

Development and Mechanical Performance of Sustainable Concrete with Partial Replacement of Coarse Aggregate by Agri-waste Oil Palm Kernel Shell and Coconut Endocarp

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Abstract - Concrete is one of the most widely used construction materials in civil engineering due to its strength, durability, and versatility. However, the excessive utilization of natural aggregates in concrete production has resulted in depletion of natural resources and environmental degradation.. The cost of making concrete is going up because the prices of cement, sand and big rocks are rising. Using much sand and rocks is also causing worries about running out of these resources and harming the environment. So finding other waste materials to use of these rocks is an important area of research. In view of sustainable construction practices, the present study focuses on the utilization of OPKS and Coconut Endocarp as partial replacement materials for conventional coarse aggregate in M25 grade concrete.

In this investigation, Oil Palm Kernel Shell was used as partial replacement of coarse aggregate at replacement levels of 10%, 20%, 30%, and 40%, along with a constant addition of 3% Coconut Endocarp. The experimental program was carried out to evaluate both fresh and hardened properties of concrete. Fresh concrete properties were studied using slump test and compaction factor test, while hardened concrete properties were evaluated through compressive strength, split tensile strength, and flexural strength tests at curing periods of 7, 14, and 28 days.

The compressive strength results demonstrated that the strength increased with curing age for all mixes. The conventional concrete achieved a 28-day compressive strength of 31.98 MPa, whereas the OPKS20% + 3% CEP mix attained the highest strength of 34.11 MPa, showing an increase of approximately 6.66%. Similarly, the split tensile strength increased from 3.42 MPa for conventional concrete to 3.56 MPa for the OPKS20% + 3% CEP mix, indicating an improvement of about 4.09%. The flexural strength also improved from 4.56 MPa to 4.82 MPa, corresponding to an enhancement of approximately 5.70%. Among all mixes, OPKS20% + 3% CEP was identified as the optimum replacement level for achieving improved strength and satisfactory

workability. The study concludes that OPKS and Coconut Endocarp can be effectively utilized as sustainable alternative aggregate materials for the development of eco-friendly concrete suitable for structural applications.

Key Words: Concrete, Oil Palm Kernel Shell (OPKS), Coconut Endocarp (CEP), Sustainable Concrete, Mechanical Strength Properties.

1.INTRODUCTION (Size 11, Times New roman)

Concrete is an useful material for building things. It is used a lot in engineering because it is strong and can be used in many different ways. To make concrete you need a basic things like cement, sand, big rocks, water and special chemicals. Because many cities are growing fast people need a lot of concrete to build new things. This has caused some problems for the environment. Making rocks and processing them releases bad things into the air, which makes the earth get too hot. Taking much sand from rivers and lakes also hurts the environment it causes erosion and it makes it hard for the water to stay in the lakes and rivers. So we really need to find materials that are good for the earth and use them to make concrete. This way we can build things without hurting the environment. Concrete is very important. We need to make sure that we can use concrete without making the earth sick. We have to find a way to make concrete that's good for the earth and this will help us build things in a way that is friendly to the environment and, to concrete.

1.1 Utilization of Agricultural waste in concrete

Concrete is a popular building material because it is strong, durable and versatile. However the construction industry is growing fast. Using up a lot of natural resources like cement, sand and coarse aggregates. At the time we are producing a huge amount of waste from industries, farms and homes which causes environmental and disposal problems. So using waste materials in concrete is an area of research for sustainable construction.

1.3 Types of Agricultural Wastes

Agricultural wastes are the leftover things we get when we do farming grow crops pick crops and take care of animals. We get a lot of these wastes over the world. We can group them based on where they come from and what they're like. It is very important to use wastes properly. This is because we need to take care of the earth and use things in a way that's good for the earth.

Agricultural wastes can be grouped into a types. These are

- Crop Residues,
- Industrial Wastes,
- Animal Wastes
- Forestry Residues.

