EFFECT OF PLASTIC AGGREGATE AND SILICA FUME ON PROPERTIES OF FRESH AND HARDENED CONCRETE.

Session: BECE. Fall 2019

Project Supervisor: Engr. Shahrukh Pasha

Submitted By

Noor Muhammad Ali

Inzimam Jabbar

Sadan Ahmed

Department of Civil Engineering

Abasyn University Islamabad Campus

Certification

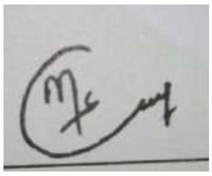
This is to certify that Noor Muhammad Ali [3601], Inzimam Jabbar [3443] and Sadan Ahmed [3340] have successfully completed the final project "EFFECT OF PLASTIC AGGREGATE AND SILICA FUME ON PROPERTIES OF FRESH AND HARDENED CONCRETE.", at the Abasyn University Islamabad Campus, to fulfill the partial requirement of the degree B.E Civil Engineering.

External Examiner

Engr Tofeeq Ahmed.

Director & COO,

Aryan LLC



Project Supervisor

Engr.Shahrukh Pasha

Lecturer, Department Of Civil Engineering, AUIC

Chairman

Department of Civil Engineering, Abasyn University Islamabad Campus.

EFFECT OF PLASTIC AGGREGATE AND SILICA FUME ON PROPERTIES OF FRESH AND HARDENED CONCRETE.

Sustainable Development Goals

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9 ☑	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11☑	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12☑	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13☑	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14☑	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15☑	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	☑
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	☑
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	☑
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	☑
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	☑
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	☑
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

Urbanization has significantly increase the demand for concrete. Concrete consist of coarse and fine aggregates bound together by cement and water. These materials are not renewable and must be obtained from nature. The electronic waste is also increasing day by day which cause pollution. The production of cement directly contributes in the emission of greenhouse gases by producing CO2. We conducted this research to help save natural resources, minimise emissions of greenhouse gases, and recycle electronic waste without affecting the qualities of concrete. In this research work NCA was substituted by PCA which was made of E-waste. The PCA was treated with sand to make strong bonding between PCA and other components of concrete. Additionally, SF substitutes cement. The substitution of PCA and SF was 10%, 15%, 20% and 5%, 10%, 15% respectively. The findings indicate that the workability of concrete significantly enhanced as PCA replaced NCA. At maximum replacement the CS and STS were reduced by 25.8% and 27.27% respectively as compare to natural concrete. While the STS was increased by 8.4% as compare to natural concrete at 10% replacement of cement and 15% replacement of NCA. After this research work it was concluded that we can use PCA and SF as substitute of NCA and cement to make environment friendly concrete with equivalent properties as natural concrete.

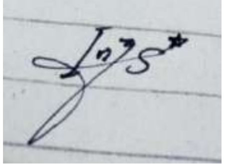
Keywords: E-Waste, Sand coated plastic coarse aggregate, Silica fume, natural coarse aggregate, cement

Undertaking

I certify that the project EFFECT OF PLASTIC AGGREGATE AND SILICA FUME ON PROPERTIES OF FRESH AND HARDENED CONCRETE is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

Noor Muhammad Ali

3610



Inzimam Jabbar

3443

Sadan Ahmed

3340

Acknowledgement

We truly acknowledge the cooperation and help make by Engr. Shahrukh Pasha**,** Lecturer, of Department Of Civil Engineering, AUIC**.** He has been a constant source of guidance throughout the course of this project. We would also like to thank Engr. Khawar Ali SDO, of PWD-AJ&K for his help and guidance throughout this project.

We are also thankful to our friends and families whose silent support led us to complete our project.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ABS	Acrylonitrile Butadiene Styrene
ASTM	American Society of Testing Materials
BS EN	British Standard European Norm
C	Control/Natural Concrete
CS	Compressive Strength
FA	Fly Ash
FS	Flexural strength
HDPE	High-Density Polyethylene
ITZ	Interfacial Transition Zone
NCA	Natural Coarse Aggregate
OPC	Ordinary Portland Cement
PCA	Plastic Coarse Aggregate
PET	Polyethylene Terephthalate
SCC	Self-Compacting Concrete
SEM	Scanning Electron Microscopy
SF	Silica Fume
STS	Split Tensile Strength
S5P10	Replacing Cement by 5% SF and NCA by 10% PCA

Chapter 1

1.1 Introduction

Concrete, a widely utilized construction material, it is formed through the bonding of cement and water, with the majority of its composition consisting of fine and coarse aggregates (D, 2018). The need for concrete is rising as the building industry expands. The materials used in the manufacture of concrete are not renewable and must be obtained from nature. Scarcity can result from over usage of certain materials. To avoid this problem, it is vital to locate more building materials (Guleria & Salhotra, 2016).

