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# EXPERIMENTAL INVESTIGATION ON WASTE MATERIAL OF STRENGTH DEVELOPMENT IN CONCRETE

[1]Puneet Sabharwal, [2]Kapil Vashistha
1 Research Scholar, M-Tech Student Department of Civil Engineering IIMT University Meerut Uttar Pradesh. India
2 Assistant Professor, Department of Civil Engineering. IIMT University. Meerut Uttar Pradesh. India
Email:1 puneets241998@gmail.com, 2kapil3380@gmail.com

**ABSTRACT**

One way of attaining sustainable and environmentally friendly structures is to use industrial waste as a construction material. Oil palm shells (OPS) obtained from palm oil extraction process from the palm oil industry are a promising material and are also lightweight, which can be used as a replacement of coarse aggregate (gravel) in conventional concrete. OPS are found to absorb more water compared to gravel aggregates. Water absorption test shows OPS have a water absorption rate of 20-24% which is 4-5 times higher than the gravel aggregates. Hence, surface treatment is carried out for OPS aggregates with silicon-hydrogen (Si-H) compound. This surface treatment reduces the water absorption in OPS aggregate to a normal level. Treated oil palm shell aggregates are designated as “TOPS” and Non-Treated oil palm shell aggregates are designated as “NTOPS”.

The physical and chemical properties of TOPS and NTOPS aggregates are tested and studied. Physical properties like water absorption, density, aggregate impact value and the specific gravity of TOPS and NTOPS aggregates are carried out. Water absorption of OPS aggregate is minimized from 25% to 8% by using organosiline compound admixture. Density of OPS concrete is 25% less when compared to conventional concrete. Chemical composition of TOPS and NTOPS aggregates are examined using X-ray diffraction analysis. Scanning Electron Microscope analysis is carried out to know the pore structure of OPS aggregates.

In this research study mechanical properties of TOPS concrete and NTOPS concrete is compared with conventional concrete. Compressive strength of 29 MPa for 28 days is noticed in TOPS concrete whereas 13.2 MPa is noticed in NTOPS concrete. Microstructural analysis and interfacial transition zone is also investigated for TOPS and NTOPS concretes using digital image processing for finding out the bond break between matrix phase to aggregate phase. The results of investigation are compared with conventional concrete. Durability properties of TOPS concrete is examined and compared with standards.

Keywords: Lightweight concrete, Oil Palm Shells, Water absorption, Microstructure, Interfacial transition zone.

## I. INTRODUCTION

Concrete is the largest material that is consumed by the construction industry. This industry consumes a large number of natural and non-renewable sources such as water, sand

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and gravel. Global concrete industry roughly consumes 7.5 billion tons annually. This reduces stone deposits and causes ecological imbalances. Concrete is not an environmentally friendly material. Construction industry has a significant social, economic and environmental impact. Using waste from the industries and the by-products available as waste can be used as raw materials as best alternative materials to achieve sustainable development of the concrete.

Concrete made with lightweight aggregates to produce structural concrete is said to be Lightweight Concrete (LWC). Lightweight aggregates can either be natural lightweight aggregates or artificial lightweight aggregates. Natural aggregates are pumice, scoria and perlite. Artificial aggregates are shale, expanded clay and slate. Aggregates from industrial waste can also be used to produce lightweight concrete. Lightweight aggregates produced in the rotary kiln are expanded clays and shale which are termed as LECA aggregates. Lightweight aggregates produced by water jet or slag expanded mechanically are termed as FOAMED lightweight aggregates. Sintered pulverized fuel ash aggregates are termed as LYTAG aggregates.

Artificial aggregates are used for decades. These lightweight aggregates help in reduction in deadweight, reduction in sizes of the members and thermal protection. This helps in imperviousness to fire of the structures. Concretes produced with these lightweight aggregate types had a density of 1400-1750 kg/m3 with maximum compressive strength of 18-25MPa. According to ACI 318-R, lightweight concrete producing more than 25MPa are said to be structural lightweight concrete. Researchers used coconut shells, eggshells and many other types as a replacement for coarse aggregate to some extent. All the studies represent that any replaced material in concrete can be used only for producing non-structural elements in the construction. Waste products from industries such as oil palm shells, recycled plastic and recycled rubber are also used as lightweight aggregates in making of lightweight concrete.