1.3.1 Agro-Industrial Wastes

Agro-industrial wastes are the leftovers from when we process farm products in factories that make food and other things from farms. We get a lot of these wastes from factories that make sugar, rice, palm oil, coconut, coffee and timber and from food factories. Usually people think industrial wastes are not worth much. They just throw them away.. The truth is, agro-industrial wastes can be really useful in different ways. If we do not get rid of industrial wastes properly it can cause big problems for the earth like making the land, air and water dirty. So it is very important that we find ways to use agro-industrial wastes and make sure they do not hurt the environment.

1.3.2 Production of Agricultural waste

Agricultural waste materials are generated in large quantities during farming and food processing activities. Materials such as coconut shells and palm kernel shells are commonly discarded as waste, leading to environmental pollution and disposal problems. In recent years, these agricultural wastes have been effectively utilized in concrete production as partial replacement for conventional aggregates. The use of such waste materials not only reduces environmental impact and conserves natural resources but also promotes sustainable and eco-friendly construction practices.

1.4 Hybrid Waste Material

The growth of farms and factories has led to a lot of waste causing problems for the environment and disposal. Among farm wastes Coconut Endocarp and Oil Palm Kernel Shell are produced in amounts from coconut and palm oil industries. These wastes are usually thrown away. Burned, causing pollution and wasting useful natural resources. Coconut Endocarp and Oil Palm Kernel Shell have properties like being hard, tough, light and durable. This makes them suitable as aggregates in making concrete.

1.4.1 Oil Palm Kernel Shell (OPKS)

Oil Palm Kernel Shell or OPKS is a waste material from the palm oil industry. It comes from processing oil palm fruits. When palm oil is extracted from fruit bunches the palm kernels are separated and cracked. This leaves behind an outer shell, which is called Oil Palm Kernel Shell.

Properties of OPKS

- It is lightweight, tough durable. Has a rough surface.
- These properties make it suitable for use in production as a lightweight coarse aggregate.
- Using OPKS in concrete helps make structures lighter without losing strength.
- Also using OPKS of natural aggregates helps save natural resources.
- It reduces the harm caused by quarrying activities.
- OPKS also helps manage waste by turning waste into a useful building material.
- This supports eco- sustainable construction practices, in civil engineering.

1.4.2 Coconut Endocarp (CEP)

The Coconut Endocarp also known as CEP is the inner shell of a coconut. It is located between the coconut husk and the edible kernel. We get CEP as a waste material when coconuts are processed for food, oil and other agricultural products. In countries where coconuts are grown a lot a huge number of coconut shells are produced every year. Usually these shells are thrown away. Used as low-quality fuel. This causes disposal and environmental problems.

1.5 Problem Statement of the Work

The construction industry is growing fast and this is causing a lot of problems. We are using up many natural resources like stones and sand. This is making our environment dirty. Hurting our planet. At the time we have a lot of waste from farms and factories that process coconuts and palm oil. This waste, like Coconut Endocarp and Oil Palm Kernel Shell is usually just thrown away. Burned. This is also bad for our environment.

1.6 Scope of the Work

This study is about using Coconut Endocarp and Oil Palm Kernel Shell as ingredients in making concrete. We are trying to replace some of the ingredients with these waste materials from farms. We want to see how strong the concrete is when we use Coconut Endocarp and Oil Palm Kernel Shell together.

We did some experiments to find out how strong the concrete is. We checked how weight it can hold how well it can stretch and how strong it is when it is bent.

1.7 Objectives of the Study

- ❖ To investigate the suitability of Coconut Endocarp (CEP) and Oil Palm Kernel Shell (OPKS) as partial replacement materials for conventional coarse aggregates in concrete.
- ❖ To develop sustainable hybrid waste aggregate concrete using combined OPKS and CEP materials.
- ❖ To evaluate the mechanical properties of concrete such as compressive strength, split tensile strength, and flexural strength.
- ❖ To compare the performance of conventional concrete and hybrid waste material concrete.
- ❖ To identify the optimum percentage of hybrid waste aggregate replacement for achieving satisfactory strength properties.
- ❖ To encourage sustainable development and conservation of natural aggregate resources.

2.2 Literature Survey

Several researchers have investigated the use of agricultural waste materials such as Coconut Shell (CS), Coconut Endocarp (CEP), and Oil Palm Kernel Shell (OPKS) in concrete production to develop sustainable and lightweight construction materials. The increasing demand for natural aggregates and the environmental problems associated with waste disposal have encouraged the use of these materials as alternative aggregates in concrete. Previous studies mainly focused on the mechanical, durability, and lightweight characteristics of concrete containing shell-based aggregates.

