ISSN (online): 2349-784X

Polyethylene Terephthalate (PET) and Slag as Aggregates in Precast Concrete Pavers

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Abstract

Present construction industry has shown marked improvement in pavement construction. Pavement laying in conventional concrete, which was the case earlier, used to be highly rigid and labor and technology intensive; however, recent progress in interlocked concrete pavers has opened doors to flexible, decorative and relatively stronger pavements. Essential elements of interlock pavement are ingredients with which the precast block has been prepared and geometry of the interlock block. Both these elements define strength of the blocks. The present study focuses at the ingredients Slag as replacement for conventional fine aggregates and addition to add PET fibres in M35 mix of concrete. The replacement level of sand with slag is 0%, 25%, 50% and percentage of pet fibre was 0, 0.5, and 1.0 by the weight of cement. There is huge scope of improvement and further testing in manufacturing interlock blocks by successfully replacing aggregates of in conventional concrete.
Keywords: Paver blocks, PET fibre, Metal slag

I. Introduction

Globally, concrete paving blocks are fast replacing traditional concrete as viable option for laying down pavements. It is both an attractive as well as economically viable option. Moreover, it is easy to lie down and it appears very attractive. When concrete paving blocks are made of traditional concrete, its ingredients are cement, fine aggregate, coarse aggregate and chemical colors to give them specific colors. The performance of concrete depends on composition of the concrete, water-cement ratio and curing process adopted. Principally, aggregates form bulk volume of the concrete and hence are extremely important in attaining required strength, workability, durability and stability. However, recent research of concrete industry is focused to use waste materials like PET and Slug as an alternative construction material. PET is being used as reinforcement or as aggregate in precast blocks.

The problem of recycling of waste material has posed a serious challenge to modern civilization; therefore, if waste material is used as an ingredient in concrete, it will be a win-win situation as waste material will be positively utilized in concrete. In modern civilization, plastic has become a nuisance and serious threat to the environment. Principally, Polythene and Polyethylene terephthalate (PET) are being used all over the world. Mammoth rise in the usage of PET in recent years, has forced researchers to think some feasible and innovative method to recycle it. Using PET as an aggregate in conventional concrete provides a good solution as PET can act as fibre reinforcement. PET as reinforcement tends to fill micro cracks in the concrete, thus increases its tensile strength which concrete lacks.

Slag, on the other hand, is a metal slag aggregate. Slag is the by-product generated during manufacturing of pig iron and metal. Its main ingredients are limestone (CaO) and silica (SiO_2). Other components of blast furnace slag may include alumina, magnesium oxide (MgO) and miniscule amount of sulfur (S). Moreover, metal making slag contains iron oxide (FeO) and magnesium oxide (MgO).

In nutshell, some of the failings of conventional concrete such as less tensile strength, less resistant to cracking and abrasion may be improved by reusing some of the industrial waste as fine or coarse aggregate of the concrete.

The principal focus of this study is to study the usage of PET and Slag as aggregate in the concrete and thus appraise the strength and durability properties of concrete paving block. In this study, metal slag is used as a partial replacement of fine aggregate with addition of waste PET fibres in different proportions. Concrete reinforced by metal slag and PET will be analyzed and its compressive strength, abrasion strength and water absorption will be examined.

II. Interlocking Concrete Paver Block (ICBP)

Many countries have been using Interlocking Concrete Blocks as a viable solution to conventional concrete in pavement construction where conventional concrete has been less useful and durable due to many operational and environmental constraints. ICBPs can tolerate high deflections without structural failures. Moreover, unlike conventional concrete pavement, ICBPs remain unaffected by changes in temperatures. Therefore, they immune to thermally induced expansions and contractions. Therefore, they do not easily crack, break or buckle like pouring asphalt or poured concrete.

Shapes of the ICBP do affect structural performance of the pavement. These can broadly be divided into three types of shapes: fully interlocking on both axes, interlocking on one axis and non-dentate which mean basic square and rectangular shapes. The pavements which receive frequent traffic should employ first type of blocks while remaining two types may be used to construct the pavements often used by pedestrians or light traffic. There are numerous shapes such as hexagon, octagons, Milano, triangular and key-hole shapes.

A. *History of Paver Block*

Interlocking concrete Pavers are also called Segmental Pavers. This special type of of pavers has emerged in the United States over the last few decades. The credit of interlocking pavers goes to Holland and the reason why researchers advocated use of interlocking pavers was that Holland lies below sea level because of which the ground in Holland shifts, moves and sinks. This convinced structural designers that they needed flexible roads to help them save from cracking. Individual units not set in concrete and placed in sand perform far better than concrete. Before the paver was made from concrete, either real stone or a clay product was used. The first concrete pavers called 'Holland Stones' were of the shape of a traditional brick with its dimensions as 8"*4". They are being used in different parts of the world even now but since then variety of geometric shapes of interlocking pavers have been launched.

