

Experimental Study on Fibre Reinforced Polymer Concrete

Prof. S.Vijaya Bhaskar Reddy¹ and Vadla Santhosha²

¹Head Of The Department of civil Engineering, CMR Technical Campus, Kandlakoya(V), Medchal(M), R.R Dist., Telangana, India.

²Student, In Structural Engineering, CMR Technical Campus, Kandlakoya(V), Medchal(M), R.R Dist., Telangana, India.

Abstract

Energy saving in building technology is among the most critical problems in the world. Thus it is a need to develop sustainable alternative to conventional concrete utilizing more environmental friendly materials. One of the possibilities to work out is the massive usage of geo polymer concrete to turn them to useful environmental friendly and technologically advantages cementitious materials. Polymer concrete has superior mechanical properties compared to conventional types of concrete. The experimental researches concerning the polymer concrete had investigated the mechanical characteristics of epoxy polymer concrete prepared with fly ash as filler. For obtaining good mechanical properties the filler is used with higher dosages. The experimental values of mechanical strengths for polymer concrete without steel fibres were smaller than that for polymer concrete with fibres. A huge amount of work has been done on literature of polymer concrete which has concluded that use of 14% resin by weight of polymer concrete would give better results. Various other parameters like micro fillers, aggregate type, resin type, fibre reinforcement and curing regime affects the polymer concrete. The polymer concrete specimens are casted and tested for compressive strength for 7, 28, 60 and 90 days, Split Tensile Strength and Flexural Strength for 7 and 28 days and cured at ambient temperature. It was concluded that the mix with 10% fly ash and 2% steel fibre has got best results. Considering the fact that fly ash is cheaper so the mix also considered to be the economical one.

INTRODUCTION

Polymer concrete will dominated in testing materials in the structural designing field, with them being described by a high estimation of the compressive quality and extreme compressive strain, and in addition by a decent synthetic protection when contrasted with that of customary cements. Polymer concrete framed by polymerizing a blend of a monomer and total. Polymer concrete has been in business use since the 1950s. Contingent upon the materials utilized, Polymer cement can create compressive qualities of the request of 140 MPa (20,000 psi) inside hours or even minutes and is in this way appropriate for crisis cementing employments in mines, burrows, and interstates.

Concrete is comprised of sand or stone, known as total, joined with bond glue to tie it. Total can be of different sizes. It is comprehensively classified as fine (ordinarily sand) and coarse (regularly squashed stone or rock). The more noteworthy extent of cement is total which is cumbersome and moderately less expensive than the concrete.

As a great part of the constituents of solid originate from stone, it is frequently suspected that solid has similar characteristics and will keep going forever. Concrete has been called simulated stone, cast stone, reproduced stone and reconstituted stone. In any case, concrete must be thought of as an unmistakable material to stone. It has its own particular qualities as far as strength, weathering and repair.

Concrete is a moderately solid and vigorous building material, yet it can be seriously debilitated by poor make or an extremely forceful condition. Various 2 notable solid structures show issues that are identified with their date of cause. These issues can be illuminated by utilization of polymer in solid development.

A polymer is an expansive particle containing hundreds or thousands of atoms framed by joining one, two or incidentally more sorts of little atom (monomers) into chain or system structures. The fundamental polymer material utilized as a part of solid development are polymer altered cement and polymer concrete.

Polymer adjusted cement might be separated into two classes: polymer impregnated cement and polymer bond concrete. The first is created by impregnation of pre-thrown solidified Portland bond concrete with a monomer that is in this manner changed over to strong polymer. To deliver the second, some portion of the bond fastener of the solid blend is supplanted by polymer (regularly in latex frame). Both have higher quality, bring down water porousness and better protection from chemicals, and more prominent stop defrost soundness than ordinary cement.

Polymer cement or tar solid comprises of a polymer folio which might be a thermoplastic yet more every now and again is a thermosetting polymer, and a mineral filler, for example, total, rock and pulverized stone. PC has higher quality, more noteworthy protection from chemicals and destructive operators, bring down water retention and higher stop defrost soundness than regular Portland bond concrete.

Plain concrete has numerous alluring properties however it likewise has numerous confinements. Its low rigidity, poor sturdiness (protection from stop and defrost), and weakness to sulfate and corrosive assault has restricted its utilization. These issues have been illuminated for a few applications. Concrete has been strengthened with imbedded steel in regions of pliable powers. Air-entraining specialists have been utilized when the solid needed to oppose serious solidifying and defrosting. Extraordinary bonds have been produced for concrete subjected to sulfate assault and defensive coatings put on concrete presented to acids. Every one of the previous medicines endeavored to enhance concrete and did, truth be

told, give an answer for a specific issue. In any case, there has been no single arrangement •which would enhance or take care of every one of the four noteworthy issue regions. Since 1966, another approach has been contemplated and it indicates awesome guarantee of unfathomably enhancing the properties of cement by the arrangement of a composite material, "polymer concrete"

Polymer concrete is like common cement since it contains fine and coarse totals, yet the water powered cover is completely substituted with a polymer material. The totals are limited together by the polymer. Polymer concrete contains no bond or water. The execution of polymer concrete relies upon the polymer properties, kind of filler and totals, curing temperature, segments dose, and so on.

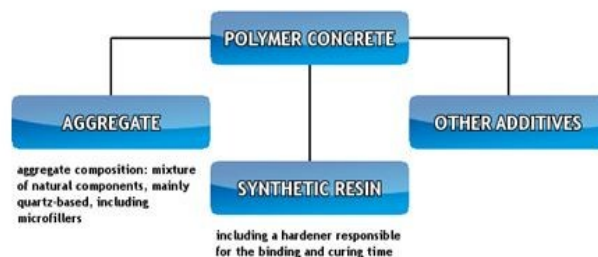
Polymer adhesive can be thermoplastic, yet more every now and again a thermosetting polymer. The polymers most every now and again utilized depend on four kinds of monomers or prepolymer framework: methyl methacrylate, polyester prepolymerstyrene, epoxide prepolymer hardener and furfuryl liquor. The totals utilized as a part of dry state can be silicates, quartz, rock, limestone, calcareous, stone, dirt, and so forth. In the creation can be utilized additionally the filler. Diverse kinds of fine materials can be utilized, for example, fly powder, silica seethe, phosphogyps, soot, and so forth. Filler, particularly fly fiery debris, can enhance the properties of polymer concrete.

Polymer cement can be strengthened with filaments like: glass, boron or common strands like: coconut, banana filaments, carbon, cellulose. Break properties can be enhanced by expansion of short glass or carbon filaments. On account of normal filaments just coconut strands can be phenomenal fortification for polymer concrete. Sugar stick bagasse can be an option and banana fiber isn't shown for utilizing as support.

The mechanical attributes, for example, compressive quality, flexural quality and split elasticity were researched on fiber strengthened polymer concrete made with various measurements of filler, the fiber dose additionally being changed for all blends. The creations utilized as a part of the present examination get from a past one which researched a substantial number of organizations utilizing diverse measurements of gum and filler.

POLYMER CONCRETE

Polymer concrete, referred to likewise as gum concrete, is a constructional composite, a variety of cement, in which customary cover - bond, has been totally supplanted with engineered gums with a solidifying operator and filler: blend of sand-and-rock and quartz powder. Folio of polymer concrete is vital for enhanced quality in connection to conventional cement, and especially for synthetic protection. The weakest piece of standard cement - the water driven mineral folio was disposed of from polymer concrete.