Prusty et al. (2015) Properties of Fresh and Hardened Concrete Using Agro-Waste as Partial Replacement of Coarse Aggregate: study looked at the properties of hardened concrete. They used waste materials to replace some of the coarse aggregate. The study found out that coconut shell and oil palm shell can make lightweight aggregate materials. These materials can be used to make concrete that has satisfactory strength.

Azunna et al.(2019) Compressive Strength of Concrete with Palm Kernel Shell as Partial Replacement for Coarse Aggregate: on the strength of concrete. He used Palm Kernel Shell to replace some of the aggregate. The results showed that using OPKS made the concrete lighter.. When more OPKS was used the compressive strength went down. This was because shell aggregates are not as stiff as stone aggregates.

Ikponmwo et al.(2019) Comparative Study and Empirical Modelling of Pulverized Coconut Shell,

Periwinkle Shell and Palm Kernel Shell as Pozzolans in Concrete: did a study comparing pulverized coconut shell, periwinkle shell and palm kernel shell. They looked at how these materials can be used in concrete as materials. The study found that coconut shell and palm kernel shell have a lot of silica compounds. This means they can replace some of the cement in production and still have acceptable strength.

Alengaram et al.(2019) Use of Oil Palm Shell as an Aggregate in Cement Concrete: reviewed the use of Oil Palm Shell as an aggregate in cement concrete in 2020. They found that oil palm shell concrete can have strengths from 16 MPa to 54 MPa. This makes it suitable for structural concrete applications with good durability.

Kareem et al.(2020) Viability of Agricultural Wastes as Substitute of Natural Aggregate in Concrete: on using waste materials as substitutes for natural aggregates in concrete. They found that coconut shell and oil palm shell aggregates can make concrete lighter. This also provides mechanical and durability properties for sustainable construction.

Futami et al.(2021) Application of Oil Palm Shell as



Aggregate in Concrete – Towards Realising a Pollution-Free Environment and Sustainable Concrete studied the use of coconut and palm oil fibers in cement-based materials in They found that adding fibers improves crack resistance, tensile strength and durability characteristics of concrete composites.

2.3 Research Gap

- ❖ People have studied Coconut Shell and Oil Palm Kernel Shell for a time but mostly they looked at them separately. Not many people have tried to use them in concrete.
- ❖ Most people who did research only looked at how strong the concrete's when you press on it. They did not check important things like how well the concrete can withstand being pulled or bent or how heavy it is or how well it lasts over time.

- ❖ We also do not know how well this kind of concrete will perform after a time or how it will behave in different environments.
- ❖ There is not information on how the cement and the Coconut Shell and Oil Palm Kernel Shell work together at a very small scale.

2.4 Expected Outcomes

- ❖ Development of sustainable and eco-friendly concrete using hybrid agricultural waste materials.
- ❖ Reduction in the consumption of natural coarse aggregates and conservation of natural resources.
- ❖ Effective utilization of Coconut Endocarp and Oil Palm Kernel Shell waste materials in concrete production.
- ❖ Production of lightweight concrete with reduced self-weight compared to conventional concrete.
- ❖ Identification of optimum replacement percentage for achieving satisfactory strength properties.
- ❖ Improvement in sustainable waste management and reduction of environmental pollution.
- ❖ Achievement of adequate compressive, split tensile, and flexural strength for structural or non-structural applications.

3.2 COMPONENT MATERIALS OF CONCRETE

Concrete is a material we use to build things. It is made by mixing cement, sand, gravel and water in the right amounts. Sometimes we also add things to make the concrete better. Each of these parts is important for making the strong long lasting and easy to work with. We need to choose the materials with the right properties to make good concrete. In this study we are using concrete materials and also some new materials, like Coconut Endocarp and Oil Palm Kernel Shell. We want to see if these new materials can help us make concrete in a sustainable way. Concrete is what we are focused on. We want to make sure the concrete we produce is good. We are looking at how Coconut Endocarp and Oil Palm Kernel Shell can be used in production to make the concrete more sustainable.

