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# A review on Application of Coconut Shell in Concrete

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***Abstract:*** **-- The rising cost of material is a matter of concern in this developing construction environment. The reason for the increase in cost is high demand and less availability of materials. The research on alternative materials which can reduce the cost of construction and on the other hand increases the strength and durability of structures is on demand, with regard to this the research on waste material such as fly ash, rice husk, slag and sludge is going on. Coconut shell is an agricultural waste which is abundant to the environment and also raises the risk to health as well as environment. From the previous research, it has been found that coconut shell ash (CSA) can increase the strength of concrete and coconut shells can be used as a replacement to the aggregate in concrete. Silica is important oxide present in coconut shell ash that can help in increasing strength of the concrete. Therefore the research in the extraction of silica from CSA as well as the use of coconut shell either in the form of reduced size or the burnt ash is going on. The present paper provides a review of the application of coconut shell in the concrete along with details of experimental work done by various researchers for investigation of the use of coconut in the construction industry. The paper describes the use of coconut shell as partial replacement to the coarse aggregate as well as use of CSA for partial replacement of cement and use of silica extracted from CSA as an admixture along with their effects on properties of concrete.**

***Index Terms*****: - Buildings, Catastrophic, Earthquake, Heritage.**

## I. INTRODUCTION

In today's era use of natural resources in construction industry is increasesing day by day. Due to this the shortage of natural resources comes into picture. Because of the shortage, cost of natural material is also increasesing. Depletion of natural material is causing threat to the environment. Due to this, sometimes quality of construction may get compromise. To avoid this, replacement of natural resources by alternative material is necessary. Concrete is a widely used structural material. Cement is used as binder or mortar so consumption of it in construction is high, for this search for alternative material is required.

Recently, many studies have been carried out on the possibility of reuse of waste material especially with regard to the building and construction material such as cement, concrete and brick blocks. The technical importance of using waste material in mortar or concrete production is normally assisted by its performance.

Disposal of agricultural waste materials such as coconut shell, rice husk, groundnut husk, corn cob and have constituted an environmental challenge, hence there is a need to convert them into useful materials to minimize their negative effect on the environment. The use of waste material having cementatious properties as an addition or replacement of cement in cement mortar or in concrete has become the thrust area of construction of material experts and researchers.

This review briefly addresses various aspects of use of coconut shell and effect of coconut shell, CSA and extracted silica in concrete and mortar.

## II. LITERATURE REVIEW

Amarnath Yerramala, Ramachandrudu C [1], Parag S. Kambli, Sandhya R. Mathapati [2], S. A. Kakade, Dr. A. W. Dhawale [3], K.Gunasekaran, P.S.Kumar [4] these authors work on partial and full replacement of coconut shells to course aggregate and study the properties of concrete to enhance strength of concrete. Utsev, J. T., Taku, J. K. states that the cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement. [5] Vignesh Kumar Nagarajan, S. Aruna Devi, S. P. Manohari, M. Maria Santha study partial replacement of coconut shell ash to cement in concrete [6].

Oyedepo OJ, Olanitori LM and Akande SP study comparison between coconut shell ash and palm karnel shell ash replacement to the cement in concrete. [7] Neetesh Kumar and

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Dilip Kumar study Utilization of Coconut Shell in different Forms in Concrete. [8] S.sivasubramanian and kurcharlapati sravanthi worked on synthesis and characterisation of silica nano Particles from coconut shell. [9]

state of art of use of coconut shell

**3.1 Application of Coconut shells (CS) as replacement to the aggregate**.

In order to investigate properties of CS concretes, six mixes were employed. Control mix (M1) that is, without CS was made. Coarse aggregate was then replaced with CS in 10 (M2), 15 (M3), 20 (M4) percentages to study effect of CS replacement. Furthermore, a mix with both CS and fly ash (M5) was also employed, in which, 20% of CS was replaced with aggregate and 25% of fly ash was replaced with cement. M6 mix contained 20% of coconut shells and 5% of fly ash both replaced with aggregate. Free water to cement ratio was maintained constant at 0.6 for all concrete mixes. Extra water was added if required.[1]

| concrete name | Cement, kg/m$^3$ | f, kg/m$^3$ | CA, kg/m$^3$ | FA, kg/m$^3$ | CS, kg/m$^3$ | w/cm |
|---|---|---|---|---|---|---|
| M1 | 300 | 0 | 1170 | 750 | 0 | 0.6 |
| M2 | 300 | 0 | 1053 | 750 | 117 | 0.6 |
| M3 | 300 | 0 | 994.5 | 750 | 175.5 | 0.6 |
| M4 | 300 | 0 | 936 | 750 | 234 | 0.6 |
| M5 | 225 | 75 | 936 | 750 | 234 | 0.6 |
| M6 | 300 | 96 | 813.12 | 750 | 203.28 | 0.6 |

CS-coconutshells, f- fly ash, CA- coarse aggregate, FA-fine aggregate, cm-cementitious materials (c+f)