Properties of polymer concrete

Utilizing adhesive materials rather than customary fastener enable us to get a progression of intriguing properties, for example, high concoction protection from numerous destructive compound substances or high mechanical quality. If there should be an occurrence of conventional cement, the quality properties of cured bond glue are no less than a few times lower than the comparing highlights of the mother rocks of the total, and the attachment of cover and-total is moderately little. The circumstance is diverse if there should be an occurrence of sap cements: the elasticity of solidified gum cover is substantially higher, and the compressive quality is like the quality of the stones from which the total was gotten.

Types of polymers

There are essentially three kinds of strong polymers: Elastomers, thermoplastic polymers and thermosetting polymers. Elastomers are rubbers or rubberlike versatile materials. Thermoplastic polymers are hard at room temperature, however on warming turn out to be delicate and pretty much liquid and can be shaped. Thermosetting polymers can be shaped at room temperature or above, yet when warmed all the more unequivocally turn out to be hard and infusible. These classifications cover impressively yet are in any case accommodating in characterizing general zones of utility and kinds of structures.

The auxiliary qualities those are most critical in deciding the properties of polymers are:

- The level of inflexibility of the polymer particles,
- The electrostatic and van der Waals alluring powers between the chains,
- The degree to which the chains tend to shape crystalline areas, and
- The level of cross-connecting between the chains.

Thermosetting polymers normally are made from relatively low molecular-weight, usually semifluid substances, which when heated in a mould become highly cross- linked, thereby forming hard, infusible, and insoluble products having a three-dimensional network of bonds interconnecting the polymer chains.

The different types of thermoset polymer matrices used are: Bis-Maleimids (BMI), Epoxy (Epoxide), Phenolic (PF), Polyester (UP), Polyimide, Polyurethane (PUR), Silicone. In

the present study epoxy polymers are used in construction field for betterment of the mechanical properties of concrete.

CHARACTERIZATION OF EPOXY RESINS

Determination of epoxy equivalent of epoxy resins

The epoxy equivalent of the resins is determined by pyridine-pyridinium chloride method. Epoxy equivalent is reported in terms of epoxide equivalentl or epoxy equivalent weightl and is defined as the weight of resin in gram, which contains one gram equivalent of epoxy. The term epoxide group contentl is expressed as milli moles of epoxide group per one kg of resin.

Curing of epoxy resins

The epoxy resin can be cured by variety of hardeners such as bisphenol-C- formaldehyde resin (BCF), tetrachloro phthalic anhydride (TCP), pyromellitic dianhydride (PMDA), 1,1'-bis(4-amino phenyl) cyclohexane (DDC) and 4,4'-diamino diphenyl methane (DDM) of varying composition (10-50%) at different temperatures

(150-360 C) for 1-5h. The solubility of cured resins is checked in different solvents.

Thermal Analysis of Cured Resins

Thermal analysis of polymers provides information on polymer molecular architecture as well as degradation mechanism under specified conditions. It also provides useful temperature range for various applications. Cured resins are analysed by DTA and TGA at the heating rate of 15^o C / min. in an N₂ atmosphere.

Preparation of Epoxy-Bcf Composites

he inclusion of reinforcing particles in thermoplastic or thermosetting matrices is an outstanding method to prepare composite materials, which includes the characteristics of both matrix and filler. Incorporation of fibrous material in this study steel fibre with polymeric material enhances the mechanical strength dramatically. The composite of polymeric matrix with manmade fibres like glass, carbon, Kevlar, aramid etc. are practiced not only in aerospace application but also find their use in domestic, industrial and construction applications as well. The resin content in the composites is determined gravimetrically.

Physico-Chemical Properties of Composites :

Mechanical properties of composites

Mechanical properties of the composites are vital for application perspective in various fields. Mechanical properties of epoxy composites are subject to number of variables of which the accompanying are the most vital:

- Resin used
- Hardener used
- Fillers and modifiers used
- Type of reinforcement
- Resin and hardener contents of composite
- Curing conditions

However, the mechanical properties can be improved according to needs of application by modifying reinforcements, resin or hardener. The ultimate markets of epoxy composites are numerous. The most important use is to provide the efficient high strength to weight ratio. To meet the requirements of various applications, composite materials should be approved mechanically also. Most applications of composites need load-bearing capacity. The geometrical response to loading lead to a wide range of mechanical properties grouped under stress-strain properties, visco- elasticity and failure properties. These properties in turn largely determine the polymer structure (i. e. molecular weight, cross linking, branching, segmental structure and morphology) and the nature and extent of compounding when characterizing the mechanical properties.

Among the mechanical properties, tensile strength, wear resistance, fatigue resistance and impact resistance are common tests that determine the material as engineering plastic for final applications. The tensile behaviour is probably the most fundamental mechanical property used in the evaluation of polymers. The basic aspect is to measure the yield strength, ultimate strength, % weight loss and various moduli, which are significantly employed to decide mechanical application.

Surface Coating of Mixed Resins on Metals

Covering utilization of blended pitches on various metal substrate, for example, copper, tin and gentle steel and tried for their electrical conductance and water, corrosive and salt protection.

The extraordinary glue property of epoxy tars was first perceived by Preswerk. Around then epoxy sap cements were perceived as the principal cast set up glues including a flexible substance usefulness and an exceptional low shrinkage on curing. This prompted cement joints with low inner pressure. Out of the blue, it was conceivable to get solid cement joints with incredible attachment, auxiliary honesty and exceptional grip to all sort of substrates.

Bonds could be made to metals without falling back on the use of weight sporadic surfaces. In this way the disclosure of the holding capacity of epoxy saps presented another idea in sticky materials and introduced the advanced way to deal with the innovation of glue holding.

Current glue innovation has prompted the improvement of numerous kinds of epoxy based glue frameworks. Glues have been detailed to meet different determinations and utilize criteria. The primary applications are in the field of basic

metal holding, especially in the aeronautic trade and in military types of gear, and additionally in different.

Epoxy pitches are progressively utilized polymeric species in coatings, cements, varnishes and finishes applications, as they are discovered artificially responsive with enhanced physico-substance properties in different mixes of hardeners, diverse unsaturated fats, polyesters, fillers and shades. This awesome concoction reactivity thusly gives various creations of coatings to different substrates, pertinent in various natural conditions.

The epoxy resins offer advantages like

- Excellent flexibility
- Better chemical resistance
- Excellent durability
- Good adhesion
- Ease of handling
- Rapid air dry or back curing

Factors affecting polymer concrete:

Mixing Temperature

The effect of condition temperature amid blending, which is basically impacted by the climate. The mugginess in the environment too assumes a critical part in polymer solid blending. As the temperature expands the polymer begins setting so it is prompted not to keep up high temperature and not very low temperature, if the temperature noticeable all around is low then the totals and the polymer are to be warmed in a broiler in order to guarantee the best possible workability of the blend contingent upon the conditions.

