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Effect of Polymer and Micro silica in Preplaced Ballast Concrete

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Abstract - **This paper presents the study of Preplaced Ballast (Aggregate) Concrete method in railway track for providing ballast less track. Preplaced Ballast Concrete method employing the injection of cement mortar into voids between preplaced ballast aggregates has recently emerged as a promising approach for the makeover of existing ballasted railway tracks to concrete tracks. This method typically involves the use of a polymer liquid to enhance the durability of the resulting recycled aggregate concrete. However, the effects of the amount of polymer on the mechanical properties of recycled ballast aggregate concrete were not clearly understood. In addition, the effects of the cleanness condition of ballast aggregates were never examined. This study targeted at investigating these two aspects through Ballast samples taken from the track and conducting compression, tensile strength of concrete. The amount of polymer (3%, 6%, 9%) added to the concrete and the test were conducted. The use of a higher polymer ratio improved the microstructure of the interfacial transition zones between recycled ballast aggregates and injected mortar. In order to enhance the compressive strength of concrete, Micro silica (5%, 10%, 15%) were used and the test results revealed the increase in mechanical properties of concrete in Polymer and Micro silica mix. In addition, a higher cleanness level of ballast aggregates generally enriched the mechanical and durability qualities of concrete.**

Keywords- **Ballast, Polymer, Micro silica, Interfacial transition zone, recycled aggregate**

I. INTRODUCTION

In modern times, the enhancement of the traveling speed and capacity of trains have been among the main issues facing public transportation systems around the world. Despite many modifications over its history, the ballasted track system continues to present considerable problems, such as changes in the track geometry, fast deteriorations of track components, and rising maintenance and repair costs due to increasing train speed and transport capacity. Accordingly, the need for non-ballasted railway tracks with higher durability has gradually increased worldwide. The use of slab tracks has also risen in many European countries.

Recently, an effective method for upgrading existing ballasted tracks to non-ballasted tracks has been developed Cast-in-situ Ballastless track is a track in which ballast is particularly replaced by cement-base materials (concrete). It is a known fact that steel is the main construction material used in railways, but with the introduction of ballast less technology, the application of concrete in the railway has increased largely. It's an observed fact that Cast-in-situ ballast less track construction offers an effective alternative to the conventional methods due to the enormous reduction of maintenance work and the long service life with constant serviceability conditions, furthermore the application of higher cant and cant deficiency allow the reduction of the minimum values like radii for curves or the increase of speed for lines equipped with ballast less track

1. Structure of Cast-in-situ BLT

Preplaced Aggregate Concrete (PAC) is referred to a kind of concrete making by first placing coarse aggregate in the formwork and then injecting a sand-cement mortar to fill the voids imprisoned between the coarse aggregate particles (FIG. 1.1). In order to operate safely, it is highly essential to maintain railway tracks over specific periods of time so that any detected defects in track components become obviated. Preplaced Aggregate Concrete (PAC) cost and maintenance activity of railway tracks decrease over their lifetime.

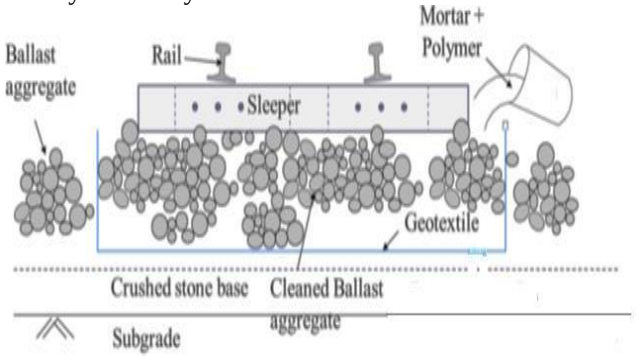

Fig.1 Making of concrete.

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2. Polymer

Polymers with different kinds of fillers are used as construction materials. They have good binding properties and good adhesion with aggregates. They have long chain structure, which helps in developing long range network structure of bonding. In contrast, cement materials provide short range structure of bonding. Some polymer materials may provide good adhesion to other materials as well as resistance to physical damage (abrasion, erosion, and impact) and chemical attack. The workability of the fresh mixture is markedly improved over that of ordinary concrete, because of plasticizing and air entraining effects of the polymers.

