# “UTILIZATION OF WASTE MATERIALS IN CONSTRUCTION OF RIGID PAVEMENT”

A

PROJECT REPORT

*Submitted in partial fulfillment of the requirements for the award of the degree*

*of*

**BACHELOR OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

*Under the supervision*

*of*


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# STUDENT DECLARATION

I hereby declare that the work presented in the Project report entitled **"UTILIZATION OF WASTE MATERIALS IN THE CONSTRUCTION OF RIGID PAVEMENT"** is submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at the **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Amardeep.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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Date: 14/05/2022

# CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"UTILIZATION OF WASTE MATERIALS IN THE CONSTRUCTION OF RIGID PAVEMENT"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Sonam Dorji (181647), Sonam Tshering (181650) and Abhay Sharma (181607)** during a period from July 2021 to May 2022 under the supervision of **Dr. Amardeep** (Assistant professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: 14/5/2022

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# ABSTRACT

The goal of the project is to find the best waste materials generated by various industries and the environment as a substitute for cement and aggregate in highway construction. Several studies have been undertaken across the world to determine the negative impact of various waste items on the environment and human health. Therefore it becomes important to find the best replacement of cement with other materials having similar binding properties and required strength. The use of waste materials in the rigid construction reduces the use of cement which is causing a lot of harmful effects and there is a significant reduction in the cost of the materials. The man behind the use of waste materials in the rigid pavement must have precise knowledge about the design and its characteristics. As a result, mistakes in design or construction, as well as poor material selection, have a significant impact on the pavement's service life. It is also demonstrated that the durability of concrete pavements is not just dependent on the quality of the concrete, but also on effective site-building methods such as placing, compaction, and curing. Pavement engineers must therefore comprehend and solve concerns such as suitable material selection, mixed design and details, prevailing drainage conditions, construction processes, and pavement performance. This project mainly focuses on the use of plastic waste and Electric Arc Furnace (EAFS) as a replacement for coarse aggregate and cement respectively. Different tests were performed on cement, Plastic waste, and EAFS to check the standards values of the materials and their ranges. A relationship was established between different proportions of plastic aggregate and EAFS vs. compressive strength value to see the optimum value of the plastic aggregate and EAFS as the replacement of natural coarse aggregate and cement respectively. Finally, the theoretical strengths collected from different research papers of different proportions are being compared to the laboratory values for 7, 14, and 28 days, to check their compressive, tensile, and flexural strengths. By 20% replacement of cement by EAFS there is an increment of 4.58MPa for the compressive strength of 7 days. For the 28 days, the highest value was recorded for unmodified concrete. There is less deviation in compressive strength value with an increase in percentage replacement of coarse aggregate. The optimum value was found for 2.5% replacement of coarse aggregate by plastic aggregate for 7 and 14 days, whereas for 28 days the highest value was recorded for 5% replacement of coarse aggregate by plastic aggregate.

**Key words*:* -** EAFS, plastic aggregate, compressive strength, curing time

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| | |
|---|---|
| **EAFS** | **Electric Arc Furnace Slag** |
| **PPC** | **Portland Pozzolana Cement** |
| **OPC** | **Ordinary Portland Cement** |
| **UTM** | **Universal Testing Machine** |
| **IS** | **Indian Standard** |
| **W/C** | **Water Cement Ratio** |
| **IST** | **Initial Setting Time** |
| **FST** | **Final Setting Time** |
| **BF** | **Blast Furnace** |
| **SM** | **Steel Making** |

# CHAPTER 1

# INTRODUCTION

## 1.1 General

Manufacturing sustainable construction employing modern technologies such as self-compacting concrete made from various industrial wastes ensures environmental degradation prevention while also providing a durable construction material. Concrete is the most commonly utilized building material. Concrete is made up mostly of cement, sand, coarse aggregate, and water. By replacing cement with pozzolanas [fly ash, silica fume, rice husk ash, metakaolin, Electric Arc Furnace Slag(EAFS), and crushed granulated blast furnace slag], the cost of concrete is reduced. Along with its structural stability and strength, concrete is a commonly utilized construction material for a variety of constructions. The earth's crust provides all of the ingredients needed to produce such large amounts of concrete. As a result, it depletes its resources every year, putting ecological stresses on the environment. Recent technical advancements have demonstrated that these materials are valuable inorganic and organic resources and that they may be used to make a variety of useful goods. Plastic Waste, Fly ash, EAFS, rice husk, silica fume, and destroyed construction materials are the most common solid wastes. Partial cement replacement is used to meet the rising demand for cement and concrete. When industrial by-products are employed as a partial replacement for energy-intensive Portland cement, significant energy and cost savings can be realized. By-products are an environmentally responsible way to dispose of enormous amounts of materials that might otherwise harm the land, water, and air. The usage of extra cementing materials will meet the majority of the increase in cement demand. Any place's economic and social development is largely dependent on its infrastructure. Pavements are a critical component in improving rural communication systems.

## 1.2 Introduction

Due to increasing levels of urbanization and economic growth, an increase in the rate of plastic production and consumption is occurring in many areas around the world. So, it becomes significant to manage this waste as it causes health-related issues and space problems. The different waste materials produced are plastics, fly ash, rice husk ash, EAFS, etc. The use of plastic waste in rigid construction becomes very productive as it takes time to decompose and has a long life cycle. Plastic garbage when it is not properly disposed of causes environmental and economic issues. Food chain contamination, biodiversity loss, energy waste, and economic loss are all consequences of the massive amount of plastic waste now being created. When EAFS are being kept in industries like that it has a lot of health-related problems for the workers and also it makes the place uncomfortable to work. Therefore use of EAFS and plastic waste in the rigid pavement is the best option to deplete this waste from the surroundings. The usage of this material is eco-friendly and efficient in many ways and can be used effectively in concrete with numerous advantages.

## 1.3 Cement

Cement is an adhesive that binds materials together in the building by setting, hardening, and sticking to them. Instead of being utilized on its own, cement is often employed to bind sand and gravel together. Concrete is created from sand and gravel, while masonry mortar is made from cement mixed with fine aggregate. Concrete has a huge carbon footprint since it contains cement. Cement is responsible for greenhouse gas emissions, posing a hazard to the environment due to global warming, as well as recent price increases. As a result, an alternative material must be developed that has extremely similar qualities to the cement while still being environmentally benign and economically effective.

## 1.4 Slag

There are two types of slag namely Blast furnace (BF) slag and steel-making (SM). One of the SM slags is an electric arc furnace (EAFS), which is made by refining recycled steel scrap in an electric arc furnace. The high free calcium oxide (free-CaO) and Fe oxide concentration of EAFS is its key chemical features.

EAFS (electric arc furnace oxidizing slag) is a by-product of the steelmaking industry that is produced after liquid steel is melted and acid refining. It's a rocky material that's simple to crush and utilize as concrete aggregate. The utilization of EAFS is not only a partial solution to environmental and ecological problems, it also enhances the microstructure of concrete, which is difficult to achieve with pure Portland cement. The pictorial representation of EAFS passing a 90-micron sieve for use in the project.

**Fig 1.1** EAFS Passing 90µ Sieve.

**Table 1.1** Characteristics and Applications of BF Slag and EAFS (reference 6)

| | Characteristics | Applications |
|---|---|---|
| BF Slag | Fertilizer component (CaO, $SiO_2$) | Calcium silicate fertilizer and Soil improvement |
| | Low $Na_2O$ and $K_2O$ | Raw material for cement clinker (replacement for clay) |
| | The strong latent hydraulic property when finely ground | Raw material for Portland blast furnace slag cement,<br>Blending material for Portland cement,<br>Concrete admixtures. |
| | Lightweight, large angle of internal friction, large water permeability | Material for civil engineering works, Ground improvement material (Backfill material, earth cover material, embankment material, road sub grade improvement material, sand compaction material, ground drainage layers, etc.) |
| ETFS | Fertilizer components (CaO, $SiO_2$, MgO, FeO) | Fertilizer and soil improvement |
| | Large angle of internal friction | Material for civil engineering works, ground improvement material (Material for sand compaction piles) |
| | FeO, CaO, and $SiO_2$ components | Raw material for cement clinker |

**Table 1.2** Chemical composition of Electric arc furnace slag (reference 7)

| Oxides | Electric arc furnace slag (EAFS) (Wt %) |
|---|---|
| $SiO_2$ | 13.2 |
| $Al_2O_3$ | 6.17 |
| $Fe_2O_3$ | 34.6 |
| CaO | 21.6 |
| $Na_2O$ | 0.13 |
| $K_2O$ | - |
| $TiO_2$ | 0.57 |
| MnO | 5.77 |
| MgO | 3.75 |
| $SO_3$ | 0.28 |
| BaO | 0.17 |
| $P_2O_5$ | 0.34 |
| $Cr_2O_5$ | 2.38 |
| $V_2O_5$ | 0.13 |
| Cl | - |

## 1.5 Plastic Aggregate

From 2.3 million tonnes in 1950 to 448 million tonnes in 2015, plastic output rose at an exponential rate. Many plastics are thrown after only a single usage, resulting in tremendous waste and major environmental implications. Plastic waste accounts for around 3% of all waste created each year, harming the environment and wildlife. Plastic waste disposal is a major environmental concern (reference 8). It can contaminate the environment if put in landfills, causing air and water erosion, plugging drains and drainage channels, causing disease and mortality in grazing animals, and polluting construction fill. Dumping on open land is likewise a wasteful use of a limited land resource.

If these materials are used in road construction, land contamination and the disposal of waste plastic will be greatly reduced. Plastic wastes can be added to engineering and construction materials, or natural materials can be partially replaced, to achieve engineering sound and environmentally friendly properties for strength and durability that are comparable to and sometimes better than, materials formulated with more expensive and increasingly unsustainable traditional construction materials like Portland Cement (PC).

**Fig 1.2** Plastic aggregate

**Table 1.3** Physical and chemical properties of Recycled polyethylene (reference 8)

| | |
|---|---|
| Ultimate analysis | |
| C (%) | 85 |
| H (%) | 13.8 |
| N (%) | 0 |
| S (%) | 0 |
| O (%) | 0 |
| Ashes (%) | 1 |
| Moisture (%) | 0.2 |
| Low heating value(KJ/Kg) | 45,500 |
| Starting devolatilization temperature (°C) | 250 |
| Devolatization temperature (°C) | 410 |
| Particle density(kg/m^3) | 940 |
| Bulk density (kg/m3) | 570 |

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 General

The following literature was reviewed, and it was concluded that waste materials are a good substitute for cement in the production of rigid pavement, which are having pozzolanic properties. As a result, waste materials are employed as a partial replacement for cement. Fly ash, plastic waste, rice husk ash, and electric arc furnace slag are some of the waste products. Not only cement is replaced but the coarse aggregate is also replaced with plastic waste. The project is based on two waste items from the waste materials available, plastic garbage and electric arc furnace slag.

## 2.2 Literature Review

### 2.2.1 Plastic Aggregate

Ahmad (2019) examined the dry density properties of concrete that use plastic wastes and polymer fiber to replace coarse aggregate, then determined the concrete's compressive, tensile, and flexural strength, and finally compared the performance of concrete that uses plastic wastes and polymer fiber vs. concrete that only uses plastic wastes. Plastic wastes were used in concrete at percentages of 10%, 20%, and 30%, and polymer fiber at percentages of 2%, 4%, and 6%, respectively, in an extended experimental investigation. The polymer-modified concrete had a reduced density, according to the findings. Concrete's compressive and flexural strength is reduced when the waste polymer is used to replace cement. This is most likely owing to the fibers' bridging function.

Rahaman (2017) conducted an experiment on polystyrene polymer which is used as an alternative to coarse aggregate in partial replacement of brick aggregate. The use of polystyrene polymer is increasing day by day with economic growth. However, this polystyrene polymer is not decomposed and causes a serious environmental problem by increasing as solid waste. Therefore, an alternative process of recycling such materials as a coarse aggregate by partial use in concrete may reduce solid waste and make lightweight concrete. The conventional coarse aggregate in concrete was replaced with 0%, 5%, 10%, 15%, 20%, 30%, and 40% (by volume) of EPS, and the ordinary Portland cement was replaced with fly ash as the same percentage. A mix proportion of 1:1.68:2.49 with a water/cement ratio ranging from 0.35 - 0.56 was used and polystyrene granules were cast, and specimens were tested at 7, 14, and 28 days after natural curing. Test results exhibited that the compressive strength, splitting tensile strength, and unit weight gradually decreases with the increase of recycled polymer aggregate and the water absorption decreased with the higher replacement of recycled polymer aggregate.

