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# An experimental investigation on strength of polymer concrete

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***Abstract*— This experimental study is intended to identify the mix ratios for M20 grade of polymer Concrete. Compressive strength of polymer concrete and parameters that affect it are analyzed and proved experimentally. From the test results it was clear that polymer concrete possesses good compressive strength and offers good durability characteristics. Polymer concrete can be use deficiently in concrete industry especially in precast members. Based on an extensive experimental investigation it has been reported that in the polymer (Polyester resin) concrete gives greatly improved compressive strength and other properties, whole compare with ordinary cement concrete. It is also observed that by adding 9 to 14% of polyester resins, it is possible to obtain maximum efficiency. The quantity of polyester resins considered in this study is 10%, 11%, 12% and 13%.**

***Index Terms*— polymer concrete, compressive strength test, split tensile test, resin promoter, catalysis.**

## I. INTRODUCTION

### COMPOSITE MATERIALS

The development of composite materials has been a subject of intensive interest for at least 15 years but the concept of using 2 or more elemental materials combined to form the constituent bases of a composite solid has been employed ever since materials where first used. From the earliest uses, the goals for composite development have been to achieve a combination of properties not achieve a combination of properties not achieves by any of the elemental materials acting alone; those solid could be prepared from constituents which, by themselves could not satisfy a particular design requirement. Because physical, chemical, electric and magnetic properties might be involved, input from investigators of various disciplines was required. In the various volume of this treatise references to specific materials have generally only included the man made or synthetic composites, but certainly the broad definitions of composite materials must include naturally occurring materials such as wood. Chapters of this project dealing with analytical studies of course can apply equally to synthetic are naturally occurring composites.

Composites materials are being applied in building increasing amounts for essentially the same reasons as in applications; namely they provide properties and behaviour attainable in single phase material or they provides these features more efficiency or at low cost or both.

The types of composites materials or composites structural principally found in buildings are:

1. Fibrous: Fibres embedded in continuous matrix.
2. Laminar: Layers of materials boned together a possibly interpenetrated by a binding material.
3. Particulate: Particles embedded in a continuous material.

An important sub category of the laminar class composite is the structural sandwich, in which two relative thin, strong, stiff, dense facing are ones to a relative thick, light weight, less strong and less stiff core.The various classes are not mutually exclusives; examples, elements if class 1 and 3 may form the components class 2, especially subclasses of sandwiches.

In a somewhat different category are the member employed in a variety of tension of tension structure, including the supported by cables and masts, or by air under modern pressure.

### ADVANTAGES

Advantages of composite material over cement concrete and polymer concrete.

1. Because of low tensile strength, the cement concrete is not even able to support the usual minimum service loads. This in turn paves the ways to the reinforcement of material i.e., the ultimate failure if the concrete.
2. In the application of water related structures the cement concrete has its own drawbacks such as erosion etc., whereas because of its polymer content and the special chemical properties the composite materials have their own restriction to such drawbacks.
3. The durability of composite material is far better than the cement structures, because of their long standing against the chemical change.

APPLICATIONS

Several structural applications appear to be very popular in India.

1. Structural such as foundations, columns, roof structures, floorings etc., in chemical and quasi chemical industries. For example,
    a. Fertiliser industry structures
    b. Sugar industry Structures
    c. Food processing industry structures
    d. Daily form structures
    e. Petrochemical industry Structures
    f. Electro plating unit structures, etc.,
2. Storage and transport structures such as processing tanks and pipes, electroplating tanks and effluent carrying pipes
3. Sanitary structures such as sewer and sewage pipes and tanks.
4. Structures along the coast line of the country, which are subject to attack by air borne salt, water pipes, piles and railway sleepers.
5. Prestressed concrete structures, including fresh water pipes.
6. Marine and off-shore structures.
7. Aircraft runways and Industrial floors subjected to heavy impact and abrasion forces.
8. Repair of damaged structures and quick structures joining of precast concrete structural elements.
9. Various electrical power structures for example columns and cross bars (where superior electrical characteristics load considerable economy), transformer buses and foundations (where transformer oil severally attacks reinforced concrete)
10. Irrigation and hydraulics structures such as canals, deep structures outlet and spilling erosion resistance is required.

## II.POLYMER CONCRETE

GENERAL

Polymer concrete composites are obtained by combining polymers with the ingredients cement composites or with the lime and aggregate. Polymer concrete composites denote not a single set, but a range of composites.

TYPES OF POLYMER

Depending upon the process and materials used polymer concrete composites can be in the three major types.