3. Micro silica

Micro silica is a by-product resulting from the reduction of high-purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or silicon alloys. Micro silica is known to improve both the mechanical characteristics and durability of concrete.

II.LITERATURE SURVEY

Several researchers attempted to use a polymer to enhance the microstructure of ITZs in concrete **(Ohama 1995; Su 1995; Kardon 1997; Kim and Robertson 1998).**

Ohama and Su (1995), suggested that the polymer formed continuous films or membranes in the microstructure of concrete. They proposed that the polymer films bound cement hydrates to one another and to aggregates, and filled pores in the concrete**.** Thus, the polymer helped to create a denser microstructure by reducing the volume of porous transition zones and to strengthen the binding of aggregates to the cement-based matrix

(Shaker et al. 1997; Choi et al. 2016b; Liu et al. 2018; Qudoos et al. 2018). This was considered capable of improving the durability of concrete as a consequence. **(Ohama 1995; Su 1995; Kardon 1997; Shaker et al. 1997; Rossignolo and Agnesini 2004; Aggarwal et al. 2007).** However, the properties of concrete are likely influenced by the type and amount of polymer (Ohama 1995), which has not been fully understood to date.

Mandel and Said (1990), conducted research on the effect of an acrylic polymer on the mechanical properties of mortar and found that the mechanical properties of mortar and the adhesion between mortar and a steel fiber improved with the addition of an acrylic polymer into the system.The use of silica fume in concrete has engineering potential and economic advantage. It is reported by most researchers.

(**Gafoori and Hamidou, 2007, Yogendran et al., 1987, Khayat et al., 1997, Ramakrishnan and Srinivasan, 1982, Bayasi, 1993)** that workability is reduced on silica fume inclusion. Kadri and Dual reported increase in workability on replacement of cement by silica fume. It is also reported (Gafoori and Hamidou, 2007, Yogendran, 1987, Khayat, 1997, Ramakrishnan and Srinivasan, 1982, Kadri and Dual, 1998) that compressive strength is increased upto optimum replacement level of silica fume. Strength of silica fume concrete is affected by several factors viz. type of cement, quality and proportion of silica fume and curing temperature.

Sakr, (2006), suggested that the main contribution of silica fume to concrete strength development at normal curing temperature takes place from about 3 to 28 days. The contribution of silica fume to strength development after 28 days is minimal.

Cong et. al,. (1992), reported that concrete containing silica fume as a partial replacement of cement exhibits an increased compressive strength in large part because of the improved strength of its cement paste constituent.

Slaniska and Lamacska (1991), reported that at different replacement level of cement by silica fume (3.75 – 10.25%) increase in compressive strength in the range of about 12 - 57% is observed.

Detwiler and Mehta (1989), reported that silica fume concrete showed improved compressive strength in the range of 11.56 - 18.89% than the conventional concrete at different water cement ratio.

Aggarwal et al,. (2007), studied the properties of polymer modified mortars using epoxy and acrylic emulsion, and found that these materials had superior strength properties and better resistance to the penetration of chloride ions and carbon dioxide than PMCs based on vinyl acetate, copolymers of vinyl acetate–ethylene, styrene–butadiene, styrene–acrylic, and acrylic styrene butadiene rubber emulsions.

III. MATERIAL COLLECTION

1. Cement

IS: 8112-1989 for 53 Grade of OPC. The properties of cement tested were Fineness (90µSieve) = 6%, Normal consistency = 27.5%, and Specific gravity of 3.1.

2. Fine aggregate

Locally available river sand passing through 4.75 mm IS sieve, conforming to grading zone-II of IS: 383-1970.was used. The physical Properties of sand like Fineness Modulus, Specific Gravity, water absorption and Moisture Content were 2.473, 2.60, and 1.5% and 0.8%.

3. Coarse aggregate (Ballast)

The ballast aggregates used in this study were acquired from a real ballasted railway track. The recycled ballast aggregates were prepared at three different levels of surface cleanness (i.e., H-, M-, or L-level). H-level aggregates represented the highest level of cleanness among the three categories; they were cleaned using a hand cleaning with using water until all visible dusty particles attached to the surface were removed.

M-level aggregates represented the medium level of cleanness among the three categories in contrast, L-level aggregates represented the lowest level of cleanness; no cleaning treatment was applied to them.

