fig (13): Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With Shear failure mode, No Fire

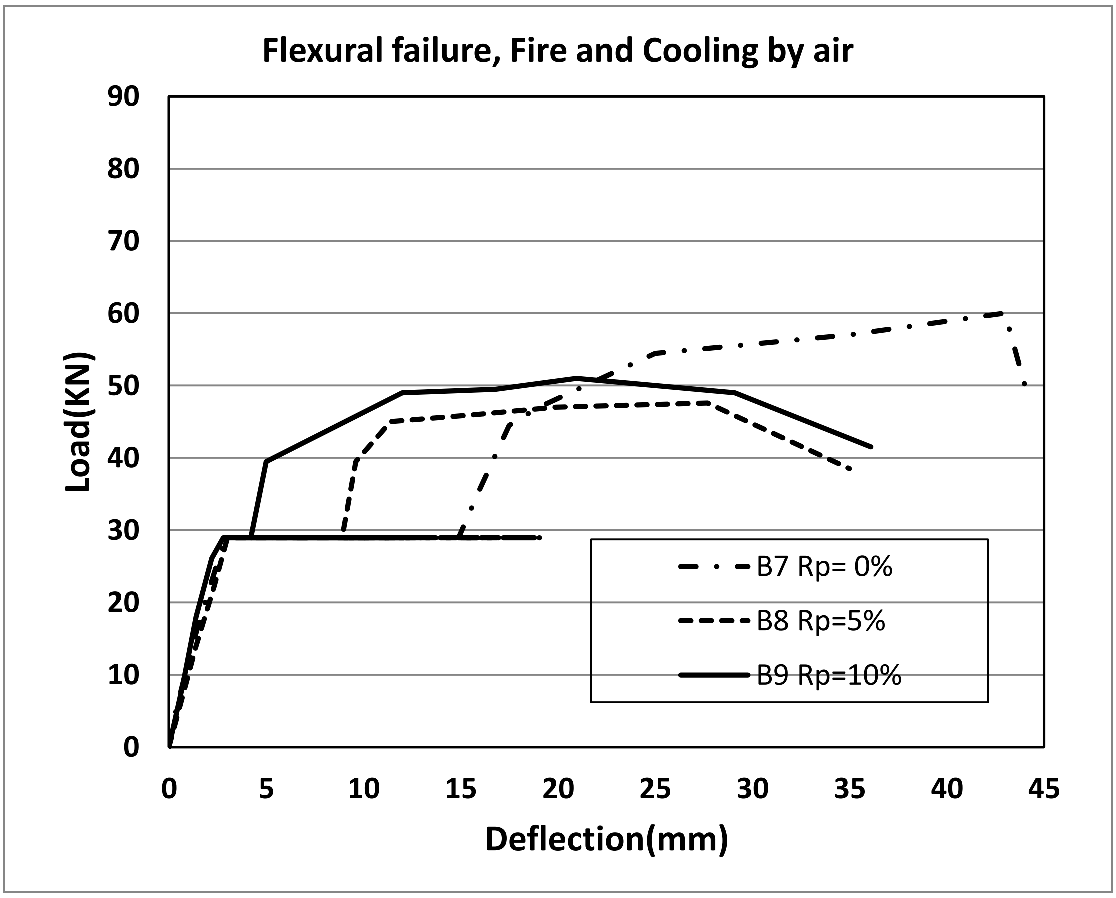


Fig (14) Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With flexural failure mode,Fire and Cooling by air

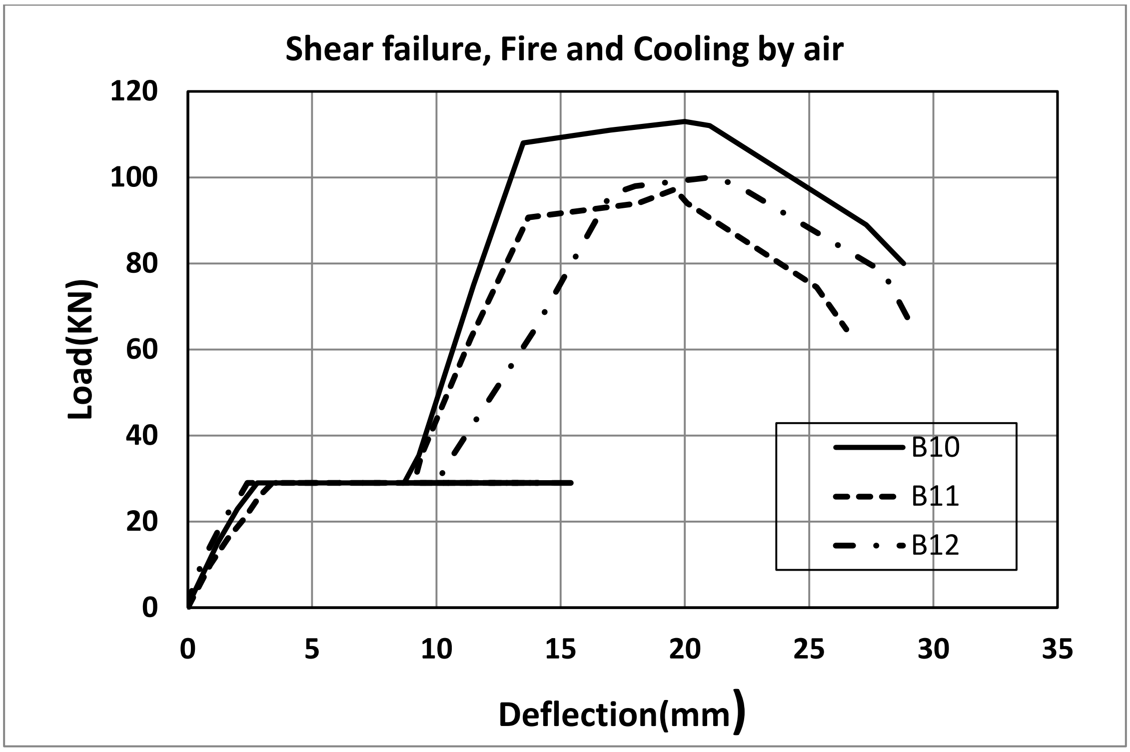


Fig (15): Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With shear failure mode,Fire and Cooling by air.