Suwansaard (2021) examined Plastic waste used with sand aggregate in mortar to improve several qualities of the mortar while also lowering pollution and solving the problem of natural sand scarcity. Polystyrene (PS) and high-density polyethylene (HDPE) wastes were investigated as possible sand substitutes in mortar. Water absorption, bulk dry density, flow value, and compressive strength of mortar containing these plastic wastes were all investigated. The thermal conductivity of wall models plastered with plastic waste-containing mortar was also examined. The following were the key findings: The particle sizes of the plastic debris and the sand were similar. The qualities of PS mortar were found to be superior to those of HDPE mortar. The water absorption of PS mortar was equivalent to that of the reference mortar; however, it was lower than that of HDPE mortar. The PS mortar has much better compressive strength than the HDPE mortar. The thermal conductivity of a wall plastered with PS mortar dropped as the PS content rose, whereas the thermal conductivity of a wall plastered with HDPE mortar increased as the HDPE concentration increased. According to the findings, 10 percent PS might be utilized as a partial substitute for sand in mortar and improve certain of the mortar's qualities.

## 2.2.2 Electric Arc Furnace Slag

Bassey (2011) conducted a study by using Electric Arc Furnace Slag as a partial replacement for cement in concrete blocks. The tests carried out on cement and finely ground slag to determine their compositions and Physico-chemical properties as well as the evaluation of the results are presented. It was found that the compressive strength of concrete blocks ranged from 1.4 - 4.0 N/mm$^2$ for 50% - 20% replacement of cement with EAF slag respectively. While that of standard cement block was 4.5 N/mm2. The result of the study shows the possibility of replacing up to 20% of cement with EAF slag in concrete blocks without sacrificing strength significantly. Using the slag in the construction industry will bring some economic benefits and as well mitigate the negative impact of this waste on the environment.

Sharma (2018) conducted a Steel slag that was used as a partial substitute for coarse aggregate in this study. The current study looks at M35 concrete using steel slag as a partial replacement for coarse material. The compressive strength, flexural strength, and split tensile strength of the material examined were determined experimentally after 7 and 28 days. The results were compared to the properties of standard concrete. The study found that partially substituting around 0%, 15%, 30%, 45, and 60% of steel slag particles by weight with natural aggregates boosted concrete strength. A minor loss in strength is seen after the 45 percent substitution of coarse material with steel slag. However, it is still greater than 0% replacement with no negative impact on concrete strength.

Tran (2021) examined the Electric Arc Furnace Slag Concrete with EAF slag material, fly ash, and silica fume (CEAFS). In the CEAFS mixes, EAF slag was used to substitute natural coarse aggregates. CEAFS was made by combining 50% crushed stone and 50% EAF slag in coarse aggregates, with fly ash (FA) and silica fume (SF) partially substituting cement at content levels (i.e. FA: 0, 20, 30, and 40 percent; SF: 0, 5, and 10 percent ). The ideal moisture level for CEAFS mixes incorporating EAF slag aggregate fly ash and silica fume was determined using the soil compaction method. The weight of CEAFS units and their mechanical properties were investigated using a testing procedure (compressive strength, flexural strength, and elastic modulus). Furthermore, changes in the concentration of mineral additives FA and SF in adhesives, as well as the CEAFS mixed aggregate ratio, affect compressive strength, flexural strength, and elastic modulus at all ages. However, CEAFS mixtures containing EAF slag aggregate and (FA0 percent +SF10 percent; FA10 percent +SF0 percent; FA10 percent +SF10 percent; and FA20 percent +SF10 percent) exhibit increased mechanical properties over time. CEAFS pavements can be created with EAF slag aggregate fly ash and silica fume, according to this study. A formula correlation was also suggested for calculating CEAFS (i.e. compressive strength with elastic modulus and compressive strength with flexural strength).

Mathew (2013) examine a study, in were Steel slag aggregate (SSA) was substituted for natural coarse aggregates (NCA) in varying amounts of 20%, 40%, 60%, 80%, and 100%. The compressive strength, flexural strength, and split tensile strength of concrete with varying percentages of steel slag aggregate were all tested. Compressive strength is reduced by 2% in 20 percent replacement, 16 percent in 40 percent replacement, 17 percent in 60 percent replacement, and 19 percent in 100 percent replacement when slag is incorporated in coarse aggregate. The flexural strength of concrete reduces as the amount of steel slag aggregate (SSA) increases, yet all of the mixes meet the minimum flexural strength of concrete necessary for rigid pavement (4 MPa as per IRC 58-2002). The split tensile strength drops when the proportion of SSA is increased by 3.8 percent for 20% replacement and 8% for 40% replacement 12.6% for 60% replacement, 18% for 80% replacement and 30% for 100% replacement.

## 2.3 Research Objective

- To identify a better substitute for coarse aggregate and cement in the construction of rigid pavements.
- To examine the effect of different waste materials used in the present study on the strength properties of concrete mix.
- To propose the guidelines in order to use the plastic aggregate and EAFS as the replacement of coarse aggregate and cement respectively for rigid pavement construction.

# CHAPTER 3

# MATERIALS AND METHODOLOGY

## 3.1 General

This chapter describes the materials need and mix design of M40 concrete that is used in the project. After reading several research articles, it was discovered that cement may be substituted with waste materials containing a large level of materials having similar properties. Fundamentals tests are performed on the materials like cement, plastic waste, and EAFS based on the given guidelines in IS code.

## 3.2 Materials

### 3.2.1 Cement

The cement that is used in the project is Pozzolana Portland Cement (PPC), fly ash based, 43 grade. PPC is a type of Portland cement characterized by the presence of pozzolanic materials like fly ash, and volcanic ash which is added to Ordinary Portland Cement (OPC) in a ratio of 15% to 35%.

### 3.2.2 Fine Aggregate (sand)

The sand used in the project was locally sourced and met Indian Standard Specifications IS: 383-2016. To remove any particles larger than 4.75 mm, the sand was sieved through a 4.75 mm sieve. Specific density, bulk density, fineness modulus, water absorption, and sieve analysis are among the additional tests performed. Grading zone II applied to the fine aggregate. This aggregate has a specific gravity of 2.83 and a 1% absorption rate. The Fine aggregate had a Bulk Specific Gravity of 2.7 and a Fineness Modulus of 2.61.

### 3.2.3 Coarse Aggregate

The material which is retained on IS sieve no. 4.75mm is termed a coarse aggregate. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. 20 mm coarse aggregate is used in casting samples.

The plastic waste retained in a 12.5 mm sieve is used as a replacement for coarse aggregate during the sampling.

## 3.3 Different Types of Tests

### 3.3.1 Normal Consistency Test on Cement

IS 4031(4)-1988 is used to perform the typical consistency test. Vicat's equipment and consistency plunger are used in the test. The test is carried out to establish the amount of water required to make a standard-consistency cement paste that is simple to use, put, and carry.

**Fig 3.1** Vicat’s Apparatus.

### 3.3.2 Initial Setting Time (IST) and Final Setting Time (FST)

The test is carried out in accordance with IS.4031 (5)-1988. The initial setting time is the amount of time it takes to postpone the hardening process. The paste has achieved its final setting period when it has completely lost its elasticity.

The amount of water to be added is calculated as

$$0.85 \times \mathrm{p} \times \frac{\text{weight of cement}}{100} \tag{i}$$

Where,

p = normal consistency of cement.

**Fig 3.2** IST and FST Test Setup.

### 3.3.3 Soundness of Cement

The test follows IS 4031-3(1988). The presence of extra lime (CaO) in cement affects its soundness. This surplus lime slowly hydrates and becomes slaked lime, which takes up more space than the original free calcium oxide. The soundness of cement relates to the consistency of volume change during the setting and hardening processes.

The amount of water to be added is calculated as:

$$\frac{0.78 \times P \times Weight\ of\ cement}{100} \tag{ii}$$

**Fig 3.3** Le-Chatelier’s Setup.

### 3.3.4 Fineness of the Cement

Cement fineness refers to the size of the cement particles and the experiment is performed based on IS: 4031-Part1-1996). The percent weight retained on a 90 micron IS sieve over the total weight of the sample is used to determine cement fineness. Cement fineness is determined in one of two ways: sieving or measuring the specific surface by air permeability. (Weight of residue shouldn’t be more than 10% of initial weight)


**Fig 3.4** Sieve Analysis (90µ).

### 3.3.5 Specific gravity (IS.4031 (11)-1988)

Specific Gravity of cement is the ratio of the mass of a substance to the mass of a reference substance. It plays an important role in the weight of proportions of concrete as well as determining the concrete mix.


(a) (b) (c)

**Fig 3.5** (a) Le-Chatelier's Flask for Specific Gravity of Cement, (b) Pycnometer Method for Specific Gravity of Fine Aggregate and (c) Wired Bucket Method for Specific Gravity of Plastic Aggregate

### 3.3.6 Compressive Strength (IS.4031 (6)-1988)

Under a progressively applied force, compressive strength is the greatest compressive stress that a solid material can sustain without cracking. Some materials deform permanently, while others shatter when they reach their compressive strength limit. When designing structures, compressive strength is a significant consideration. Concrete compressive strength is the most common performance measurement used by engineers when designing buildings and other structures.

(a) (b)

**Fig 3.13** (a) Compressive Strength Casting (Cube-15cm*15cm*15cm) (b)Compressive testing using UTM

### 3.3.7 Flexural Strength (IS: 516 1959)

Flexural Strength is one of the measures of the tensile strength of concrete. It measures the tensile strength of unreinforced concrete beams and slabs to resist failure in bending. The test was done using a rectangular beam of 50cm*10cm*10cm dimensions.

**Fig 3.14** Flexural Strength Testing using third point loading

### 3.3.8 Tensile Strength (IS 5816:1999)

The largest stress a material can sustain without cracking when stretched, divided by the material's original cross-sectional area, is called tensile strength. Mix 300 g of cement, 900 g of sand, and water (P/5 + 2.5) thoroughly. Fill the briquette mould halfway with the mixture. Open the sample after 24 hours and place it in the curing tank for 3 to 7 days. The cylinder with 30 cm height and 15 cm diameter was used in the test experiment.

**Fig 3.15** Split Tensile Strength Testing using UTM (Cylinder, h=30cm, d=15cm)

### 3.3.9 Aggregate Impact Test

Aggregate Impact Value refers to a material's capacity to withstand a rapid impact or shock load. The Impact Value of Aggregate may also be described as the resistance of aggregate to failure by impact load. The aggregate impact value test determines the toughness of the aggregate (i.e. property of a material to resist impact). The impact value of aggregates to be utilized for wearing the course should not exceed 30%.

**Table 3.1** Aggregate Impact Value Range (IS: 2386 (Part IV) -1963.

| Aggregate Impact Value | Classification |
| --- | --- |
| <20% | Exceptionally Strong |
| 10 – 20% | Strong |
| 20-30% | Satisfactory for road surfacing |
| >35% | Weak for road surfacing |

(a) (b)

**Fig 3.11** (a) Sieve Analysis of Plastic Waste (b) Impact Test for Plastic Waste

## 3.3.10 Los Angeles Abrasion Test

The Los Angeles (L.A.) The abrasion test is a commonly used aggregate relative quality measurement. A spinning steel drum with an abrasive charge of steel balls tests the abrasion and impact degradation of standard aggregate grading.

**Table 3.2** Los Angeles Abrasion Value (IS. 2386(4) 1963)

| Sl. No. | Type of Pavement | Max. permissible abrasion value in % |
|---|---|---|
| 1 | Water bound macadam sub base course | 60 |
| 2 | WBM base course with bituminous surfacing | 50 |
| 3 | Bituminous bound macadam | 50 |
| 4 | WBM surfacing course | 40 |

**Fig 3.12** Los Angeles Abrasion Test

## 3.4 Mix Design

The objective of this study is to replace cement with waste material that is plastic waste and coarse aggregate with EAFS in different proportions in road construction. As a result, the mix design of M40 grade concrete was carried out in accordance with Indian specifications, particularly IRC 15, IRC 44 and IS: 10262-2019. The amount of concrete required for 1 cubic meter can be calculated using these codes.

