Experimental Study on Properties of Self Compacting Concrete Blended with Palm Oil Fuel Ash

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ABSTRACT

Low flow-resistance concrete known as self-compacting concrete (SCC) can be poured and compacted by its own weight without the aid of external vibration, bleeding, or segregation. It is less tolerant to abrupt changes in aggregate moisture content, chemical admixtures, and water content. POFA (Palm oil fuel ash), as an OPC replacement, provides an opportunity to reduce carbon footprints, enhance cost-saving, and mitigate and reduce waste materials in landfills. POFA in cementations materials, as an additive or partial substitute, to cut down on cement consumption globally. POFA can be utilized for the production of lightweight, durable, and cheap concrete because of its availability in significant quantities. SCC is a highly flowable and self-leveling concrete that can be easily placed and compacted without the need for vibration, due to the addition of POFA can improve the workability and flowability of SCC and make it easier to handle and place. Combining POFA and SCC has the potential to strengthen the connection between concrete paste and aggregates by adding strength as a result of pozzolanic reactions, which will increase the concrete's resilience. Since POFA is a waste material, it is often available at a lower cost than other materials used in concrete production, using POFA in SCC can help reduce the cost of construction projects while still maintaining the quality of the final product. As a result, this study explores the influence of POFA as an addictive substance in a range from 0% to 40%. Testing of fresh properties is done using the Slump, L-Box, and V-funnel methods. To determine the strength, compression tests were also performed.

Keywords: POFA, Waste management, Carbon footprint

1 Introduction

Self-compacting factual (SCC) is new hardened that compacts on allure own outside out side vibration. It flows under allure own pressure. When utilizing vibrators to combine actual is questionable, it is second hand in explanation. Self-compacting concrete has the volume for contents and passing in addition to opposition to separation. Fresh SCC offers better flow kinds that stop blame and grant pardon material combination and self-compaction without issues accompanying separation.

POFA, that has fine piece size and pozzolanic traits, is repeatedly linked accompanying SCC. Concrete permeability can be abated and endurance raised by using POFA in SCC. Due to the extreme silica aggregation of POFA, the SCC's substance is improved. The size of waste produce for one result of palm lubricate can be dropped off with the custom of POFA in SCC. POFA is a more environmentally companionable alternative to cement cause its diminished element content decides place in the range of 0% to 40% POFA has an addictive effect. Slump, L-Box and V-Funnel forms are used to test new face. Compression tests were too performed to judge substance. The adding of touch oil ruins as pozzolan until 20% upgraded the mechanical and staying power characteristics of actual. In addition, extensive soil situation accompanying touch lubricate fuel ash upgraded allure mechanics properties [1].

The POFA content raised and the machinelike features and microstructure of foam concrete revised considerably. Capillary assimilation and vapor permeability gradually upgraded when POFA was second

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hand, and optimum water absorption and warm generated power were worked out accompanying 30% POFA [2]. Use of PFA (palm lubricate fuel ruins) in actual and its effect on practicability, compressive substance (CS), stiffness (STS) and durability of factual. To judge the practicability of utilizing palm lubricate fuel ruins (POFA) and flee ash (FA) a suggestion of choice for common Portland cement (OPC) in self-compacting hardened (SCC). Temperatures and compressive strength of SCC microstructure made of POFA with 15 wt% cement replacement fractions. The experimental study will involve the production of SCC using different percentages of POFA as an SCM.

2 Characteristics of Palm Oil Fuel Ash

In Figure.1 POFA is depicted. As a pozzolanic material, POFA reacts chemically with calcium hydroxide to generate cementitious compounds when moisture is present. As it has a particle size smaller than cement, it might fill the voids left by the bigger aggregate particles in concrete. Due of its POFA properties, it can potentially replace some cement in the production of concrete. POFA has pozzolanic properties because of its high silica content, which also improves the strength and longevity of concrete. It is useful for some concrete kinds where a lighter colour is required that it has a light colour.