1. Polymer Concrete (PC)
2. Polymer Impregnated Concrete (PIC)
3. Polymer Modified Cement Composite (PMCC)

POLYMER CONCRETE (PC)

Polymer concrete is a composite, where in the polymer system is employed as the sole binder of aggregate system totally replacing the cement water binder system. General polymer concrete is very durable and strong.

POLYMER IMPREGNATED (PIC)

Polymer impregnate concrete is a composite obtained by the impregnation of low viscosity monomer (Precursor to polymer) into the pore system of cured and hardened cement concrete. PIC is a near impermeable, durable and strong composite.

POLYMER MODIFIED CEMENT COMPOSITE (PMCC)

Here polymeric materials are incorporated into cement composites during the mixing stages and the mix is cast as cured, more or less in a conventional manner to obtain PMCC.

POLYMER CONCRETE (PC)

Polymer concrete is obtained by using polymer as the binder for an aggregate system comprising cores and fixing aggregates those PC is being prepared by the integral mixing of polymerizable materials such as liquid resin or fillers and aggregate. Polymerization and curing process are being accomplished through a catalyst promoter system. Amount of polymers as binders in polymer concrete are normally from 8% to 25% (by weight) of total weight. The properties of the polymer concrete depend largely on the properties and amount of polymer binders in them. Monomer is the low viscosity liquids such as styrene, Methyl methacrylate, epoxy polyester etc., polymerization may be performed in any one of the following methods.

1. Thermal catalytic method:
   In this method the temperature is being maintained 80 degree centigrade and catalyst only used
2. Ambient temperature method:
   In this method, catalyst and promoter both are used at room temperature
3. Radiation polymerization method:
   In the polymerization is being done by using gamma radiation

In all those methods ambient temperature method is much suitable for our circumstances. We can explain the manufacturing process of polymer concrete as follows,

Aggregates used here should be clean, sound, having moisture content of 1% or less to ensure adequate bond to the monomer. The response of the most PC is more depend upon time and temperature then for PIC or PMCC. Creep is more pronounced, especially at elevated temperature. However, PC is usually more ductile then for PIC or Normal concrete.

## III.MATERIALS USED FOR POLYMER CONCRETE IN PRACTICAL

POLYESTER RESIN

By far the most widely used of all laminating resins are the unsaturated polyester resins. The essential part of this resin is that they are unsaturated and can be cross linked or used through the unsaturated links to give hard, infusible, insoluble, thermo set solids. This is done with the aid of a catalyst at room temperature (or) by applying heat.

PROMOTER [COBALT OCTATE (COOC)]:

Cobalt octate was used as promoter. It is pale pink incolour. Its specific gravity at 20 degree Celsius is 0.95. Normally DMA will be used as promoter with the Cobalt octate.

CATALYST [METHYL ETHYL KETONE PEROXIDE (MEKP)]:

The catalyst used in this study is MEKP. Sometimes it is used as hardening agent for the production of Reinforced fibre glass parts for cars, soil boats, recreational vehicles and chemical storage tanks. Generally, Ketone peroxide is mixtures of peroxides.Ketone peroxides are used primarily on room temperature initiated curing of polyester resins using transition – metal promoters (Cobalt octate) since those

peroxides contained the Hydroperoxy (-OOH) groupings and those, behave much like the Hydroperoxides (except that they are mixtures with somewhat lower thermal stability). It is having specific gravity of 1.13 at 20 degree centigrade an viscosity 24 ocp at 20 degree centigrade.

CO-PROMOTER [DIMETHYL ANELENE(DMA)]:

DMA was used as a co-promoter. In order to accelerate the curing rate of the resin concrete to improve its early stage of strength, it was used.

FINE AGGREGATE**:**

Sand was used as fine aggregate in the concrete mix. Sand used was river sand containing large portion of quartz. The sand was sieved by the sieves no.14 (1.18mm) and no.16 (1 mm) placed one upon the other. Then the sand retained on the no.13 sieve was collected though the sand particles sizes between 1 mm to 1.18 mm were obtained. The finest modulus of sand was found to be 2.861. The specific gravity of sand was 2.65. Number of impurities was found in the sand. Also the sand was dried as much as possible so that there won't be any moisture in it.

COARSE AGGREGATE**:**

The coarse aggregate is the strongest and the least porous component of concrete. The coarse aggregate of sizes between 10mm to 12mm amounts were obtained. In this same manner the coarse aggregate of the sizes between 5mm to 10mm were collected and then those 2 set aggregates were used in the preparation of 1:2 (5 to 10 mm aggregates, 10 to 12 mm aggregates). Some important properties of coarse aggregate like crushing strength and gradation need special consideration while selecting the coarse aggregates.