## Stipulation for Proportioning

a) Grade designation - M40

b) Type of cement - PPC 43 grade

c) Type of mineral admixture - Fosroc Auramix 350 Superplasticizer

d) Maximum nominal size aggregate = 20mm

e) Workability (Slump) = 75mm

### 3.4.1 Test Data for Materials

1) Cement used = PPC 43

2) Specific gravity of cement = 3.07

3) Specific gravity of slag = 3.17

4) Specific gravity of coarse aggregate = 2.85

5) Specific gravity of fine aggregate = 2.82

6) Water Absorption

Coarse aggregate = 0.65%

Fine aggregate = 1%

7) Free Moisture

Coarse aggregate = 2-0.65= 1.35%

Fine aggregate = 5-1= 4%

### 3.4.2 Target Strength

Fck = fck+1.65s

= 40+1.65*5

= 48.25 N/mm$^2$

### 3.4.3 Air Content

20mm, entrapped air = 1 % (table 3)

Volume of entrapped air = 0.01 $m^3$

### 3.4.4 Selection of W/C Ratio

Mix Calculation

a) Total Volume = $1m^3$

b) Volume of entrapped air in wet concrete = $0.01m^3$

c) Volume of Cement

= (Mass of cement /SG of cement)*1/1000

, = (411/3.07)*1/1000

= 0.134 $m^3$

d) Volume of Water = (mass of water/SG of water)*1/1000

= (148/1)*1/1000

=0.148 $m^3$

e) Volume of super plasticizer = $0.0036m^3$

f) Volume of aggregate (g) = 1- 0.01-0.134-0.148-0.0036

= $0.704m^3$

g) Mass of coarse aggregate = g*volume of coarse aggregate*specific gravity of coarse aggregate*1000

= 0.704*0.65*2.85*1000

= $1304kg/m^3$

h) Mass of Fine Aggregate = 0.704*0.35*2.82*1000 = $695kg/m^3$

## Mix Proportions of Concrete for $1m^3$

| | |
|---|---|
| Cement | = 411Kg/$m^3$ |
| Water | = 148kg/ $m^3$ |
| Fine Aggregate | = 695kg/$m^3$ |
| Coarse Aggregate | = 1304kg/ $m^3$ |
| Chemical Admixture | = 4.1kg/ $m^3$ |
| Water Cement Ratio | = 0.36 |

## Estimation of the Quantity of Concrete Mix

The calculations of concrete as per unit volume shall be measured as follows:

The volume of cubes = 0.15m*0.15m/0.15m*3 = 0.01012 $m^3$

Cement = 411 X 0.01012 = 4.16 kg/ $m^3$

Sand = 695 X 0.01012 = 7.03 kg/ $m^3$

Aggregate = 1304 X 0.01012 = 13.19 kg /m3

Water = 148 X 0.01012 = 1.49 kg /$m^3$

# CHAPTER 4

# RESULT ANALYSIS

## 4.1 General

The average compressive, tensile, and flexural strengths are obtained from several research articles, and the data is shown in a graph and scatter plot. Conclusions are generated based on the graphs in order to better understand the data. And these data are being compared to laboratory results considering the design and mix proportion.

## 4.2 Test Result for the Materials

**Table 4.1** Different Test Results for the Materials.

| S.No | Experiments | Results |
|---|---|---|
| 1 | Normal Consistency Test | 32% |
| 2 | Initial Setting Time | 120 minutes |
| 3 | Final Setting Time | 5 hour 30 minutes |
| 4 | Soundness of Cement | 1mm |
| 5 | Fineness of Cement | 1% |
| 6 | Specific Gravity of Cement | 3.13 |
| 7 | Specific Gravity of Fine Aggregate | 2.82 |
| 8 | Specific Gravity of Coarse Aggregate | 2.85 |
| 9 | Specific Gravity of EAFS | 3.13 |
| 10 | Aggregate Impact test on Plastic Waste | 0% |
| 11 | Los Angeles Abrasion Test | 0% |

## 4.3 Compressive Strength for Unmodified Cement

The compressive strength of the PPC cement was cast for 7, 14, and 28 days of curing. As per the IS: 1489 guidelines.

**Table 4.2** Compressive Strength of Cement - as per IS: 1489

| Age in days | Portland Pozzolana Cement ($N/mm^2$) | Result: Laboratory Value | | | |
|---|---|---|---|---|---|
| | | Sample 1 ($N/mm^2$) | Sample 2 ($N/mm^2$) | Sample 3 ($N/mm^2$) | Average ($N/mm^2$) |
| 7 | 19.6-21.6 | 18.5 | 17.5 | 19.1 | 18.4 |
| 14 | 25.5-32.4 | 26.2 | 24.6 | 25.1 | 25.3 |
| 28 | 36.3-47.1 | 39.4 | 38. | 37.7 | 38.6 |

## 4.4 Tensile Strength for Unmodified Cement

The flexural strength test for the PPC cement was cast for 7, 14, and 28 days of curing. As per the IS: 1489 guidelines.

**Table 4.3** Tensile Strength of Cement

| Age in days | Result: Laboratory Value | | | |
|---|---|---|---|---|
| | Sample 1 ($N/mm^2$) | Sample 2 ($N/mm^2$) | Sample 3 ($N/mm^2$) | Average ($N/mm^2$) |
| 7 | 1.8 | 1.5 | 1.7 | 1.7 |
| 14 | 2.3 | 1.9 | 2.2 | 2.1 |
| 28 | 3.1 | 3.4 | 2.9 | 3.1 |

## 4.5 Average Slag Replacement based on previous research

These compressive, flexural, and tensile values are taken from several research works considering the geographical (landscape) and climatic conditions. For 20% replacement of cement, there is an increment of 4.58 MPa for the compressive strength of 7 days over 10% replacements. For flexural strength, it was found that 30% gives the optimum result for 28 days, and for the 7 days, the highest value was recorded for 40% replacement of cement by EAFS. For the split tensile strength, there is an increment with increases in percentage replacement, and the maximum result was for 40% replacement of cement by Slag.

**Table 4.4** Average Slag Replacement based on Previous Research.

| S.No | Slag Replacement | Compressive Strength(N/mm$^2$) | | Flexural Strength(N/mm$^2$) | | Tensile Strength(N/mm$^2$) | |
|---|---|---|---|---|---|---|---|
| | | 7days | 28days | 7days | 28days | 7days | 28days |
| 1 | 0% | 19.12 | 32.44 | 3.44 | 4.76 | 2.35 | 3.24 |
| 2 | 10% | 19.13 | 26.83 | 3.38 | 4.49 | 2.56 | 3.11 |
| 3 | 20% | 23.7 | 31.47 | 3.82 | 5.11 | 3.24 | 3.66 |
| 4 | 30% | 21.15 | 31.1 | 4.33 | 5.49 | 3.35 | 3.89 |
| 5 | 40% | 21.91 | 31.71 | 4.45 | 5.46 | 3.63 | 4.02 |

## 4.6 Compressive Strength Test of EAFS for 7 Days

The optimal value of compressive strength was found for 30% replacement of cement by EAFS in laboratory testing. The compressive strength of concrete increases as the proportions are increased to 30%, then it decreases.

**Table 4.5** Compressive Strength by using Slag for 7 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 15.7 | 16.2 | 15.4 | 15.7 |
| 10% | 17.2 | 15.4 | 16.5 | 16.3 |
| 20% | 17 | 18.9 | 17.1 | 17.3 |
| 30% | 19.1 | 18.7 | 18.2 | 18.7 |
| 40% | 14.5 | 15.3 | 15.4 | 15.1 |

## 4.7 Comparison between Previous Research and Laboratory Data for 7 Days Compressive Strength of EAFS

The average compressive strength based on research data collected from several types of research and laboratory data were compared and the optimal value of compressive strength was found for 30% replacement of cement by EAFS for the laboratory testing, whereas the optimal value was for 20% replacement in a research paper. There is a decrement of 6.4 MPa of compressive strength value for 20% replacement of cement by EAFS for laboratory testing compared to the previous paper.

**Table 4.6** Laboratory and Theoretical Compressive Strength Comparison of 7 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 15.7 | 19.12 | -3.42 |
| 10% | 16.3 | 19.13 | -2.83 |
| 20% | 17.3 | 23.7 | -6.4 |
| 30% | 18.7 | 21.15 | -2.45 |
| 40% | 15.1 | 21.91 | -6.81 |

## Representation of Laboratory and Theoretical Average (7 Days)

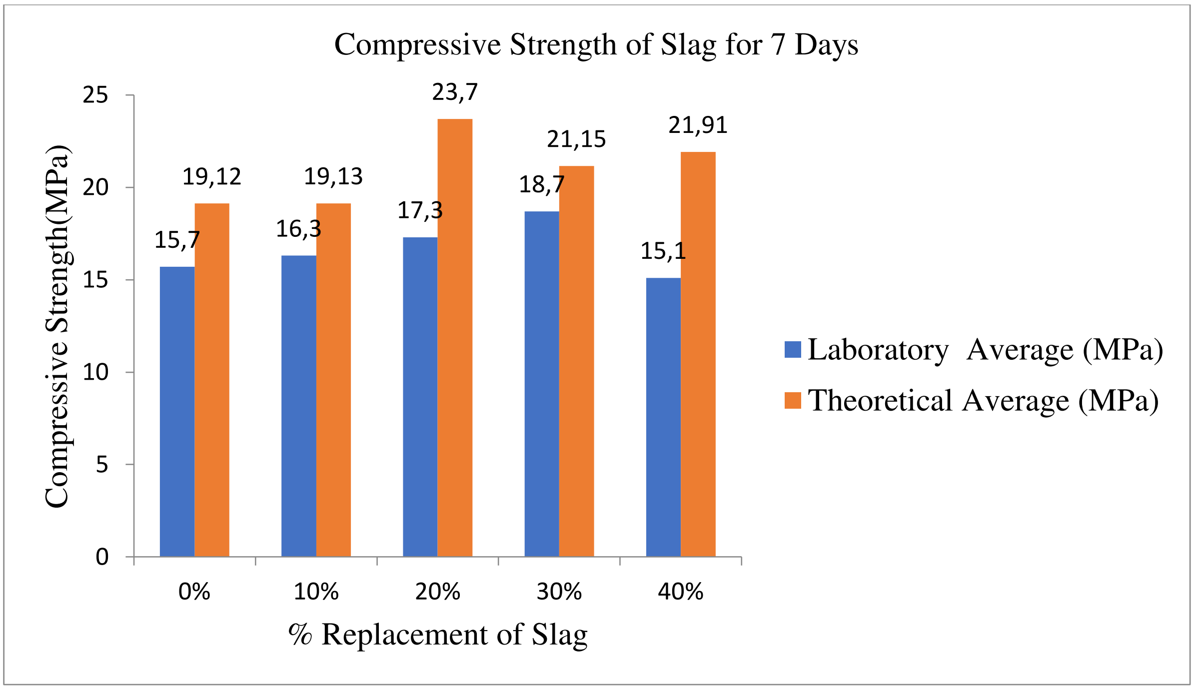


**Fig 4.1** Graph of Slag for Compressive Strength 7 Days vs. % Replacement of EAFS

## 4.8 Compressive Strength Test of EAFS for 14 Days

The maximum compressive strength was found for 30% replacement of EAFS.

**Table 4.7** Compressive Strength by Using Slag for 14 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Average (MPa) |
|---|---|---|---|---|
| 0% | 30.1 | 28.5 | 29.4 | 29.3 |
| 10% | 28.2 | 30.1 | 28.7 | 29.0 |
| 20% | 31.2 | 32.1 | 29.4 | 30.9 |
| 30% | 32.5 | 33.2 | 33.4 | 33.3 |
| 40% | 24.5 | 29.3 | 28.5 | 27.4 |

## 4.9 Graph of Compressive Strength of EAFS for 14 Days

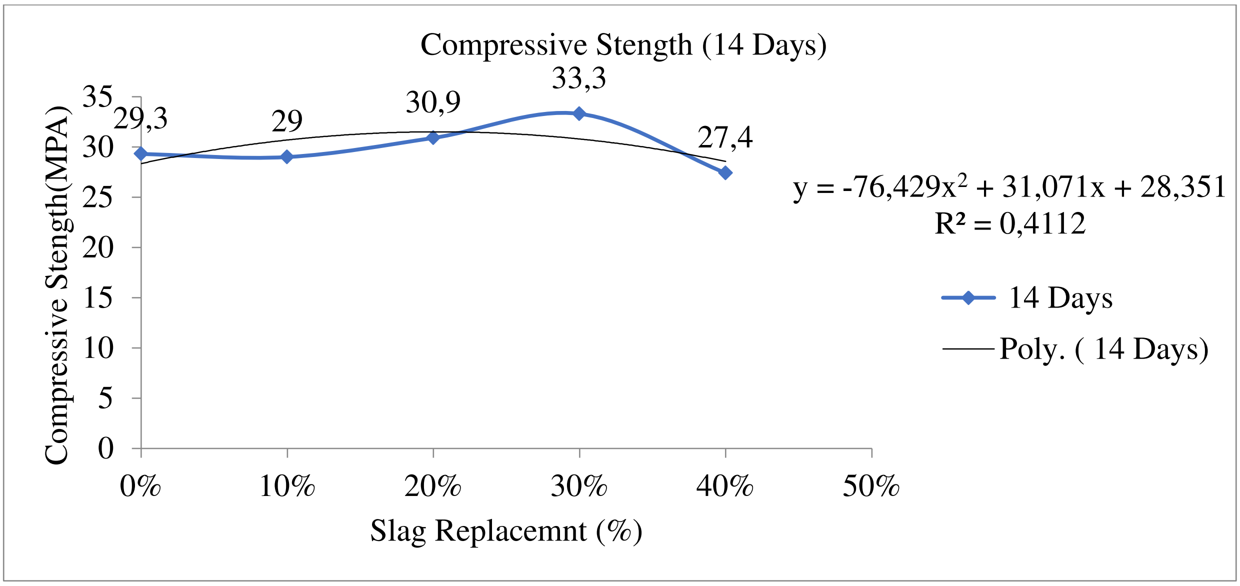


**Fig 4.2** Scatter Plot of Slag for Compressive Strength 14 Days vs. % Replacement of EAFS

## 4.9 Compressive Strength Test of EAFS for 28 Days

The optimal value of compressive strength for 28 days was found for 30% replacement of cement by EAFS for laboratory testing.