Duration of Mixing

The general time taken to combine the fixings has got unmistakable quality in this sort of cement. The blending time must be little it ought not surpass 15 minutes else the solid may begin setting in light of its snappy setting properties and early pick up of quality. In any case the setting time can be controlled by shifting the temperature of fixings. Indeed, even the transportation of materials from broiler to blending place must be mind taken with the outside climatic conditions as the temperature may descend fast and blending may not be done fittingly. In this examination temperature has had an essential impact on the grounds that the temperature in the surroundings fluctuated from 15 to 20 degree centigrade.

Duration of Compaction

Indeed, even this factor has an indistinguishable clear reasons from specified in the over two cases. The blend arranged must be compacted as right on time as conceivable soon after blending in light of the fact that the time spared in blending

must not be squandered in compaction. What's more, compaction must be done in three layers with each layer packing for not over one moment. In this investigation mechanical vibrators were utilized for better compaction comes about and precised filling of voids which causes in polymer to stream down snappy at a decent rate of vibration.

Significance of polymer concrete

Polymer and polymer bond cements have more noteworthy elasticity and are not so much weak but rather more powerless to misshapening than bond cements. They have higher water impermeability and protection from frosty, scraped area, and forceful fluids and gases.

Polymer and polymer cements are utilized for floors in modern plants, carports and healing facilities. They are utilized as a part of the creation of brilliant street and landing strip pavings and for repairing harmed solid surfaces and fixing splits.

Polymer bond blends and polymer cements with fine totals are utilized as waterproofing and defensive covers, completing and enlivening confronting materials and mastic. Polymer cements with light weight totals for instance, claydite or perlite sand are utilized to make warm protecting pieces. Polymer cements are additionally utilized as a part of generation of non-fortified thin walled articles and models of different structures, and in addition in underground structures (in the development of segments of mine help and sewers).

Scope

This examination was directed on an exceptional cement named polymer solid where diverse kinds of tars are utilized to improve the mechanical properties of solid structures and to research the impact of microfillers and steel fiber increments to the solid. The exploratory work arranged in this examination comprised of 32 3D shapes of size 100x100x100 mm estimate for getting compressive quality, 32 3D squares of size 100x100x100 mm for acquiring split rigidity and 48 light emissions 40x40x160 mm for getting flexural quality of polymer concrete for various blends of increases utilized. The compressive, flexural and split rigidity tests were performed at 7 and 28 days. The aftereffects of cement containing distinctive blends of admixtures have been exhibited as tables and figures and contrasted and those of control concrete. The conclusions with respect to the impact of the different parameters have been introduced.

Test programme

The following test programme was planned to investigate the mechanical properties of polymer concrete:

- To obtain the physical properties of the concrete constituents i.e. polymer, sand, coarse aggregate and mineral admixture used i.e. FA and as per relevant Indian Standard Codes of Practice.

- Development of various mix combinations for concrete.
- Casting and air curing.
- To obtain the mechanical properties of polymer concrete and fibre reinforced polymer concrete containing 1%, 1.5% and 2% by weight fraction (total concrete) of steel fibres, each volume fraction containing 5% and 10% fly ash content.
- Determining the effects of replacement of cement by FA by various percentages on the compressive strength, flexural strength and split tensile strength of concrete.

MATERIALS

The properties of materials utilized as a part of cement are resolved in research facility according to pertinent code of training. Diverse materials utilized as a part of the present investigation were polymer alongside hardener, coarse totals, fine totals, FA, steel fiber. Consequences of the tests directed to decide physical properties of materials are accounted for and talked about in this segment. The materials when all is said in done, fit in with the particulars set down in the important Indian Standard Codes. The materials utilized were having the accompanying qualities:

Polymer (Epoxy Resin)

An epoxy based gum utilized as folio with hardener for influencing polymer to concrete. Albeit all materials that go into solid blend are fundamental, polymer is all the time the most essential since it is typically the sensitive connection in the chain. The capacity of polymer with hardener is as a matter of first importance to tie the sand and stone together and second to top off the voids in the middle of sand and stone particles to frame a smaller mass. Despite the fact that it constitutes just around 14 percent of the heaviness of solid blend, it is the dynamic segment of restricting medium and is the main deductively controlled element of cement. Any variety in its amount influences the compressive quality of the solid blend. Epoxy with hardener combined is appeared in fig. 3.1

Aggregate

Waterway sand made of pulverized totals was utilized as fine total. Locally accessible squashed stone total with most extreme size 10 mm were utilized as coarse totals. The total % is a blend of three evaluations in particular I, II and III in the proportion of 40:34:26 by weight of evaluations I:II:III, review I having molecule measure from 4.76 to 10 mm fig. 3.2, review II having molecule estimate from 2.38 to 4.76 mm fig. 3.3 and grade III having molecule estimate from 0.15 to 0.3 mm fig. 3.4. This proportion compares to the upgraded total blend extent having slightest void.

Table 3.1: showing the aggregates used

Grading	Particle size	Percentage of particles to be used (%)
I	4.76 to 10 mm	40
II	2.38 to 4.76mm	34
III	0.15 to 0.3 mm	26

Table-3.2: Chemical analysis of fly ash

Chemical compositions (%)	Percentage
SiO ₂	56.77
Al ₂ O ₃	31.83
Fe ₂ O ₃	2.82
CaO	0.78
K ₂ O	1.96
TiO ₂	2.77
Na ₂ O ₃	0.68
MgO	2.39
Physical properties	-
Specific surface area (m ² /g)	2.30
Specific gravity	1.24
Moisture content	0.20
Wet density (gram/cc)	1.79
Turbidity (NTU)	4.59
pH	7.3

Fibres

Just steel filaments have been utilized as a part of the creation of fiber strengthened polymer concrete, yet these may decrease flowability and passing capacity. Trials are consequently expected to build up the ideal sort, length and amount to give all the expected properties to both the new and solidified cement. Strands can be utilized to enhance the steadiness of fiber fortified polymer concrete, as these assistance counteract settlement and breaking because of plastic shrinkage of the solid. Steel strands are utilized to alter the flexibility/durability of the solidified cement. Their length and amount is chosen relying upon the most extreme size of total and on basic necessities. On the off chance that they are utilized as a substitute for ordinary support, the danger of blockage is not any more appropriate however it ought to be accentuated that utilizing fiber strengthened polymer concrete in structures with typical fortification altogether builds the danger of blockage. Layered steel filaments of 0.5mm measurement and 10mm long at various fiber volume divisions in the scope of 1.0%, 1.5% and 2% were utilized.

Concrete Mix

Concrete mixes with binary and ternary blends of cement and mineral admixtures were prepared with constant mix

proportion and water/binder ratio and different binder combinations are shown under

Polymer/hardener ratio	Fine aggregate/polymer ratio	Coarse aggregate/polymer ratio
0.5	10.96	7.30

RESULTS AND DISCUSSION

The objectives of this study were to determine the behaviour of Polymer Concrete (SCC) and Fibre Reinforced Polymer Concrete under static flexural with different volume fraction of steel fibres, each volume fraction having different fly ash contents as partial replacement to concrete by weight. To study the properties of Polymer concrete and fibre reinforced polymer concrete i.e.; compressive strength test, flexural strength test and split tensile test were determined.

Therefore, an experimental programme was planned, in which a total of 32 cubes for compressive strength, 32 cubes for split tensile test and 48 beam specimens for flexural tests for polymer concrete and fibre reinforced polymer concrete incorporating 0.5%, 1.0%, 1.5% and 2% fibre volume fraction, were tested. The detailed analysis and discussion of the test results as obtained from the experimental programme is presented in following sections. Results of the test performed are as shown under in table 4.1, 4.2, 4.3 .