OPS are a waste material from the palm oil industries. Malaysia, Nigeria and India are well known for the production of palm oil worldwide. Typically, around 110 million tons of OPS waste is produced by these countries (Shafigh, Mahmud, Jumaat, & Zargar, 2014). Research in OPS as aggregate in concrete is attracting researchers continuously. Using OPS as aggregate for the making of structural lightweight concrete is studied in this research. Lightweight aggregates usually contain large pores in their internal structure. They are called lightweight because they have density than the conventional aggregates. Concrete made with lightweight aggregates is termed as lightweight concrete. Lightweight concrete has a density of less than 20-25% of conventional concrete made with gravel as coarse aggregate. Lightweight concrete is widely used as its consumption increases year by year globally.

## II. REVIEW OF LITERATURE

A review of the literature on lightweight concrete and lightweight aggregates is presented. This includes the use of industrial waste as coarse aggregate for producing lightweight concrete, replacement of conventional aggregate with different lightweight aggregates, the effect of lightweight concrete in bond, interfacial transition zone thickness and compressive strength.

## Review on lightweight concrete made with lightweight aggregates

Durisol and Fixolite proposed using lightweight aggregate in 1937. In 1932, Alex Bosshard patented the first lightweight aggregate made from wood fibers. To lessen the material's overall weight, it was suggested that lightweight aggregate wood fibers be used instead of regular aggregates. For use as filler in walls, lightweight concrete blocks measuring 200mm x 200mm x 500mm were made ready. The density of wood fiber lightweight concrete is 750 kg/m3. In time, these surpassed traditional aggregates as the preferred choice.

Port of Cosa was constructed in 273 B.C. on the west coast of Italy using lightweight stones such as pumice and scoria. Instead of using the readily accessible materials (beach sand and gravel), the builder opted to employ natural lightweight aggregates. Density ranges from 450 to 850 kg/m3 for concrete using natural lightweight particles. Reports indicate that the mechanical behavior of concrete made with natural aggregates is satisfactory, and the port is still in operation.

As may be seen in Fig. 2.1, the Pantheon Dome was built in 27 B.C. with a circumference of 43.3 m. The construction crew utilized two distinct kinds of low-density aggregates. Aggregates with higher densities were employed at the base to maintain the loads emanating from there, while aggregates with lower densities were utilised at the dome's apex, where the tensions are minimal. Even after hundreds of years, worshippers continue to visit the Pantheon. The ancient amphitheatre Coliseum was built between the years 75 and 80 A.D.

Designed to hold 50,000 people and built accordingly. Porous-tufa cut stone was utilized for the walls, and crushed volcanic lava was used for the Coliseum's base. (ACI Committee 213, 2003).
Since the Romans didn't employ lightweight aggregates very often, their production and commercial availability didn't occur until the 20th century. Stephen J. Hyde received a patent in 1981 for his process of creating lightweight aggregates. He used a rotary kiln to heat and expand materials like clay, shale, and slate to create lightweight aggregates. The first concrete ship in the United States Navy made use of expanded aggregates.

Since the second half of the twentieth century, several high-rise structures have been built using lightweight concrete. Lightweight concrete was used in the construction of a 42-story high rise in Chicago, as well as hotels with a lightweight concrete structure and flat plate flooring in Dallas.

Concrete using lightweight particles typically has less mechanical strength than regular concrete. Since coarse aggregate makes up roughly 70% of concrete, its behaviour is crucial. Lightweight concrete's mechanical

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properties are affected by the lightweight aggregates used in its creation. Weightlessness of numerous kinds Many academics looked into aggregates as a way to enhance the mechanical behaviour of lightweight concrete.

Lightweight concrete is used in a wide variety of architectural types, from skyscrapers to bridges to maritime structures. The Stolmen Bridge in Norway was built using lightweight concrete in 1998. Lightweight concrete, totaling 1600 m3, was used in the bridge's construction; its mean compressive strength after 28 days was 70.4 MPa, and its mean density was 1940 kg/m3.

Basri et al. (1999) reported that satisfactory mechanical behaviour may be achieved in concrete by partially replacing coarse aggregate with OPS. Lightweight concrete made with OPS has a density of just 1856 kg/m3 and a compressive strength of 15-20 MPa. Lightweight concrete made with oil palm shells as coarse aggregate can have its mechanical qualities enhanced by increasing the cement concentration, as indicated by Shafigh et al. (2011).