Electronic gadgets have become an integral part of our daily lives. As the use of electronic gadgets rose, so did the generation of E-waste. E-waste decomposition is more challenging than that of conventional waste materials. In 2013, 299 million tonnes of plastic goods were manufactured (Ahmad et al., 2021).

Silica fume is an industrial residue of silicon metal and ferro-silicon alloy. Its use as a sustainable alternative to cement in concrete has recently grown (Khodabakhshian et al., 2018). For the most part, fly ash and silica fume are used for high strength concrete. Concrete's fresh and hardened qualities are improved when silica fume replaces cement at the right percentage (Roy & Sil, 2012).

1.2 Statement of the Problem

The creation of E-waste is increasing as the usage of electronic devices increases. This waste is disposed of at a landfill, causing harm to the environment. As a result, we must discover a means to repurpose this waste.

Cement production contributes to greenhouse gases in two ways, by producing carbon dioxide during the thermal decomposition of calcium carbonate, and by consuming energy, mainly from burning fossil fuels. To stop global warming, we must find a sustainable strategy to reduce the usage of cement.

1.3 Goals/Aims & Objectives

The primary goals of this research are as follows:

1. To evaluate the mechanical and durability properties of concrete comprising of sand treated plastic aggregate and silica fume.

2. To investigate the micro-structure and thermal performance of concrete mix incorporated with sand treated plastic aggregate and silica fume.

3. To draw a conclusion on the optimum replacement of coarse aggregate and cement used in concrete based on the test results.

1.4 Methodology

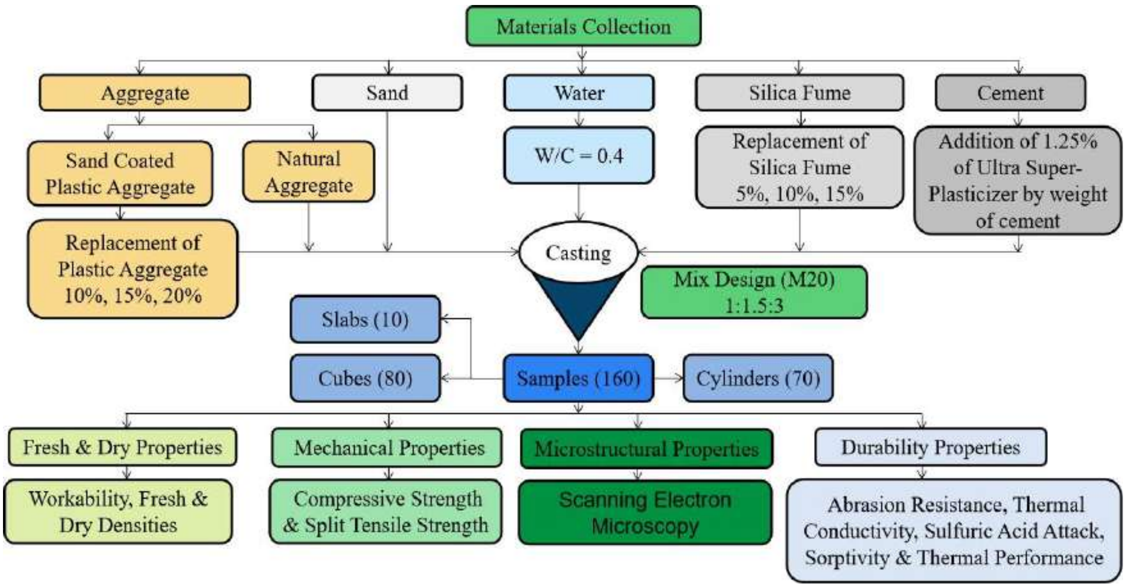


Fig.1 Methodology

1.5 Report Overview

Thesis is entitled " Effect of plastic aggregate and silica fume on fresh and hardened properties of concrete." This research thesis is involve these six chapters.