Table 4.1: Results of different tests performed for 10% fly ash at 7 days with varied steel fibre %.

10% flyash (7days) all units in MPA				
Test	Steel Fibre (%)			
	0	1.0	1.5	2.0
Flexural strength	32.92	32.71	33.69	35.89
Compressive strength	71.60	78.20	80.30	84.70
Split tensile strength	11.00	11.23	11.53	12.17

Table 4.2: Results of different tests performed for 10% fly ash at 28 days with varied steel fibre %.

10% flyash (28days)				
Test	Steel Fibre (%)			
	0	1.0	1.5	2.0
Flexural strength	33.48	35.10	35.56	38.61
Compressive strength	85.00	88.00	91.90	100.10
Split tensile strength	11.42	11.68	12.17	16.18

Table 4.3: Results of different tests performed for 5% fly ash at 7 days with varied steel fibre %

5% flyash (28days)				
Test	Steel Fibre (%)			
	0	1.0	1.5	2.0
Flexural strength	31.59	32.92	33.81	34.39
Compressive strength	77.10	81.30	82.60	85.00
Split tensile strength	10.54	12.62	13.11	13.80

Compressive strength

The results of the compressive strength tests on polymer concrete and fibre reinforced polymer concrete mixes tested in this investigation are given in Fig.-4.1, 4.2. These present the variation of compressive strength with fraction of steel fibres by weight of concrete for different fly ash contents used, whereas, Table-4.5 and Fig.-4.3, 4.4 present the results with percentage increase / decrease over the control mix. It may be noted that polymer concrete with 5% fly ash has been taken as control mix for comparison of results. Figure-4.5 and 4.6 shows the variation of compressive strength with steel fibre content used for different percentages of steel fibres at different days. The results indicate that in general, amongst all the fibre percentages tested, the maximum compressive strength equal to 100.10 MPa is achieved with the mix containing fibre percentage of 2% with 10% fly ash content at 28 days. There is an increase in compressive strength by 29.87% compared to control mix on addition of 2% of fibres having 10% fly ash as partial replacement by weight of concrete at 28 days. With the addition of 2% fibres by weight of concrete and 5% fly ash together, mix shows decrement values of compressive strength.

Table 4.5: showing the change in compressive strength with respect to a control mix

S.No.	Flyash (%)	Steel fibre (%)	7 Days Compressive Strength (MPa)	Increase (%)	28 Days Compressive Strength (MPa)	Increase (%)
1	5	0.0	70.40	0.00	77.10	0.00
2	5	1.0	75.80	7.6	81.30	5.44
3	5	1.5	80.00	13.6	82.60	7.13
4	5	2.0	83.00	17.89	85.00	10.24
5	10	0.0	71.60	1.70	85.00	10.24
6	10	1.0	78.20	11.07	88.00	14.13
7	10	1.5	80.30	14.06	91.90	19.19
8	10	2.0	84.70	20.31	100.10	29.83

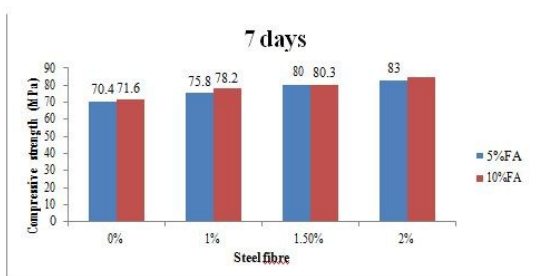


Figure 4.1 Compressive strength versus fibre content by weight for 5% and 10% fly ash at 7 days

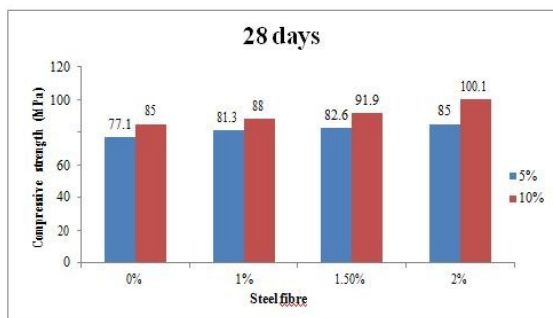


Figure 4.2: Compressive strength versus fibre content by weight for 5% and 10% fly ash at 28 days

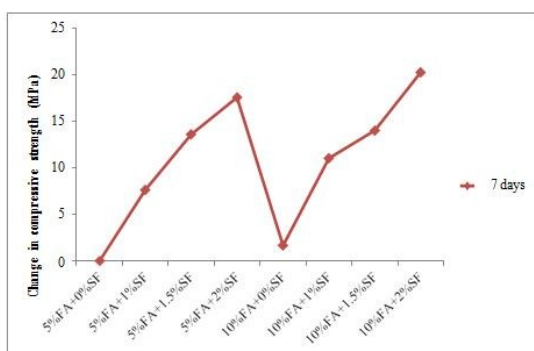


Figure 4.3: Increase in compressive strength versus different mixes at 7 days w.r.t. control mix

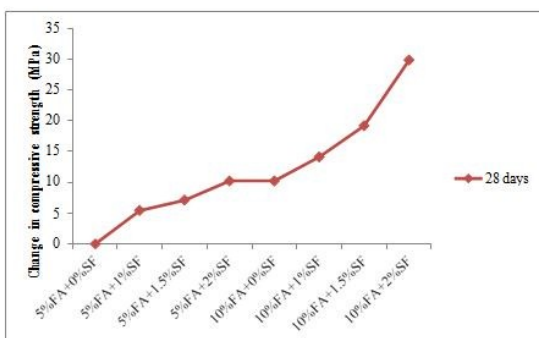


Figure 4.4: Increase in compressive strength versus different mixes at 28 days w.r.t. control mix

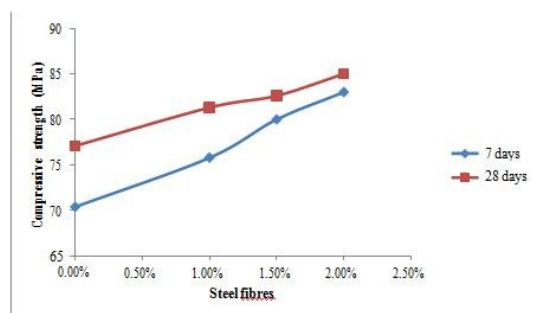


Figure 4.5: Variation of compressive strength at 7 and 28 days with 5% fly ash content

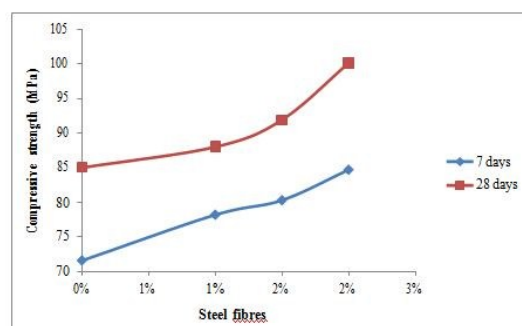


Figure 4.6: Variation of compressive strength at 7 and 28 days with 10% fly ash content