**Table 4.8** Compressive Strength by Using Slag for 28 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 35.6 | 36.3 | 36.5 | 36.1 |
| 10% | 40.1 | 35.4 | 29.2 | 34.9 |
| 20% | 32.3 | 38.2 | 34.9 | 35.0 |
| 30% | 39.1 | 40.2 | 41.2 | 40.1 |
| 40% | 35.4 | 37.2 | 34.8 | 35.8 |

## 4.10 Comparison between Previous Research and Laboratory Data for 28 Days Compressive Strength of EAFS

The optimal value of compressive strength for 28 days was found for 30% replacement of cement by slag for the laboratory testing whereas the optimal value was found for unmodified concrete in the research paper. There is an increment in compressive strength value of 28 days for laboratory testing compared to the previous paper. There is an increase of 9 MPa in compressive strength value for 30% replacement of EAFS by cement in laboratory testing compared to the previous paper.

**Table 4.9** Laboratory and Theoretical Compressive Strength Comparison of 28 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Incremental Value |
|---|---|---|---|
| 0% | 36.1 | 32.44 | 3.66 |
| 10% | 34.9 | 26.83 | 8.07 |
| 20% | 35.0 | 31.47 | 3.53 |
| 30% | 40.1 | 31.1 | 9 |
| 40% | 35.8 | 31.71 | 4.09 |

## Representation of Laboratory and Theoretical Average (28 Day)

The maximum strength was found for 30% replacement of EAFS in the laboratory but in previous research, the efficient strength was found for unmodified concrete.

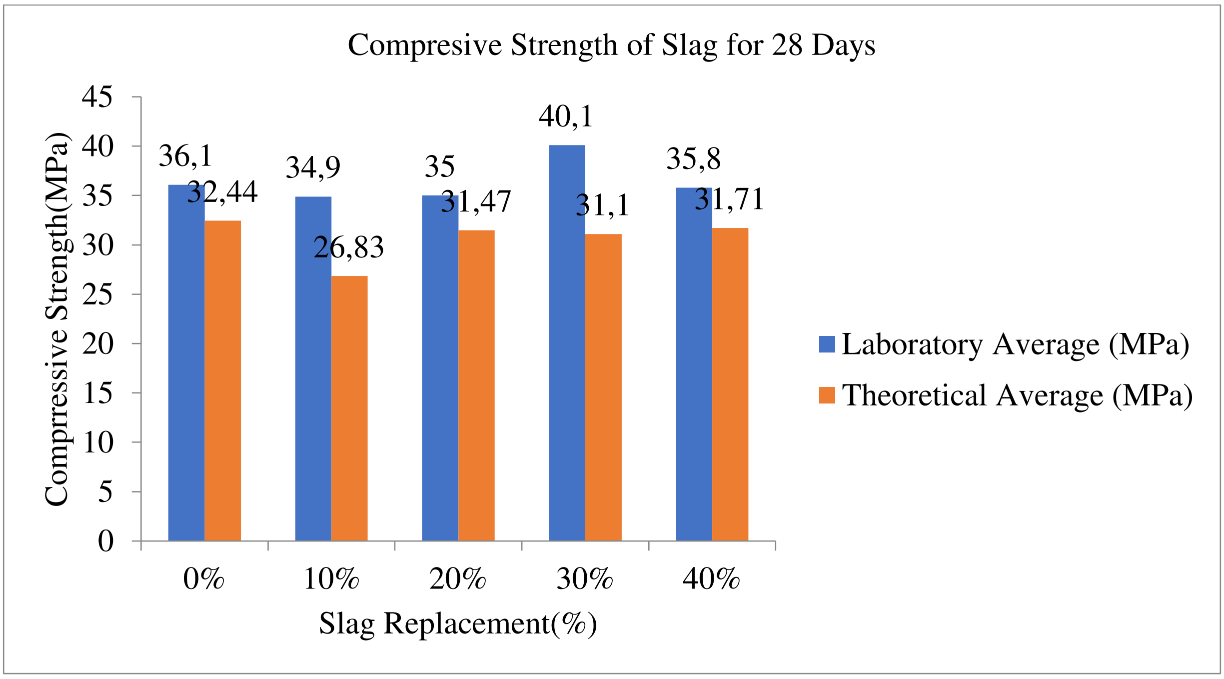


**Fig 4.3** Graph of Compressive Strength vs. % Slag replacement for 28 Days

## 4.12 Flexural Strength Test of EAFS for 7 Days

The flexural strength value for 7 days increases up to 20% replacement of cement by EAFS for the laboratory testing and the optimal value was found for 20% replacement of slag in laboratory testing and 40% in research.

**Table 4.10** Flexural Strength by Using Slag for 7 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 2.9 | 3.1 | 2.9 | 2.9 |
| 10% | 3.2 | 2.8 | 3.4 | 3.1 |
| 20% | 3.5 | 3.5 | 2.9 | 3.3 |
| 30% | 2.8 | 2.6 | 2.7 | 2.7 |
| 40% | 2.7 | 2.5 | 2.7 | 2.6 |

## 4.13 Comparison between Previous Research and Laboratory Data for 7 Days Flexural Strength of EAFS

The flexural strength of concrete varies as the proportions are increased. Compare to laboratory data, the theoretical strengths are higher. This may be due to the use of different additives, an increase in the water-cement ratio, and also the due quality of cement used.

**Table 4.11** Laboratory and Theoretical Flexural Strength Comparison of 7 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 2.9 | 3.44 | -0.54 |
| 10% | 3.1 | 3.38 | -0.28 |
| 20% | 3.3 | 3.82 | -0.52 |
| 30% | 2.7 | 4.33 | -1.63 |
| 40% | 2.6 | 4.45 | -1.85 |

## Graphical Representation of Laboratory and Theoretical Average (7 Days)

The strength increases in the case of previous research but in the laboratory, the strength increases to 20%, and then it decreases.

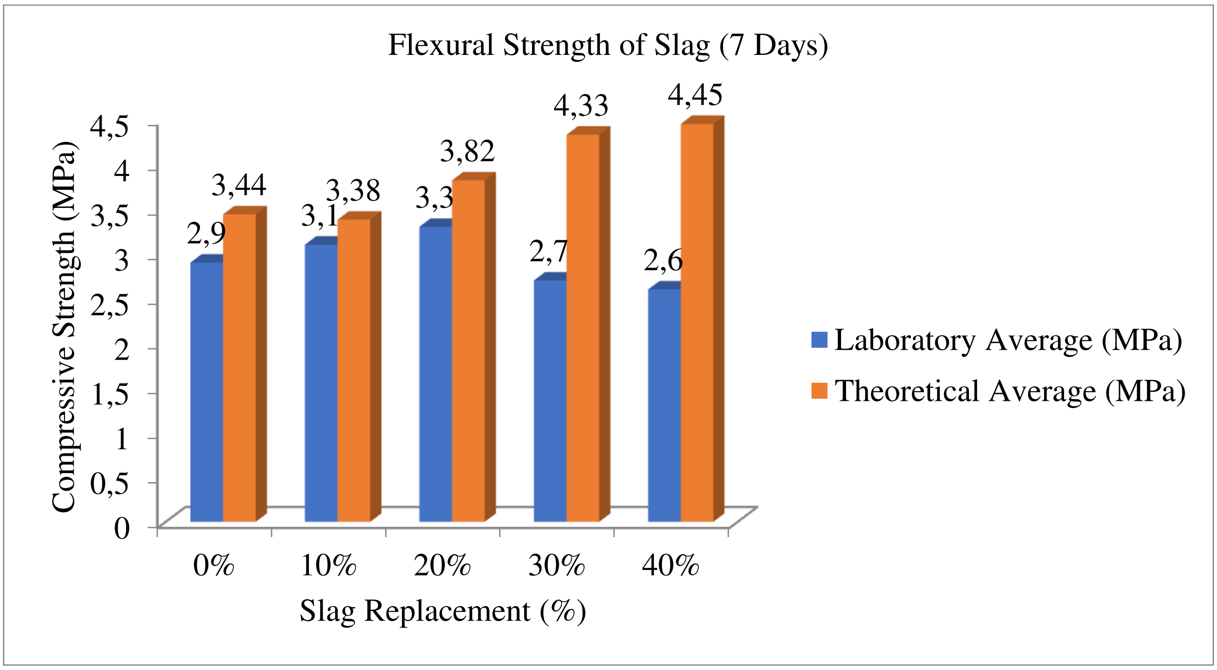


**Fig 4.4** Graph of Slag for Flexural Strength 7 Days

## 4.14 Flexural Strength Test of EAFS for 14 Days

**Table 4.12** Flexural Strength by Using Slag for 14 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 3.2 | 2.5 | 2.8 | 2.8 |
| 10% | 2.4 | 2.6 | 2.7 | 2.6 |
| 20% | 2.1 | 2.5 | 3.5 | 2.7 |
| 30% | 3.6 | 3.2 | 3.4 | 3.4 |
| 40% | 2.4 | 3.1 | 2.8 | 2.7 |

## 4.15 Graph of Flexural Strength of EAFS for 14 Days

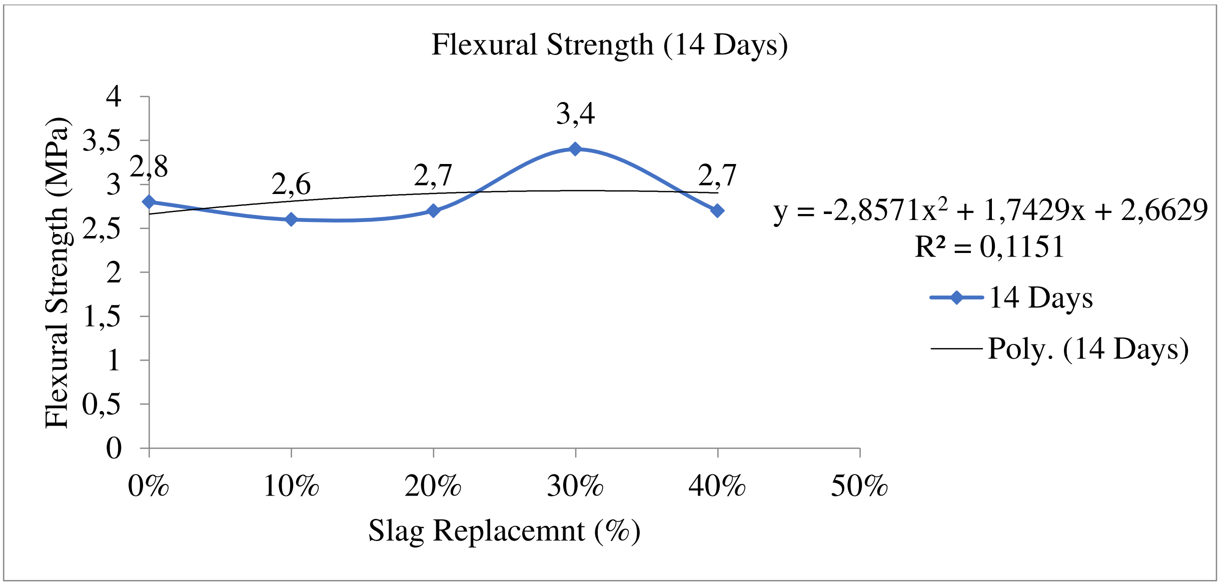


**Fig 4.5** Scatter Plot of Slag of Flexural Strength 7 Days vs. % Replacement of EAFS

## 4.16 Flexural Strength Test of EAFS for 28 Days

The optimal value for flexural strength for 28 days was found for 20% replacement of cement by slag in laboratory testing and 30% in a research paper.