1. Introduction: Provides an overview of the research topic, outlining the background and rationale for the study. It clearly states the objectives and

scope of the research while highlighting the significance of investigating the influence of PCA and SF on concrete.

2. Literature review: Includes existing research and studies related to the use of PCA and SF in concrete. This chapter will help establish a foundation for the current study and identify any knowledge gaps or areas where further investigation is needed.
3. Methodology: The proposed set up for this study has been explained in detail in this section. Also, various tests carried out and their detailed description throughout the experimental tests is also provided.
4. Results and discussions: Presents the empirical findings obtained from the experiments conducted. It includes data, charts, graphs, and tables to support the analysis. The results are then critically analyzed, discussing how PCA and SF affect the fresh and hardened properties of concrete. This section helps readers understand the practical implications of the research.
5. Summary and Future work: This section gives an overview of the main points of your thesis/project and explains where you think the results can lead you. What do you think are the next steps to take?
6. Conclusions, and recommendations: The section offers practical recommendations for incorporating these materials in concrete mixes and suggests potential areas for future research.

Chapter 2

2.1 Literature Review

This chapter includes existing research and studies related to the use of PCA and SF in concrete. This chapter will help establish a foundation for the current study and identify any knowledge gaps or areas where further investigation is needed.

2.1.1 Mechanical Properties

In this research, the utilization of plastic as partial substitute for natural coarse aggregate (NCA) in concrete was examined. Various proportions of coarse aggregates were replaced with plastic (0%, 2.5%, 5%, 7.5%, and 10%) while maintaining an M25 mix design. The study encompassed an evaluation of concrete's compressive strength (CS), split tensile strength (STS), flexural strength (FS), and workability, comparing these properties to concrete devoid of plastic aggregate. The outcomes demonstrated that replacing NCA with plastic led to an improvement in workability and STS, with an increase of up to 5%. However, as the substitution of coarse material with plastic exceeded 5%, both workability and STS began to decline. The inclusion of 2.5% plastic as a substitute for NCA resulted in a slight enhancement of CS and FS, while further increases in plastic content led to reductions in these strength parameters (Khajuria & Sharma, 2019).

By the addition of plastic aggregate the CS, STS and FS decreased. The maximum decrease in CS, STS and FS was at 50% replacement. The research findings recommend replacing up to 30% of NCA with PCA to maintain concrete strength of M25. For non-structural lightweight elements, a replacement level of 40-50% is suitable (Ahmad et al., 2021).

The study investigated the impact of incorporating recycled plastic waste in concrete, finding that it generally reduced CS due to inadequate cement and plastic adhesion. However, they noticed that using silica fume (SF) as substitution of cement could enhance concrete strength when combined with various recycled aggregates, offering a potential solution to boost the mechanical properties of plastic concrete (Saxena et al., 2018).

2.1.2 Durability Properties

This study aimed to assess how the curing conditions affect the durability of concrete mixes that incorporate PCA. The concrete was prepared by incorporating 0%, 7.5%, and 15% of NCA with plastic, specifically polyethylene terephthalate (PET) aggregate. Additionally, the study examined the influence of using fine and coarse plastic aggregates separately and the impact of their shape on concrete properties. Various tests, including shrinkage, water absorption through immersion, water absorption via capillary action, carbonation, and chloride penetration, were conducted to evaluate the concrete's performance. The test results revealed that concrete containing plastic aggregates exhibited reduced durability compared to conventional concrete. Furthermore, all specimens performed worse when subjected to drier curing conditions. However, sensitivity analyses indicated that, overall, concrete mixes incorporating PCA tended to experience less deterioration in their properties when exposed to progressively drier curing conditions compared to traditional concrete (Silva et al., 2013).

The sorptivity of concrete incorporating SF and FA has been researched. For this investigation, SF and FA were utilized as a substitute for cement in self-compacting concrete (SCC). At first, they only used class F FA to substitute 0%, 12.9%, 20%, 30%, 40%, and 50% cement. To evaluate the collective impact of SF and FA, the amount of FA was held constant at 25% while the quantities of SF were 0%, 5%, 10%, and 15%. Normally, F FA is categorised as a 15-25% replacement of cement. As a result, FA and SF replaced 25%, 30%, 35%, and 40% of the total cement, respectively. The experiments' findings showed that using SF and FA in place of cement lowers the sorptivity and absorption of surface water. When cement was substituted with just 20% FA, there was a noticeable decrease in sorptivity. Additionally, it was shown that SF had a stronger impact on water absorption than FA (Leung et al., 2016).