Table 4.6: Showing the change in compressive strength with respect to a control mix

S.No.	Fly Ash (%)	Steel fibre (%)	60 Days Compressive Strength(MPa)	Increase (%)	90 Days Compressive Strength (MPa)	Increase (%)
1	5	0.0	70.42	0.00	77.12	0.00
2	5	1.0	75.82	7.61	81.32	5.45
3	5	1.5	80.04	13.66	82.62	7.14
4	5	2.0	83.05	17.82	85.02	10.25
5	10	0.0	71.62	1.71	85.02	10.25
6	10	1.0	78.24	11.08	88.02	14.14
7	10	1.5	80.35	14.07	91.92	19.21
8	10	2.0	84.76	20.32	100.12	29.84

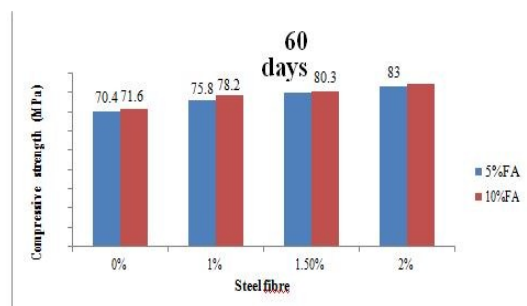


Figure 4.1 Compressive strength versus fibre content by weight for 5% and 10% fly ash at 60 days

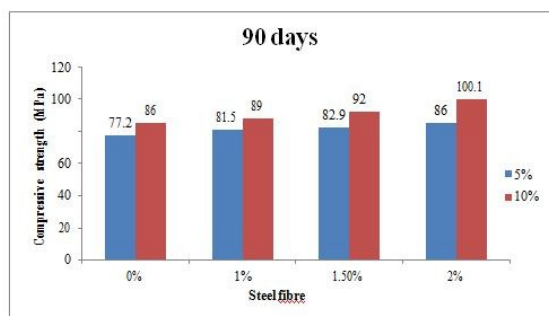


Figure 4.2: Compressive strength versus fibre content by weight for 5% and 10% fly ash at 90 days

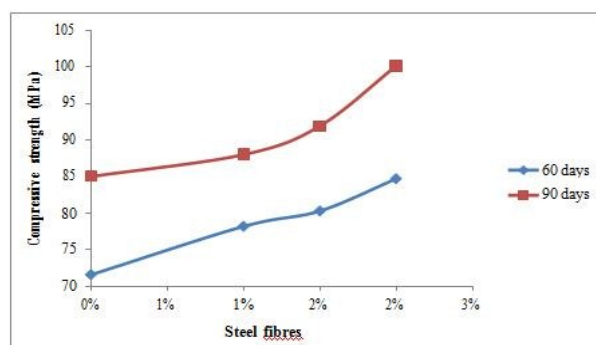


Figure 4.6: Variation of compressive strength at 60 and 90 days with 10% fly ash content

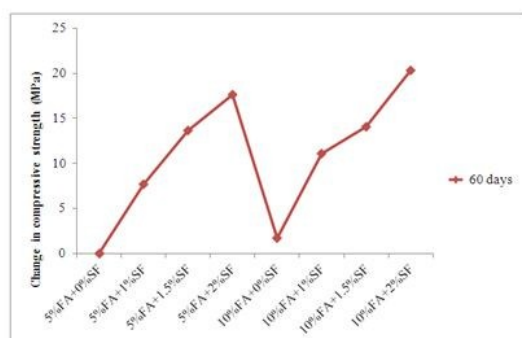


Figure 4.3: Increase in compressive strength versus different mixes at 60 days w.r.t. control mix

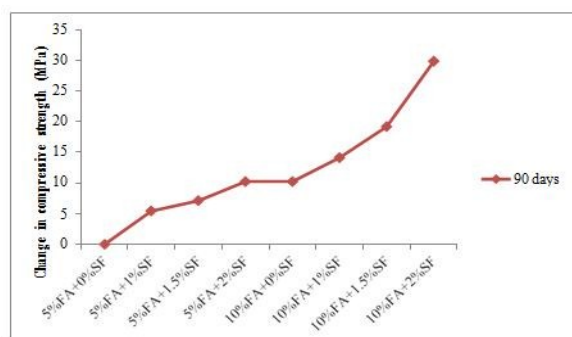


Figure 4.4: Increase in compressive strength versus different mixes at 90 days w.r.t. control mix

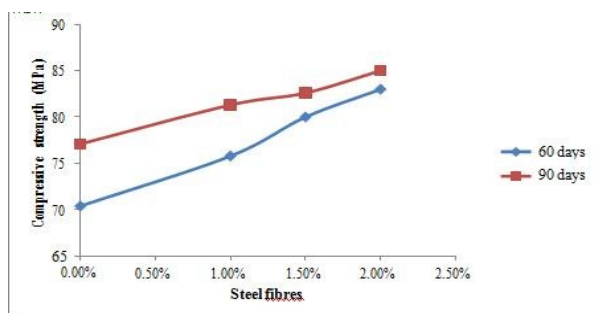


Figure 4.5: Variation of compressive strength at 60 and 90 days with 5% fly ash content

Table 4.6: Showing the change in flexural strength with respect to a control mix

S. No.	Fly Ash (%)	Fibres (%)	7 Days flexural Strength (MPa)	Increase MPa	28 Days flexural Strength (MPa)	Increase MPa
1	5	0.0	29.25	0.00	31.59	0.00
2	5	1.0	31.82	8.78	32.92	4.21
3	5	1.5	33.69	15.17	33.81	7.02
4	5	2.0	34.39	17.57	35.02	10.85
5	10	0.0	32.92	12.54	33.48	5.98
6	10	1.0	32.71	11.82	35.10	11.11
7	10	1.5	33.69	15.17	35.56	12.56
8	10	2.0	35.89	22.70	38.61	22.22

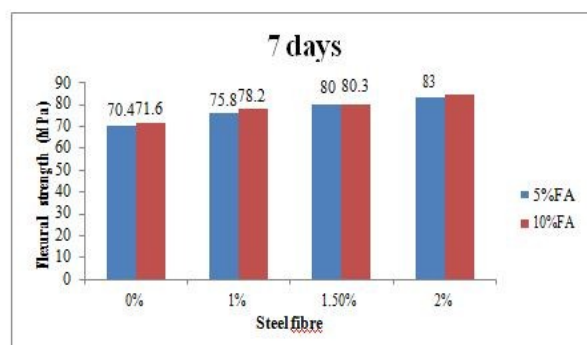


Figure 4.7: Flexure strength versus fibre content by weight for 5% and 10% fly ash at 7 days

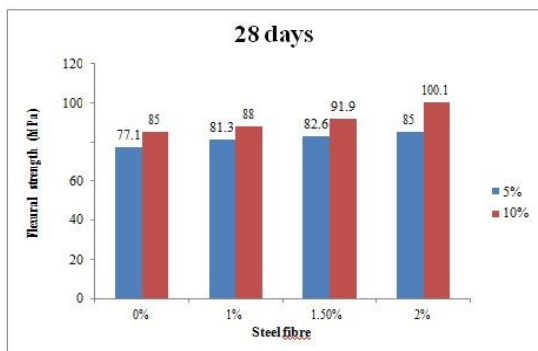


Figure-4.8: Flexure strength versus fibre content by weight for 5% and 10% fly ash at 28 days