Figure 1: *Palm oil fuel ash*

3 Test on Materials

3.1 Materials used

3.1.1 Cement

In Figure 2, the experiment, grade 53 balanced Portland cement in accordance with ACI 211191 was working. OPC 53 cement is a type of Ordinary Portland Cement namely usual in the building manufacturing on account of allure superior compressive substance and grit possessions. The "53" in OPC 53 cement refers to allure minimum compressive substance in megapascals (MPa) following in position or time 28 days of helping cure. This way that OPC 53 cement has a minimum compressive substance of 53 MPa, making it an extreme-substance cement. OPC 53 cement is fashioned by abrasive noise, thick, and added supplements in a cement mill. It has an extreme portion of tri-calcium silicate (C3S) and di-calcium silicate (C2S) compounds, that enhance allure superior substance and early scene features.

Figure 2: *Cement*

OPC 53 cement also has a low water-cement ratio, which improves its durability and resistance to environmental factors such as moisture and temperature changes.

Table 1: *Physical Properties of Cement*

Properties	Range	IS Specification	Test Result
Fineness	10%	IS1226-1987	10%
Specific gravity	3.15-3.19	IS2720(PARTIII)-1986	3.14
Consistency	26-33%	IS4031-1988	30.5%
Initial setting time	≤30min	IS4031-1988	50min

In table 1, summarizes essential physical properties that are relevant for construction and engineering purposes. Each property provides insights into how cement performs and behaves in various applications.

3.1.2 Fine aggregate

In Figure 3, manufactured sand was used. M sand, also known as Manufactured Sand, is a type of fine aggregate that is made by crushing hard granite or bas alt rocks. M sand is a sustainable alternative to river sand, which is being depleted rapidly due to excessive mining and illegal extraction. M sand has similar properties to river sand, but it is free of impurities and has a consistent particle size distribution.

Figure 3: *M sand*

M sand is commonly used in the construction industry as a fine aggregate in concrete mix designs. It has several advantages over river sand, including better workability, increased compressive strength, and improved durability. M sand also has a lower water absorption rate, which reduces the risk of shrinkage and cracking in concrete structures.

In addition to its use in concrete, M sand is also used in plastering, laying bricks, and other construction applications that require a fine aggregate. M sand is eco-friendly and sustainable, as it reduces the dependence on river sand, which is a non-renewable resource. It is also cheaper than river sand and can be produced locally, reducing transportation costs and carbon emissions.

Table 2: *Physical Properties of FA*

Properties	Range	IS specification	Test result
Fineness modulus	2.6-3	IS 383-1970	3
Specific gravity	2.5-2.9	IS 2386(PART III)-1963	3.14
Water absorption	<3%	-	0.5%

In table 2, provides an overview of important physical properties of fine aggregate used in construction and concrete production. Understanding these properties helps engineers and builders select the right materials for specific applications and ensure the desired performance of concrete mixes

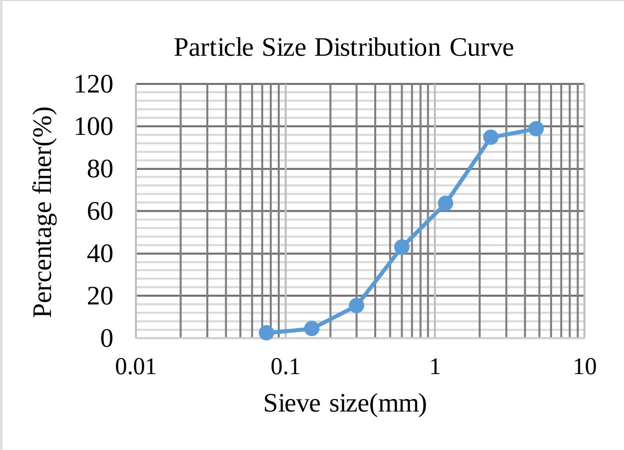

Figure 4: *Gradation curve of fine aggregate*

In Figure 4, a particle size distribution curve of fine aggregate visually represents the sizes of particles within the sample and their distribution. It is a critical tool for engineers and concrete producers to assess and control the properties of concrete mixes, ensuring they meet project requirements.