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4. Polymer

Acrylic polymer is used to increase the durability and reduce the voids in concrete.

- Type – Acrylic
- Physical state – liquid
- Appearance – milky white
- Solid content (%) - 30+/-1
- Specific Gravity - 1.020+/-0.01
- pH 9-11
- Pot Life (Cement Slurry) - 60 mint.

5. Micro silica

- The details of the physical and chemical properties are illustrated in Tables.

Table 1 Physical Properties of Micro silica

Physical Properties	Result
Physical State	Micronized Powder
Odour	Odourless
Appearance	White Colour Powder
Colour	White
Pack Density	0.76gm/Cc
Ph Of 5% Solution	6.9
Specific Gravity	2.63
Moisture	0.058%

Table 2 Chemical Properties of Micro Silica

Chemical Properties	Results
Silica (Sio2)	99.886%
Alumina (Al2o3)	0.043%
Ferric Oxide (Fe2o3)	0.04%
Titanium Oxide (Tio2)	0.001%
Calcium Oxide (Cao)	0.001%
Magnesium Oxide (Mgo)	0.000%
Pottasium Oxide (K2o)	0.001%
Sodium Oxide (Na2o)	0.003%
Loss Of Ignition	0.015%

IV. BALLAST RECYCLING

Fig. 4 Ballast surface dust cleaning with water.

Fig.5

H – Level: Ballast surface cleanliness at high level
M – Level: Ballast surface cleanliness at medium level
L – Level: Ballast surface cleanliness at low level.

1. Mix Design

Type of cement = OPC (53 grade)
Maximum size of aggregate = 70mm
Design grade of concrete = M40
Specific gravity of coarse aggregate = 2.82
Specific gravity of fine aggregate = 2.76
Workability = 140mm slump
Method of design =ACI 211.1 – 91

2. Method of Casting

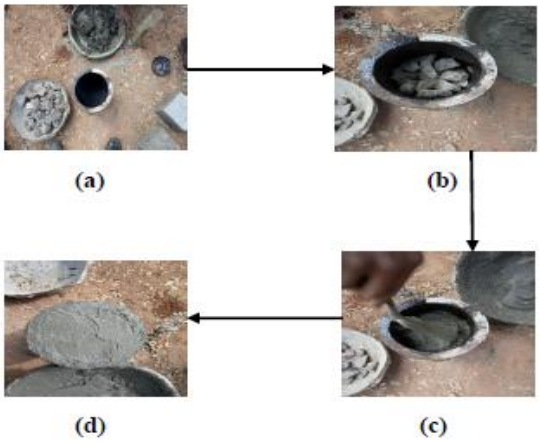

Fig .5
(a) Preparation of mould and mortar
(b) Filling a ballast in mould
(c) Pouring the mortar
(d) Finishing of casting.

3. Demoulding

Fig. 6 Demoulding.

While demoulding the cubes without polymer having more voids compared to cubes with polymer as shown in fig 4.5 & fig 6.

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Fig.7 (a) Without Polymer (b) With Polymer

V. TEST ON COARSE AGGREGATE

1. Abrasion Test

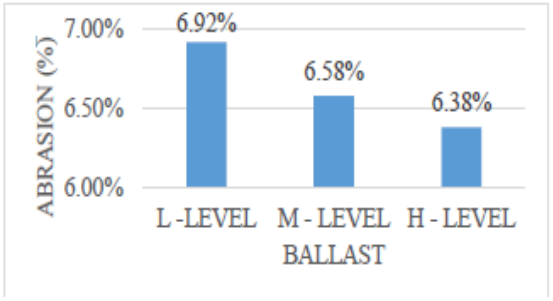

Fig.8 Comparison of Abrasion value with Ballast.

2. Water Absorption Test

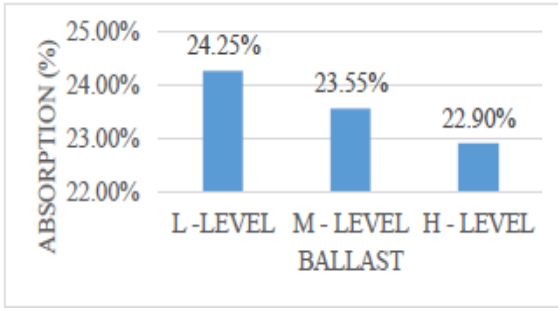

Fig.9 Comparison of Absorption value with Ballast.