Lightweight concrete was made by Mannan and Ganapathy (2002) by using OPS, an agricultural waste, as an aggregate. The highest compressive strength, at 28 days, was around 21 MPa, regardless of the mix proportions used. OPS concrete has a flexural strength of 2-4 MPa and a splitting tensile strength of 2.41 MPa without the use of any admixture in its production. Drying shrinkage in OPS concrete is 14% more than in control concrete, with a range of 0.70-0.76*104 N/mm2. The ability for absorption of OPS is greater.

Expanded perlite was employed by Demirbog (2003) as a lightweight aggregate. Expanded perlites are utilised in place of coarse aggregate, while silica fume and fly ash are used to replace 30% of the cement. After 30% silica fume and fly ash is substituted, thermal conductivity and dry unit weight are reduced by up to 18.6%. The density of concrete can be reduced by using more lightweight particles like perlite.

Scoria lightweight aggregates with mineral admixtures can produce high-strength lightweight concrete, according to Atis (2003). Slightly less dense than water, scoria lightweight concrete (at 1955 kg/m3) has a compressive strength of 40 MPa. High-strength lightweight concrete was made by combining varying amounts of fly ash with silica fumes. Aggregates of scoria are seen in Fig 1.1.

**Fig 1.1** Scoria aggregates

Lightweight concrete made from volcanic pumice can be made by substituting 25% of the cement with fly ash, as reported by Hossain (2004). Volcanic pumice lightweight concrete reaches a maximum bulk density of 1183 kg/m3. The aggregate density is and the maximum cement content is 490 kg/m3 when

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designing a mix. The water-to-cement ratio is 0.45.

Volcanic pumice concrete has a compressive strength that is 40-45% lower than standard concrete. Volcanic pumice concrete has a higher split tensile strength, at 3.7 MPa compared to the control concrete's 2.6 MPa. Used are granules of volcanic pumice.

pumice concrete with an aggregate/cement ratio of 6:1, while it is 5015 MPa for pumice concrete with an aggregate/cement ratio of 15:1.

The effect of cementitious elements in palm kernel shell concrete was described by Alengaram and Jumaat (2008). Lightweight concrete constructed from palm kernel shells was tested for 90 days to determine the impact of cementitious ingredients and curing conditions. The report also examines the effect of silica fumes in concrete. The compressive strength of concrete at 28 days varied from 26 MPa to 36 MPa depending on the mix design and the percentage rise of silica fumes. The compressive strength of concrete is unaffected by curing conditions, with only a 3–5% range.

Suba (2009) detailed the outcomes of including fly ash into lightweight concrete made from expanded clay aggregate. The mechanical qualities of concrete vary depending on the percentage of fly ash used to replace the cement (0%, 10%, 20%, and 30%). When comparing the strength ratings of cement with different percentages of fly ash replacements, 10% cement replacement with fly ash is the strongest. Compressive strength measured at 41.27 MPa for 450 kg/m3 cement compared to 15.60 MPa for 300 kg/m3 cement. The enlarged clay aggregate and cement paste were examined under a microscope to confirm the strength of their binding. Buildings can be made with less weight when using expanded clay aggregate concrete.

Industrial waste oil palm shells were used as coarse aggregate by Alengaram and Jumaat (2010) to create lightweight concrete. After palm oil is made from palm oil fruit, the husks are extracted. When using OPS as aggregate, the maximum dry density of the resulting concrete is 1850 kg/m3. OPS concrete has a 22% lesser density than regular concrete. The moment capacity of concrete beams built using lightweight OPS concrete and standard concrete is greater in the former. As can be seen in Fig 1.2, palm oil concrete exhibits the same flexural behaviour of reinforced concretes as regular concrete does because palm kernel shells have the same hard qualities as regular aggregate. OPS concrete has the same amount of deflection as regular concrete.

**Fig 1.2** Oil palm shell

Mechanical qualities equivalent to those of conventional concrete have been found in tests in which cement was replaced with fly ash, silica fume and furnace slag, and in which conventional aggregate was replaced with expanded clay aggregates, pumice, scoria, oil palm shells and so on. To improve the ductility and mechanical behaviour of lightweight concrete, Ali et al. (2011) used hybrid fibres into a mix of natural pumice. Lightweight concrete is crucial in enhancing buildings' resistance to seismic activity.

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Oil palm shells are an industrial waste that can be used to make lightweight aggregates for concrete. All other lightweight aggregates come from naturally occurring materials. By substituting OPS for coarse aggregate in concrete, we may lessen the amount of trash left over from palm oil production, and in turn, we can lessen air pollution.