3.1.3 Coarse aggregate

In Figure 5, for the exploratory work, rude aggregate of compressed muted silver in color accompanying a size of 12 mm was second hand. Coarse aggregate accompanying a insignificant height of 10 to 12.5 mm is usually second hand in the building manufacturing for making concrete. It is a type of coarse material that is to say containing quelled pebble, pebbles or muted silver in color. The rude aggregate provides substance and strength to the actual by delivering the loads used to it identically. Coarse aggregate with a nominal size of 10 to 12.5 mm is suitable for making medium-strength concrete that is used in various construction applications such as buildings, bridges, pavements, and dams. This size of coarse aggregate is commonly used in concrete mix designs as it provides a good balance between workability and compressive strength.

Figure 5: *Coarse aggregate*

In addition to providing strength to concrete, coarse aggregate also plays a key role in reducing the risk of shrinkage and cracking in concrete structures. The presence of coarse aggregate helps to reduce the water demand of concrete mixes, which in turn helps to reduce the risk of shrinkage and cracking.

Overall, coarse aggregate with a nominal size of 10 to 12.5 mm is an essential component of concrete mix designs. It provides strength, stability and durability to concrete structures, and helps to ensure that they can withstand the loads and stresses applied to them.

Table 3: *Physical Properties of CA*

Properties	Test result of CA	Range
Specific gravity	2.7	2.5–3
Water absorption	0.5%	0.1%-2%
Bulk density	1.552	-
Void ratio	0.419	-
Porosity	0.295	-

In table 3, provides a comprehensive overview of the physical properties of coarse aggregate, which is a critical component in concrete production and construction. These properties influence concrete mix design, workability, durability, and overall performance in various applications. Understanding and selecting the right coarse aggregate for a specific project is essential to achieving the desired concrete characteristics.

3.1.4 Water

Potable water was second hand for joining the hardened.

3.1.5 Fly ash

Figure 6, describes fly ruins Class C is a type of bitumen combustion product that is to say made when bitumen is charred in capacity plants to generate power. It is top-secret as Class C established allure synthetic composition and possessions. Fly ruins Class C is rich in calcium group of chemical elements (Cao), that gives it superior self-sealing properties when oppose water and added aggregates. Fly ruins Class C is usually second hand as a pozzolanic material in concrete join designs. It helps the practicability and staying power of hardened by lowering water demand, increasing compressive substance, and lowering the risk of decrease and breaking. Fly ruins Class C is also an persuasive substitute for Portland cement in factual, lowering the element footmark of concrete result. In addition to its use in concrete, Fly ash Class C is also used as a soil stabilizer and as a component in the production of lightweight aggregate.

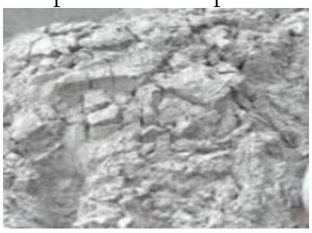

Figure 6: *Fly ash*

Table 4: *Physical Properties of Fly Ash*

Properties	Test result	Range	IS Specification
Specific gravity	2.12	2.1-3.0	-
Fineness	10%	-	-
Consistency	32%	25-35%	

In table 4, provides a comprehensive overview of the physical properties of fly ash, a valuable supplementary material in concrete production. Fly ash is known for its ability to improve concrete performance, reduce the environmental impact of construction, and enhance long-term durability. Understanding these properties is crucial for engineers and builders when incorporating fly ash into concrete mix designs.

3.1.6 Super Plasticizer

In Figure 7, Cera Hyper Plast XR-W40 is second hand. Cera Hyper Plast XR W40 is a type of superplasticizer namely usually used in the explanation manufacturing to raise the practicability and flowability of hardened mixes. It is a high-efficiency blending that is to say particularly planned to increase the slump and reduce the water content of factual mixes, outside prejudicing on allure substance and durability possessions.