The E-waste concrete specimens' weights are measured both before and after they are immersed in water. The weight difference between the samples showed that when the amount of E-waste increased from 0% to 20%, there was a considerable decrease in water absorption, which led to a decrease in the sorptivity coefficient. This was shown by the specimens' different weights. The sorptivity values are lower than they would be if e-waste plastic were capable of absorbing water. E-waste replaced 10%, 15%, and 20% of the NCA, respectively, resulting in 12.2%, 14.5%, and 29.0% reduced sorptivity coefficient values (Manjunath, 2016).

2.1.3 Fresh and Dry Properties

This study focused on evaluating the properties of concrete incorporating sand-coated recycled High-Density Polyethylene (HDPE) and E-wastes as replacements for NCA. The plastic materials were processed by crushing, melting, and grinding to create aggregates with a size of 20 mm. The replacement levels for NCA with HDPE and E-wastes varied from 0% to 30%, with the addition of SP-675 superplasticizer and wet lock sealant. During testing, it was observed that the workability of concrete containing sand-coated PCA was slightly lower compared to concrete with uncoated PCA. The use of SP-675 superplasticizer had a significant impact on improving the workability of all concrete mixes, regardless of the presence of plastic aggregates. It was recommended to use 2% of the weight of cement as Superplasticizer SP-675 to maintain adequate workability without compromising the strength properties of concrete. Furthermore, the addition of wet lock sealant enhanced the strength properties of all concrete mixes without negatively affecting workability. The recommended dosage of wet lock sealant in the concrete mix was 2 kg per bag of cement, ensuring improved strength properties while preserving workability (Abbas et al., 2022).

The effectiveness of concrete modified with E-waste as a partial substitute of NCA was assessed. The findings demonstrate that at 10%, 20%, 30%, 40%, and 50% substitution of NCA by PCA, the workability of concrete incorporating PCA increased by 16.4%, 46.3%, 83.2%, 113%, and 140.9%, respectively, in comparison to natural concrete. The unit weight of the materials used in concrete affects the density of the concrete. Because PCA has a lower unit weight than NCA, the fresh and dried density of plastic concrete fell in comparison to the natural concrete. After the testing, it was determined that plastic aggregate's complete lack of water absorption was responsible for the increase in workability (Ahmad et al., 2021).

Chapter 3

3.1 Methodology

The proposed methodology adopted in this research endeavor is briefly explained in this chapter. An organized stepwise methodology is followed to obtain the goals set of this research work which was comprised of collection of material, initial testing on material and laboratory testing samples to determine the properties of concrete.

For this research we performed various test determine the mechanical properties, durability properties and fresh and dry properties. For this study we used different ratios of plastic coarse aggregate (PCA) and silica fume (SF) as a replacement of natural coarse aggregate (NCA) and cement. Different mix types were prepared of compare the results.

3.1.1 Tests Performed

Table 1: Mechanical Properties

Tests	**Standards**
Compressive Strength	ASTM C39
Split Tensile Strength	ASTM C496

Table 2: Durability Properties

Tests	**Standards**
Abrasion Resistance	ASTM C131
Thermal Conductivity	ASTM E1530
Sulfuric Acid Attack	ASTM C1898
Sorptivity	ASTM C1585
Scanning Electron microscopy (SEM)	ASTM E986
Thermal Performance	ASTM 1363

Table 3: Fresh and Dry Properties

Tests	**Standards**
Workability	ASTM C143
Fresh Density	ASTM C138
Dry Density	BS EN 12390-7

Table 4: Mix Types

Mix Type	**Coarse Aggregate**	**Cement**	**Plasric Aggregate**	**Silica Fum e**
C	100%	100%	0%	0%
S5P10	90%	95%	10%	5%
S10P10	90%	90%	10%	10%
S15P10	90%	85%	10%	15%
S5P15	85%	95%	15%	5%
S10P15	85%	90%	15%	10%
S15P15	85%	85%	15%	15%
S5P20	80%	95%	20%	5%
S10P20	80%	90%	20%	10%
S15P20	80%	85%	20%	15%