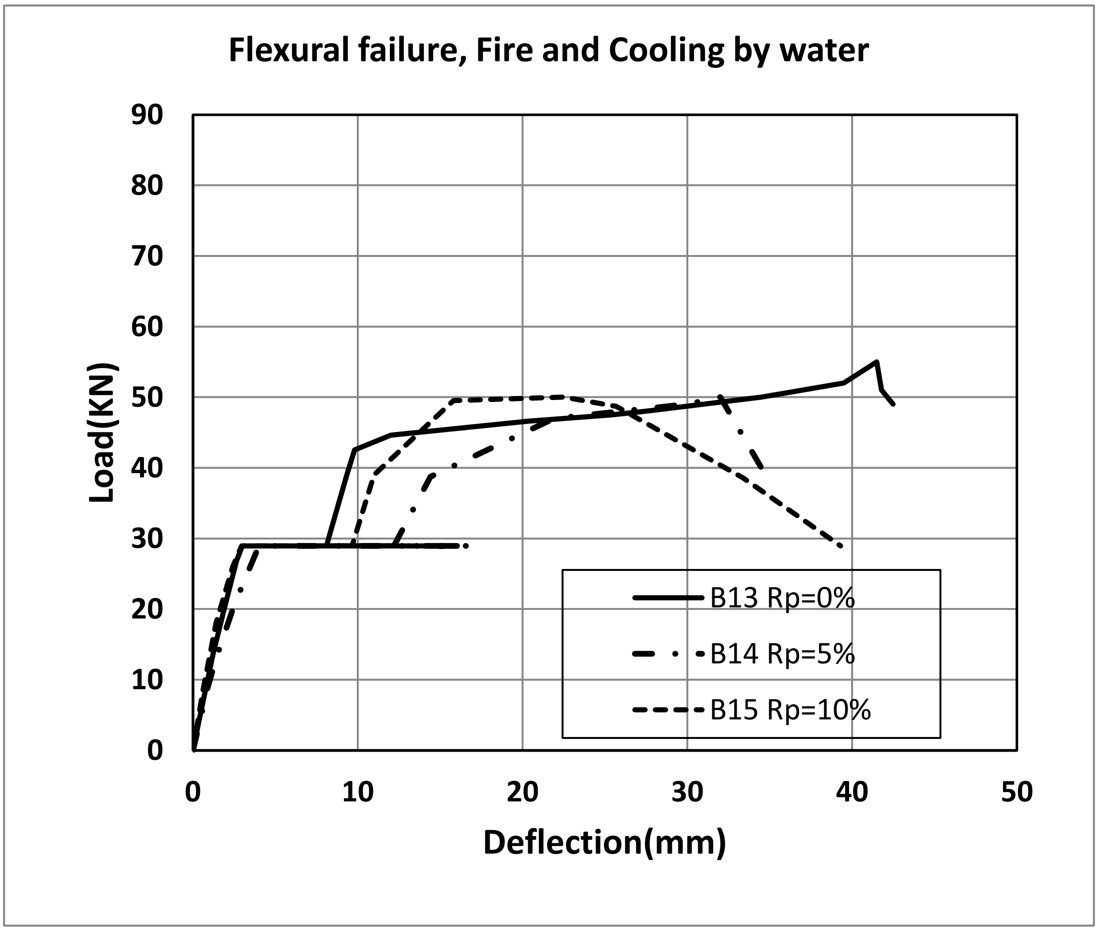


Fig (16): Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With flexural failure mode, Fire and Cooling by Water