- Cement,
- Fine Aggregates,
- Coarse Aggregates,
- Oil Palm Kernel Shell (OPKS),
- Coconut Endocarp (CEP),
- Water

3.2.1 Cement

Cement is a material that we use to stick things together when we build something. It gets hard when it meets water and that makes the structure strong. The word cement comes from the Romans who used to make a kind of masonry with crushed rocks and burnt lime. They mixed these things together to make a binder. On people started using volcanic ash and powdered bricks with burnt lime to make a special kind of cement that can get hard even when it is wet.

3.2.2 Aggregates

Aggregates make up most of the concrete in terms of volume. They play a role in determining how good the concrete is. Concrete is like a man-made stone where aggregate materials are held together by cement that has mixed with water. Fine aggregates and coarse aggregates usually take up around 70 to 75 percent of the volume of



concrete.

1. Fine Aggregates
2. Coarse Aggregates



3.2.3 Oil Palm Kernel Shell (OPKS),

The Oil Palm Kernel Shell used in this study had sizes from 5 mm to 20 mm with thickness between 2 mm and 5 mm. Most of the collected samples were medium-sized, between 6 -16 mm making up about 40 % of the total. We mainly used these sized particles for our experiment because they are suitable for making concrete.

The easy availability of OPKS in the Kakinada region reduces transportation costs. Supports using local waste materials in construction. So OPKS, from palm oil industries can be conveniently used for experimental investigations related to lightweight and sustainable concrete production.

3.2.4 Coconut Endocarp (CEP),

Coconut Endocarp is really an useful plant in tropical areas. People often call it the "Tree of Life" "King of Tropical Flora" and "Mans Useful Tree". This is because coconut has uses both at home and in business. Coconut is scientifically known as Cocos nucifera. It is widely grown in regions.

3.2.5 Water

The quality of water used to make concrete is really important for getting the strength, durability and workability of concrete right. According to the Bureau of Indian Standards guidelines in IS 456:2000 the water used to mix and cure needs to be clean and free from bad substances that can cause problems. Water Quality Requirements for Concrete (As per IS 456:2000)

3.3 Characterization of Constituent Materials

The characterization of materials is a step in concrete research. This is because the properties of these materials greatly affect how durable and well concrete performs. In this study we carefully checked all the materials used to make concrete. These materials include cement, aggregate coarse aggregate, Oil Palm Kernel Shell and Coconut shell. We tested them as per Indian Standard codes before using them to make concrete.

3.3.1 Cement

1. Cement Particle Fineness
2. Consistency Test
3. Setting Time of Cement
- Initial Setting Time Test:
- Final Setting Time Test:
4. Relative Density Test

3.3.2 Fine Aggregates

1. Particle Size Analysis of Fine Aggregates
2. Specific Gravity Test and Water Absorption

3.3.3 Coarse Aggregates

1. Particle Size Analysis of Coarse Aggregates
2. Specific Gravity Test

3.3.4 Oil Palm Kernel Shell

1. Specific Gravity

3.3.5 Coconut Endocarp

1. Test Procedure for Specific Gravity

3.4 Mix Proportion Calculation

To get the strength and durability in concrete we need to calculate the mix proportion. This is a step, in designing the concrete mix. We have to mix the amounts of cement, fine aggregate coarse aggregate, water and other materials. We follow the Indian Standard guidelines to get the grade of concrete. If we do this correctly the concrete will be uniform, cost-effective and work well when it is being used

3.4.1 Mix Design for M25 Grade Concrete

We did the mix design for M25 grade concrete following IS 10262:2019. Is 456:2000 standards. The goal was to get the compressive strength, workability and durability, for M25 grade concrete. To achieve this we chose the materials found the perfect water-cement ratio calculated the material quantities and mixed the ingredients just right for 1 m³ of M25 grade concrete.

