

ECOSMART

MAXIMAL STRUCTURAL POTENTIAL

BUILDING AN ECOSMART FUTURE



Mix design

	Control Mix	5%	10%	30%
Cement	20 kg	19 kg	18 kg	14kg
MBP Liquid	-	1 kg	2 kg	6 kg
MBP Powder	-	0.4kg	0.8kg	2.4kg
Sand	30 kg	30 kg	30 kg	30 kg
Aggregate	60 kg	60 kg	60 kg	60 kg
Water	8 liters	7.6 liters	7.2 liters	5.6 liters
W/C	0.4	0.4	0.4	0.4
W/Cm actual	0.4	0.42	0.43	0.56

Materials

The ordinary Portland cement “Bestway cement” conforming to cem1 42.5N was used. Physical and chemical properties of cement used are presented below.

<u>Properties</u>	<u>Obtained Values</u>
Consistency	30 %
Specific Gravity	3.13
Initial Setting Time	140 min
Final Setting Time	213 min
Blain Fineness	309 m ² /kg

Chemical composition of cement

Sr.	Element	Cement
1.	CaO	62.13
2.	MgO	2.29
3.	SiO ₂	20.25
4.	SO ₃	2.57
5.	Al ₂ O ₃	5.05
6.	Fe ₂ O ₃	3.13
7.	Cr ₂ O ₃	--
8.	L.O.I	4.42
9.	Cl	--
10.	K ₂ O	0.74
11.	Na ₂ O	0.24

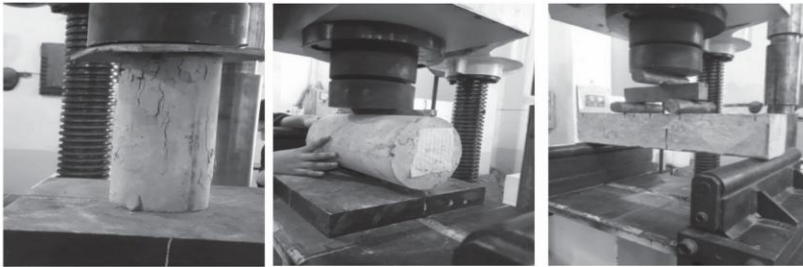
MBP properties

Type	White liquid MBP emulsion
Density at 25 °C	Approximately 1.00 kg/lit
Chloride content	NIL(EN934-2)
Hardness Range	30 – 95
Tensile Strength	3.5 – 20.5 MPa
Elongation	450 % – 600 %

Physical properties of sand and crushed stone

Physical properties	Sand	Crushed stone
Water absorption (%)	1.2	0.6
Specific gravity (kg/dm ³)	2.76	2.65
Compacted bulk density (kg/dm ³)	1.73	1.63
Loose bulk density (kg/dm ³)	1.59	1.42
Aggregate Impact value (%)	---	13.5
Fineness Modulus	2.2	6.48

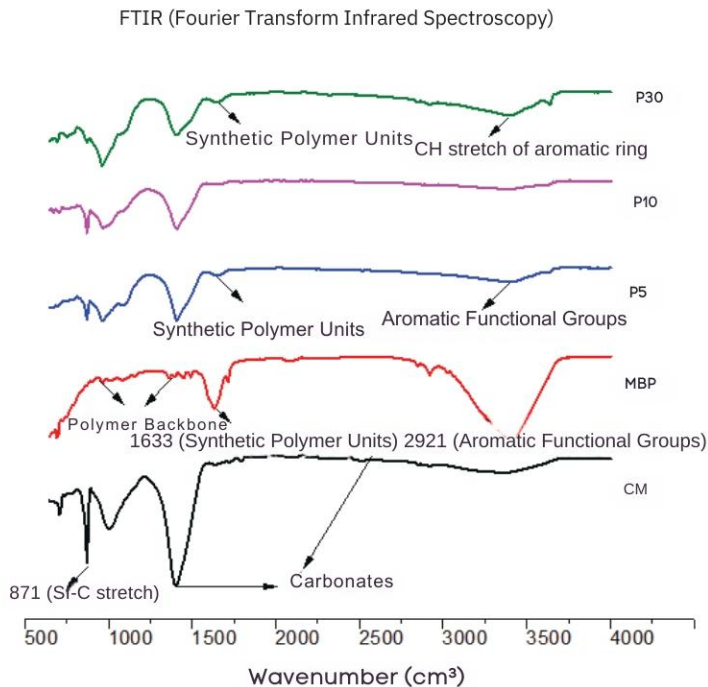
RESEARCH STUDY TEST MBP



Testing Modified Binder Polymer (MBP) integrated on concrete samples.