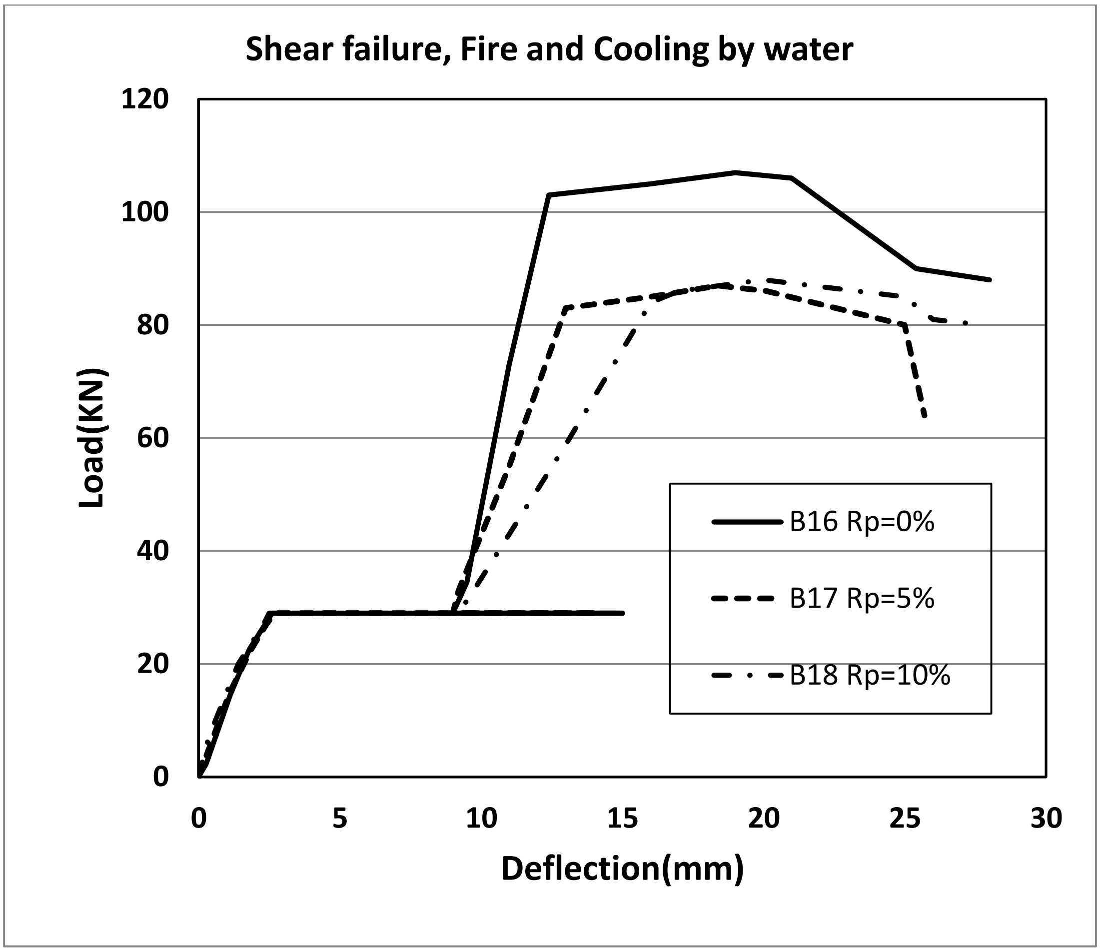


Fig (17): Effect of (SBR) polymer ratio on Load Deflection Curve for Beams With shear failure mode, Fire and Cooling by Water

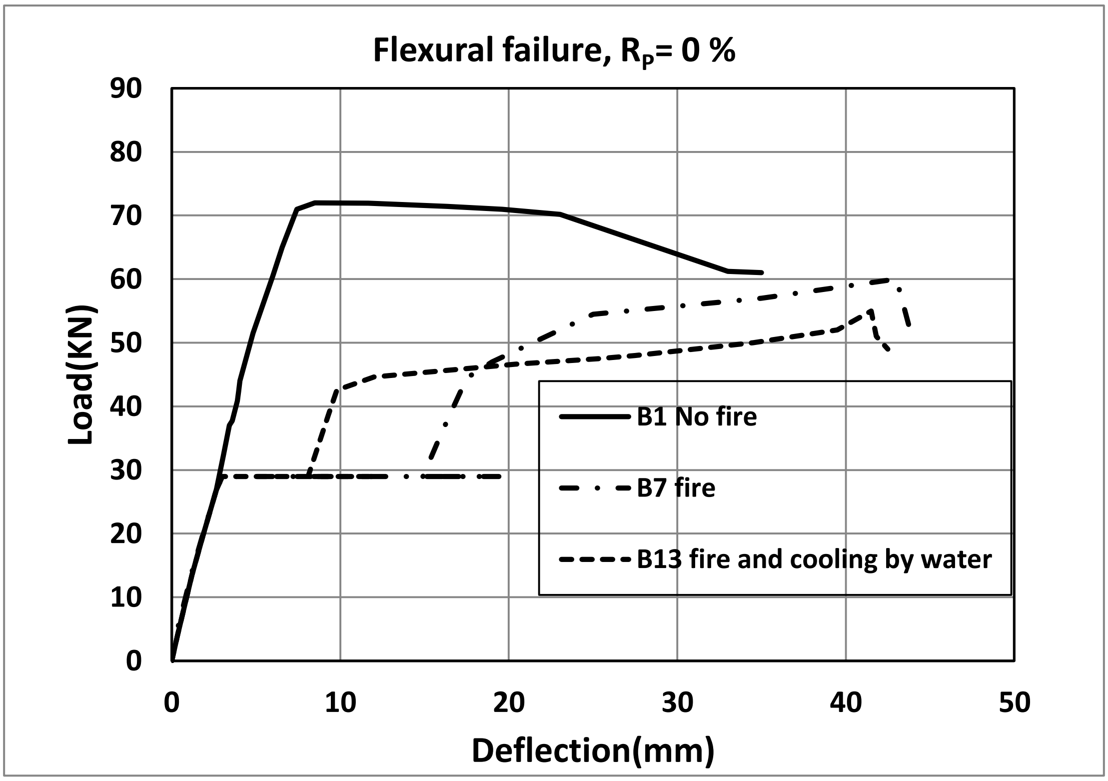


Fig (18): Effect of Fire and Cooling on Load Deflection Curve for Beams with Flexural failure, R_P= 0 %