## III. THE PROPOSED METHODOLOGY

The work to be done.

### Methodology for producing oil palm shell lightweight concrete

OPS have different properties as compared to conventional aggregate. The methodology followed for oil palm shell lightweight concrete is shown in Fig. 3.1. In this study, the following steps are considered to produce oil palm shells lightweight concrete and conventional concrete.

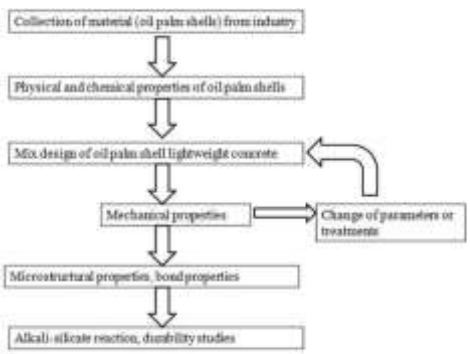


**Fig 1.3** Methodology for producing oil palm shell lightweight concrete.

Oil palm shells, a byproduct of the palm oil industry, and conventional aggregate, sourced from factories, are the first materials to be gathered. Since they originated as industrial waste, the aggregate could contain any number of harmful substances. After collection, materials undergo processing and sanitation.

Step two is to identify physical characteristics. Traditional aggregates are compared to OPS aggregates in terms of their physical qualities. Conventional aggregate and oil palm shell aggregates are compared based on their physical qualities such as specific gravity, water absorption, aggregate impact value, elongation index, and flakiness index.

The third stage is to create a mix design for both types of concrete, in this case, regular concrete and concrete made from oil palm shells. Lightweight aggregate made from oil palm shell is designed with a mixture based on prior investigations. The International Standard (IS) 10262:2009 governs the creation of typical concrete mixes.

The fourth step is to compare OPS concrete to regular concrete in terms of its mechanical qualities. All ready-mixed concretes are cured properly. Compressive strength testing is used to evaluate the mechanical properties of concrete after it has cured. Finding the microstructural properties of OPS lightweight concrete is the next step if the results are on par with those of regular concrete. Lightweight concrete parameters are adjusted and the process is restarted from the mix design phase if the results are still unsatisfactory.

The fifth step is to compare regular concrete and OPS lightweight concrete for its

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microstructural and bonding qualities. Microstructural analyses of both concretes focus on ITZ thickness and bond qualities.

The next stage is to compare the durability attributes of lightweight concrete to those of regular concrete. Concrete's longevity is a key factor to consider. OPS concrete permeability testing and analysis are described. Research into the alkali-silicate reaction is a vital part of understanding how long concrete will last. Concrete now includes oil palm shell, which may be exposed to high silica or contain other chemical compositions. The effects of alkali-silicate reaction and sulphate assault on oil palm shells have to be investigated.

**Methodology for making lightweight concrete with TOPS aggregate**.

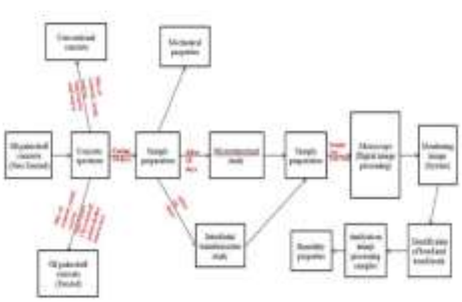

**Fig 1.4** Block scheme diagram for lightweight concrete.

## IV RESULTS AND DISCUSSION

### Water absorption test

For water absorption test, oil palm shell samples of 100 g is taken for testing as shown in Fig 1.1, and calculated using the formula. The sample taken is kept in water for 24 hours according to ASTM C 127. The sample is taken out and wiped with a dry cloth considered as surface dry aggregate. The sample is kept in over for 24 hours and weight of the sample is taken as weight of oven dry sample.

C= Weight of saturated surface dry aggregate reading.

D= Weight of the oven dry sample.