3.1.2 Material Collection

This section involves gathering of all the necessary materials and resources required to conduct this research. In this study on the materials played a pivotal role, with the sand meticulously sourced from Lawrencepur and the natural coarse aggregate diligently selected from the renowned Margalla region. By deliberately choosing Lawrencepur as the origin of the sand and Margalla as the source of the NCA, the study ensured not only the accurate representation of the materials' regional properties but also facilitated a deeper understanding of how these specific materials uniquely interacted with the plastic aggregate and silica fume, ultimately influencing the concrete's fresh and hardened properties in an unparalleled manner. The material size of NCA and PCA used for this study was according to ASTM C33 standard. The E-waste (Acrylonitrile butadiene styrene, ABS) utilized for this research was meticulously sourced from various reliable channels, including recycling centers, electronics disposal facilities, and collection drives. These sources ensured a diverse and representative collection of discarded electronic devices, encompassing items such as computers, mobile phones, laptops, printers, and other electronic appliances, forming a comprehensive foundation for the e-waste aggregate production process. The process of manufacturing of plastic aggregate is shown in Fig. 2.

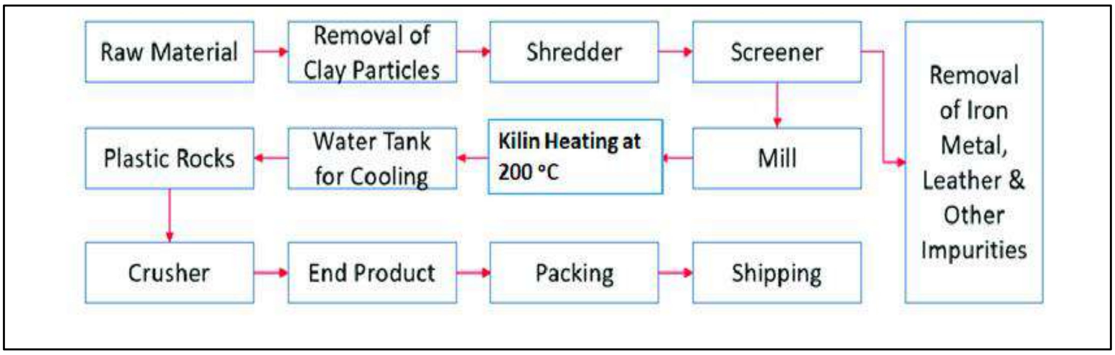


Fig.2 Process of manufacturing of plastic aggregate.

For this project we used sand coated plastic aggregate. For sand coating the sand was heated in a pan for 10-15 minutes, then the plastic aggregate is added in it and mixed well until the whole surface of plastic aggregate is covered with sand. The binding material employed in this study was Ordinary Portland Cement (OPC) from the Fauji brand. Regular tap water was utilized for all mix types. Ultra super plast 437 was used as a super-plasticizer to enhance the workability of concrete. Silica fume used in this study was sourced from local batching plants. Silica fume, Ultra super plast 437, sand, NCA, PCA and sand coated PCA is shown in Fig. 3.