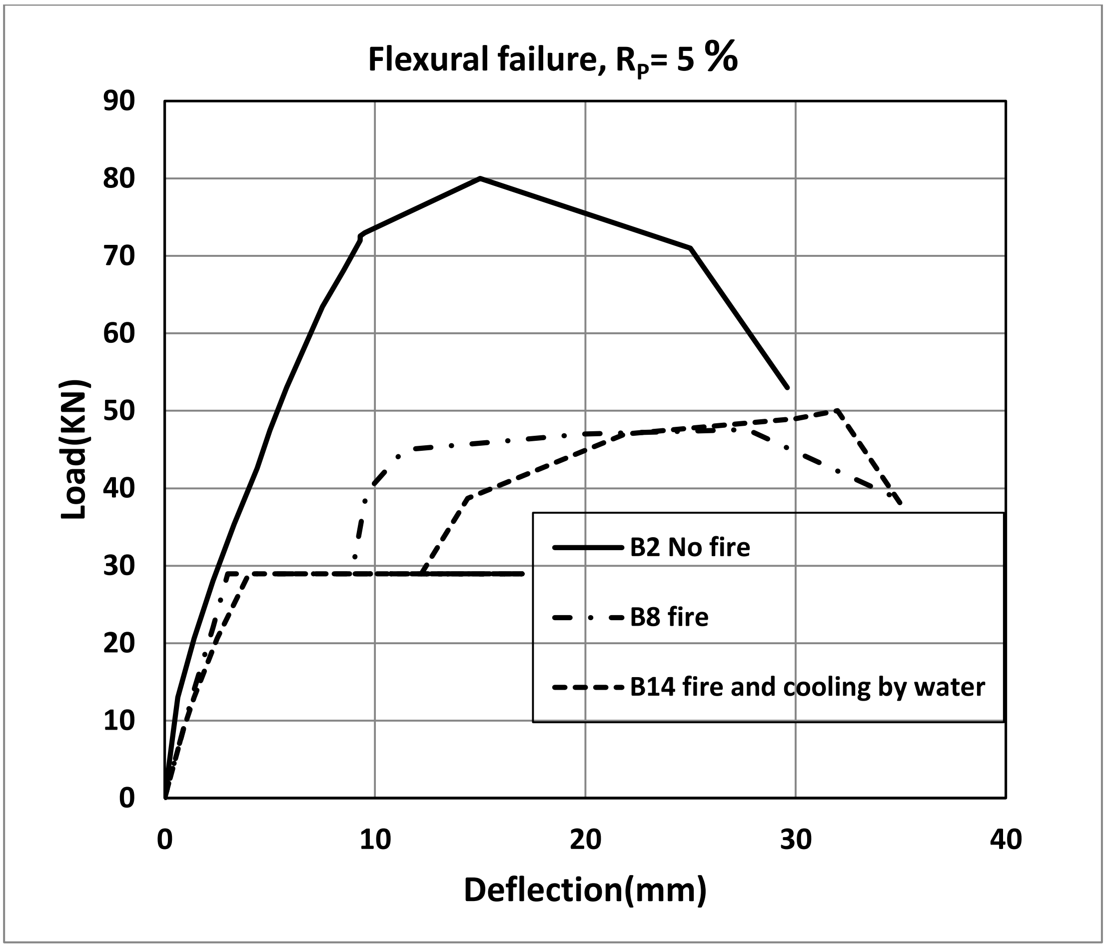


Fig (19): Effect of Fire and Cooling on Load Deflection Curve for Beams with Flexural failure, R_P=5%

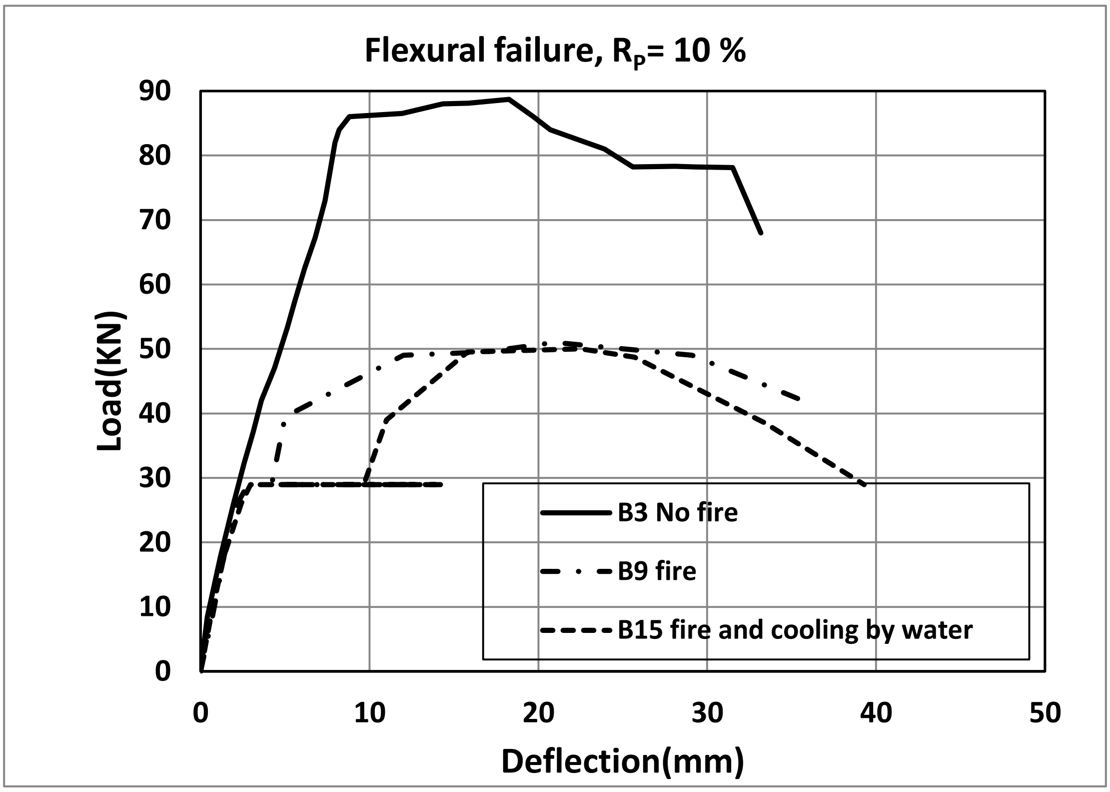


Fig (20): Effect of fire and cooling on load deflection curve for beams with Flexural failure, R_P=10%.