Control mix was prepared (1:1.5:3) with constant water cement ratio of 0.4. The PMC samples were prepared using a traditional laboratory concrete mixer. The mixture prepared with 5%, 10% (as normal cement replacement) and 30% (as high cement replacement). The mix design of control concrete and PMC's are given in table below. After casting, they were left for three days in moulds under wet conditions.

In the hardened concrete, the mechanical tests like compressive strength test, split tensile strength test and flexural strength test were carried out. Toughness was determined by calculating the area under stress-strain curve. FTIR analysis and SEM microscopy at 90 days were conducted.

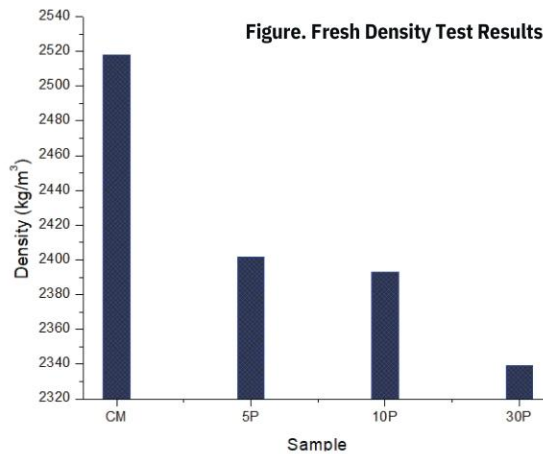


FTIR analysis

FTIR analysis was conducted to study the interaction between the control mix (CM) and the Modified Binder Polymer (MBP), as shown in the FTIR analysis. The peak at 1000 cm^{-1} indicates the presence of polymer backbone components. New peaks observed around 2900 cm^{-1} and 1600 cm^{-1} suggest that the MBP is well-distributed within the CM matrix. Apart from these peaks, the absence of any other peaks confirms the lack of a covalent network in CM-MBP blends. This increased interaction may lead to an increment in **flexural strength and water resistance**.

Density Test

Density of concrete was decreased by increasing polymer content. At 30% replacement of cement content with polymer, minimum value of density is obtained. The Figure demonstrates the results of the fresh density tests carried out immediately after casting.



Flexural Strength Test

The pavement design theory is based on flexural strength (NRMCA guideline). Though for conventional concrete, compressive strength is considered as design criteria for pavement.

Flexural strengths are increased by replacing cement content by MBP. **Up to 3-fold increase in strength was achieved at only 5% replacement of cement content by MBP.** Sample 5P had better performance as compared to the other samples prepared. Figure 4 represents two point loading test.

The increase in flexural strength may be linked to the high flexural strength of the individual Modified Binder Polymer (MBP). MBP acts as a flexible filler in concrete, enhancing its overall flexural strength. However, a decrease in flexural strength at higher replacement levels may occur because MBP exhibits its own properties at these levels, rather than merely serving as an admixture or simple filler. Furthermore, the use of MBP indicates a gain in long-term durability, while also showing an improvement in toughness by up to 5 times, potentially at the cost of flexural and tensile strength noticeably at higher mixtures above 10% MBP