1. Material Properties

Table No: 11 Material Properties

S.No	Material	Specific Gravity
1	Cement	3.15
2	Fine Aggregate	2.65
3	Coarse Aggregate	2.74
4	Oil Palm Kernel Shell	1.80
5	Coconut Endocarp	1.18

2. Target Mean Strength

Characteristic compressive strength: $f_{ck}' = f_{ck} + 1.65S$,
Where: f_{ck} = Characteristic compressive strength = 25 MPa, S = Standard deviation = 4 MPa
 $f_{ck}' = 25 + 1.65(4) = 31.6$ MPa,
Target mean compressive strength = 31.6 MPa.

3. Selection of Water-Cement Ratio

Based on IS Recommendations: Water-Cement Ratio=0.45

4. Water Content

For 20 mm aggregate and medium workability: Water Content= 186 litres

5. Cement Content

Cement Content= $0.45 / 186 = 413.33$ kg/m³, Adopted cement content = 413 kg/m³

6. Volume of Materials

Volume of Cement = $V_c = 413 / (3.15 \times 1000) = 0.131$ m³

Volume of Water, $V_w = 186 / 1000 = 0.186$ m³

Volume of Entrapped Air For 20 mm aggregate: $V_a = 0.02$ m³

Volume of Aggregates = $V_{agg}=1-(V_c+V_w+V_a)$

$V_{agg}=1-(0.131+0.186+0.02)=0.663 \text{ m}^3$

7. Quantity of Fine Aggregate

For Zone II sand, fine aggregate proportion = 35%, VFA = $0.35 \times 0.663 = 0.232 \text{ m}^3$

For coarse aggregate proportion = VCA = $0.65 \times 0.663 = 0.431 \text{ m}^3$

8. Mass of Aggregate

MFA = $0.232 \times 2.65 \times 1000 = 615 \text{ kg/m}^3$

MCA = $0.431 \times 2.74 \times 1000 = 1181 \text{ kg/m}^3$

9. Final Mix Proportion

The final mix proportion for M25 grade concrete was obtained as: Mix Ratio, 1:1.63:2.87

10. Material Proportion Table for M25 Grade Concrete

Table No: 12 Material Proportion Table

S.No	Mix Type	ID	Cement (kg/m ³)	FA (kg/m ³)	CA (kg/m ³)	OPKS (kg/m ³)	CEP (kg/m ³)	Water (L/m ³)
1	CC	CC	413	672	1185	0	0	186
2	OPKS10%+ 3% CEP	KCS-I	413	672	1032	118.5	35.5	186
3	OPKS20%+ 3% CEP	KCS-II	413	672	913	237	35.5	186
4	OPKS30%+ 3% CEP	KCS-III	413	672	795	355.5	35.5	186
5	OPKS40%+ 3% CEP	KCS-IV	413	672	676	474	35.5	186

3.5 Mixing of Concrete Constituents

3.6 Fabrication of Concrete Specimens



3.7 Curing of Concrete Specimens



4.2 Evaluation of Concrete Properties

- Tests on Fresh Concrete
- Tests on Harden Concrete

4.2.1 Tests on Fresh Concrete

1. Slump Cone Test



S.No	Mix Type	ID	Slump (mm)
1	CC	CC	85
2	OPKS10%+ 3% CEP	KCS-I	80
3	OPKS20%+ 3% CEP	KCS-II	78
4	OPKS30%+ 3% CEP	KCS-III	88
5	OPKS40%+ 3% CEP	KCS-IV	92

2. Compaction Factor Test

S.No	Mix Type	ID	P C	F C	C F
1	CC	CC	14.4	15.8	0.9
2	OPKS10%+ 3% CEP	KCS-I	14.9	16	0.9
3	OPKS20%+ 3% CEP	KCS-II	15	16.1	1
4	OPKS30%+ 3% CEP	KCS-III	14.1	15.8	0.9
5	OPKS40%+ 3% CEP	KCS-IV	13.7	15.9	0.9