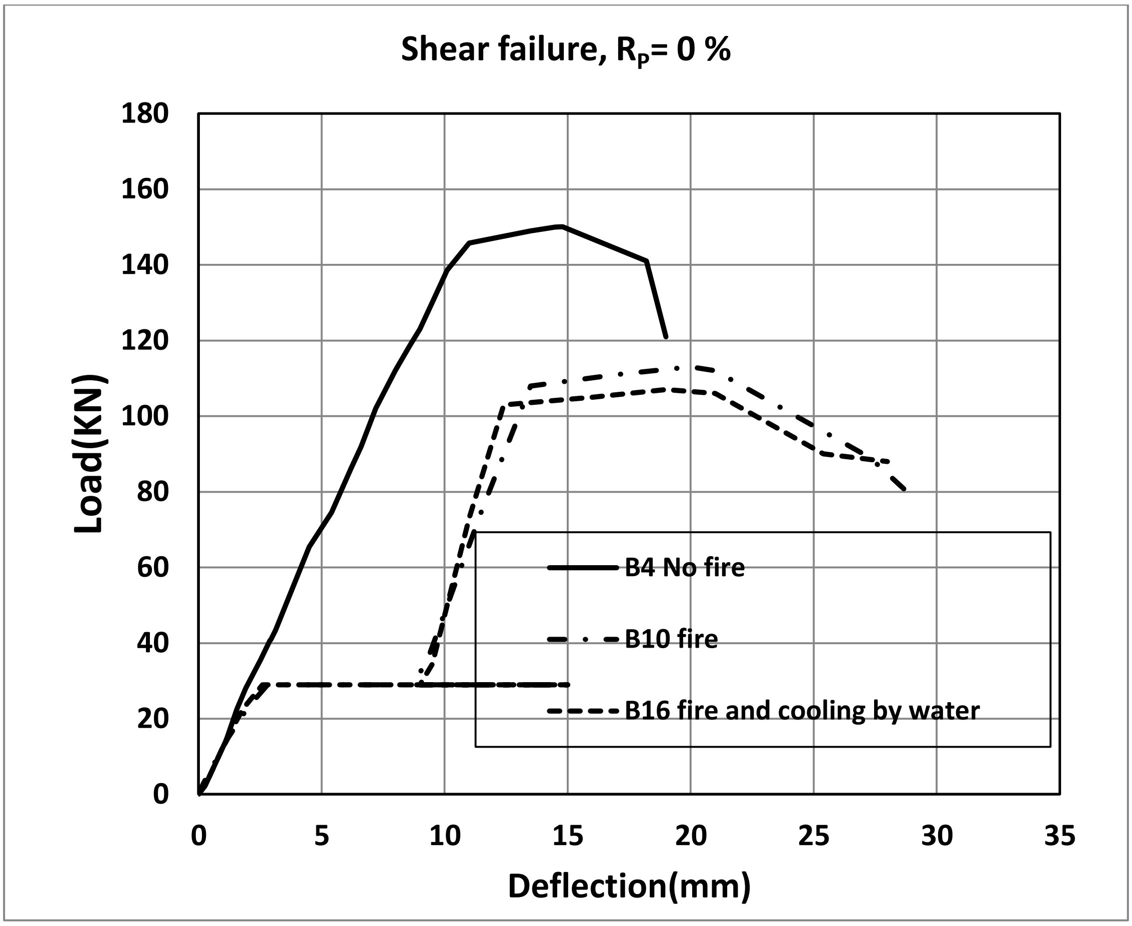


Fig (21): Effect of Fire and Cooling on Load Deflection Curve for Beams With Shear failure, R_P=0%.

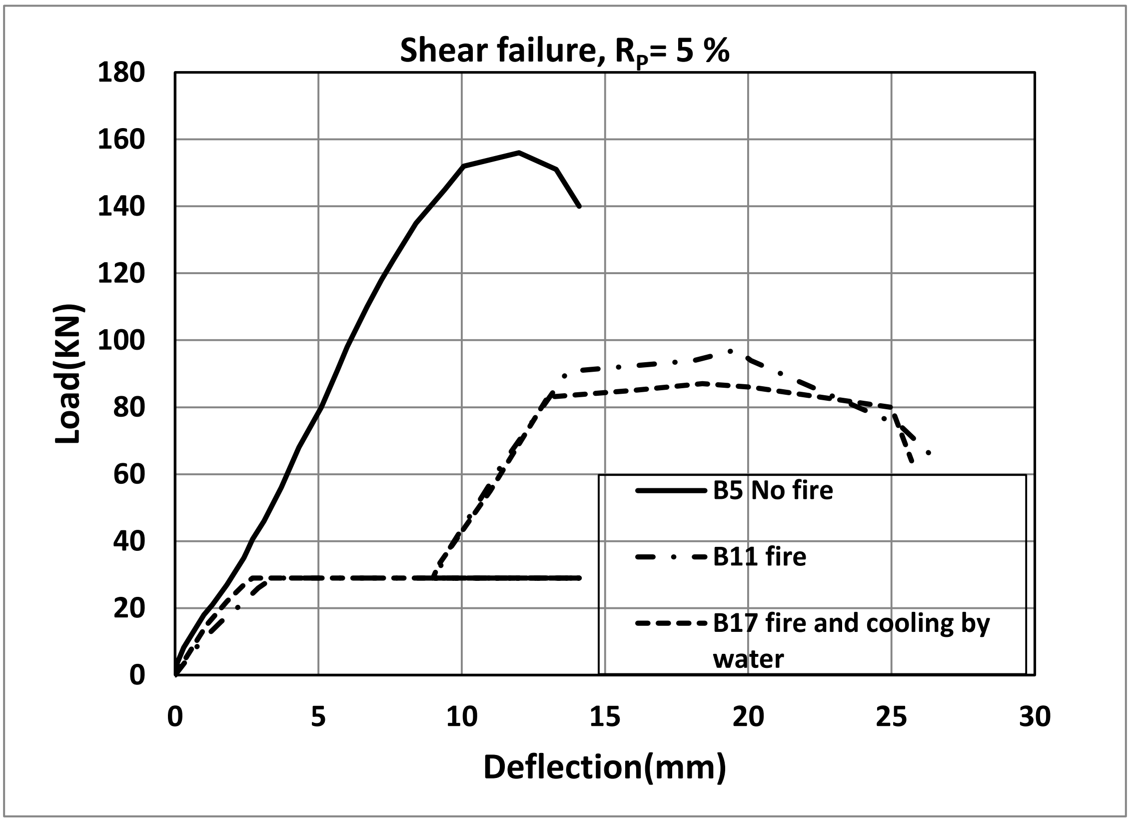


Fig (22): Effect of Fire and Cooling on Load Deflection Curve for Beams With Shear failure, R_P=5%.