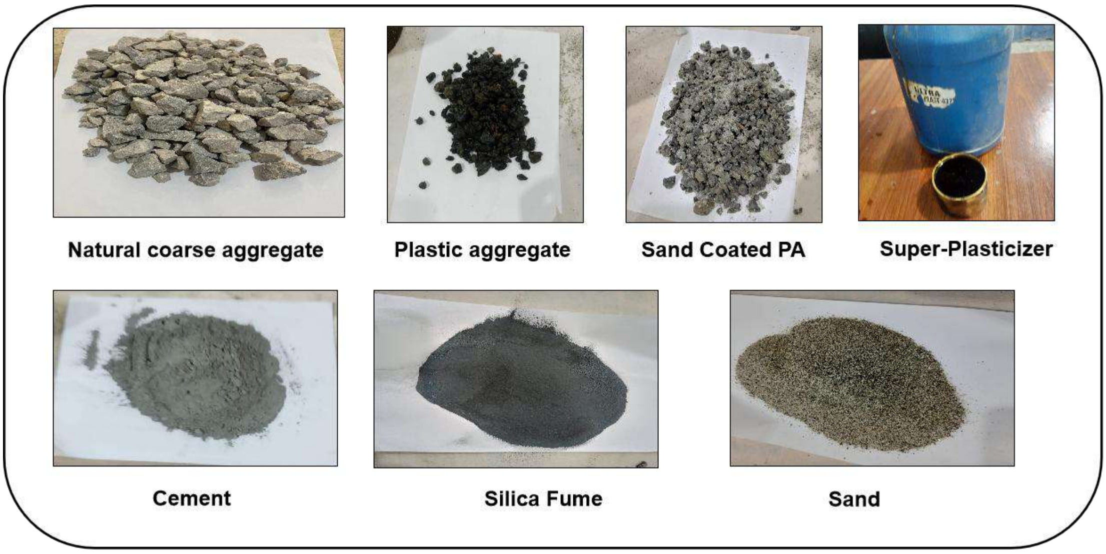


Fig.3 Materials

Chapter 4

4.1 Proposed Solution/Results & Discussion

This chapter presents the outcomes of all the tests conducted as part of our research. Initial testing results of natural coarse aggregate (NCA) and plastic coarse aggregate (PCA) are also discussed in this chapter. Mechanical, durability and fresh properties of concrete containing PCA and silica fume (SF) as partial substitutes for NCA and cement are compared with natural concrete in this chapter.

4.1.1 Compressive Strength

ASTM C39 was used to assess compressive strength (CS). Results show that the CS of concrete increase as the replacement of cement by SF increased but the CS decreased as the replacement of NCA with PCA increased. The CS of natural concrete was higher then all other mix types. Mix type S15P10 had the closest CS to the natural concrete. The CS of natural concrete was 31 Mpa and the CS of mix type S15P10 was 30Mpa. Higher plastic content introduces porosity and weak zones which reduce the concrete's compressive strength while Silica fume enhances compressive strength by fostering a pozzolanic reaction, forming additional cementitious compounds and improving the concrete's microstructure.

4.1.2 Split Tensile Strength

ASTM C496 standard was followed for this test. Results show that mix type S10P15 have higher STS then natural concrete. Mix types S5P15 and S15P15 had STS same as natural concrete. All other concrete mix types had STS less then natural concrete.

4.1.3 Abrasion Resistance

The abrasion resistance test was conducted according to ASTM C131. It was noticed that concrete mixes with higher compressive strength also exhibited greater abrasion resistance. Specifically, mix type S15P10 demonstrated the lowest loss in abrasion value, measuring only 3.5%, in comparison to the natural concrete.

4.1.4 Thermal Conductivity

This test was conducted in accordance with ASTM Standard E1530. The inclusion of PCA in concrete reduces its thermal conductivity and increases thermal resistivity compared to natural concrete. The most significant reduction of 2.02% in thermal conductivity was observed in mix type S5P20. Higher plastic content tends to increase thermal conductivity and decrease resistivity in concrete due to the insulating nature of plastics, reducing the material's ability to resist heat flow.

4.1.5 Sulfuric Acid Attack

Sulfur acid attack test was used to measure the weight loss and loss in compressive strength of concrete when subjected to sulfuric acid. This test was performed in accordance to ASTM C1898 standard. Incorporating of PCA into concrete has weaken its CS during acid attack due to increased porosity, reduced bonding, and micro-structural changes caused by plastic particles. While incorporation of SF in concrete helps reduce CS loss due to acid attack by creating a denser micro-structure, forming a stronger gel, improving bonding, and limiting pore connectivity. Plastics in concrete has potentially act as a barrier against acid penetration, reducing the weight loss caused by acid attack. Similarly, the incorporation of SF into concrete reduced weight loss due to acid attack.

4.1.6 Sorptivity

This test was conducted following the ASTM C1585 standard. The sorptivity coefficient of concrete mix types having higher percentage of PCA as replacement of NCA increased because PCA is more porous and absorbs water more readily than NCA. The introduction of SF reduced the sorptivity coefficient of the concrete. When SF was incorporated in concrete it fills the voids between cement particles and aggregates, resulting in a denser and less porous matrix. The sroptivity coefficient of S15P10 was lower then the natural concrete. All other mix types have sorptivity coefficient higher then natural concrete.

4.1.7 Scanning Electron Microscopy (SEM)

SEM analysis was conducted following ASTM E986 procedures. SEM image of the control mix concrete show a strong bond between the NCA and the cement matrix. The Interfacial Transition Zone (ITZ) of natural concrete is small and the bonding is strong because in the natural concrete, the aggregates and cement paste have compatible properties and a good chemical affinity. SEM images demonstrate that as the substitution of cement with SF increases, there is a clear enhancement in the bonding between the PCA and cement paste. Replacing cement with SF improves bonding through chemical reactivity, reduced porosity, enhanced micro-structure, and increased strength, leading to stronger adhesion between aggregates and cement paste. Substituting NCA with PCA weakens bonding due to material property differences and smoother surface characteristics of PCA. This makes it harder for the cement paste to stick well compared to the rougher and more porous surface of NCA.