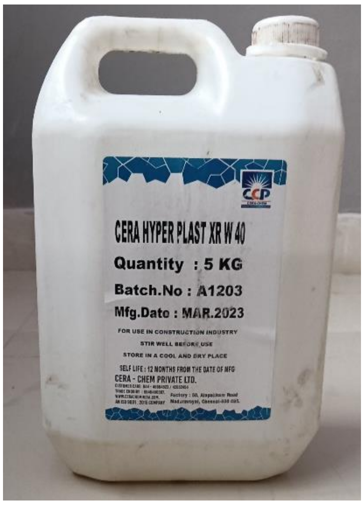

Figure 7: *Superplasticizer*

Cera Hyper Plast XR W40 belongs to the polycarboxylate ether (PCE) family of superplasticizers, which are known for their excellent dispersing and water-reducing properties. It has a unique molecular structure that allows it to disperse cement particles more efficiently, resulting in a more homogenous concrete mix. Cera Hyper Plast XR W40 also has a longer retention time, which means that it can maintain its workability for a longer period of time, even in hot and humid conditions.

Cera Hyper Plast XR W40 is usually used in the explanation of extreme-strength and extreme-depiction concrete buildings, to a degree bridges, tunnels, and high-rise constructions. It is too used in hardened products, to a degree pipes, poles, and railroad sleepers. Cera Hyper Plast XR W40 offers several advantages over other types of superplasticizers, including improved workability, reduced water demand, and increased strength and durability. It is still environmental and tenable, as it reduces the amount of water and cement wanted in concrete result, that in proper sequence reduces the element footmark of factual construction.

3.1.7 POFA

In Figure 8, the things produced of blazing empty crop bunches, fibers and oil palm case. POFA endures Palm Oil Fuel Ash, that is a product of blazing touch oil waste in capacity plants. POFA is top-secret as a pozzolanic material on account of allure extreme silica and alumina content, that provides superior cementitious possessions when argue water and additional aggregates.

POFA is usually second hand as a biased replacement for Portland cement in actual join designs. It develops the practicability and durability of hardened by lowering water necessities, growing compressive substance and reducing the risk of decrease and breaking. POFA also helps reduce the carbon footprint of concrete production, as it is a waste that is often dumped in landfills. In addition to being used in concrete, POFA is also used as a soil stabilizer and as a component in the production of lightweight aggregates. It is a tenable and environmentally companionable material cause it reduces the need for Portland cement and reduces the amount of touch lubricate waste make use of dump.

Figure 8: *Palm oil fuel ash*

Table 5: *Physical Properties of POFA*

Properties	Test results
Fineness	25 %
Specific gravity	1.9
Consistency	35%
Initial setting time	95 min

In table 5, provides a comprehensive overview of the physical properties of palm oil fuel ash (POFA), a valuable supplementary material in concrete production and other construction applications. These properties influence how engineers and builders incorporate POFA into concrete mix designs and sustainable construction practices, contributing to both environmental benefits and enhanced material performance.

3.2 Mix Proportioning

To investigate and compare the compressive strength at various percentages of replacement with that of traditional SCC, concrete mixtures for M30 were created. The cement was substituted for the percentages of 10, 20, 30, and 40. The combination had a water content of 0.5 and a percentage of 1: 1.62: 1.48: 0.43. The substance was judged subsequently 7, 14, and 28 days of cure. Fresh SCC was endangering the Slump test, L-Box test, and V-Funnel test to evaluate the practicability. Hardened concrete's compressive strength test results were established.

4 Test on Concrete

4.1 Fresh properties

Self-Compacting Concrete (SCC) is a type of factual namely planned to flow and fill into formwork outside the need for quivering. SCC is well feasible and has superior flow possessions, making it ideal for use in complex or blocked formwork.

Fresh feature tests are used to judge the practicability and flow features of SCC. Three usually secondhand new possessions test for SCC are the slump test, V pour test, and L box test.