**Table 4.13** Flexural Strength by Using Slag for 28 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 4.8 | 4.2 | 3.1 | 4.0 |
| 10% | 5.1 | 4.8 | 4.6 | 4.3 |
| 20% | 5.4 | 4.6 | 4.5 | 4.8 |
| 30% | 4.2 | 3.5 | 3.7 | 3.8 |
| 40% | 4.2 | 4.1 | 3.7 | 4.0 |

## 4.17 Comparison between Previous Research and Laboratory Data for 28 Days Flexural Strength of EAFS

There is a decrement of 0.31 MPa and 1.69 MPa of flexure strength value for 28 days for 20% and 30% replacement of cement by EAFS respectively

**Table 4.14** Laboratory and Theoretical Flexural Strength Comparison of 28 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 4.0 | 4.76 | -0.76 |
| 10% | 4.3 | 4.49 | -0.19 |
| 20% | 4.8 | 5.11 | -0.31 |
| 30% | 3.8 | 5.49 | -1.69 |
| 40% | 4.0 | 5.46 | -1.46 |

## Representation of Laboratory and Theoretical Average (28 Days)

For fig 4.6 there is the increment in flexure strength value after 10% replacement of cement by EAFS in the previous paper whereas the highest value was recorded for 20% replacement of cement by EAFS in laboratory testing.

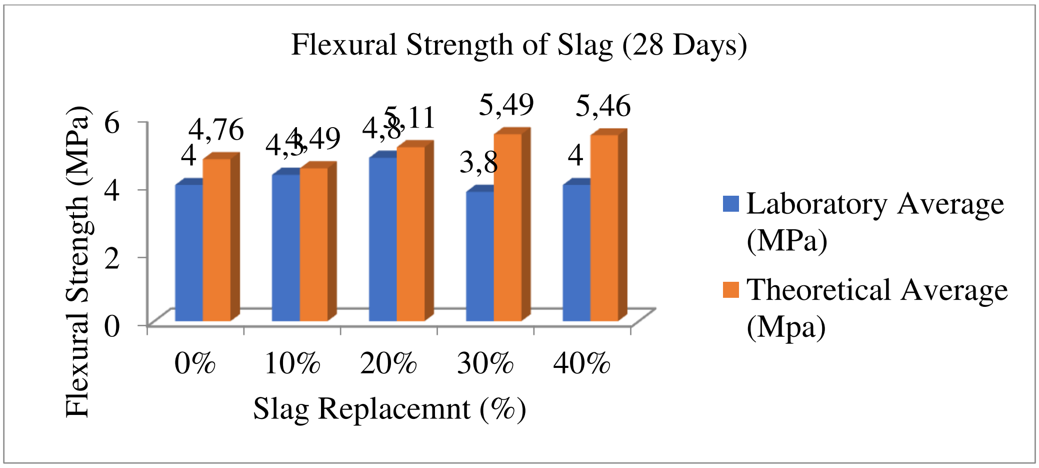


**Fig 4.6** Graph of Slag for Flexural Strength 28 Days

## 4.18 Split Tensile Strength Test of EAFS for 7 Days

The optimal value of tensile strength of laboratory testing for 7 days was found for 10% and 40% replacement of slag whereas in the research paper the optimal value was found for 40% replacement of slag only.

**Table 4.15** Split Tensile Strength by Using Slag for 7 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 2.4 | 2.5 | 2.1 | 2.3 |
| 10% | 2.5 | 2.9 | 3.1 | 2.8 |
| 20% | 2.1 | 3.1 | 1.9 | 2.4 |
| 30% | 1.8 | 2.5 | 2.1 | 2.1 |
| 40% | 2.5 | 2.8 | 3.2 | 2.8 |

## 4.19 Comparison between Previous Research and Laboratory Data for 7 Days Split Tensile Strength of EAFS

The optimal value of tensile strength of laboratory testing for 7 days was found for 10% and 40% replacement of slag whereas in the research paper the optimal value was found for 40% replacement of slag only.

**Table 4.16** Laboratory and Theoretical Tensile Strength Comparison of 7 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value | Incremental Value |
|---|---|---|---|---|
| 0% | 2.3 | 2.35 | 0.05 | - |
| 10% | 2.8 | 2.56 | - | 0.24 |
| 20% | 2.4 | 3.24 | 0.84 | - |
| 30% | 2.1 | 3.35 | 1.25 | - |
| 40% | 2.8 | 3.63 | 0.83 | - |

### Representation of Laboratory and Theoretical Average (7 Days)

In fig 4.7 there is an almost linear variation of tensile strength with an increase in percentage replacement in theoretical average but in laboratory testing, the strength varies differently.

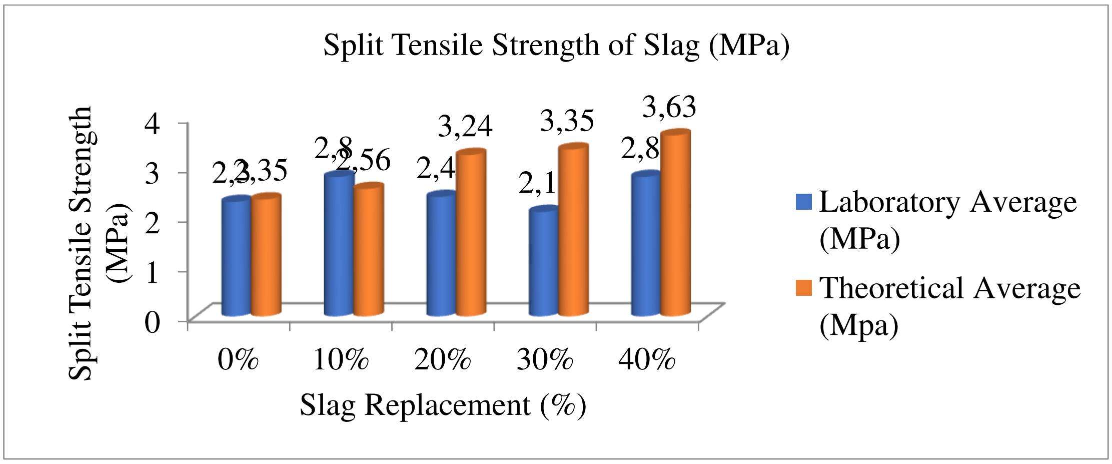


**Fig 4.7** Graph of Slag for Tensile Strength 7 Days vs. % Replacement of EAFS

### 4.20 Split Tensile Strength Test of EAFS for 14 Days

**Table 4.17** Split Tensile Strength by Using Slag for 14 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 3.2 | 2.8 | 2.7 | 2.9 |
| 10% | 2.4 | 2.8 | 3.1 | 2.7 |
| 20% | 2.3 | 2.7 | 3.0 | 2.6 |
| 30% | 2.1 | 2.3 | 3.1 | 2.5 |
| 40% | 3.1 | 2.8 | 2.4 | 2.7 |

### 4.21 Graph Split Tensile Strength Test of EAFS for 14 Days

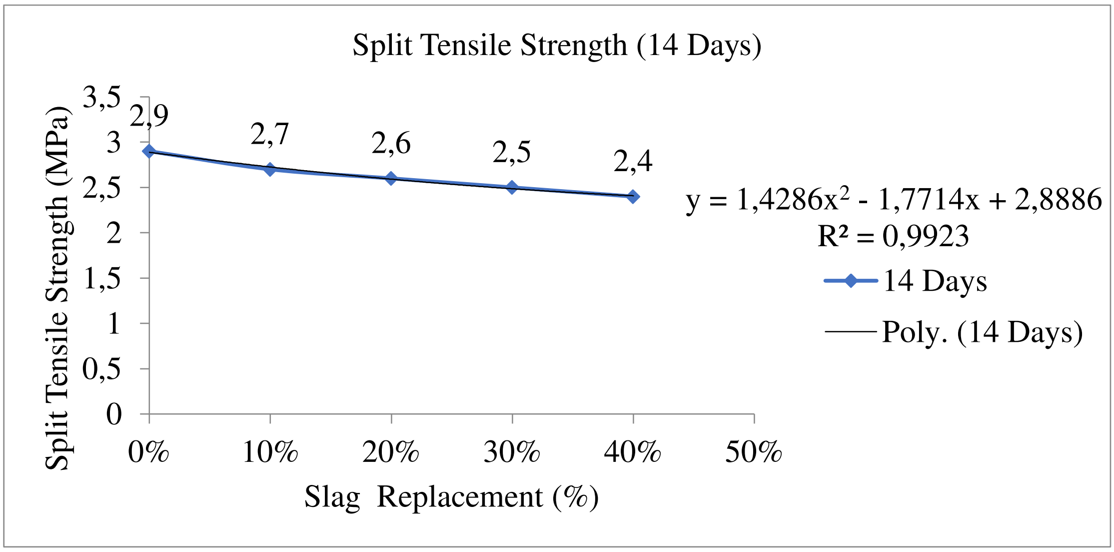


**Fig 4.8** Scatter Plot of Slag for Tensile Strength 7 Days vs. % Replacement of EAFS

### 4.21 Split Tensile Strength of EAFS for 28 Days

The optimal value of tensile strength of laboratory testing for 28 days was found for 20% replacement of slag whereas in the research paper the optimal value was found for 40% replacement of slag only.

**Table 4.18** Split Tensile Strength by Using Slag for 28 Days

| % Replacement of Slag | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 3.2 | 3.4 | 2.9 | 3.1 |
| 10% | 3.1 | 2.9 | 2.8 | 2.9 |
| 20% | 3.5 | 2.9 | 3.6 | 3.3 |
| 30% | 3.4 | 3.2 | 2.9 | 3.1 |
| 40% | 2.7 | 2.8 | 3.1 | 2.8 |

## 4.22 Comparison between Previous Research and Laboratory Data for 28 Days Split Tensile Strength of EAFS

There is a decrement of 0.36 MPa split tensile strength value for 28 days for 20% replacement of cement by EAFS for laboratory testing compared to the previous paper

**Table 4.19** Laboratory and Theoretical Tensile Strength Comparison of 28 Days

| % Replacement of Slag | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 3.1 | 3.24 | 0.14 |
| 10% | 2.9 | 3.11 | 0.21 |
| 20% | 3.3 | 3.66 | 0.36 |
| 30% | 3.1 | 3.89 | 0.79 |
| 40% | 2.8 | 4.02 | 1.22 |

**Representation of Laboratory and Theoretical Average (28 Days)**

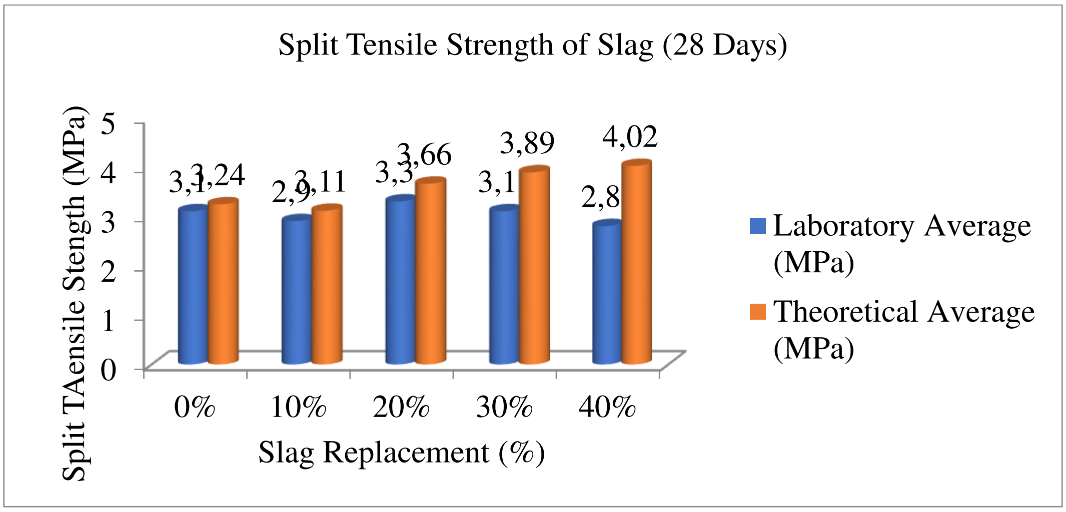


**Fig 4.9** Graph of Slag for Tensile Strength 28 Days vs. % Replacement of EAFS

## 4.23 Average Plastic Aggregate Replacement based on Previous Research

Initially, data related to the variation in compressive strength with the inclusion of plastic aggregate were extracted from previous research papers, and a relationship was established between the both as shown below.

**Table 4.20** Average Value for Plastic Replacement based on Research Papers.

| % Replacement of Plastic Aggregate | Average Compressive Strength (Mpa) | | | Average Flexural Strength (Mpa) | | | Average Split Tensile Strength (Mpa) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7days | 14days | 28days | 7days | 14days | 28days | 7 days | 14days | 28days |
| 0 | 14.11 | 23.4 | 32.8 | 3.68 | 4.87 | 6.09 | 2.26 | 2.71 | 3.34 |
| 2.5 | 14.8 | 24.7 | 30.06 | 4.55 | 5.03 | 6.26 | 2.52 | 2.83 | 3.46 |
| 5 | 13.81 | 23.8 | 32.9 | 4.095 | 5.02 | 6.28 | 3.46 | 3.76 | 4.15 |
| 7.5 | 13.34 | 22.9 | 31.87 | 4.145 | 5.05 | 6.33 | 3.26 | 3.64 | 4.47 |

## 4.24 Compressive Strength Test of Plastic Aggregate for 7 Days

The optimal value of compressive strength for 7 days was found for 5% replacement of coarse aggregate by plastic waste in laboratory testing whereas the optimal value in the research paper was found for 2.5% replacement.