4.2.2 Tests on Harden Concrete

1. Compressive strength of concrete



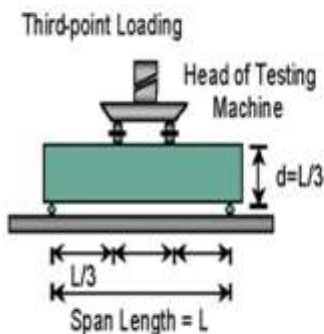
M 25 Grade Concrete Compressive Strength Test (MPa)					
S.No	Mix Type	ID	7 Days	14 Days	28 Days
1	C C	C C	21.84	26.7	31.98
2	OPKS10%+ 3% CEP	KCS-I	22.42	28.23	32.22
3	OPKS20% + 3% CEP	KCS-II	23.84	29.35	34.11
4	OPKS30% + 3% CEP	KCS-III	21.96	27.84	31.27
5	OPKS40% + 3% CEP	KCS-IV	20.88	26.45	30.14

2. Split Tensile Strength Test



M 25 Grade Concrete Split Tensile Strength Test (MPa)					
S.No	Mix Type	ID	7 Days	14 Days	28 Days
1	C C	C C	2.2	2.96	3.42
2	OPKS10%+ 3% CEP	KCS-I	2.18	2.92	3.48
3	OPKS20% + 3% CEP	KCS-II	2.26	3.04	3.56
4	OPKS30% + 3% CEP	KCS-III	2.08	2.81	3.26
5	OPKS40% + 3% CEP	KCS-IV	1.96	2.62	3.08

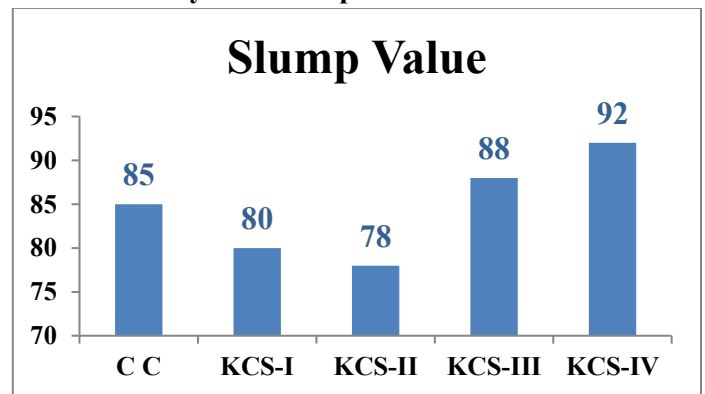
3. Bending Strength Test



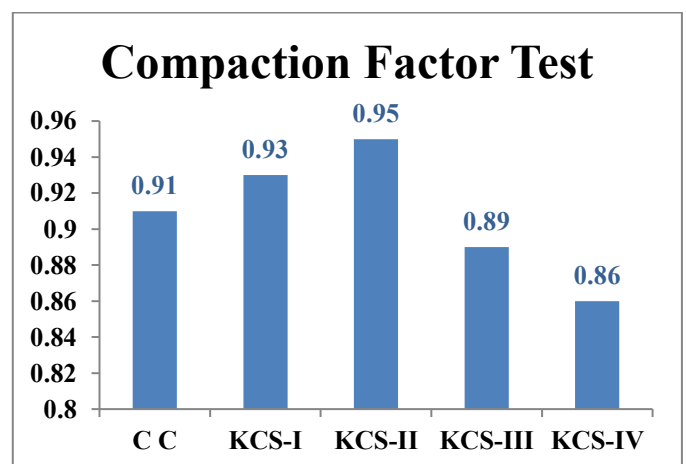
M 25 Grade Concrete Flexural Strength Test (MPa)					
S.No	Mix Type	ID	7 Days	14 Days	28 Days
1	C C	C C	3.08	4.02	4.56
2	OPKS10%+ 3% CEP	KCS-I	3.12	4.08	4.68
3	OPKS20% + 3% CEP	KCS-II	3.24	4.18	4.82
4	OPKS30% + 3% CEP	KCS-III	2.94	3.86	4.32
5	OPKS40% + 3% CEP	KCS-IV	2.76	3.64	4.08