TABLE 3: PHYSICAL PROPERTIES OF COARSE AGGREGATE

| Sl.No | Tests Conducted | Value |
|---|---|---|
| 1 | Specific gravity | 2.8 |
| 2 | Water absorption(%) | 0.3 |
| 3 | Impact value($N/mm^2$) | 17.4 |
| 5 | Crushing value($N/mm^2$) | 18.56 |

## IV.MIX DESIGN

GENERAL

The design of concrete mix is not a simple task on account of the widely varying properties of the constituent materials the considered that prevails at the site of work and the considered that are demanded for a particular work for which the mix is designed. But the last two parameters are negligible when compare to the first one. So the design of the concrete mix requires complete knowledge of the various properties of the concrete materials. Design of concrete material needs not only the knowledge of material properties and properties of concrete materials. Design of concrete material needs not only the knowledge of material properties and properties of concrete in plastic condition. It also needs wider knowledge and experience of concreting. Even then the proportion of the material of concrete found at the laboratory requires modifications and readjustments to suit the field conditions.

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining then relative proportions with the object of producing concrete of certain strength and durability as economically as possible. From a given set of ingredients, concretes of variable quality can be obtained. Also ingredients of widely varying qualities can be used to produce concrete of acceptable of quality. The relative economy depends primarily on cost of materials rather than cost of labour. This may be kept in mind in the design of concrete mix.

The polyester resin is several times costlier than aggregate. Hence the quantity of polyester resin should be used to minimum extent possible without sacrificing the desired properties. In achieving this, variability is also consideration. Lesser the difference better is the mix.The following points may be kept in mind before doing the mix design.

a. Compressive strength
b. Workability
c. Durability
d. Maximum size of aggregate
e. Quality control

All the above factors equally influence the mix design.

MIX PROPORTION

The properties of the polymer of the polymer concrete largely on the types and properties of the polymer binders and the properties of aggregates. Regardless of the binder types, there is typical mix proportions (by weight) used in Japan are binder fillers. Fine aggregate and course aggregate mixtures as 1: (1 to 15): (8 to 8.5) Polymerisation and curing process are usually accomplished through an initiator – promoter system. According to the above proportion the author Y. Ohama had chosen the following mix proportion (by weight) Polyester resin: Cement: Fine aggregate: Coarse aggregate 1:1:3.6:4.4 Different set of specimen were casted by changing the amount of polyester resin, by keeping the amount of other materials are constant.

DETAILS OF TESTING

CURING DETAILS

Curing of unsaturated polyester resin takes place by free radicals polymerisation through the unsaturated groups (double bond) both in the polyester chain and the styrene or other manner. Those are described below.

The free radicals are provided by the peroxide as decomposes and it is the rate at which those free radicals are produced which governs the gel and cure time of the resin.

A polyester resin will begin to cure as soon as the catalyst has been added, however with the hear curve system and in particular sheet and dough moulding components curve does not progress until a certain minimum temperature has been reached. This is the activation or critical temperature of the organic peroxide. Those temperature is allowed in the presence of an accelerator. The curing of a polyester resin can be considered to take place in three stages.

1. Geletion: where the resin changes from the free flowing liquid to a sift gel.

2. Hardening: where the resin cure from the soft gel to hard material capable of being removed from the mould.
3. Final cure of maturing: where the resin achieves its full mechanical and chemical properties. This can takes from few hours at elevated temperature to several hours at room temperature.

Several parameters can be changed to modify the curing process. Those can be summarised as follows:

- A reduction in the catalyst content will increase gel time.
- A reduction in accelerator content will increase the gel time.
- Increasing the curing temperature reduces gel time.
- Increasing film or laminate thickness reduces the gel time.
- The addition of the fillers tends to increase the gel time.

TABLE 5: SPLIT TENSILE STRENGTH OF VARIOUS MIX
RESULTS OF SPECIMEN

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete work. Systematic testing of raw materials fresh concrete and hardened concrete arenseparable part of any quality program for concrete, which helps to achieve higher efficient of the material used and greater assurance of the performance of the concrete with regard to both strength and durability

COMPRESSIVE STRENGTH

The important property of concrete is its strength in compression. The aim of these experimental tests is to determine the maximum load carrying capacity of the specimen. Cubes of sizes 150 x 150 x 150 mm were cast. Three numbers of specimens were tested for 28 days. The specimens are casted for M20 Grade concrete with different proportions of calcium carbonate.