Water absorption of OPS aggregate =C−DX100 D

**Table 1.1** Water absorption in oil palm shells

| S.No | Determination | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| 1 | Weight of saturated surface dried sample in g (C) | 131 | 132 | 127 |
| 2 | Weight of oven-dried sample in g (D) | 105 | 104 | 102 |
| 3 | Water absorption = c-d/D X100% | 24.7% | 25.7% | 24.5% |
| | Average water absorption rate (%) = | 24.9 | | |

### Aggregate impact value for OPS aggregates

Table 1.2 shows the aggregate impact value of conventional and OPS aggregates. The weight of sample taken to conduct the impact value test for conventional aggregate is 420 g. After the test procedure weight of sample passing through sieve size of 2.36 mm is 75 g. In case of OPS aggregate, sample taken for conducting the test is 118 g weight. The weight of sample passing through 2.36 mm sieve is 35 g. OPS aggregate impact value is 29.6 % which is higher than the conventional AIV. The higher impact value of OPS aggregate can decrease the strength of the concrete. However higher compressive strength is noticed with the higher impact value as reported by Shafigh et al. (2011).

**Table 1.2** Aggregate impact value of conventional and OPS aggregate

| Conventional aggregate | OPS aggregate |
|---|---|
| Total weight of sample = 420 g | Total weight of sample = 118g |
| Weight of sample passing 2.36mm sieve =75g | Weight of sample passing 2.36 mm sieve = 35 g |
| Aggregate impact value = 17.85 % | Aggregate impact value = 29.6 % |

## Chemical analysis for TOPS and NTOPS aggregate

X-Ray Diffraction (XRD) analysis of OPS aggregate is carried out to know the mineralogical characteristics. XRD analysis is carried out with an interval 2 θ between 10°-90° with the count of 0-600; strip K-alpha with Rechinger testing method. Fig 1.5 shows the XRD analysis peaks of OPS aggregate. OPS aggregate having peaks at 13.2, 18.6, 22.8 and 37.3 which represent calcium, aluminium, silica and magnesium. Whereas the chemical composition of conventional aggregate is taken from the previous research studies (Vargas et al., 2017), as the conventional aggregate is well-known material from so many decades. Chemical composition percentages are taken from the standard software and crosschecked with manual calculations and listed in Table 1.3

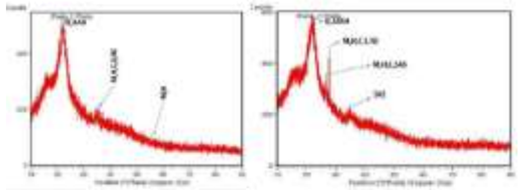

**Fig 1.5** OPS and TOPS XRD peaks with 2-Theta position.

**Table 1.3** Chemical composition of aggregates in percentages

| Chemical composition | Weight in percentages: Conventional Aggregate (Vargas et al., 2017) | OPS Aggregate | TOPS Aggregate |
|---|---|---|---|
| $SiO_2$ | 58.43 | 51.4 | 50.2 |
| $Al_2O_3$ | 13.46 | 8.6 | 27.5 |
| $Fe_2O_3$ | 8.33 | 7.2 | 7.2 |
| MgO | 6.00 | 2.8 | 4.63 |
| CaO | 7.17 | 4.3 | 5.9 |
| $Na_2O$ | 1.89 | - | - |
| $SO_3$ | 0.09 | 0.2 | 0.18 |

## Mix proportions for TOPS and conventional concretes.

Two types of concretes are investigated to know the compressive strength. LWC made with TOPS aggregates and NWC with conventional aggregates. All the ingredients were blended in a pan mix. Concrete is prepared to conduct slump test and then prepared concrete is transferred to moulds of standard cubes of 150X150X150 mm and cylinders of 100 X200 mm for compressive strength test and split tensile strength test. The samples prepared are demoulded after 24 hours and are cured for 28 days in room temperature.

**Table 1.4** Details of mix design for lightweight concrete and normal weight concrete

| Mix | Cement (kg) | Water (liter) | w/c (ratio) | Sand (kg) | Coarse aggregate: OPS (kg) | Coarse aggregate: Gravel (kg) | Slump (mm) | Density ($kg/m^3$) |
|---|---|---|---|---|---|---|---|---|
| NWC | 380 | 152 | 0.4 | 750 | - | 1080 | 75 | 2362 |
| LWC | 450 | 180 | 0.4 | 780 | 375 | - | 90 | 1785 |

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## Mix proportion of LWC with replacement of binder content

After making different combination for binder ratios and water/cement ratios, the details of constituent materials are listed in Table 1.5 Addition of mineral admixtures like silica fume and GGBS can improve the mechanical properties of lightweight concrete as seen in session 3.3.2. Cement content is taken as 500 kg/m3 instead of 550 kg/m3 as this quantity of cement are sufficient to fill the concave shape of the TOPS aggregates after different trail mixes. For NWC cement content is taken as 400 kg/m3 instead of 450 kg/m3. Replacement of 20% cement content with SF and GGBS in TOPS concrete is considered to study the behaviour of concrete and is represented as LWC SF 20 and LWC GGBS 20. Cement content is 400 kg/m3 and remaining 100 kg/m3 will be SF or GGBS as shown in Table 1.5 Water/cement ratio is 0.4 for NWC and for LWC.