4.1.8 Thermal Performance

ASTM 1363 was used to perform this test. Ten concrete slabs were cast and cured for 28 days. Sunlight was used as the heat source for this test. At the maximum substitution of NCA and cement with PCA and SF, the temperature decreased by 2.1°C.

4.1.9 Workability

This test was performed according to ASTM C143 standard. Firstly we performed this test on all concrete mix types without adding plasticizer. The slump value increased with the increase in substitution of PCA because of zero water absorption from PCA, and it decreased as the substitution of cement by SF increased. The slump values for all mix types were greater than those of the natural concrete. To enhance the workability, super-plasticizer was used at a rate of 1.25% by weight of cement. The slump value of natural concrete before addition of plasticizer was 25mm and after addition of plasticizer the slump value increased to 125mm.

4.1.9 Fresh and Dry Densities

ASTM C138 was used to measure the fresh density of concrete. For this test 10 cubes of 150x150x150 mm of different mix types were cast. The fresh density of concrete with PCA as substitute of NCA was lower than natural concrete. This is due to the lightweight nature of PCA.

BS EN 12390-7 was used to measure the fresh density of concrete. All samples were rested for 24 hours after casting so they can get hard and dry. The dry density of concrete with PCA as a substitute for NCA was lower than natural concrete. This difference is attributed to the lightweight properties of PCA. The dry density of all concrete mix types were lower then their fresh density. This is because of the removal of water particles from the concrete after getting hard.

Chapter 5

5.1 Summary and Future Work

5.1.1 Summary

In this study we used E-waste and silica fume in concrete to investigate its mechanical and durability properties. To increase the bonding between PCA and other components of concrete we treated the surface of PCA with sand. The natural coarse aggregate and cement were substituted with PCA and SF at varying ratios, including 10%, 15%, 20% for NCA, and 5%, 10%, 15% for cement, respectively. Various tests were performed to access the mechanical, durability and fresh properties of concrete. After the results it was concluded that the S15P10 mixture closely matched the properties of the natural concrete.

5.1.2 Future Work

The future work should be done on accessing the fire performance of this concrete. Conduct long-term durability studies to assess how the concrete performs over extended periods, especially in harsh environmental conditions. This could involve exposure to factors like freeze-thaw cycles, aggressive chemicals, and environmental weathering. Evaluate the environmental impact of using plastic aggregate and silica fume in concrete. Consider conducting a life cycle assessment (LCA) to understand the overall environmental benefits and drawbacks of the proposed materials. Also evaluate the economical impact of using plastic aggregate and silica fume in concrete. Future work can be done on the seismic performance of this concrete.

Chapter 6

6.1 Conclusion & Recommendation

6.1.1 Conclusions

The following conclusions has been made after this study:

- Concrete's compressive strength improved when more SF was used in place of cement, but it dropped as more PCA was used in place of NCA. The compressive strength of natural concrete was greater then all other mix types. Mix type S15P10 had the closest compressive strength to the natural concrete. At maximum replacement the reduction was 25.8%.
- At maximum replacement of cement and NCA by SF and PCA the split tensile strength was reduced by 27.27% as compare to natural concrete. While the split tensile strength was increased by 9.09 % as compare to natural concrete at S10P15.
- It was noticed that concrete mixes with higher compressive strength also exhibited greater abrasion resistance. Mix type S15P10 demonstrated the lowest loss in abrasion value at 3.5%, compared to natural concrete.
- The inclusion of PCA in concrete reduces its thermal conductivity and increases thermal resistivity compared to natural concrete. The most significant reduction of 2.02% in thermal conductivity was observed in mix type S5P20.
- Replacement of SF and PCA lowered the weight loss of concrete by acid attack. At maximum replacement the reduction in weight loss was 79% as compare to natural concrete.
- The lowest decrease in compressive strength after sulfuric acid attack was 22.2% for mix type S15P10 at 56 days.
- The slump value increased as the replacement of PCA increased, whereas it decreased with the higher substitution of cement by SF. The slump value of all mix types were grater then the slump value of control mix. The slump value of natural concrete before addition of plasticizer was 25mm and after addition of plasticizer the slump value increased to 125mm.