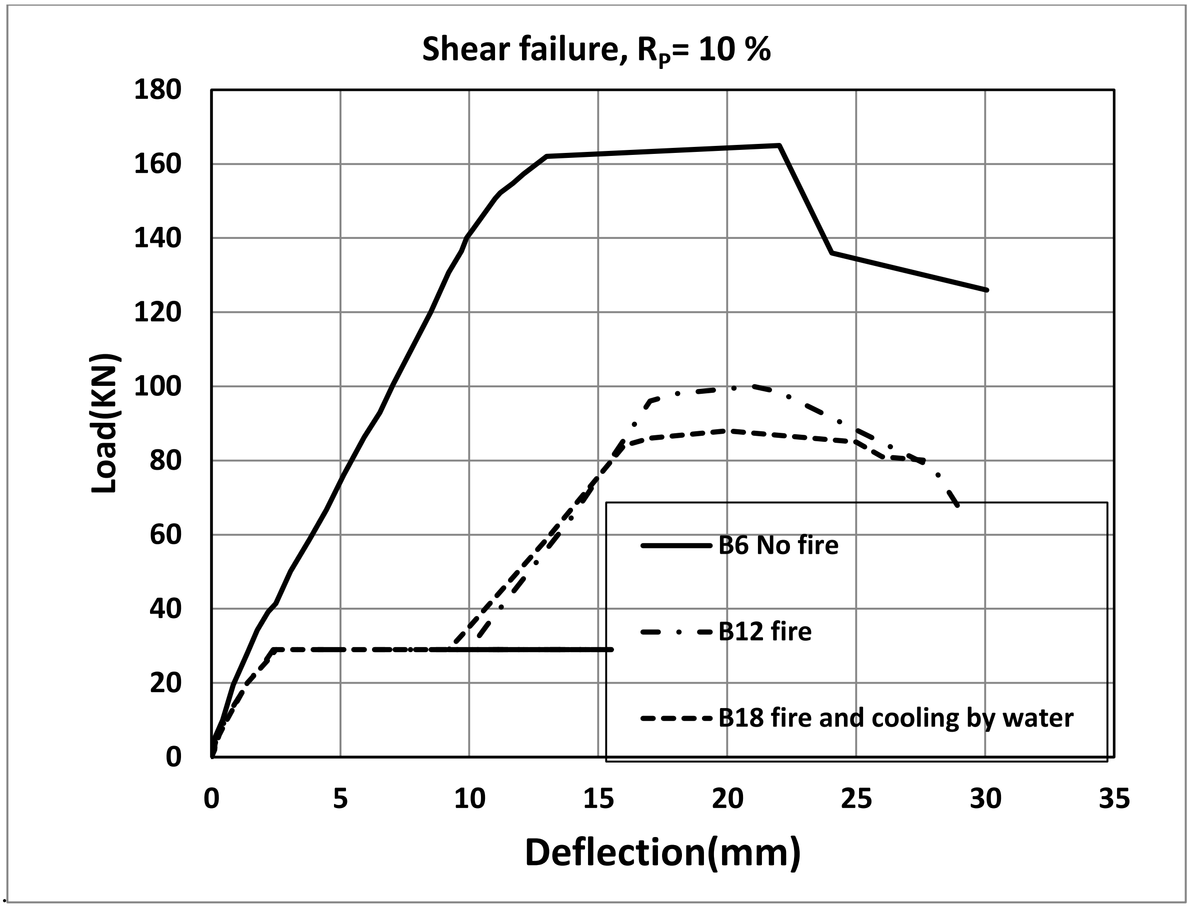


Fig (23): Effect of Fire and Cooling on Load Deflection Curve for Beams with Shear failure, R_P=10%