5.2 Result and Analysis

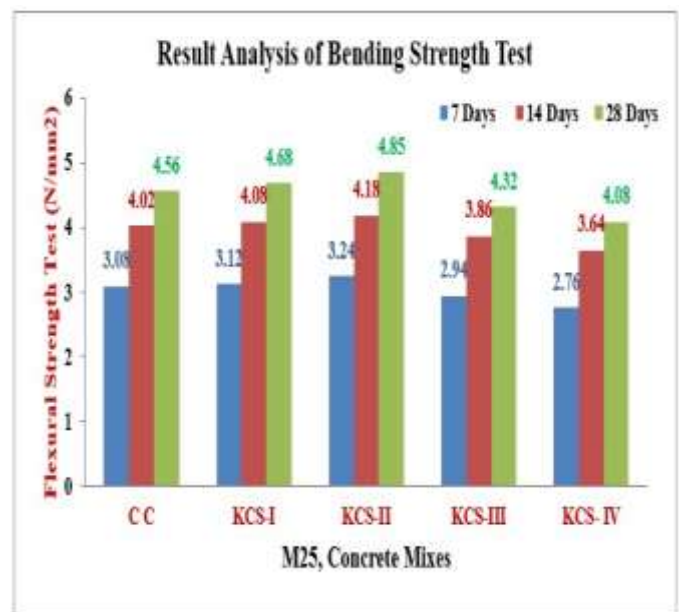
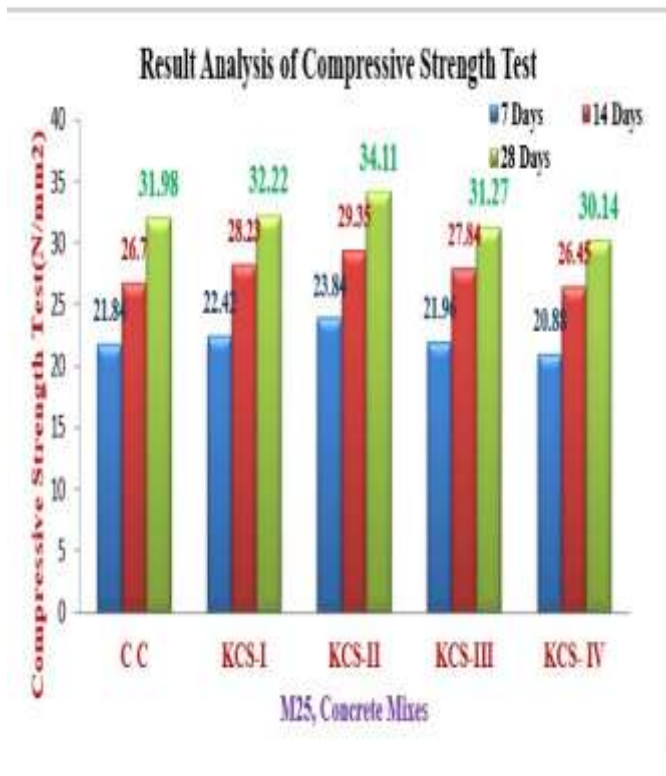
1. Result Analysis of Slump Test



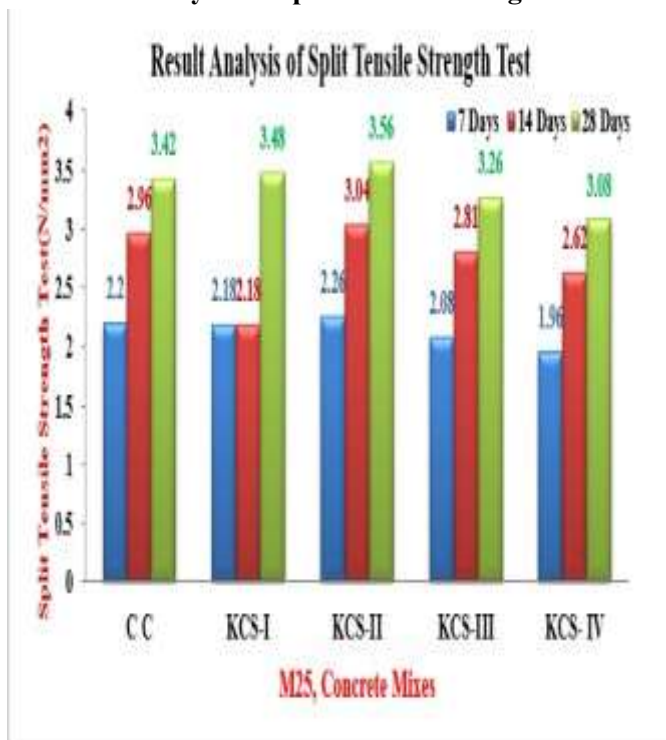
2. Result Analysis of Compaction factor test