**Table 4.21** Compressive Strength by Using Plastic Waste for 7 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 12.7 | 13.6 | 13.4 | 13.2 |
| 2.5% | 15.2 | 14.6 | 13.5 | 14.4 |
| 5% | 13.7 | 15.7 | 14.8 | 14.7 |
| 7.5% | 14.2 | 13.1 | 12.8 | 13.4 |

## 4.25 Comparison between Previous Research and Laboratory Data for 7 Days Compressive Strength of Plastic Aggregate

There is a decrement in compressive strength value for 7days in laboratory testing of 0.91 MPa for normal concrete and 0.4 MPa for 2.5% replacement by plastic aggregate. There is an increment in compressive strength value after 5% replacement by plastic waste for 7 days.

**Table 4.22** Laboratory and Theoretical Compressive Strength Comparison of 7 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value | Incremental Value |
|---|---|---|---|---|
| 0% | 13.2 | 14.11 | 0.91 | - |
| 2.5% | 14.4 | 14.8 | 0.4 | - |
| 5% | 14.7 | 13.81 | - | 0.89 |
| 7.5% | 13.4 | 13.34 | - | 0.06 |

**Representation of Laboratory and Theoretical Average (7 Days)**

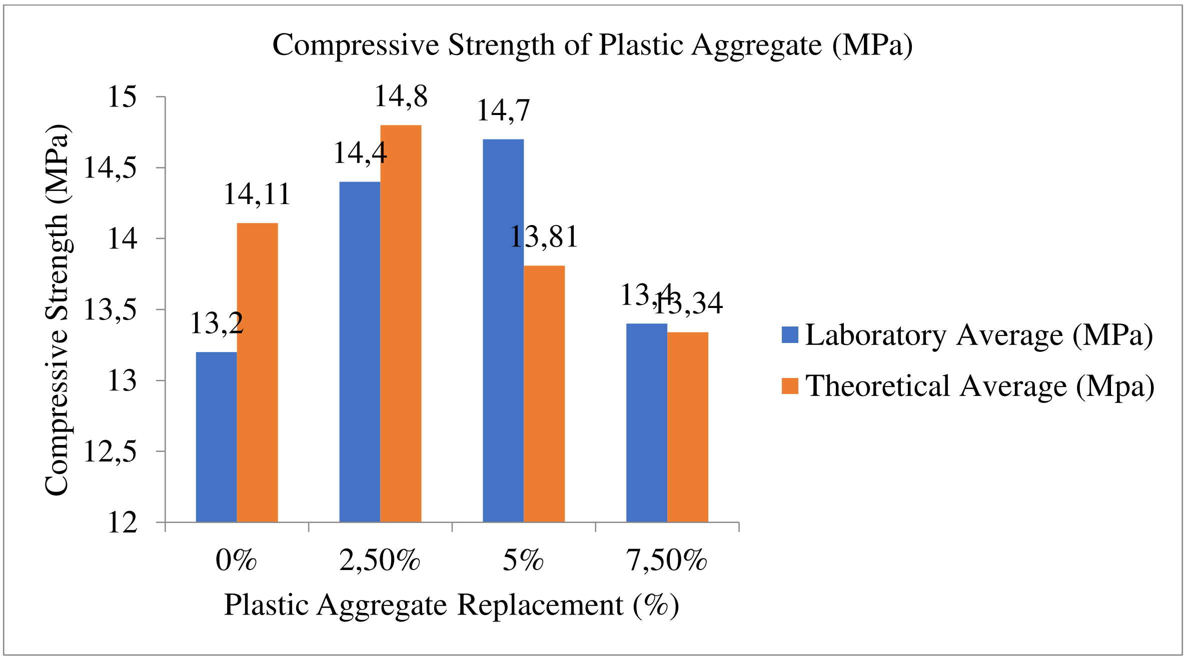


**Fig 4.10** Graph of Compressive Strength 7 Days vs. % Replacement of Plastic Aggregate

## 4.26 Compressive Strength Test of Plastic Aggregate for 14 Days

There is a decrement of 0.2 MPa for the optimal value of compressive strength for 14 days in laboratory testing.

**Table 4.23** Compressive Strength by Using Plastic Waste for 14 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 24.1 | 23.1 | 25.4 | 24.2 |
| 2.5% | 26.3 | 24.1 | 23.2 | 24.5 |
| 5% | 22.1 | 24.1 | 23.5 | 23.2 |
| 7.5% | 20.3 | 22.1 | 25.1 | 22.5 |

## 4.27 Comparison between Previous Research and Laboratory Data for 14 Days Compressive Strength of Plastic Aggregate

The compressive strength value increases for normal concrete for 14days after plastic aggregate replacement there is a small decrement in compressive strength for laboratory testing.

**Table 4.24** Laboratory and Theoretical Compressive Strength Comparison of 14 Days

| % Replacement of Plastic Waste | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value | Incremental Value |
|---|---|---|---|---|
| 0% | 24.2 | 23.4 | - | 0.8 |
| 2.5% | 24.5 | 24.7 | 0.2 | - |
| 5% | 23.2 | 23.8 | 0.6 | - |
| 7.5% | 22.5 | 22.9 | 0.4 | - |

### Representation of Laboratory and Theoretical Average (14 Days)

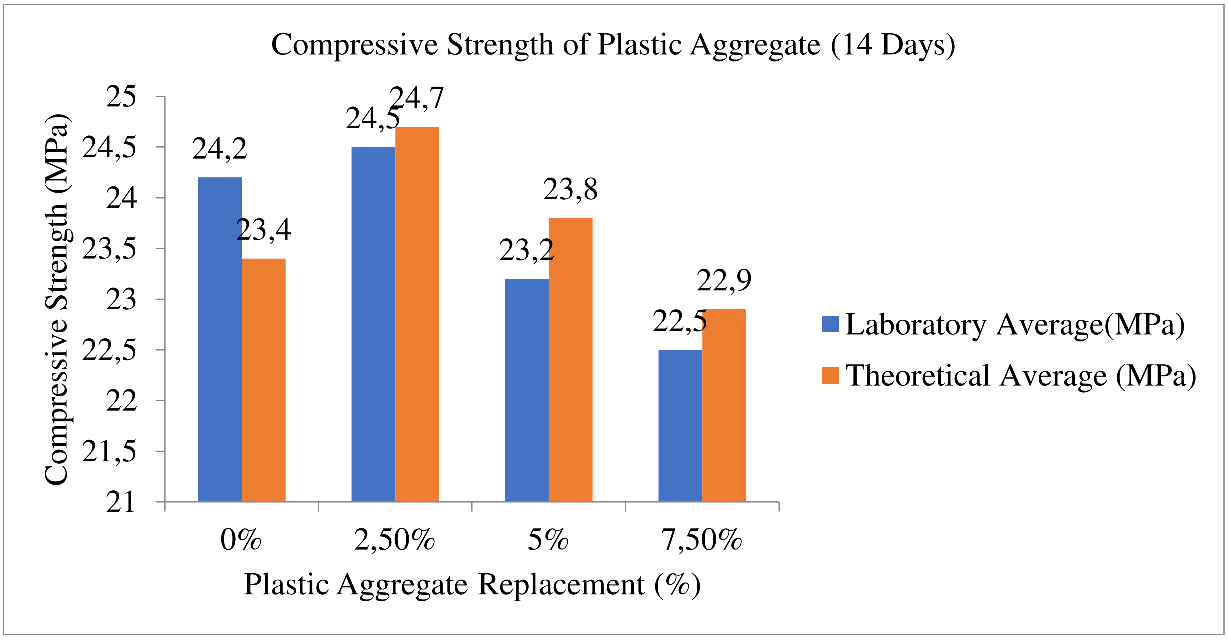


**Fig 4.11** Graph of Compressive Strength 14 Days vs. % Replacement of Plastic Aggregate

## 4.28 Compressive Strength Test of Plastic Aggregate for 28 Days

For 28 days, the optimal value was found for unmodified concrete in laboratory testing and in the research paper.

**Table 4.25** Compressive Strength by Using Plastic Waste for 28 Days

| % Replacement of Plastic Aggregate | Sample1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 35.6 | 32.6 | 33.1 | 33.8 |
| 2.5% | 31.2 | 30.5 | 29.5 | 30.4 |
| 5% | 33.2 | 30.5 | 29.7 | 31.2 |
| 7.5% | 32.5 | 31.2 | 33.2 | 32.3 |

## 4.29 Comparison between Previous Research and Laboratory Data for 28 Days Compressive Strength of plastic aggregate

There is an increment of 0.43 MPa in compressive strength for 28 days in laboratory testing compared to the previous paper.

**Table 4.26** Laboratory and Theoretical Compressive Strength Comparison of 28 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value | Incremental Value |
|---|---|---|---|---|
| 0% | 33.8 | 32.8 | - | 1 |
| 2.5% | 30.4 | 30.06 | - | 0.34 |
| 5% | 31.2 | 32.9 | 1.7 | - |
| 7.5% | 32.3 | 31.87 | - | 0.43 |

**Representation of Laboratory and Theoretical Average (28 Days)**

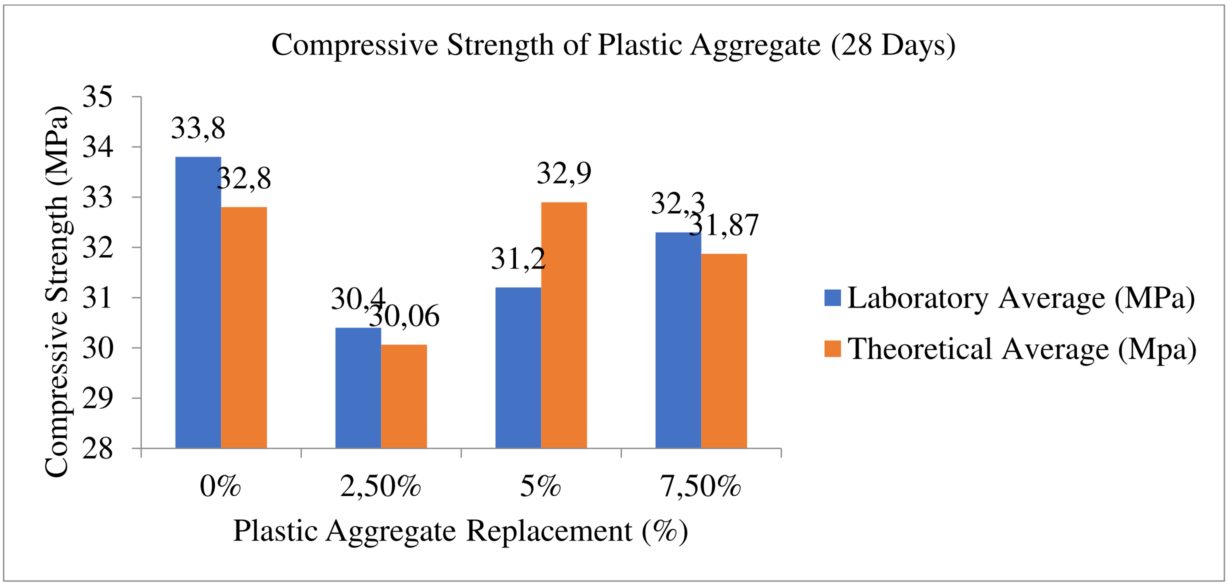


**Fig 4.12** Graph of Compressive Strength 28 Days vs. % Replacement of Plastic Aggregate

## 4.30 Flexural Strength Test of Plastic Aggregate for 7 Days

The highest value of flexure strength for 7 days was recorded for 2.5% replacement of coarse aggregate by plastic aggregate.

**Table 4.27** Flexural Strength by Using Plastic Waste for 7 Days

| % replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 3.4 | 3.3 | 3.8 | 3.5 |
| 2.5% | 4.1 | 4.3 | 4.6 | 4.3 |
| 5% | 3.8 | 4.3 | 4 | 4.1 |
| 7.5% | 3.7 | 4.2 | 4 | 3.9 |

## 4.31 Comparison between Previous Research and Laboratory Data for 7 Days Flexural Strength of Plastic Aggregate

The optimal value for flexure strength for 7 days was found for 2.5% replacement of coarse aggregate by plastic waste in laboratory testing and in the research paper. There is an increment of 0.005 MPa of flexure strength value for 7 days for 5% replacement of plastic aggregate for laboratory testing.