Table 6: *Fresh Properties of SCC Blended With POFA*

Percentage of POFA added	V-Funnel	L-Box	Slump
10	6.23	0.8	640
15	7	0.6	680
20	8.4	0.53	670
30	15.36	0.25	430
40	28.93	0.12	400

In table 6, provides an overview of the fresh properties of self compacting concrete (SCC) blended with palm oil fuel ash typically includes various parameters and measurements that help asses the characteristics of the concrete mix at the point of mixing and during its fresh state

4.2 Slump Test

The slump test is a natural and established test to decide the practicability and flow characteristics of Self-Compacting Concrete (SCC). It measures the upright conclusion of SCC under allure self-pressure, that displays allure flowability and constancy. To act the slump test on SCC, a standard slump circular-shaped object with pointed end is first suffused accompanying SCC in three coatings, each tier is condensed utilizing a patterned rodding process.

The circular-shaped object with pointed end is therefore raised across, and the SCC open across. The upright conclusion or slump of the SCC is measured as the dissimilarity middle from two points the climax of the strobile before and subsequently the SCC settles. In the case of SCC, the test is usually performed in a modified way compared to conventional concrete. Firstly, the cone is filled to about two-thirds of its height as SCC is highly flowable and can easily flow out of the cone. Secondly, the SCC mixture is not compacted using the traditional rodding procedure as it can lead to segregation.

The slump test is an important tool for quality control in the production and placement of SCC. It helps to ensure that the SCC has the desired flowability and consistency to fill formwork without the need for compaction. SCC with a higher slump value is generally considered more workable, while a lower value indicates less workability.

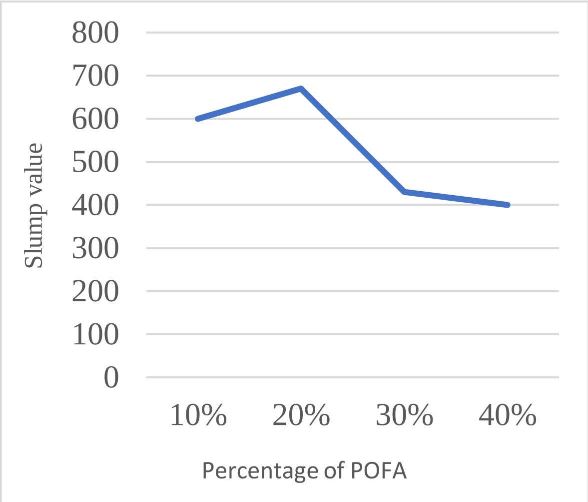

Figure 9: *Slump value of blended POFA*

In figure 9, the graph shows the slump value of SCC blended with different percentage of POFA with 20% as optimum value.

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4.3 V-Funnel

The V-pour test is a procedure for weighing the stickiness and flowability of self-compacting actual (SCC). This is a smart and smooth test that supports beneficial news about SCC's strength to flow and fill complex forms. To act the V-transmit test accompanying SCC, a V-shaped channel accompanying a standard hole fundamentally is suffused accompanying SCC. The time necessary for the SCC to flow through the storage and entirely fill the taking container is calculated. The stickiness and flowability of SCC are supposed by moment of truth necessary to flow through the pour.

The V-channel test is specifically beneficial in judging the stickiness of SCC, that is a measure of allure flow opposition. It can still signify either SCC can fill complex shapes outside compaction. Longer flow period method larger stickiness and less flow, while smaller flow period wealth lower stickiness and better flow.

The V funnel test is an important tool for quality control in the production and placement of SCC. It helps to ensure that the SCC has the desired viscosity and flowability for the specific construction application. The test is also useful in comparing the flowability of different SCC mixes, allowing for the selection of the most appropriate SCC mix for a given construction project.

Overall, the V funnel test is a quick and simple method to evaluate the viscosity and flowability of SCC. It provides important information about the SCC's ability to fill complex formwork without the need for compaction and helps to ensure that the SCC has the desired properties for use in construction.