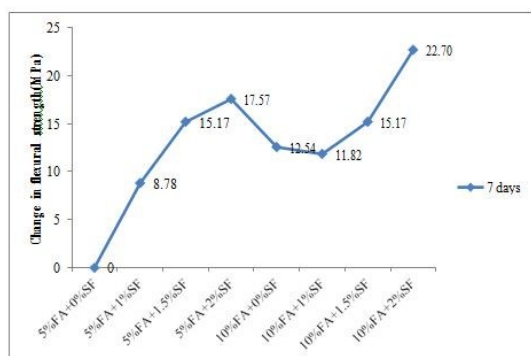


Figure-4.9: Increase in flexure strength versus different mixes at 7 days w.r.t. control mix

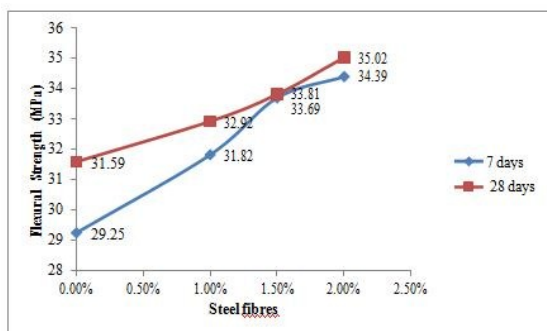


Figure 4.11: Variation of flexure strength at 7 and 28 days with 5% flyash content

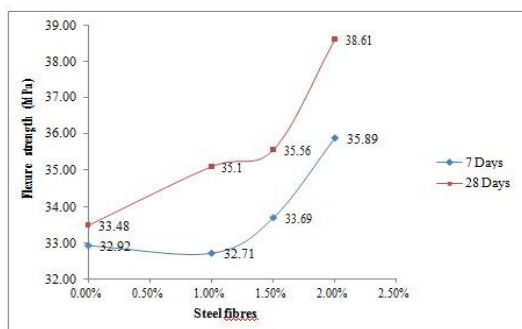


Figure-4.12: Variation of flexure strength at 7 and 28 days with 10% flyash content

Table 4.6: Showing the change in flexural strength with respect to a control mix

S. No.	Fly Ash (%)	Fibres (%)	7 Days flexural Strength (MPa)	Increase MPa	28 Days flexural Strength (MPa)	Increase MPa
1	5	0.0	29.27	0.00	31.62	0.00
2	5	1.0	31.86	8.78	32.67	4.24
3	5	1.5	33.74	15.17	33.85	7.05
4	5	2.0	34.42	17.57	35.05	10.87
5	10	0.0	32.97	12.54	33.49	5.99
6	10	1.0	32.73	11.82	35.15	11.13
7	10	1.5	33.72	15.17	35.58	12.57
8	10	2.0	35.95	22.70	38.67	22.24

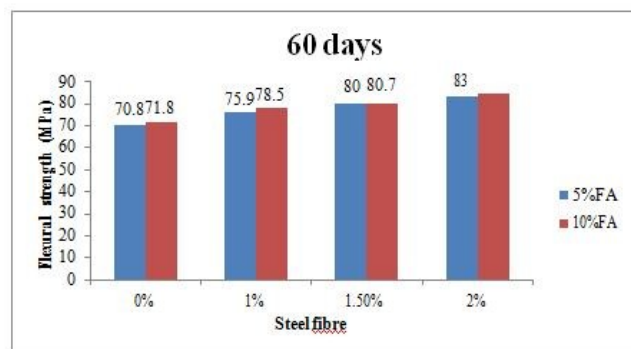


Figure 4.13: Flexure strength versus fibre content by weight for 5% and 10% fly ash at 60 days

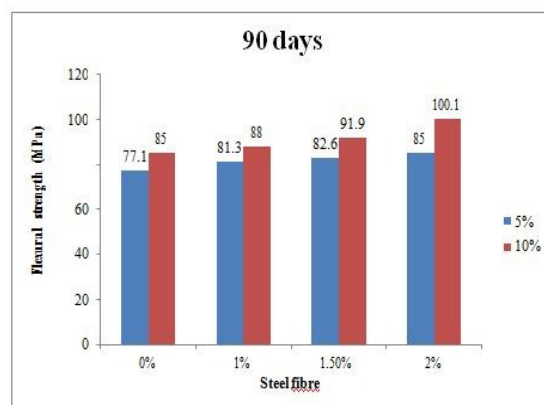


Figure 4.14: Flexure strength versus fibre content by weight for 5% and 10% fly ash at 90 days



Figure-4.15: Increase in flexure strength versus different mixes at 60 days w.r.t. control mix



Figure 4.16: Increase in flexure strength versus different mixes at 90 days w.r.t. control mix

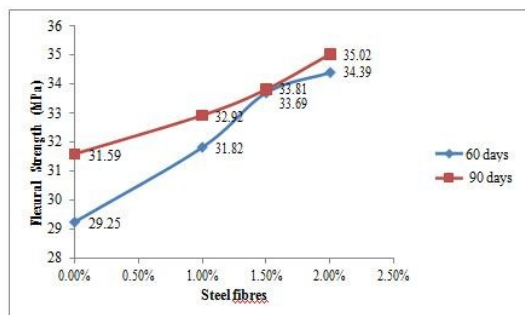


Figure 4.17: Variation of flexure strength at 60 and 90 days with 5% fly ash content

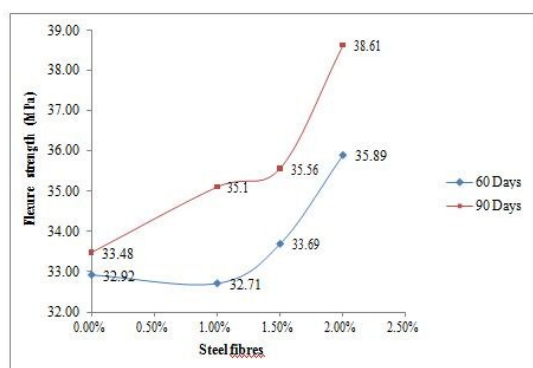


Figure 4.18: Variation of flexure strength at 60 and 90 days with 10% fly ash content

Table 4.7: Showing the change in split tensile strength with respect to a control mix

S. No.	Fly Ash (%)	Fibres (%)	7 Days split tensile Strength (MPa)	Increase MPa	28 Days split tensile Strength (MPa)	Increase MPa
1	5	0.00	8.50	0.00	10.54	0.00
2	5	1.00	9.60	12.94	12.62	19.73
3	5	1.50	10.74	26.35	13.11	24.38
4	5	2.00	12.37	45.52	13.86	31.49
5	10	0.00	11.00	29.41	11.42	8.34
6	10	1.00	11.23	32.11	11.68	10.81
7	10	1.50	11.53	35.64	12.17	15.46
8	10	2.00	12.17	43.17	16.18	53.51

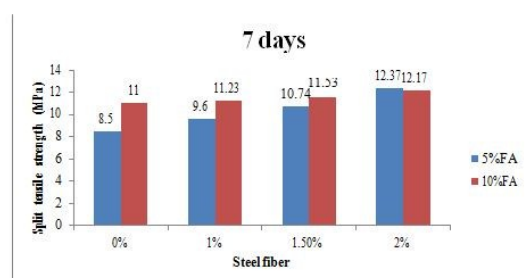


Figure 4.19: Split tensile strength versus fibre content by weight for 5% and 10% fly ash at 7 days