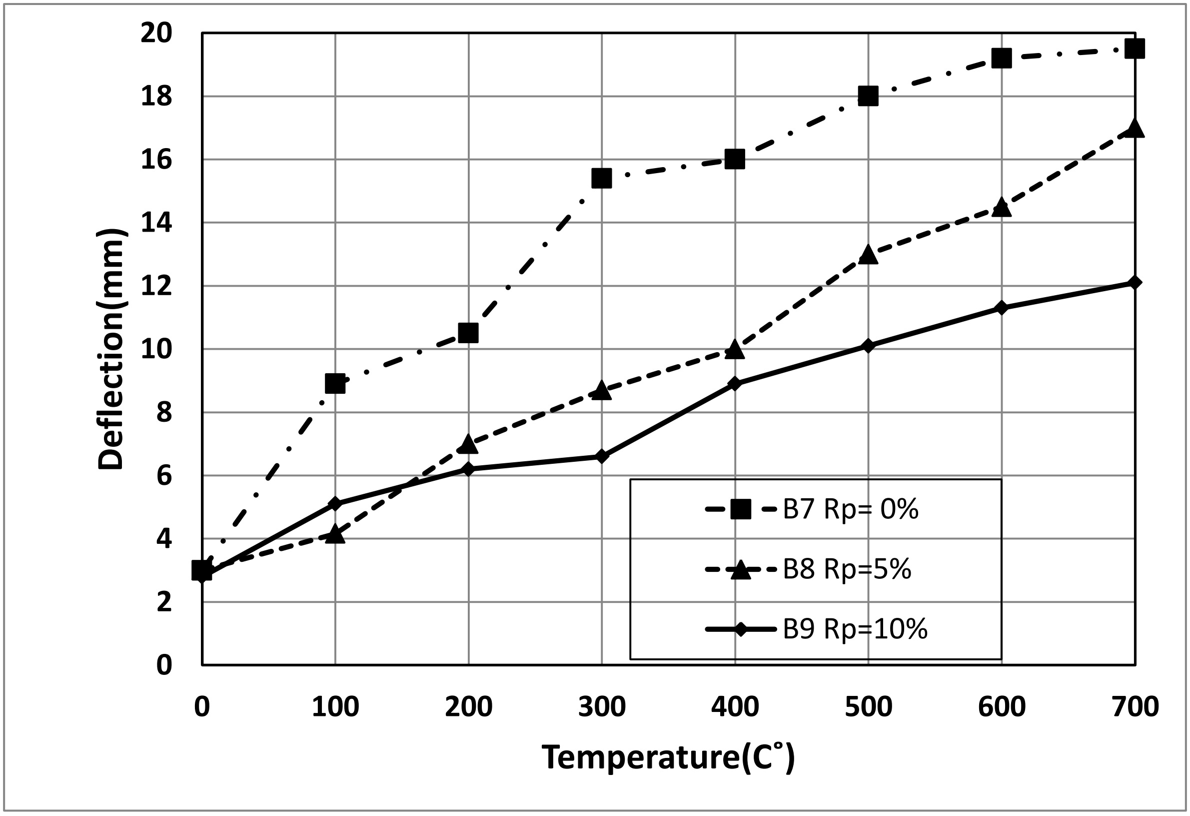


Fig (24): Effect of Temperature on Deflection for beams with Flexural failure mode