VI.TEST ON CONCRETE

1. Test on fresh concrete

The slump cone test is done to determine the workability of fresh concrete by slump test as per IS: 1199 - 1959.workability is the relative ease or difficulty of placing and consolidating concrete. When placed, all concrete should be as stiff as possible, yet maintain a homogeneous, and void less mass. Too much stiffness, however, makes it too difficult or impossible to work the concrete into the forms and around reinforcing steel. On the other hand, too fluid a mixture is also detrimental. The slump test is performed on newly mixed concrete. To perform the test, you need a slump cone and a tamping rod.

The internal surface of the mould is thoroughly cleaned and applied with a light coat of oil. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. Then the mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of mould. Each layer is tamped 25 times by the rounded end of the tamping rod (strokes are distributed evenly over the cross-section).

After the top layer is rodded, the concrete is struck off the level with a trowel. The mould is removed from the concrete immediately by raising it slowly in the vertical direction. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm is the slump of the concrete. The slump value of the given sample = 140mm While adding the polymer liquid in the concrete at 3%,6%,9%. The slump value increased and it shows the increase in workability of a concrete.

2. Test on harden concrete

2.1 Compression test

The test is done to determine the compressive strength of concrete specimens as per IS: 516 - 1959.Tests should be done at recognized ages of the test specimens usually being 3, 7 and 28 days. The ages should be calculated from the time of the addition of water to the drying of ingredients. Compression test is the most common test conducted on hardened concrete, partly because is an easy test to perform, and partly becomes most of the desirable characteristic properties of concrete are qualitatively related to is compressive strength. The compression test is carried out on specimens cubical or cylindrical in shape. The cube specimen should be in the size 150 × 150 × 150 mm. Here 28 day results are shown.

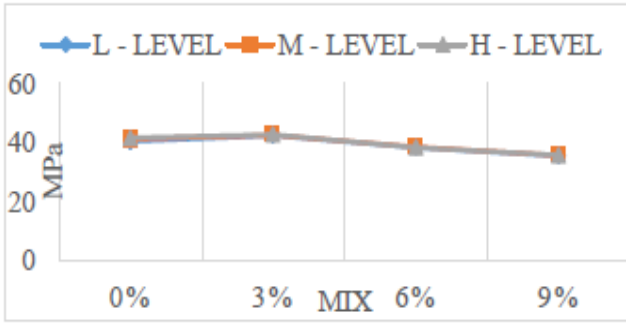

Fig. 10 Compressive strength of polymer mix after 28 days.

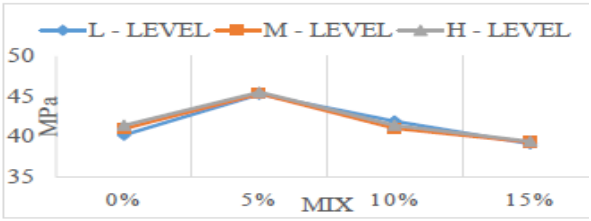

Fig.11 Compressive strength of micro silica mix after 28 days

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From the above compressive results of polymer and micro silica the peak value of 3% polymer and 5% micro silica was taken for final mix. The results are shown below in fig 10.

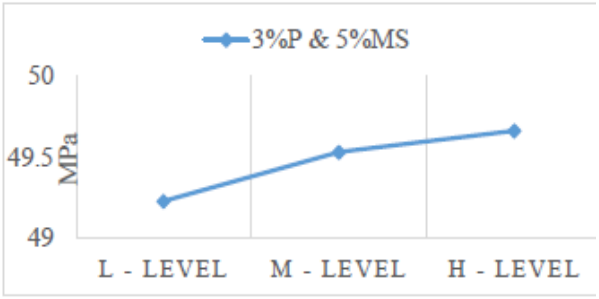

Fig. 12 Compressive strength of 3% polymer (P) and 5% micro silica (MS) after 28 days.

2.2 Split tensile test:

This method covers the determination of the splitting tensile strength of cylindrical concrete specimens. The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load. Cylinders The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS: 10086-1982.