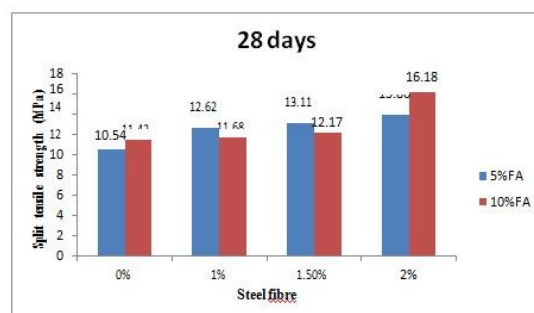


Figure 4.20: Split tensile strength versus fibre content by weight for 5% and 10% fly ash at 28 days

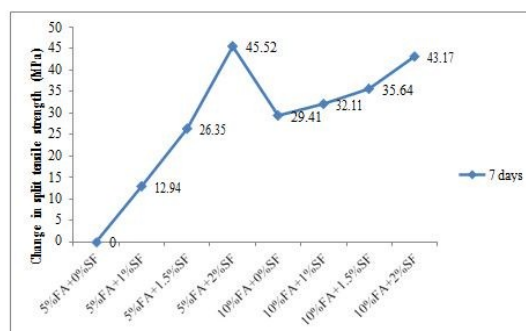


Figure 4.21: Increase in split tensile strength versus different mixes at 7 days w.r.t. control mix

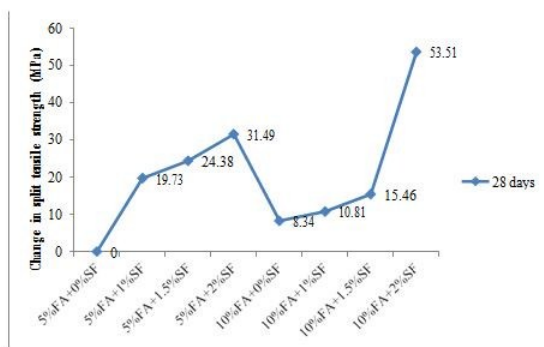


Figure 4.22: Increase in split tensile strength versus different mixes at 28 days w.r.t. control mix

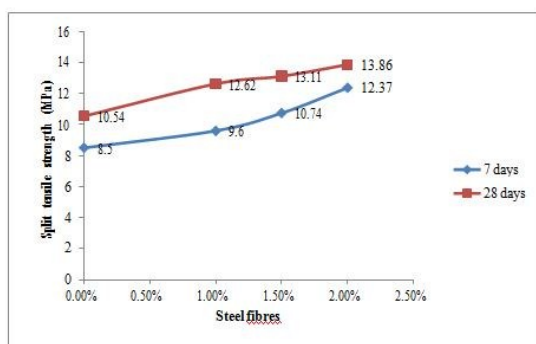


Figure 4.23: Variation of split tensile strength at 7 and 28 days with 5% flyash content

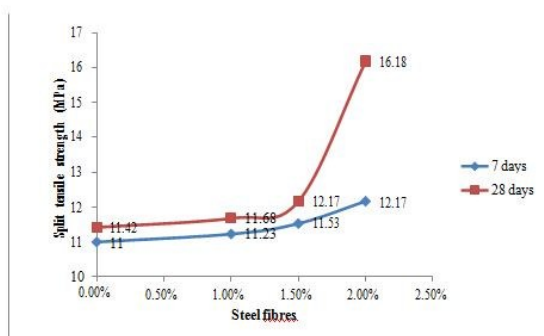


Figure 4.24: Variation of split tensile strength at 7 and 28 days with 10% flyash content

CONCLUSIONS

The experimental researches concerning the polymer concrete had investigated the mechanical characteristics of epoxy polymer concrete prepared with fly ash as filler. For obtaining good mechanical properties the filler is used with higher dosages. The experimental values of mechanical strengths for polymer concrete without steel fibres were smaller than that for polymer concrete with fibres. A huge amount of work has been done on literature of polymer concrete which has concluded that use of 14% resin by weight of polymer concrete would give better results. Various other parameters like micro fillers, aggregate type,

resin type, fibre reinforcement and curing regime affects the polymer concrete. Based on the present study the various conclusions drawn are as follows:

- Temperature of the epoxy resin played a major role at the time of casting,
- higher the temperature of polymer lowest it's setting time.
- If the temperature is kept low then the workability is reduced so it must be optimum and is 40 degree Celsius.
- This study reports that the mix with 10% flyash and 2% steel fibre reinforcement gives the maximum value of compressive strength at 28 days i.e., 100.1 MPa.
- Similarly the same mix (10% fly ash + 2% steel fibre) gives maximum value of flexural strength at 28 days i.e., 38.61 MPa.
- The mix with 10% fly ash and 2% steel fibre gives maximum increase in the percentage of compressive strength i.e., 29.83% at 28 days over the control mix with 5% fly ash and 0% steel fibre
- Similarly the same mix (10% fly ash + 2% steel fibre) gives maximum increase in the percentage of flexural strength i.e., 22.22% with respect to the control mix with 5% fly ash and 0% steel fibre.
- Coming to the split tensile strength similar to the previous two tests, the maximum value of split tensile obtained at 28 days is with the mix 10% fly ash and 2% steel fibre i.e., 16.18 MPa and so is the case with percentage increase in the strength i.e., 53.51%.
- The 7 days strength values are almost equal to the 28 days strength values in most of the cases, so that concludes polymer concrete gains strength very quickly.

REFERENCES

- [1] Abdel-Fattah H. and El-Hawary M.M. (1999), —Flexural behavior of polymer concrete, Construction and Building Materials, vol. 13, no. 5, pp. 253–262.
- [2] B̄arbut, ̄a M. and Lep̄adatu D. (2008), —Mechanical characteristics investigation of polymer concrete using mixture design of experiments and response surface method, Journal of Applied Sciences, vol. 8, no. 12, pp. 2242– 2249.
- [3] Bai W., Zhang J., Yan P., and Wang X. (2009), —Study on vibration alleviating properties of glass fibre reinforced polymer concrete through orthogonal tests, Materials & Design, vol. 30, no. 4, pp. 1417– 1421.