**Table 4.28** Laboratory and Theoretical Flexural Strength Comparison of 7 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value | Incremental Value |
|---|---|---|---|---|
| 0% | 3.5 | 3.68 | 0.18 | - |
| 2.5% | 4.3 | 4.55 | 0.25 | - |
| 5% | 4.1 | 4.095 | - | 0.005 |
| 7.5% | 3.9 | 4.145 | 0.245 | - |

### Representation of Laboratory and Theoretical Average (7 Days)

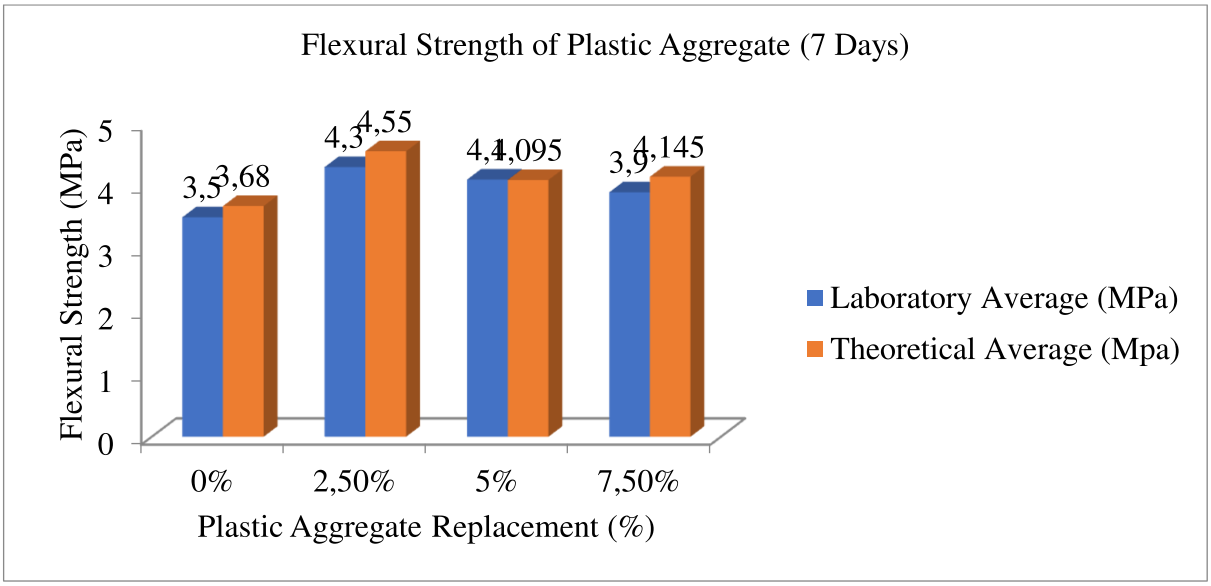


**Fig 4.13** Graph of Flexural Strength 7 Days vs. % Replacement of Plastic Aggregate

## 4.32 Flexural Strength Test of Plastic Aggregate for 14 Days

For laboratory testing of flexure strength for 14 days the highest value was recorded for normal concrete. The flexural strength value decreases with an increase in plastic aggregate replacement.

**Table 4.29** Flexural Strength by Using Plastic Waste for 14 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 4.9 | 4.2 | 5.2 | 4.7 |
| 2.5% | 4.9 | 4.2 | 3.1 | 4.0 |
| 5% | 4.8 | 3.3 | 4.6 | 4.5 |
| 7.5% | 4.9 | 3.3 | 4.1 | 4.1 |

## 4.33 Comparison between Previous Research and Laboratory Data for 14 Days Flexural Strength of Plastic Aggregate

There is a decrement of 0.17 MPa of flexure strength value for 7 days for normal concrete and 0.52 MPa for 5% replacement of plastic aggregate

**Table 4.30** Laboratory and Theoretical Flexural Strength Comparison of 14 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 4.7 | 4.87 | 0.17 |
| 2.5% | 4.0 | 5.03 | 1.03 |
| 5% | 4.5 | 5.02 | 0.52 |
| 7.5% | 4.1 | 5.05 | 0.95 |

**Representation of Laboratory and Theoretical Average (14 Days)**

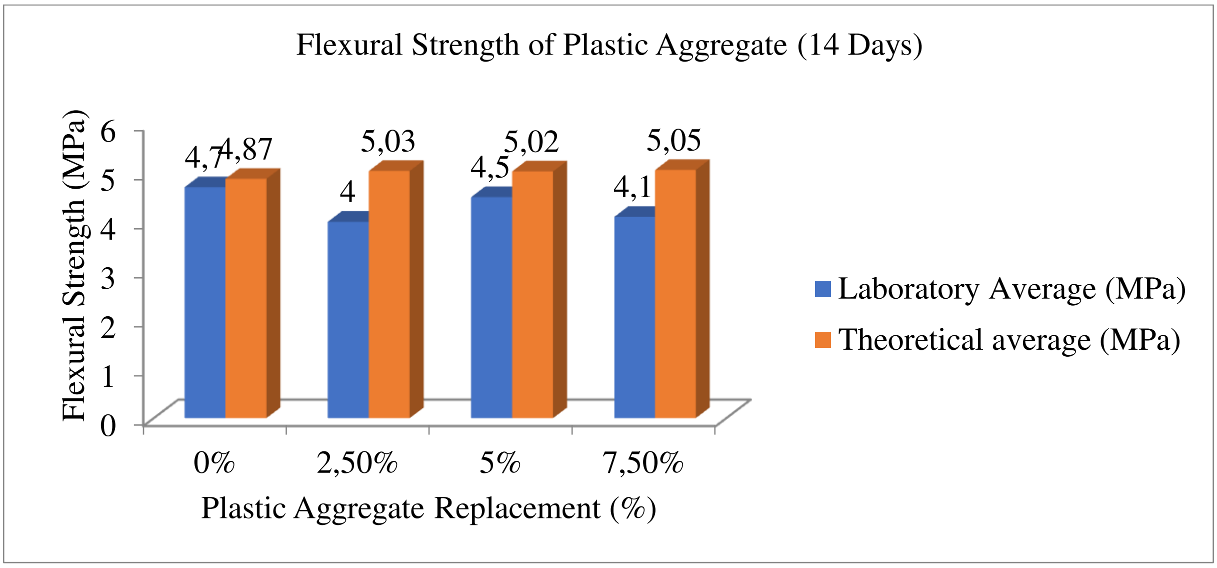


**Fig 4.14** Graph of Flexural Strength 14 Days vs. % Replacement of Plastic Aggregate

## 4.34 Flexural Strength Test of Plastic Aggregate for 28 Days

For fig 4.14 at 7.5% replacement of coarse aggregate for 28 days there is an increment of 3.94% in flexural strength value. The optimal value for flexure strength for 28 days was found for 5% and 7.5% replacement of coarse aggregate by plastic waste in laboratory testing. The optimal value for flexure strength for 28 days was found for 5% and 7.5% replacement of coarse aggregate by plastic waste in the laboratory.

**Table 4.31** Flexural Strength by Using Plastic Waste for 28 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 5.8 | 6.3 | 5.9 | 6 |
| 2.5% | 5 | 6.5 | 5.8 | 5.8 |
| 5% | 5.8 | 6.1 | 6.4 | 6.1 |
| 7.5% | 6.3 | 6 | 5.9 | 6.1 |

## 4.35 Comparison between Previous Research and Laboratory Data for 28 Days Flexural Strength of Plastic Aggregate

There is a decrement of 0.23 MPa of flexure strength value at 7.5% replacement of coarse aggregate by plastic aggregate for laboratory testing compared to the previous paper. There is less deviation in flexure strength value for the laboratory and in the previous paper for 28 days.

**Table 4.32** Laboratory and Theoretical Flexural Strength Comparison of 28 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 6 | 6.09 | 0.09 |
| 2.5% | 5.8 | 6.26 | 0.46 |
| 5% | 6.1 | 6.28 | 0.18 |
| 7.5% | 6.1 | 6.33 | 0.23 |

### Representation of Laboratory and Theoretical Average (28 Days)

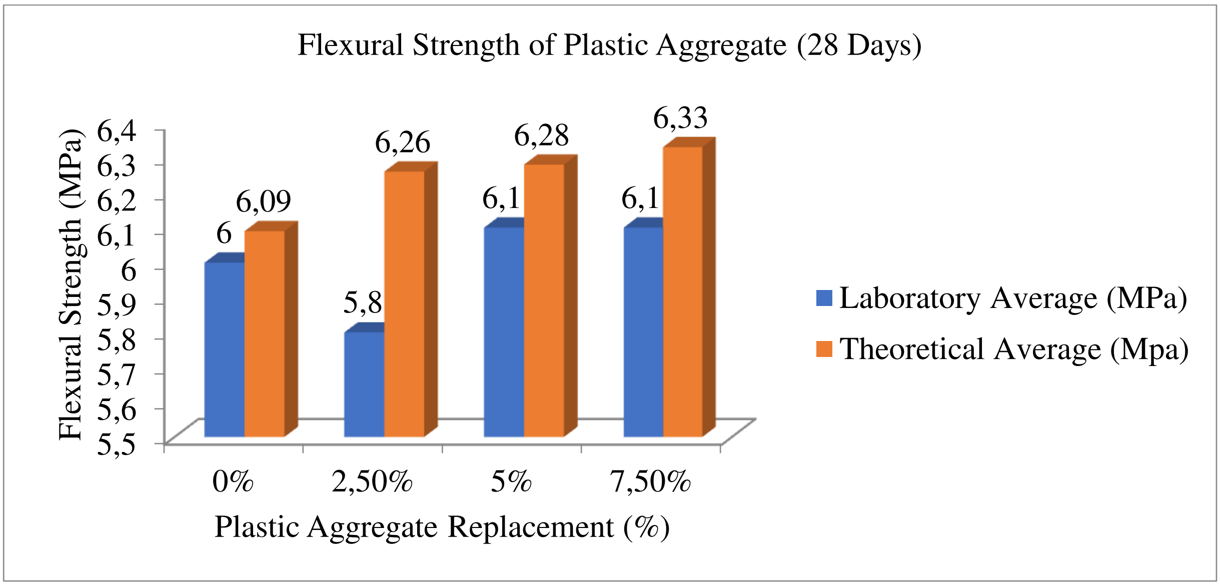


**Fig 4.15** Graph of Flexural Strength 28 Days vs. % Replacement of Plastic Aggregate

## 4.36 Split Tensile Strength Test of Plastic Aggregate for 7 Days

The optimal value of tensile strength for 7 days was found for 5% replacement of plastic waste by coarse aggregate in laboratory testing.

**Table 4.33** Split Tensile Strength by Using Plastic Waste for 7 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 1.9 | 2.6 | 3.2 | 2.6 |
| 2.5% | 2.4 | 2.8 | 3.2 | 2.8 |
| 5% | 3.1 | 3.6 | 3.9 | 3.5 |
| 7.5% | 3.3 | 3.4 | 3.7 | 3.4 |

## 4.37 Comparison between Previous Research and Laboratory Data for 7 Days Split Tensile Strength of Plastic Aggregate

**Table 4.34** Laboratory and Theoretical Tensile Strength Comparison of Plastic Aggregate

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Incremental Value |
|---|---|---|---|
| 0% | 2.6 | 2.26 | 0.34 |
| 2.5% | 2.8 | 2.52 | 0.28 |
| 5% | 3.5 | 3.46 | 0.04 |
| 7.5% | 3.4 | 3.26 | 0.14 |

**Representation of Laboratory and Theoretical Average (7 Days)**

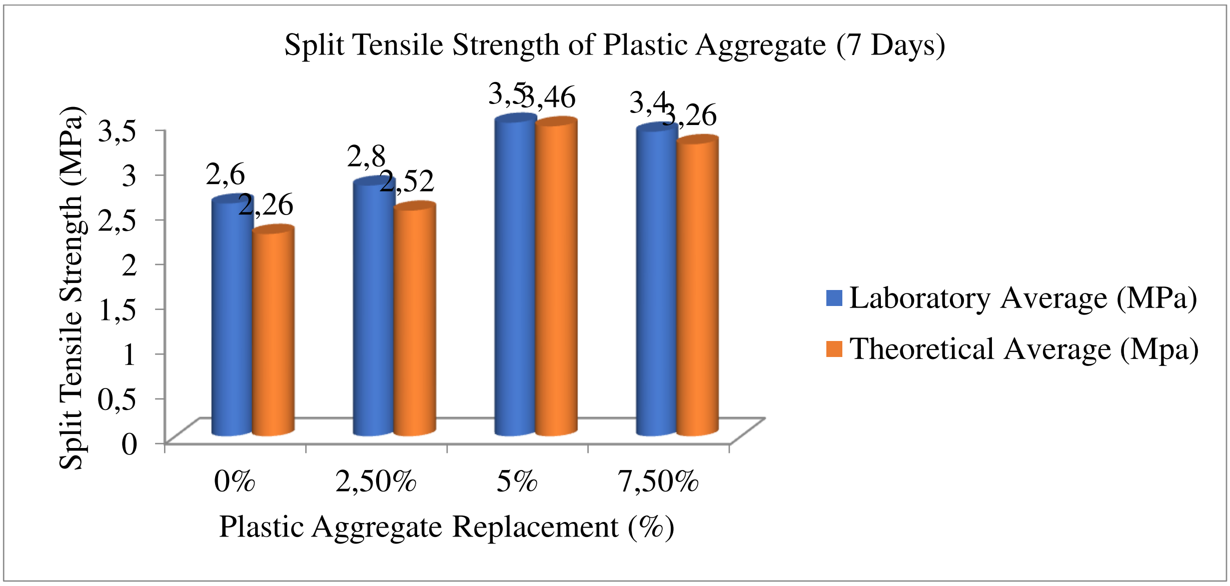


**Fig 4.16** Graph of Tensile Strength 7 Days vs. % Replacement of Plastic Aggregate

## 4.38 Split Tensile Strength Test of Plastic Aggregate for 14 Days

For fig 4.39 the highest value for 14 days was for 5% replacement of coarse aggregate by plastic waste. When plastic replacement is 5.5%, the Split Tensile comes to around 5.5 MPa.