**Table 1.5** Quantity of constituent materials as per mix design.

| Mix | Cement (kg) | | Water (liter) | w/c (ratio) | Sand (kg) | Coarse aggregate | |
|---|---|---|---|---|---|---|---|
| | | | | | | OPS (kg) | Gravel (kg) |
| NWC | 400 | | 160 | 0.4 | 750 | - | 1080 |
| LWC | 500 | | 200 | 0.4 | 650 | 360 | - |
| LWCSF 20 | Cement 400 | SF 100 | 200 | 0.4 | 680 | 360 | - |
| LWCGGBS 20 | Cement 400 | GGBS 100 | 200 | 0.4 | 680 | 360 | - |

## Effect of coating on workability of concrete

**Table 1.6** Slump value for three types of concretes

| Sample mix | Slump (mm) | Air dry Density (kg/m$^3$) | Oven dry density (kg/m$^3$) |
|---|---|---|---|
| Non-Treated OPS concrete | 65 | 1810 | 1782 |
| Treated OPS concrete | 95 | 1798 | 1776 |
| Conventional Concrete | 90 | 2409 | 2380 |

## Microstructural study of concrete

Fig 1.6 represents 2mm micro scale of treated OPS concrete with cement matrix bonding area. Image B shows NTOPS concrete with cement matrix bond break. This shows that concrete with treated OPS has good bonding between the aggregate phase and matrix phase whereas the non-treated OPS shows bond break between aggregate phase and matrix phase. Micro structural investigation of TOPS lightweight concrete and non-treated OPS (NTOPS) lightweight concrete are studied and compared with conventional concrete. ITZ thickness in all the three concretes are examined, mineralogical properties are studied with the help of XRD analysis.


**Fig 1.6** Bonding and bond break between treated OPS concrete (A) and non-treated OPS concrete (B)

## Interfacial transition zone (ITZ) thickness and morphology of concretes

Fig 1.7-1.8 shows ITZ thickness in Treated OPS concrete, Non-Treated OPS concrete and conventional concrete. Fig 1.7 represents TOPS aggregate (black colour), matrix gel (white colour) and ITZ (Red colour). ITZ is mostly in light cementious colour which can be seen in Figure 1.7, whereas in TOPS concrete or NTOPS concrete ITZ is red in colour. This is due to OPS aggregate colour traces are mixed in concrete in the initial stage of concreting. Maximum ITZ thickness in Treated OPS concrete is 400 micro meters which is same in case of conventional concrete.

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Fig 1.7 Treated OPS concrete with ITZ thickness detail


Fig 1.8 UTOPS concrete with ITZ thickness detail


Fig 1.9 Conventional concrete with ITZ thickness detail

Fig 1.9 represents the conventional concrete with ITZ thickness less than 400 micro meters. Similar thickness of ITZ is noticed in TOPS concrete which is due to the water/cement ratio of the concretes. Hongru zhang said that lower water /cement ratio helps grains to move close to the aggregate and bond with them as the higher water/cement ratio shows higher thickness of ITZ and this leads to lower compressive strength of concretes.

**Sulphate resistance for OPS concrete**

Sulphate resistance is an important durability property. According to ASTM C1012 sulphate resistance of OPS concrete is carried out. A sample of 150X150 X150 mm is cast to examine the sulphate resistance of concrete. The samples cast are immersed in solution of 5% $MgSO_4$ for 28 days and 56 days. The samples castare dried and tested for compressive strength. Comparison of compressive strength of OPS concrete before and after immersion in $MgSO_4$ solution is noticed. Reduction in compressive strength of OPS concrete is calculated using equation.