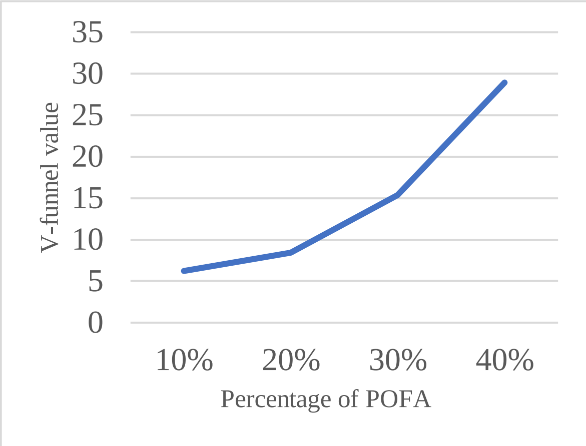

Figure 10: *V- funnel value for blended POFA with SCC*

In figure 10, the graph shows the V-Funnel value corresponding to different percentage of POFA and its value is increasing according to increased percentage.

4.4 L box

The L box test is a plan for judging the passing capability of Self-Compacting Concrete (SCC) through limited portions or clogged support. It simulates the flow of SCC through narrow breach or scopes, to a degree betwixt laboriously full fortify reinforcements or in elaborate formwork.To perform the L box test on SCC, a specially designed L-shaped box is first placed on a horizontal surface. SCC is then poured into the top of the box and allowed to flow through it. The flow of SCC is observed and measured as it passes through a narrow opening at the bottom of the box, simulating the flow of SCC through congested reinforcement.The test results in two main calculations: the altitude of the SCC pile at the end of television set and the climax of the SCC pile following in position or time pass through the opening. The distinctness betwixt two together crest displays the SCC's ability to travel narrow breach or rooms outside blocking or separation.

The L box test is an important tool for quality control in the production and placement of SCC. It helps to ensure that the SCC has the necessary passing ability to flow through congested reinforcement or narrow gaps. The test also provides information on the SCC's stability and ability to avoid segregation under restricted conditions.

Overall, the L box test is a valuable procedure to judge the passing strength of SCC in complex explanation uses. It helps to guarantee that the SCC has the unavoidable flow possessions to fill complicated formwork or flow through blocked support outside the need for compaction.

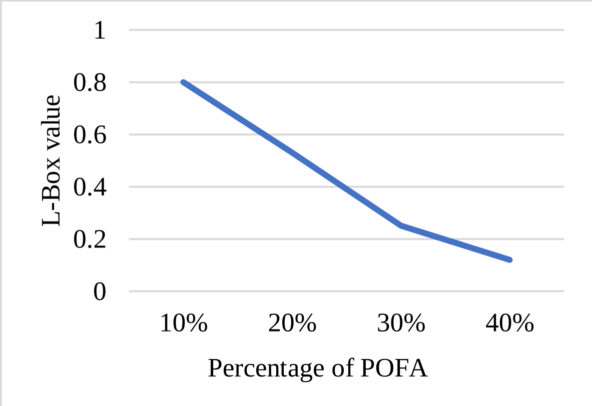

Figure 11: *L-box value for blended POFA with SCC*

In figure 11 , shows L-box value with varying percentage of POFA, here the value is decreasing according to the increased percentage of POFA.

5 Discussions

- The Compressive substance of the control join afterwards 28 days of healing was 38.44N/mm^2.
- The Compressive strength of SCC accompanying POFA as a substitute later 28 days of healing was 32N/mm^2.
- The test results of the exploratory work presented that the substance of SCC was depressed 20% replacement of cement accompanying POFA.
- The SCC win 80-85% of allure compressive substance all the while the first 7 days of helping cure. On growing the substitute after 20%, the substance was raising expected abating.