**Table 4.35** Split Tensile Strength by Using Plastic Waste for 14 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 2.6 | 2.8 | 2.7 | 2.7 |
| 2.5% | 2.7 | 2.9 | 2.5 | 2.7 |
| 5% | 3.8 | 3.6 | 3.5 | 3.6 |
| 7.5% | 3.4 | 3.6 | 3.5 | 3.5 |

## 4.39 Comparison between Previous Research and Laboratory Data for 14 Days Split Tensile Strength of Plastic Aggregate

The optimal value was recorded for 5% replacement of coarse aggregate with plastic aggregate for both laboratories and in the previous paper. There is a decrement of 0.16 MPa of split tensile strength value for 5% replacement of plastic aggregate for 14 days in the laboratory compared to the previous paper.

**Table 4.36** Split Tensile Strength by Using Plastic Waste for 14 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Decrement Value |
|---|---|---|---|
| 0% | 2.7 | 2.71 | 0.01 |
| 2.5% | 2.7 | 2.83 | 0.13 |
| 5% | 3.6 | 3.76 | 0.16 |
| 7.5% | 3.5 | 3.64 | 0.14 |

### Representation of Laboratory and Theoretical Average (14 Days)

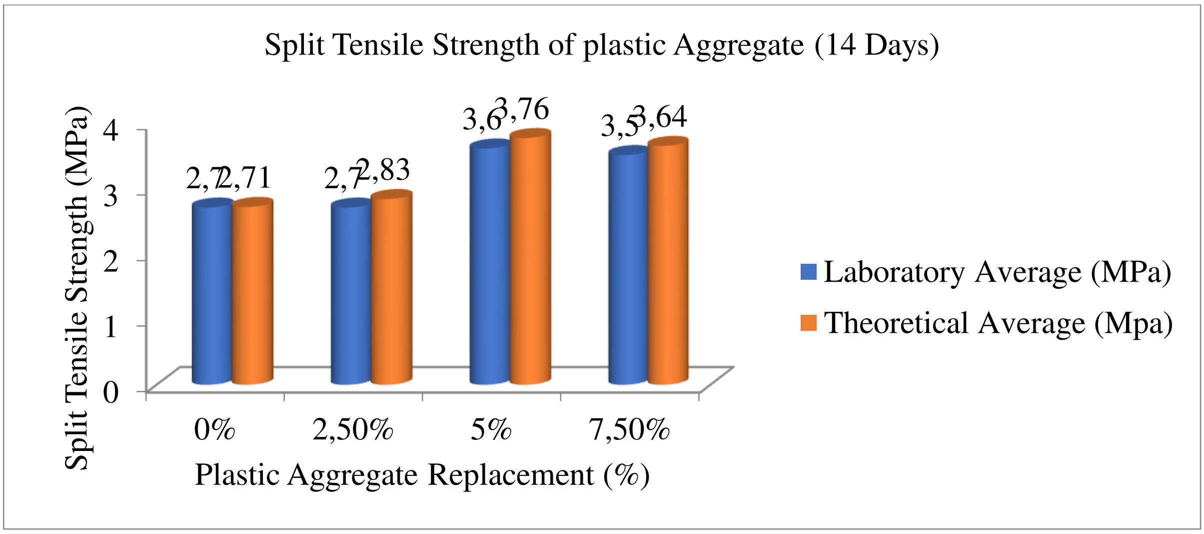


**Fig 4.17** Graph of Tensile Strength 14 Days vs. % Replacement of Plastic Aggregate

## 4.40 Split Tensile Strength Test of Plastic Aggregate for 28 Days

For fig 4.37 at 7.5% replacement of coarse aggregate by plastic aggregate for 28 days there is an increment of 33.8% of split tensile strength. The optimal value of tensile strength for 28 days was found for 7.5% replacement of plastic waste by coarse aggregate in laboratory testing and in the research paper. This may be due to the Cement aggregate ratio, because aggregates are the primary source of concrete strength, raising the cement-to-aggregate ratio will boost strength. Better grade aggregates absorb less water, allowing more water to be used for cement hydration.

**Table 4.37** Split Tensile Strength by Using Plastic Waste for 28 Days

| % Replacement of Plastic Aggregate | Sample 1 (MPa) | Sample 2 (MPa) | Sample 3 (MPa) | Laboratory Average (MPa) |
|---|---|---|---|---|
| 0% | 3.1 | 3 | 3.4 | 3.2 |
| 2.5% | 3.2 | 3.3 | 3.3 | 3.3 |
| 5% | 3.8 | 4 | 4.2 | 4 |
| 7.5% | 3.9 | 4.2 | 4.5 | 4.2 |

## 4.41 Comparison between Previous Research and Laboratory Data for 28 Days Split Tensile Strength of Plastic Aggregate

It was observed that the split tensile strength value increases with an increase in percentage replacement of coarse aggregate by plastic aggregate in laboratory testing whereas in the previous paper the split tensile strength increases to 5% replacement of plastic aggregate. There is a decrement of 0.24 MPa of split tensile strength value at 5% replacement of coarse aggregate by plastic aggregate.

**Table 4.38** Split Tensile Strength by Using Plastic Waste for 28 Days

| % Replacement of Plastic Aggregate | Laboratory Average (MPa) | Theoretical Average (MPa) | Incremental Value |
|---|---|---|---|
| 0% | 3.2 | 2.71 | 0.49 |
| 2.5% | 3.3 | 2.83 | 0.47 |
| 5% | 4 | 3.76 | 0.24 |
| 7.5% | 4.2 | 3.64 | 0.56 |

## Representation of Laboratory and Theoretical Average (28 Days)

For fig 4.18 the highest value was recorded for 7.5% replacement of coarse aggregate by plastic aggregate for laboratory testing of split tensile strength value for 28 days. The minimum value was observed for normal concrete in laboratory testing.

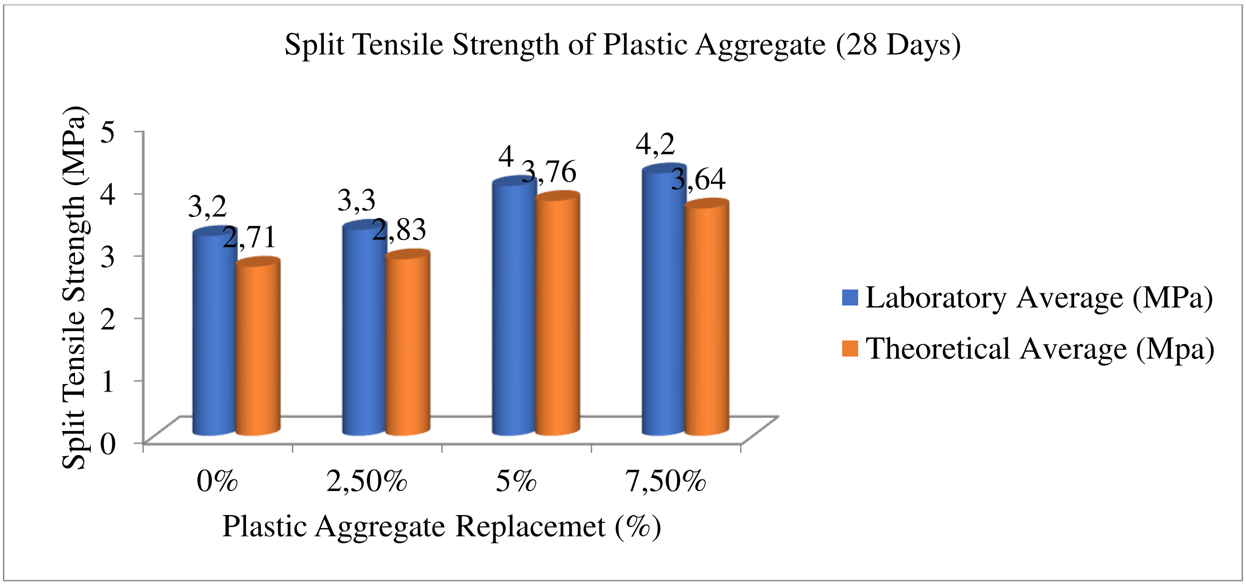


**Fig 4.18** Graph of Tensile Strength 28 Days vs. % Replacement of Plastic Aggregate

# CHAPTER 5

# CONCLUSION

## 5.1 General

To determine the suitability of available materials, various material tests are conducted. Sand, aggregate, and cement were all put through their paces. All ingredients in a mix must have the same qualities and values. Water absorption, initial and ultimate setting time, sand cement, and aggregate's specific gravity were found, and regular consistency test, Compressive strength was also assessed. The sample proportions were also computed as well based on suitability. PPC was put to the test using a variety of ways, and the results were analyzed.

## 5.2 Conclusion

- The partial replacement of EAFS with cement and coarse aggregate with plastic waste was done with a different ratio of 10%, 20%, 30%, and 40% by weight of cement and 2.5%, 5%, and 7.5% by weight of coarse aggregate respectively.
- For laboratory testing and research paper, the compressive strength value increased up to 30% replacement of cement by EAFS for 7 days. There is an increment of 19.1% of compressive strength value for 7 days up to 30% replacement of cement by EAFS compared to unmodified concrete in laboratory testing. This may be due to adding admixtures to concrete to boost its compressive strength. The maximum compressive strength was found for 30% replacement of cement by EAFS for 28 days in the laboratory. In the research paper, when the percentage of slag replaced is increased, the compressive strength for 28 days decreases. For unmodified concrete, the optimal value was obtained.
- The flexural strength of concrete (M40) was found optimum for 20% replacement of cement in the lab for 7, 14, and 28 days in the laboratory but in a research paper, the best replacement was found for 40%.
- In laboratory testing for 7 days, the optimal value of tensile strength was discovered for 10% and 40% slag replacement, but in the research report, the ideal value was only identified for 40% slag replacement. The form, size, and surface roughness of steel slag aggregate may have contributed to the increase in strength.

- The compressive strength of plastic replaced aggregate was found optimum for 2.5% replacement in the laboratory whereas in the research paper the maximum strength was for 5% replacement of coarse aggregate.
- The optimal value for flexure strength for 7days was found for 2.5% replacement of coarse aggregate by plastic waste in laboratory testing and in the research paper. There is an increment of 17.14% of flexure strength value for 7 days up to 5% replacement compared to unmodified concrete. It shows a linear variation in flexure strength value and percentage replacement of coarse aggregate by plastic waste up to 5% replacement of plastic waste. The highest value for flexure strength value for 14 days was recorded for unmodified concrete. The decrease in flexure strength value for an increase in percentage replacement of plastic waste may be due to weak bonding between cement and both natural aggregate and plastic aggregate. The optimal value for flexure strength for 28 days was found for 5% and 7.5% replacement of coarse aggregate by plastic waste in laboratory testing.
- The split tensile strength was found at an efficient 5% replacement for 7, 14, and 28 days.
- The use of waste plastic materials as aggregates in concrete is a viable option for addressing the challenges associated with the safe disposal of an increasing volume of waste plastic materials.
- It saves a lot of energy and reduces the use of natural resources to make new products by using discarded materials. The reason for the variation in optimal values for different mixes is due to the cement-aggregate bonding. Both coarse and plastic particles attach to cement, although the bond strength varies. The bond strength of concrete is also affected by the water-cement ratio, aggregate size, and cement grade. As these parameters change, differences in the findings occur. A strong bond of the given nature is indicated by an increase in strength, while a weak tie is shown by a reduction in strength

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