- [4] *Bedi R., Chandra R., and Singh S.P.(2013), —Mechanical Properties of Polymer Concrete*, Hindawi Publishing Corporation Journal of Composites Volume , Article ID 948745.
- [5] *Blaga A. and Beaudoin J.J. (1985), Polymer Modified Concrete*, Canadian Building Digest 241, Division of Building Research, National Research Council of Canada, Ottawa.
- [6] *Broniewski T., Jamroz Z., and Kapko J. (1975), —Long life strength polymer concrete*, in Proceedings of the 1st International Congress on Polymer Concretes—Polymers in Concrete, pp. 179–184, London, UK.
- [7] *Brockenbrough T.W. (1982), —Fibre reinforced methacrylate polymer concrete*, ACI Journal, pp. 322–325.
- [8] *Ferreira A.J.M. (2000), —Flexural properties of polyester resin concretes*, Journal of Polymer Engineering, vol. 20, no. 6, pp. 459–468.
- [9] *Gadhia S.T. (2004), —Studies on some synthetic building materials*, Department of Chemistry, Saurashtra University, Gujrat, India.
- [10] *Haidar M., Ghorbel E., and Toutanji H. (2011), —Optimization of the formulation of micro-polymer concretes*, Construction and Building Materials, vol. 25, no. 4, pp. 1632–1644.
- [11] *Hing L.E. (2007), —Application Of Polymer In Concrete Construction*, Universiti Teknologi Malaysia.
- [12] *Jo B.W., Park S.K., and Kim D.K., (2008) —Mechanical properties of nano-MMT reinforced polymer composite and polymer concrete*, Construction and Building Materials, vol. 22, no. 1, pp. 14–20.
- [13] *Khalid A.A., Sahari B., and Khalid Y.A. (1998), —Environmental Effects on the Progressive Crushing of Cotton and Glass Fibre/Epoxy Composite Cones*, Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies, Kuala Lumpur, 24–28 August.
- [14] *Kim H.S., Park K.Y., and Lee D.G.Q. (1995), —A study on the epoxy resin concrete for the ultra-precision machine tool bed*, Journal of Materials Processing Tech, vol. 48, no. 1-4, pp. 649–655.
- [15] *Kobayashi K. and Ito T. (1975), —Several physical properties of resin concrete*, in Proceedings of the 1st International Congress on Polymer Concretes—Polymers in Concrete, pp. 236–240, London, UK.
- [16] *Laredo Dos Reis J.M. (2005), —Mechanical characterization of fibre reinforced Polymer Concrete*, Materials Research, vol. 8, no. 3, pp. 357–360.
- [17] *Maksimov R.D., Jirgens L., Jansons J., and Plume E. (1999), —Mechanical properties of polyester polymer-concrete*, Mechanics of Composite Materials, vol. 35, no. 2, pp. 99–110.
- [18] *Mani P., Gupta A.K., and Krishnamoorthy S. (1987), —Comparative study of epoxy and polyester resin-based polymer concretes*, International Journal of Adhesion and Adhesives, vol. 7, no. 3, pp. 157–163.
- [19] *Marinela B., Arbut A. and Harja M. (2008), —properties of fibre reinforced polymer concrete*, universitatea tehnică „gheorghe asachi” din iasi, itomul liv (lviii), fasc. 3.
- [20] *Mebarkia S. and Vipulanandan C. (1992), —Compressive behavior of glass-fibre- reinforced polymer concrete*, Journal of Materials in Civil Engineering, vol. 4, no. 1, pp. 91–105.
- [21] *Muthukumar M., Mohan D., and Rajendran M. (2003), —Optimization of mix proportions of mineral aggregates using Box Behnken design of experiments*, Cement and Concrete Composites, vol. 25, no. 7, pp. 751–758.
- [22] *Ohama Y. (1973), —Mix proportions and properties of Polyester Resin Concretes*, American Concrete Institute, pp. 283–294.
- [23] *Okada K., Koyanagi W., and Yonezawa T. (1975), —Thermo dependent properties of polyester resin concrete*, in Proceedings of 1st International Congress on Polymer Concretes—Polymers in Concrete, pp. 210–215, London, UK.
- [24] *Oussama E., Elhem G., Valérie M., Mongi B.O. (2012), —Mechanical and physical properties of epoxy polymer concrete after exposure to temperatures up to 250 °C —*, Construction and Building Materials 27 pp. 415–424.
- [25] *Rebeiz K.S. (1996), —Precast use of polymer concrete using unsaturated polyester resin based on recycled PET waste*, Construction and Building Materials, vol. 10, no. 3, pp. 215–220.
- [26] *Rebeiz K.S., Serhal S.P. and Craft A.P. (2004), —Properties of polymer concrete using fly ash*, Journal of Materials in Civil Engineering, vol. 16, no. 1, pp. 15–19.
- [27] *Rebeiz K.S. (1996), —Precast use of polymer concrete using unsaturated polyester resin based on recycled PET waste*, Construction and Building Materials, vol. 10, no. 3, pp. 215–220.
- [28] *Ribeiro M.C.S., N’ovoa P.R., Ferreira A.J.M., Marques A.T., (2004) Flexural performance of polyester and epoxy polymer mortars under severe thermal conditions*, Cement and Concrete Composites, vol. 26, no. 7, pp. 803–809.
- [29] *Schoenberger Jr, R.A., McCullogh R., Crowson S. (1991), Holloway D. and Nichol T., Chemically resistant floor overlays*, in Working Papers, Int. Congress on Polymers in Concrete, San Francisco, CA, September.

- [30] *Sett K. and Vipulanandan K. (2004)*, —Properties of polyester polymer concrete with glass and carbon fibres, *ACI Materials Journal*, vol. 101, no. 1, pp. 30–41.
- [31] *Sirivivatnanon V., Tam C.T. and D. W. S. Ho (2003)*, —Special Concrete and Applications, *CSIRO*, National University of Singapore.
- [32] *Snell L.M., Gillespie H.A. and Nelson R.Y. (1972)*, —Polymer Concrete And Its Potential In the Construction Industry, *Proc. Okla. Acad. Sci.* 52: 16C).162.
- [33] *Valore R. and Naus D.J.(1975)*, —Resin bound aggregate material systems, *in Proceedings of the 1st International Congress on 12 Journal of Composites Polymer Concretes—Polymers in Concrete*, pp. 216–222, London, UK.
- [34] *Varughese K.T. and Chaturvedi B.K. (1996)*, —Fly ash as fine aggregate in polyester based polymer concrete, *Cement and Concrete Composites*, vol. 18, no. 2, pp. 105–108.
- [35] *Victor Y. Garas and C. Vipulanandan* , —Review of Polyester Polymer Concrete Properties, *Center for Innovative Grouting Materials and Technology (CIGMAT), Department of Civil and Environmental Engineering, University of Houston, Houston.*
- [36] *Vipulanandan C. and Mebarkia S. (1990)*, —Aggregates, fibres and coupling agents in polymer concrete, *in Proceedings of the 1st Materials Engineering Conference*, pp. 785–794, Denver, Colorado, August.
- [37] *Vipulanandan C., Dharmarajan N., and Ching E. (1988)*, —Mechanical behaviour of polymer concrete systems, *Materials and Structures*, vol. 21, no. 4, pp. 268– 277.
- [38] *Vipulanandan C. and Dharmarajan N. (1987)*, —Flexural behaviour of polyester polymer concrete, *Cement and Concrete Research*, vol. 17, no. 2, pp. 219–230.
- [39] *Vipulanandan C. and Paul E. (1990)*, —Performance of epoxy and polyester polymer concrete, *ACI Materials Journal*, vol. 87, no. 3, pp. 241–251.
- [40] *Vipulanandan C. and Paul E. (1993)*, —Characterization of polyester polymer and polymer concrete, *Journal of Materials in Civil Engineering*, vol. 5, no. 1, pp. 62–82.
- [41] *Xu P. and Yu Y.H. (2008)*, —Research on steel-fibber polymer concrete machine tool structure, *Journal of Coal Science and Engineering*, vol. 14, no. 4, pp. 689–692.