B. *Usages of ICBP*

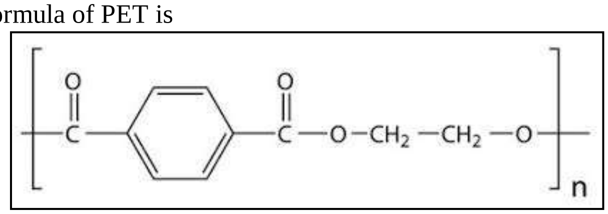
There are many ways to apply interlocking pavers because of its versatility in terms of material and construction. From residential to commercial establishments, interlocking pavers are in vogue nowadays and people use them both to beautify their buildings and to construct flexible pavers. In residential areas, patio pavers are used in balconies, courtyards, walkways and driveways. Commercial areas, however, use interlocking pavers in parking lots, loading docks and airport pavements. Interlocking pavers is one of the most fascinating inventions of modern construction industry. It gives style and beauty without sacrificing strength and durability of the pavers.

C. *Advantages of Interlocking Concrete Block Pavements*

1) Since the blocks are prepared in the factory, therefore mass production and easy availability of high-quality concrete blocks is possible.
2) Good quality blocks ensure durability of pavements.
3) ICBPs are not affected by thermal expansions and contractions.
4) ICBPs do not require curing thus these can be opened to traffic immediately.
5) ICBPs are easier to install and thus they do not require sophisticated machinery and skilled labor.
6) Concrete block pavements restrict the speed of vehicles to about 60 km per hour, which is an advantage in city streets and intersections.
7) Colored pavements can be used as permanent traffic markers.
8) ICBPs are resistant to horizontal shear forces too.
9) Because of the rough surface, these pavements are skid-resistant.
10) The block pavements are ideal for intersections where speeds have to be restricted and cornering stresses are high.
11) The digging and reinstatement of trenches for repairs to utilities is easier in the case of block pavement.
12) These pavements are unaffected by the spillage of oil from vehicles, and are ideal for bus stops, bus depots and parking areas.
13) They are preferred in heavily loaded areas like container depots and ports as they can be very well designed to withstand the high stresses induced there.
14) Use of permeable block pavement in cities and towns can help replenish depleting underground sources of water, filter pollutants before they reach open water sources, help reduce storm water runoff and decrease the quantum of drainage structures.

III. PET FIBRE IN CONCRETE BLOCK PRODUCTION

PET (polyethylene terephthalate) bottles have increasingly become an indispensable part of a common man's life. Polyethylene terephthalate is produced from ethylene glycol and dimethyl terephthalate or terephthalic acid. PET is commonly recycled, and has the number "1" as its recycling symbol. There has been an unprecedented increase in the consumption of plastic thus problems with plastic waste disposal have also aggravated. Therefore, there was need to utilize the waste plastic bottles in such a way that the problem to dispose them off is tackled effectively. That is why utilization of waste PET bottles has become an attractive alternative for disposal. Chemical formula of PET is



A. Uses of PET

PET fiber has good mixing and satisfactory reinforcing qualities. Shredded PET may be used in interlocking in varying proportion and resulting compressive strength needs to be measured. Blocks that use PET as fine aggregate are found to have greater weather resistance. They provide better shock absorption and have better sound insulation. Such blocks require less manual labour and are easy to handle.

B. Disadvantages of PET

1) Plastics have low bonding property which reduces compressive as well as tensile strength.
2) It has low melting point; therefore, it offers limited usage at place which have to face very high temperature like furnace.
3) Plastics may contain some harmful substances which pose serious threat to health and environment.

IV. SLAG IN CONCRETE BLOCK PRODUCTION

Slag is a by-product generated during manufacturing of pig iron and steel. Using slag as partial replacement of sand in concrete manufacturing may produce favorable results on concrete strength as its workability increases.

Slag is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

A. Advantages of Slag

1) It can produce concrete of exceptional quality.
2) It can reduce permeability of chloride ions.
3) It can decrease the exothermically produced temperature rise.

V. LITERATURE REVIEW

Review of the literature by various researchers in the field of using Metal slag and PET fibres in simple concrete or concrete paving concrete is as follows:

A. Metal Slag

J.SaravananN.Suganya (2015) the researchers replaced 100% coarse aggregate in the concrete with the metal slag. The compressive strength was measured thereafter it was observed that Compressive strength, Split tensile strength and Flexural strength of Metal slag concrete increases in 6%, 28% and 34% respectively compared to the conventional coarse aggregate concrete.

Mien Van Tran (2014) used 100% Metal slag as a coarse aggregate in high strength concrete which has various compressive strengths as 60, 70 and 80MPa. Results showed that the strength of the concrete using Metal slag has done improvement in the mechanical properties.