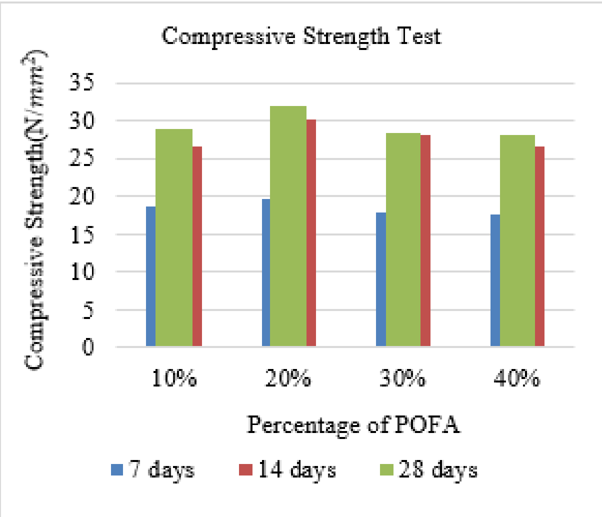

Figure 12: *Compressive strength of SCC blended with POFA*

In figure 12, the graph shows the compressive strength of SCC blended with POFA at different percentages and hence determined the optimum value.

6 Cost Analysis

In table 7, shows the cost of various components of SCC. The cost analysis was carried out based on this rate.

Table 7: *Cost of Components of SCC (Per Unit)*

Materials	Unit	Cost (Rs.)
Cement	Kg	8.4
Fly ash	Kg	-
Fine aggregate	Kg	2.61
Coarse aggregate	Kg	1.84
Superplasticizer	Kg	480
Water	Kg	-

In table 8, shows the cost of normal cost with 0% fly ash and superplasticizer.

Table 8: *Cost of Normal Concrete*

Mix 1: Normal concrete (Concrete with 0% fly ash with no SP)

Component	Density(kg/m^2)	Cost (Rs.)	Total cost
Cement	511.11	4293.32	12757.7
Fly ash	0	0	
Fine aggregate	830.86	2168.54	
Coarse aggregate	755.57	1390.24	
Superplasticizer	0	4905.6	
Water	221.34	0	

In table 9, shows the cost of control mix with 15% fly ash with superplasticizer.

Table 9: *Cost Comparison on Control Mix*

Mix 2: Control Mix (concrete with 15% fly ash with SP)

Component	Density(kg/m^2)	Cost (Rs.)	Total cost
Cement	434.44	3649.29	12113.67
Fly ash	76.67	0	
Fine aggregate	830.86	2168.54	
Coarse aggregate	755.57	1390.24	
Superplasticizer	10.22	4905.6	
Water	221.34	0	

In table 10, shows the cost comparison on optimum mix with 15% fly ash,20% POFA and with superplasticizer.

Table 10: *Cost Comparison on Optimum Mix*

Mix 3: Optimum Mix (concrete with 15% fly ash, 20% POFA and with SP)

Component	Density(kg/m^2)	Cost (Rs.)	Total cost
Cement	511.11	4293.32	
Fly ash	76.67	0	
POFA	102.23	0	
Fine aggregate	830.86	2168.54	11179.51
Coarse aggregate	755.57	1390.24	
Superplasticizer	10.22	4905.6	
Water	221.34	0	

7 Conclusions

- The replacement of up to 20% POFA increased the strength parameters of SCC.
- Increasing the percentage of replacement above 20%, the strength was found to be decreasing.
- Workability was found to be decreasing above 20% of POFA
- The replacement of cement upto 35% which includes 20% POFA & 15% fly ash and it shows friable workability and strength characteristics similar to the control mix. So, the optimum percentage of POFA blended with SCC is 20%.

8 Declarations

8.1 Acknowledgment

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How to Cite

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References

[1] Santhosh, K. G., Subhani, S. M., & Bahurudeen, A. (2022). Sustainable reuse of palm oil fuel ash in concrete, alkali-activated binders, soil stabilisation, bricks and adsorbent: A waste to wealth approach. Industrial Crops and Products, 183, 114954.

[2] Al-Shwaiter, A., Awang, H., & Khalaf, M. A. (2022). Performance of sustainable lightweight foam concrete prepared using palm oil fuel ash as a sand replacement. Construction and Building Materials, 322, 126482.