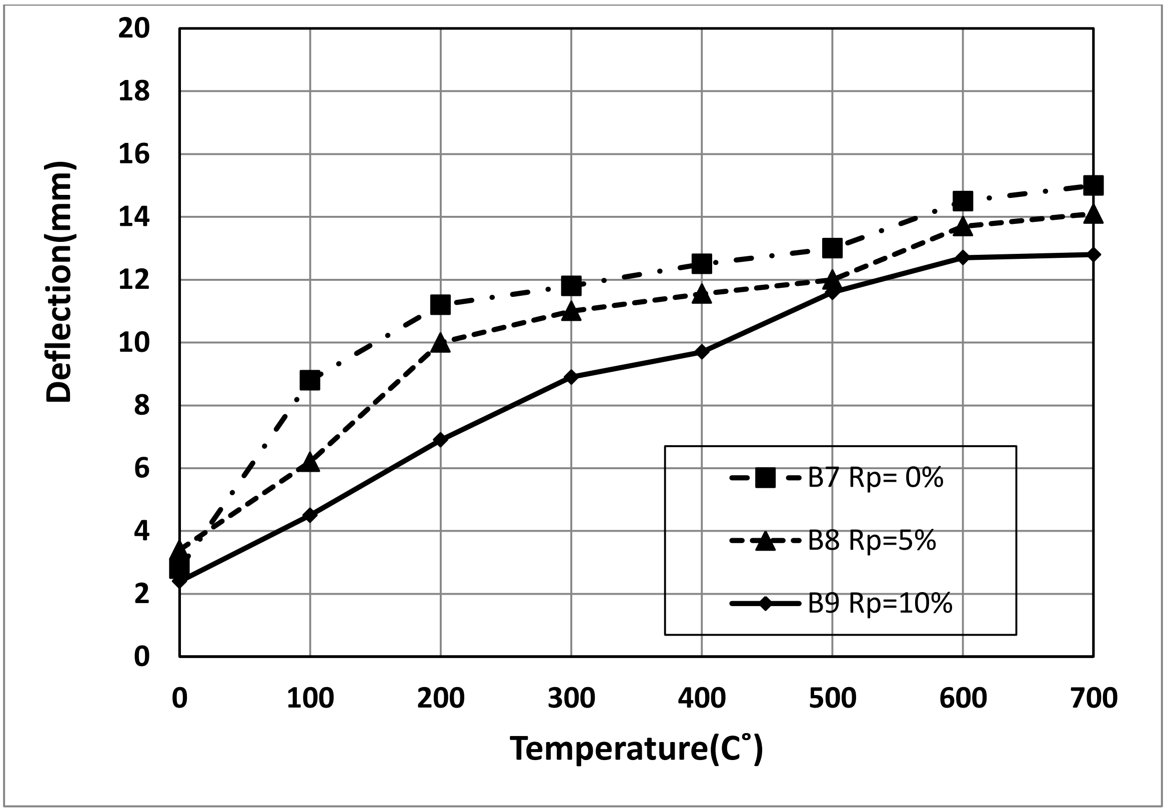


Fig (25): Effect of Temperature on Deflection for beams with Shear failure mode`

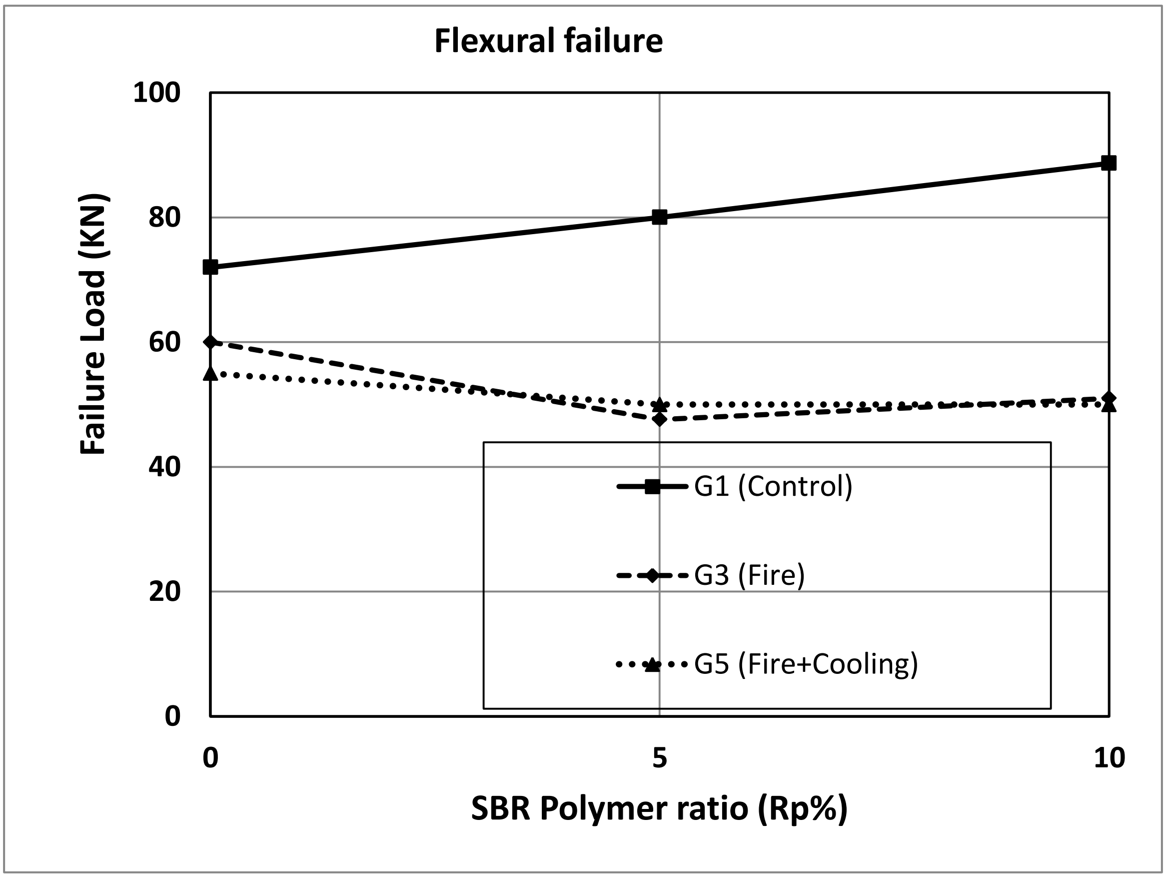


Fig (26): Relation between Failure Load and Polymer Content for Beams with Flexural failure mode and Different Fire Condition

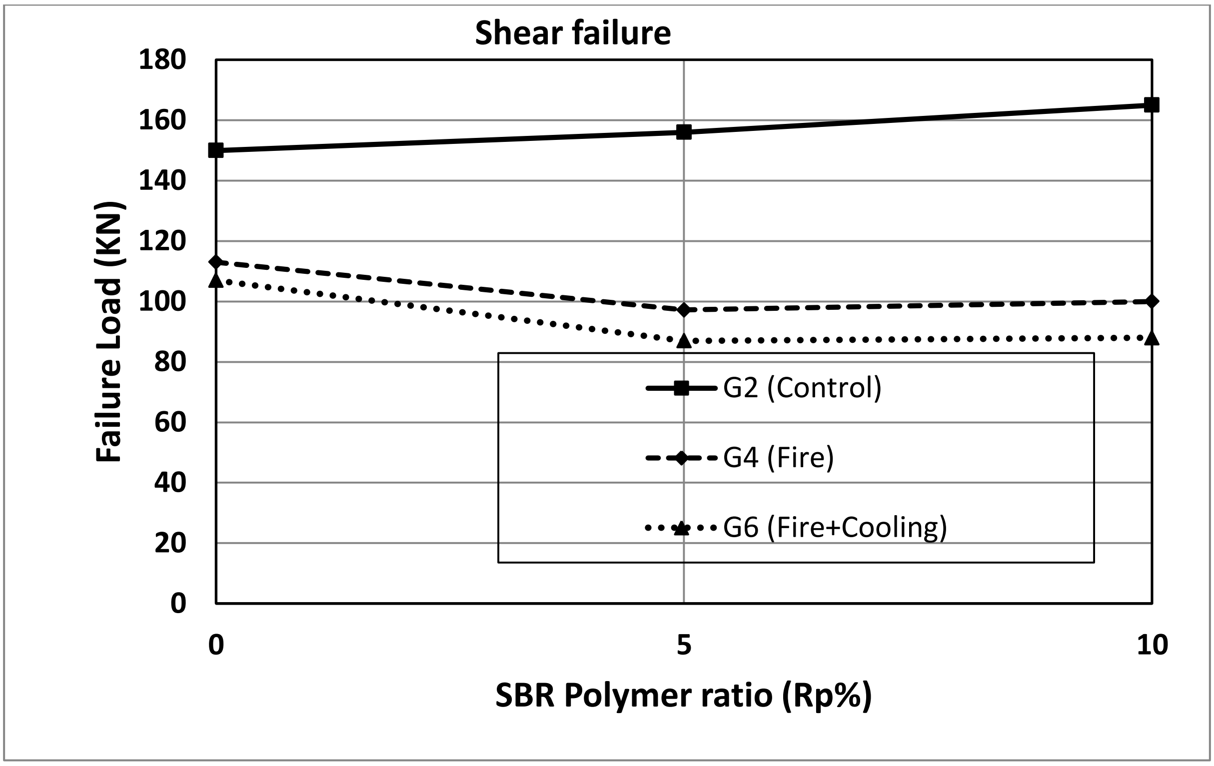


Fig (27): Relation between Failure Load and Polymer Content for Beams with Shear failure mode and Different Fire Condition