- Fresh and Dry densities of concrete having PCA was lowered because of the lightweight nature of PCA. At maximum replacement the reduction in fresh and dry density was 7.88% and 7.69% as compare to natural concrete.
- SEM images illustrate that as the substitution of cement with SF rises, there is a clear enhancement in the bonding between the PCA and cement paste.
- The sorptivity coefficient of S15P10 was 0.94% lower natural concrete. In contrast, all other mix types exhibited sorptivity coefficients higher than natural concrete.
- The findings revealed that the S15P10 mixture closely matched the properties of the natural concrete.

6.1.2 Recommendations

Here are some recommendations for future research:

- Use plasticizer to enhance the workability of concrete instead of increasing the water-to-cement ratio because plasticizers improve workability without weakening the concrete's strength and durability.
- It's beneficial to elevate the cement replacement ratio with silica fume as we've noticed that higher silica fume ratios correlate with increased concrete compressive strength.
- Conduct fire resistance tests on concrete specimens containing plastic aggregates and silica fume to evaluate their performance under high-temperature conditions.
- Perform comprehensive tests on concrete columns and beams that incorporate plastic aggregates and silica fume.

References

Abbas, S. N., Qureshi, M. I., Abid, M. M., Tariq, M. A. U. R., & Ng, A. W. M. (2022). An Investigation of Mechanical Properties of Concrete by Applying Sand Coating on Recycled High-Density Polyethylene (HDPE) and Electronic-Wastes (E-Wastes) Used as a Partial Replacement of Natural Coarse Aggregates. *Sustainability*, *14*(7), 4087.

Ahmad, F., Jamal, A., Mazher, K. M., Umer, W., & Iqbal, M. (2021). Performance evaluation of plastic concrete modified with e-waste plastic as a partial replacement of coarse aggregate. *Materials*, *15*(1), 175.

D, D. (2018). CRUSHED PLASTIC WASTE IN CONCRETE. *05*(03).

Guleria, A. N., & Salhotra, S. (2016). Effects of silica fume (micro silica or nano silica) on mechanical properties of concrete: A review. *Int. J. Civ. Eng. Technol*, *7*(4), 345-357.

Khajuria, A., & Sharma, P. (2019). Use of plastic aggregates in concrete. *International Journal of Innovative Technology and Exploring Engineering*, *9*(1), 4406-4412.

Khodabakhshian, A., De Brito, J., Ghalehnovi, M., & Shamsabadi, E. A. (2018). Mechanical, environmental and economic performance of structural concrete containing silica fume and marble industry waste powder. *Construction and Building Materials*, *169*, 237-251.

Leung, H. Y., Kim, J., Nadeem, A., Jaganathan, J., & Anwar, M. (2016). Sorptivity of self-compacting concrete containing fly ash and silica fume. *Construction and Building Materials*, *113*, 369-375.

Manjunath, B. A. (2016). Partial replacement of E-plastic waste as coarse-aggregate in concrete. *Procedia Environmental Sciences*, *35*, 731-739.

Roy, D. K. S., & Sil, A. (2012). Effect of partial replacement of cement by silica fume on hardened concrete. *International Journal of Emerging Technology and Advanced Engineering*, *2*(8), 472-475.

Saxena, R., Siddique, S., Gupta, T., Sharma, R. K., & Chaudhary, S. (2018). Impact resistance and energy absorption capacity of concrete containing plastic waste. *Construction and Building Materials*, *176*, 415-421.

Silva, R. V., de Brito, J., & Saikia, N. (2013). Influence of curing conditions on the durability-related performance of concrete made with selected plastic waste aggregates. *Cement and concrete composites*, *35*(1), 23-31.

Standards

- ASTM C39/C39M - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
- ASTM C496 - Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.
- ASTM C131/C131M-20 - Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
- ASTM C1898-20 - Standard Test Methods for Determining the Chemical Resistance of Concrete Products to Acid Attack.
- ASTM C1585-13 - Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes.
- ASTM E986 - Standard Practice for Scanning Electron Microscope Beam Size Characterization.
- ASTM-1363 - Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus.
- ASTM C143/C143M - Standard Test Method for Slump of Hydraulic-Cement Concrete.
- BS EN 12390-7:2009 - Testing hardened concrete - Part 7: Density of hardened concrete.