Strength reduction %= [(a-b)/a] X 100%

Table 1.7 Compressive strength of OPS concrete immersed in sulphate solution and immersed in distilled water.

| Compressive strength of OPS concrete in distilled water (MPa) | | Compressive strength of OPS concrete in sulphate solution (MPa) | |
|---|---|---|---|
| 28 days | 56 days | 28 days | 56 days |
| 28.5 | 28.9 | 28.3 | 28.5 |
| 27.9 | 28.2 | 27.8 | 28.1 |
| 28.2 | 28.3 | 28.1 | 28 |

**Permeability of OPS concrete**

Table 1.8 shows the co-efficient of permeability of OPS lightweight concrete. The co-efficient of permeability of OPS concrete is 14.5X10-12 m/s. Permeability of OPS concrete is ranging from 18-20X10-12 m/s as reported by Mannan et al. 2006. This shows the TOPS lightweight concrete is less permeable than the conventional concrete promising higher durability. Use of OPS as coarse aggregate in concrete reduces the permeability in concrete.

Table 1.8 Coefficient of permeability for TOPS lightweight concrete

| Sample | Discharge Q ($m^3$/s) | Time T (hr) | Head of water H (m) | Co-efficient of permeability, K (m/sec) X 10-12 |
|---|---|---|---|---|
| LWC 1 | 10 | 18 | 65.21 | 15 |
| LWC 2 | 11 | 18 | 71.6 | 14.4 |
| LWC 3 | 11 | 18 | 72.1 | 14.2 |

**V.CONCLUSIONS**

This present research involves an experimental investigation on OPS aggregate as possible replacement in concrete with the aim to find the suitability for structural application and have lower density of concrete. The initial study revealed that the OPS has higher water absorption rate, lower impact strength, lower content of aluminium oxide and larger pore size. Concrete made with OPS aggregate shows lower compressive strength, higher cement content, higher ITZ thickness and bond break between aggregate to matrix phase when compared to normal concrete. In order to improve these properties OPS aggregate is treated with organosiline compound to improve the physical, mechanical and microstructural properties. The conclusions regarding detailed experimental study on structural lightweight concrete made with NTOPS and TOPS aggregates are summarized as follows.

**Physical properties of TOPS aggregate.**

1.The water absorption rate of Treated OPS (TOPS) reduced from 25% to 8%, which lowers the water absorption rate by three times. This has an influence on water cement ratio of concrete and hence improves workability.

2.Aggregate impact value for TOPS is reduced from 29.6 % to 21.1% after treatment. This is in the range of strong impact value classification, which is absolutely fine to use as a replacement of coarse aggregate in concrete.

3.From XRD peaks, TOPS shows improved percentage of aluminium oxide from 8.6% to 27.5%. This is due to minimal segregation of silicon and aluminium compounds after treatment of OPS with organosiline compound admixture. This improves the strength property of OPS aggregate.

**Mechanical and microstructural properties of TOPS aggregate.**

4.TOPS concrete yields a compressive strength of 27.5 MPa as that of conventional concrete. This shows that TOPS concrete falls in structural property range and these can be used as structural concrete.

5.The Tops concrete produced had higher cement content and that was due to the concave shape of the OPS aggregate which consumes more quantity of cement matrix to fill the gaps. In order to reduce the cement content addition of SF and GGBS were used to match the binder requirement for making TOPS concrete.

6.The slump value in TOPS concrete increased from 65 to 90 mm. This is due to treatment of OPS aggregate with organosiline compound admixture. The water cement ratio is brought down from 0.5 to 0.4 resulting in improved workability and higher strength attainment.

7.Microstructural investigation reveals that NTOPS concrete shows bond break between the cement matrix and the OPS aggregates due to insufficient water content, whereas in TOPS concrete no traces of bond break is observed due to the lower water/cement ratios. This resulted in an increase of compressive strength from 15.6 MPa to 27.5 MPa.

8.It is observed that the water content influences the ITZ thickness of the concrete. In TOPS concrete and conventional concrete water content is lower, which helps the fine grains move close to the aggregate phase. This fine grain bonds the cement phase and aggregate phase tightly which resulted in higher mechanical properties.

9.In NTOPS lightweight concrete fine grains move away and the liquid phase comes in between coarse aggregate phase and cement phase as seen in the digital image processing microscope.

**Durability properties for TOPS concrete**

10.Immersion of TOPS concrete in sulphate solution for 56 days does not show any detoriation in concrete and attained compressive strength of 28 MPa. This indicates that TOPS concrete is free from sulphate attack and this can be used as structural concrete.

11.The permeability of TOPS concrete is 14 to 15 X 10-12 m/sec, where as in conventional concrete it is 18 to 25 X 10-12 m/sec. This shows that TOPS concrete is less permeable than the conventional concrete. This improves the durability property of TOPS concrete.