Sultan A. Tarawneh (2014) used ratio 0%,20% 40% 60% 80% 100% to replace fine and coarse aggregate with Metal slag. Thorough investigation of results have indicated that the amount of increase in compressive strength at age of 7 days are much more than that of age 28 days for all types of aggregate replacement. This indicates that the added slag could work as accelerator at early age while at 28 days age, the effect is reduced. Furthermore, the fine slag replacement showed the highest effect.

Chetan Khajuria (2014) in his research observed that when 10%, 20% and 30% iron slag was replaced with the sand significant changes in compressive strength happens. The author noted that after adding 10% iron slag in the mix, there was an increase in compressive strength of 26% after 7 days, 50% increase after 28 days and 43% increase after 56 days as compared to the control mix. By adding 20% slag increase in strength percentage were 68%, 91% and 78%. Similarly, for 30% replacement observations yielded following results for increase in compressive strength as125%, 113%, 87% 7, 28 and 56 days respectively.

B. Pet Fibres

Divyeshkumar D.Paradava(2013)found out that glassfibre tend to give higher strength than polypropylene fibres. The content and length of the fiber are also important to contributors to the strength of mortar. Research also pointed out that quantity of fiber is also important factor.

Liliana Avila Cordoba (2013) summed up her research by concluding that mechanical properties of the concrete depend on the particle size of the PET and concentration of PET used in the concrete. Compressive strength was found to be inversely proportional to the particle size. Maximum compressive strength was obtained when particle size of PET was 0.5mm2.5% volume of PET fibres.

A.Sivakumar (2013) focused his research at the toughness level of metal fibre reinforced concrete. It was observed that the various standards have same test procedure but they give different toughness measurements.

Ganesh Tapkir, Satish parihar (2014) in their research used two plastics viz, polypropylene (PP) and polyethylene Terepthalate (PET) as substitute replacements of a part of the conventional aggregates of concrete. Three replacement levels 10 %, 20 %, 30% by weight of aggregates were used for the preparation of the concrete and it is revealed that the use of 20% recycled plastic aggregate in concrete does not affect the properties of concrete. The increase the percentage in plastic decreases the strength of concrete. They also found that using the plastic in concrete mix reduces the weight of cube by 15%.

VI. DISCUSSIONS

This segment illustrates and discusses the results obtained from the tests done on interlocking concrete paver block samples cast with and without both Metal slag and PET fibre reinforcement. The principal objective of the research was to know the durability and strength aspects of interlocking paver blocks by using Metal slag as a fractional substitution for fine aggregate with the addition of PET fibres. For fulfillment of the current study proposal, the experiments were planned to determine the effect of Metal slag on compressive strength of interlocking paver blocks.

In compressive strength test, there was a maximum increase of 25.23% and 18.15% strength of concrete paver blocks by using 25% Metal slag and 0.5% pet fibre reinforcement after 7 and 28 days of curing. While combining the use of Metal slag and PET fibre reinforcement, there was an increase of compressive strength up to 8.25%, 10.81%, and 3.66% with using 1% pet fibre-25% Metal slag, 0.5%-50% and 1%-50% after 28 days respectively. The 25% replacement of Metal slag with sand and 0.5% pet fibre reinforcement addition in concrete shown a better result in both combine and separate cases. The strength gain of concrete at initial age i.e.7 days was higher than as compared to 28 days of concrete.

The combination which uses 0.5% PET fibre and 25% Metal slag gave optimum results for both Compressive strength and flexural strength. This may be attributed to the better interlocking effect of PET fibers reinforcement, to arresting micro cracks at the initial stage. In Both cases, it was observed that after a certain limit, the compressive strength and flexural strength decreased due to use of larger percentage of Metal slag and PETfibre reinforcement irrespective of the fact whether concrete used them in combination or separately. The reason behind that, the Metal slag aggregates were replaced with the sand. The reduction of strength after 25% replacement of Metal slag with sand due to the sub-angular shape of the Metal slag aggregate and the bonding region or interfacial transition zone (ITZ) in concrete weakens. Chemical reactions of hydration occur at surface level of cement-sand-water and secondly reaction also takes place slag and water. When percentage of metal slag is low, there is not any serious effect in the reaction of hydration. However, after increasing the dose of Metal slag, less water is required for Metal slag because Metal slag aggregate absorbs less water as compared to sand.

VII. CONCLUSION

This study, therefore, concludes that there is a lot of scope to use recyclable materials by replacing coarse and fine aggregates in the conventional concrete. In the present study, the combined beneficial effects by using PET and mental slag of to improve the quality of the paving blocks are studied. On one hand, it offers a viable solution to meaningfully utilize menace of plastic and waste of iron and foundry industry; on the other hand, this experiment has proved that replacing coarse and fine aggregate with PET and metallic SLAG in certain ratios increase strength of precast interlocking concrete pavers. This experiment and its tests have clearly demonstrated strength of the concrete blocks prepared from SLAG and PET; however, to ascertain practical and commercial utilizations of pavers, more experimentation needs to be done.

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