3. Result Analysis of Compressive Strength Test



4. Result Analysis of Split Tensile Strength Test



5. Result Analysis of Bending Strength Test

5.2 CONCLUSION

The experimental investigation confirmed that Oil Palm Kernel Shell (OPKS) and Coconut Endocarp (CEP) can be effectively utilized as sustainable alternative materials in M25 grade concrete.

Slump Cone Test: The slump test results indicated that lower replacement levels slightly reduced workability due to the porous and rough surface texture of OPKS and CEP, while higher replacement levels improved slump values because of the lightweight nature of shell aggregates.

Compaction Factor Test: The compaction factor test revealed that OPKS20% + 3% CEP exhibited the optimum compaction factor value, indicating better particle packing and internal cohesion.

Compressive Strength Increase: The results for strength showed that the mix of OPKS20% and 3% CEP was stronger than the regular concrete mix. After 28 days the regular concrete had a strength of 31.98 MPa. The modified concrete was stronger at 34.11 MPa. This means the strength increased by 2.13 MPa, which's about 6.66% stronger. The reason for this increase in strength is that the particles packed better the filler worked well. The bonding between the particles in the concrete was better.

Split Tensile Strength Increase: The results for tensile strength showed that the mix of OPKS20% and 3% CEP was better at handling tension than the regular mix. After 28 days the regular concrete had a tensile strength of 3.42 MPa but the modified concrete was stronger at 3.56 MPa. This is an increase of 0.14 MPa, which's about 4.09% better. The reason for this improvement is that the stress was transferred better and the concrete was more resistant to cracks.

Flexural Strength Increase: The results for strength showed that the mix of OPKS20% and 3% CEP was better at handling bending than the regular concrete. After 28 days the regular concrete had a strength of 4.56 MPa but the modified concrete was stronger at 4.82 MPa. This is an increase of 0.26 MPa, which's about 5.70% better. The reason, for this improvement is that the mix of OPKS20% and 3% CEP helped to bridge the cracks and distributed the stress more evenly in the concrete.

The overall experimental results identified OPKS20% + 3% CEP as the optimum replacement level for achieving better mechanical performance in sustainable lightweight concrete.

The utilization of OPKS and CEP helps in reducing agricultural waste disposal problems and minimizes the consumption of natural coarse aggregates.

The study demonstrates that sustainable concrete incorporating agro-industrial waste materials can be successfully used for structural and non-structural construction applications.

Overall Conclusion

The test results show that adding 20% Oil Palm Kernel Shell and 3% Coconut Endocarp to M25 grade concrete makes it stronger. When we look at all the mixes the mix with 20% Oil Palm Kernel Shell and 3% Coconut Endocarp is the best. It makes the concrete better at handling pressure, stretching and bending. The biggest difference we see is in how pressure the concrete can handle, which is about 6.66% better, than regular concrete. Oil Palm Kernel Shell and Coconut Endocarp really make M25 grade concrete perform better.

5.3 FUTURE SCOPE

- We can do research on high grade concrete that uses OPKS and Coconut Endocarp. This research can look at how the concrete lasts over time. For example we can see how the concrete does when it is exposed to chloride, sulphate and acid.
- We can also use tools like SEM and XRD to study how the OPKS and Coconut Endocarp work together in the concrete.
- We can also study how well the concrete does in earthquakes and other situations where there are a lot of forces acting on it.
- Using chemicals and minerals can help make the OPKS concrete even stronger and last longer.
- In the future we can study how well the concrete does when it is bent or pulled especially when it is used to make reinforced beams with OPKS and Coconut Endocarp.
- We should also look at how good the concrete's for the environment and if it is cost effective.

- Using OPKS and Coconut Endocarp concrete to make elements, pavements and low cost housing can be a good idea.
- We can also try mixing waste materials with industrial by products to make high performance sustainable concrete.
- This can include combining OPKS with materials to make the concrete even better.

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