TABLE 1: COMPRESSIVE STRENGTH OF VARIOUS MIX

| Sl.No | Percentage of Resin with Co-promoter | Split tensile Strength of Polymer Concrete at 28days (N/mm$^2$) |
|---|---|---|
| 1 | 0 | 3.1 |
| 2 | 10 | 3.2 |
| 3 | 11 | 4.2 |
| 4 | 12 | 3.6 |
| 5 | 13 | 3.75 |

| **Sl.No** | **Percentage of Resin with Co-promoter** | **Compressive Strength of Polymer Concrete at 28days (N/mm$^2$)** |
|---|---|---|
| 1 | 0 | 21.33 |
| 2 | 10 | 23.75 |
| 3 | 11 | 26.65 |
| 4 | 12 | 24.5 |
| 5 | 13 | 25.69 |

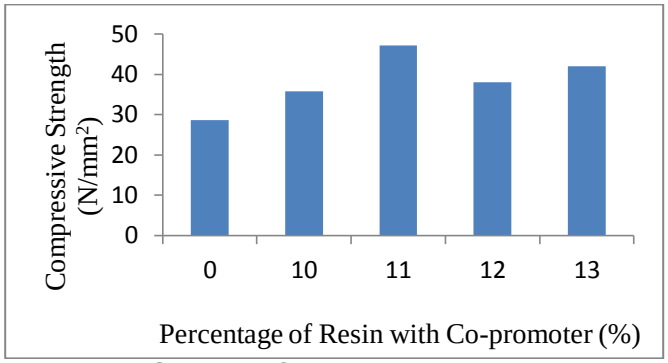
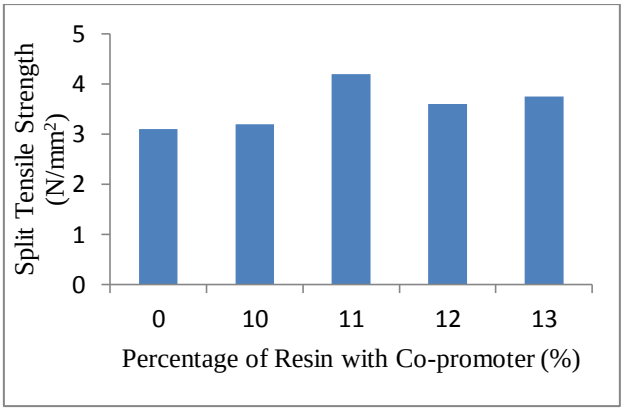



FIG.1 COMPRESSIVE STRENGTH OF POLYMER CONCRETE

SPLIT TENSILE STRENGTH

Cylinders of size 150mm diameters and 300mm height were cast. Three numbers of specimens were tested for 28 days. The specimens are casted for M20 Grade concrete with different proportions of calcium carbonate.

P is maximum load in Newton (N),
d is depth of beam in mm,
b is width of beam in mm and l is the span of specimen in mm




V. CONCLUSION

From the results shown in the tablets, it is clear that polyester resin have higher compress strength. The strength increases up to 11% resin content, then it slightly decreases the compressive strength of concrete obtained from this 11% resin content is more than 3 times, the strength of ordinary cement concrete, normally used.

Tensile strength obtained from polyester resin concrete for 11%. Resin content is 2 to 3 times of the ordinary cement concrete, normally used.

Flexural strength obtained for polyester resin concrete (11 % Resin content) is also 3 times of flexural strength of cement concrete.

The past results say that the ordinary cement concrete slab of some size used by the author can withstand only around 5 to 10 drops for filling of 1 Kg ball from 30Cm height. But the polyester resin concrete (11% resin concrete) has only 0.63% of water absorption capacity.

From past results, cement concrete is being corroded by chemicals around 10% (by weight loss) in 30 days exposure in chemicals. The polyester resin concrete (11%

resin concrete) has only 1.23%, 1.6% and 1.48% weight losses in HCL, $H_2SO_4$ and NaOH respectively for 30 days exposure.

In all the aspects 11% resin content yields the best results.

Polyester resin concrete has a very good potential for structural applications in situations where cement concrete has not been formed to be satisfactory in buildings where there is attack by acids and chemicals.

From the project we came to know that the compressive strength of polymer concrete having 11% of polyester resin (by weight) with 0.8% catalyst and 0.4% of co-promoter gives the optimum result compared to conventional concrete.

In the split tensile and flexural strength test we obtained the results little higher than ordinary conventional concrete. Thus polymer proves to be effective material when compared to cement in terms of strength.

Experimental results prove that the 11 % polyester resin content (by weight) with 0.8% catalyst 0.4% of co-Polyester resin concrete is also very cost effective in applications requiring high degree of durability and chemical resistance. Due to its very low water absorption capacity, it is also be used in offshore structures.

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