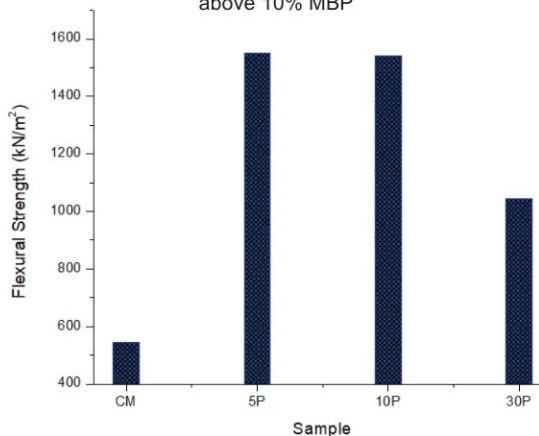


Figure. Flexural Strength Test Results

Split Tensile Strength Test

Similar to the results obtained in flexural strength, sample 5P had better performance among all other samples. An improvement in concrete strength was observed. **25% increase in tensile strength was achieved at sample 5P.** The results showed the similar trend to the observed results in flexural strength. Improvement in concrete strength at 30% was not more than 7%. Figure 5 represents split tensile strength test. The increase in tensile strength may be linked with the part played by high tensile strength of individual modified binder polymer. Decrease in tensile strength at higher replacement may be due to the fact that MBP shows its own properties at higher replacement and is not serving just as admixture or simply filler in concrete.

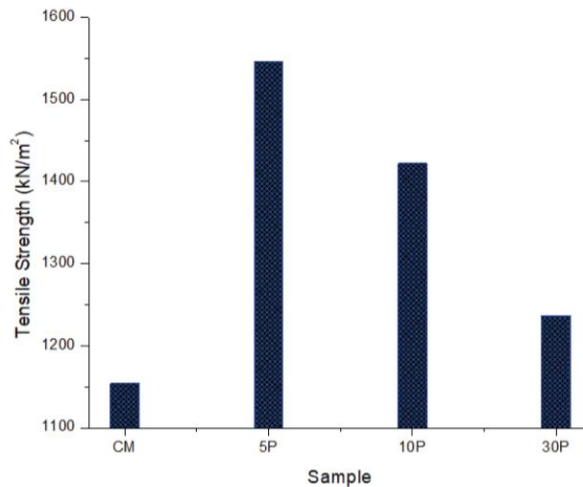


Figure. Splitting tensile strength test results

Compressive Strength Test

Compressive strength results (as seen below) showed contrary trends as compared to tensile and flexural strength. Compressive strength decreased by increasing polymer content at 5% and 10% replacement. It increased only 25% percent by replacing 30% cement content. The decrease in compressive strength may be linked to the higher air content due to modified binder polymer concrete.

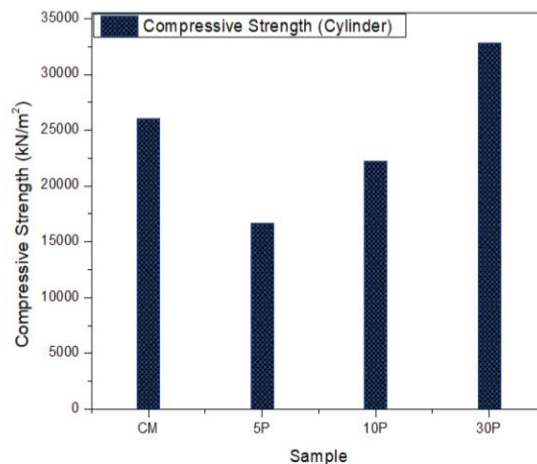


Figure. Compressive strength test results

Toughness

Toughness increased by increasing polymer content because MBP has higher toughness illustrates the results of toughness.

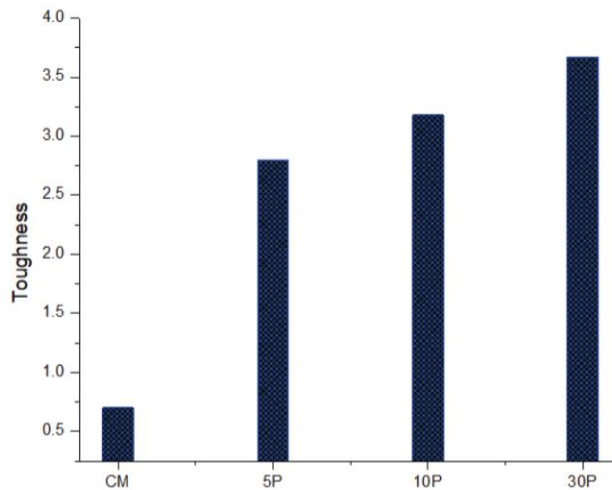


Figure. Toughness results

Scanning Electron Microscopy

The micrograph at 90 days of the Polymer-Modified Concrete (PMC) shows polymer strands bridging a microcrack, while such strands are absent in the unmodified concrete sample. This results in an increase in tensile strength and flexural strength. The figure shows that at 90 days, white-colored hydration products are visible along black pores in the concrete. However, for 5% and 10% replacement, the grayish-colored polymer is evident with smaller pieces of hydration products. For 30% replacement, fewer hydration products are formed, and the grayish polymer is visible, indicating that the concrete properties are now mainly governed by the polymers. Pores are less obvious with the increasing amount of polymer.