Hence it is concluded that usage of TOPS in structural lightweight concrete shows similar mechanical and microstructural properties that of conventional concrete. The durability property also improved. Thus the research study confirms the use of TOPS aggregate as replacement of conventional aggregate to make concrete for structural application. In addition, the density of TOPS concrete is lower by 25 % than that of conventional concrete which will result in reduced dead load and consequently reduced use of reinforcing steel.

**REFERENCES**

B.V. Bahoria, Dr.D.K. Parbat, Dr.P.B. Naganaik, Dr.U.P. Waghe, “Comprehensive literature review on use of waste product in concrete”, IJAIEM Volume 2, Issue 4, April 2020.

Chandana Sukesh, Bala Krishna Katakam, P Saha and K. Shyam Chamberlin, “A Study of Sustainable Industrial Waste Materials as Partial Replacement of Cement”, IPCSIT vol. 28 (2021) © (2021) IACSIT Press, Singapore.

A.V.S.Sai. Kumar, Krishna Rao, "Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metakaolin", International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 3, March 2019.

P.S. Kothai1, Dr.R. Malathy "Utilization of Steel Slag in Concrete as A Partial Replacement Material for Fine Aggregates", International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 4, April 2018.

Amarnath Yerramala, "Properties of concrete with eggshell powder as cement replacement", The Indian Concrete Journal October 2019

R. Kamala, B. Krishna Rao, "Reuse of Solid Waste from Building Demolition for the Replacement of Natural Aggregates", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2019.

A.M. Mustafa Al Bakri, M.N. Norazian, H. Kamarudin1, M.A.A. Mohd Salleh, and A. Alida, "Strength of Concrete Based Cement Using Recycle Ceramic Waste as Aggregate", Advanced Materials Research Vol. 740 (2017) pp 734-738 © (2017)

M. Iqbal Malik, Muzafar Bashir, Sajad Ahmad, Tabish Tariq, Umar Chowdhary, "Study of Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates", IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021, p-ISSN: 2278-8719 Vol. 3, Issue 7 (July. 2013), ||V6 || PP 08-13.

Amitkumar D. Raval, Indrajit N. Patel, Jayeshkumar Pitroda, "bco-Efficient Concretes: Use of Ceramic Powder as A Partial Replacement of Cement", IJITEE, ISSN: 2278-3075, Volume-3, Issue-2, July 2021.

Lakshmi.R, Nagan.S, "Studies on Concrete containing E plastic waste", INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES Volume 1, No 3 ,2022.

Ardakani, A and Yazdani, M. (2014). The relation between particle density and static elastic moduli of lightweight expanded clay aggregates. Applied Clay Science, 93–94, 28–34.

Aslam, Muhammad, Payam Sha, and Mohd Zamin. (2016) 'Oil-Palm by-Products as Lightweight Aggregate in Concrete Mixture : A Review', Journal of cleaner production, 126, 56-73.

Aslam M, Sha P, Zamin M and Lachemi M. (2016). Benefits of using blended waste coarse lightweight aggregates in structural lightweight aggregate concrete. Journal of cleaner Production, 119, 108–17

Asrah, H., Mirasa, A. K., and Bolong, N. (2018). The effect of calcium hydroxide, alkali dilution and calcium concentration in mitigating the alkali silica reaction using palm oil fuel ash. AIP Conference Proceedings, 020015-1 – 020015-7.

Atis, C. D. (2003). High-strength lightweight concrete made with scoria aggregate containing mineral admixtures. Cement and concrete research, 33, 1595–1599.

Basri, HB., Mannan, MA., and Zain, MFM. (1999). Concrete using waste oil palm shells as aggregate. Cement and concrete research, 29,619–622.

Batis, G., Kouloumbi, N and Pantazopoulou, P. (2005) 'Corrosion Protection of Steel in Pumice Lightweight Mortar by Coatings', Cement and Concrete Compsites, 27, 261-267.

Bogas, A., Brito, J. De, Figueiredo, M., Icist, D., and T, I. S. (2014). Mechanical characterization of concrete produced with recycled lightweight expanded clay aggregate concrete. Journal of cleaner production, 89, 187-195.

Chee, C., Kok, C., Ramli, M., and Gin, L. (2016). The engineering properties and microstructure development of cement mortar containing high volume of inter-grinded GGBS and PFA cured at ambient temperature. Construction and Building Materials, 122, 683–693.