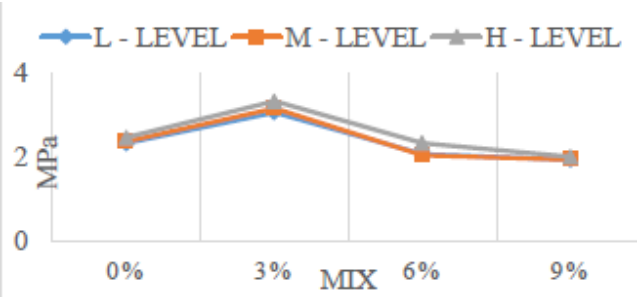

Fig.13 Split tensile test of polymer mix after 28 days.

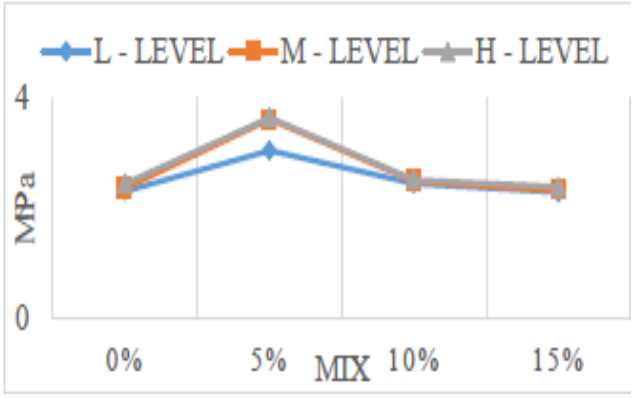

Fig.14 Split tensile test of micro silica mix after 28 days.

From the above split tensile results of polymer and micro silica the peak value of 3% polymer and 5% micro silica was taken for final mix. The results are shown below in fig 13.

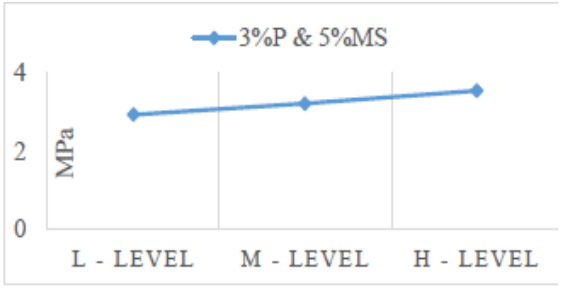

Fig.15 Split tensile strength of 3% polymer (P) and 5% micro silica (MS) after 28 days.

VII. CONCLUSION

[1]. The cleanliness of ballast is analysed and the effect in test on harden concrete gives better result on H – Level ballast than M – Level, L – Level.
[2]. The compressive and tensile strength of concrete increases while using H – Level recycled aggregate.
[3]. The usages of Polymer (Acrylic) increase the fluidity nature of mortar, reduces the voids occurrence due to high penetration into the ballast and fill up the gap between the aggregates. It also increases the durability of concrete.
[4]. The Polymer delayed the setting time of concrete.
[5]. Polymer in harden concrete slightly increases the compressive strength after 28 days at 3% of mix and it continuously reduces at 6%, 9% etc.,
[6]. Polymer increases the Tensile strength after 28 days of curing at 3% of mix and reduces gradually at 6%, 9% etc.,
[7]. Micro silica enhance the compressive strength as compared to the conventional concrete cubes.
[8]. Micro silica increases the workability of concrete.
[9]. Micro silica increase the strength of cubes at 5% of mix after 28 days and above that 10%, 15% etc., reduces both compressive and tensile strength. Upto 15% of Micro silica can be replaced by Cement.
[10]. From the above results obtained, the final proportion is taken from the peak values as 3% Polymer, 5% of Micro silica is added to the mortar preparation and the test were conducted.
[11]. From the above results obtained, the final proportion is taken from the peak values as 3% Polymer, 5% of Micro silica is added to the mortar preparation and the test were conducted.
[12]. The final result shows the Polymer mix (3%), Micro silica mix (5%) increases the compressive strength (49.66MPa) and tensile strength (3.53MPa) than
[13]. Conventional concrete at 28 days usage of H – Level recycled ballast.

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[14]. Polymers of 3% and Micro silica of 5% reduces the voids and increase the durability of a concrete.

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