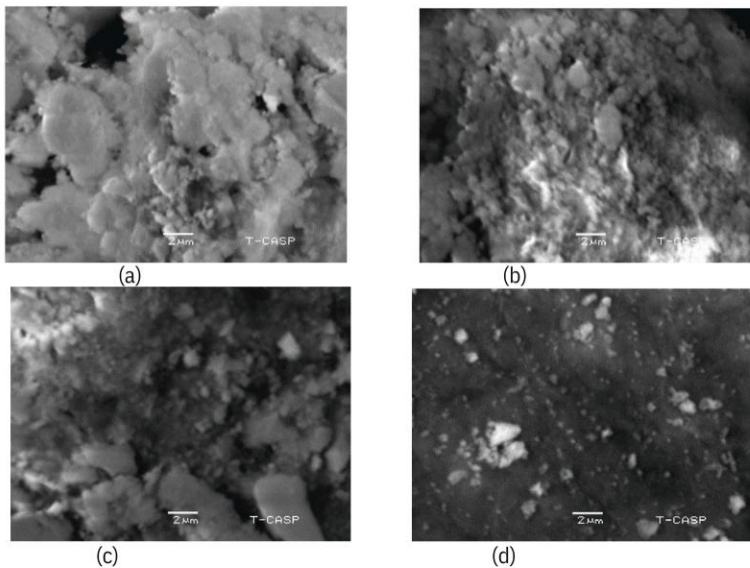


Figure. Scanning electron micrograph (a) control mix (b) 5% replacement of cement with MBP (c) 10% replacement of cement with MBP (d) 30% replacement of cement with MBP.

Conclusions

Modified Binder Polymer is an excellent choice for concrete repairs due to its enhanced properties and performance. In fact, it offers much more, as we can enhance concrete properties by intergrating MBP. The high modulus of rupture, increased flexural strength, and higher toughness of polymer-modified concrete contribute to its crack resistance and ability to plastically deform without fracturing, **resulting in a higher quality material**. The following conclusions are drawn from the present study:

The workability of concrete was enhanced tremendously with the amount of MBP because The workability of concrete was enhanced tremendously with the amount of MBP because of presence of polymeric chains.

Flexural strength increased 3 folds and tensile strength increased up to 34% by replacing cement with MBP content. Their maximum values were obtained at only 5% replacement. MBP has higher tensile and flexural strength thus it increases tensile and flexural strength of its composite. At higher replacement, MBP does not serve only as flexible filler but shows its own properties thus decrease in tensile and flexural strengths are noticed.

Toughness increased up to 4 folds by adding MBP. The increase may be linked to higher toughness of MBP.

The compressive strength decreases for MBP modified concrete except for the sample prepared at high range 30% replacement of cement. However, the decrease in strength of concrete is in the acceptable range. Furthermore, if concrete will be tested at same workability instead of water cement ratio, MBP modified concrete may have much higher compressive strength. At 30% polymer strength increase may be linked to polymer dominated matrix.

FTIR analysis showed good compatibility of MBP with concrete. The additional peaks after adding MBP into concrete indicated the increment in strength and other properties. FTIR analysis confirms suitability of MBP as concrete admixture.

SEM analysis shows that pores become less obvious with the increasing amount of MBP in concrete. At 30% replacement, less hydration products are formed and mainly MBP controls the concrete properties.

Density was decreased by increasing MBP content resulting in reduced weight, modified concrete structure will have lighter weights. Water cement ratio should be reduced accordingly when using water based MBP due to its property of increasing workability due to polymeric chains.

MBP modified concrete can be used to make crack resistant concretes with higher tensile strength, flexural strength and toughness.