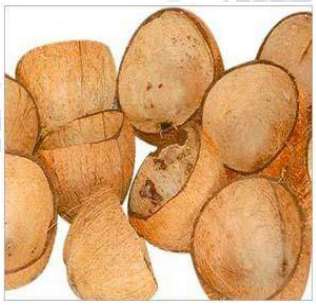
***Fig 1.Mixture proportions [1]***

The concretes were mixed in a planetary mixer of 100 l capacity. The mixing time kept to about 3 to 4 min. mixing of the materials was in a sequence: (i) portion of design water poured into mixture drum; (ii) cement gently placed; and (iii) aggregate and CS was spread over the cement and started mixing. During mixing, the remaining design water was poured into the mix for thorough mix of concretes. Specimens were then prepared and left for 24 hours. The specimens were demoulded after 24 hours and immersed in normal water for curing until the test age. [1] Natural material is coconut shell as course aggregate will be investigated to replace the aggregate in concrete. In this study, three different concrete mixes namely M20, M35 & M50 grade with different combination of natural material CS content in the proportion 0%, 10%, 20%, 30% and 40% will be replaced. Six sample specimen will be prepared for each concrete mixes. The parameters will be tested are compressive strength behaviour of cube specimens for 7 & 28 days.[2]

S. A. Kakade, Dr. A. W. Dhawale, studied different percentage replacement of CS to aggregate ie.0%, 25%, 50%. Three samples specimen will be prepare for each concrete mixes. The parameters will be tested are compressive strength, tensile strength.[3] The physical properties of crushed coconut shell aggregate and The fresh concrete properties such as density and slump and 28-day compressive strength of a lightweight concrete made with coconut shell as coarse aggregate done by K.Gunasekaran, P.S.Kumar[4]

**3.2 Application of CSA as partial replacement to the cement.**

The coconut shell was sun dried for 48 hours to remove moisture from it. It was then subjected to uncontrolled combustion using open air burning for 3hours and allowed to cool for about 12hours. The burnt ash was collected and sieved through a BS sieve (75 microns). The resulting ash, which has the required fineness, was collected for use. The oxide composition of the ash was determined. Using a mix design ratio of 1:2:4 and water binder ratio of 0.5, a total of 54 Concrete cubes of size 150mm x150mm x 150mm were cast using varying OPC-CSA Ratio of 100:0, 90:10, 85:15, 80:20, 75:25 and 70:30 respectively, i.e., 9 cubes per percentage replacement. The cubes were cured and crushed after 7, 14 and 28 days respectively to determine the compressive strength. [5] CSA is incinerated in muffle furnace at 800oC for 6 hrs to produce coconut shell ash (CSA), which in turn was used as pozzolana in partial replacement of cement in concrete production. Concrete mortar cubes were produced using replacement levels of 0 and 5 percent of OPC with CSA. The Coconut Shell ash is used for the partial replacement of cement.[6]



***(a)***

***(b)***

***(c)***

***Fig2. (a) Coconut shell (b) Muffel furness(c)Coconut shell ash.***

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The palm kernel shell (PKS) and coconut shell (CS) was sun dried and subjected to internal combustion using a furnace, burnt for 24 – 48 hours and allowed to cool for about 12 hours. The burnt ash was collected and sieved through a BS sieve (75 microns). The resulting palm kernel shell ash (PKSA) and coconut shell ash (CSA) which has the required fineness was collected for use, Using a mix design ratio of 1:2:4 and water binder ratio of 0.63, a total of one hundred and forty four concrete cubes of size 150x150x150 mm were casted using varying OPC : PKSA and OPC : CSA ratios of 100:0 , 90:10 , 80:20 , 70:30 , 60:40 and 50:50 respectively i.e. 12 cubes for each percentage of replacement. The cubes were cured and crushed after 7, 14, 21 and 28 days respectively to determine the compressive strength.[7]

### 3.3 Extraction of nano silica from CSA

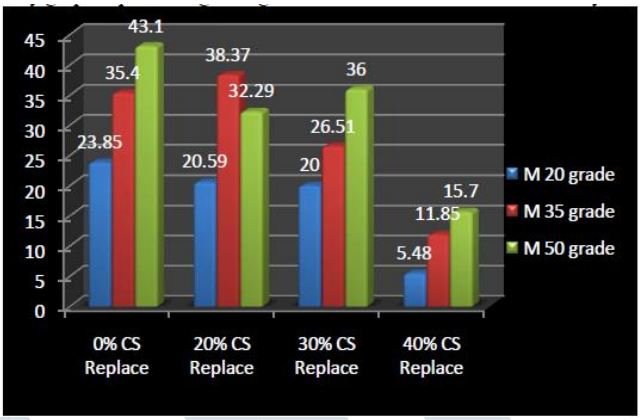
Preparation of coconut shell Ash done by following method,
50 grams of coconut shell pieces is taken in a silica crucible and heated in muffle furnace (HITECH, SUNBIM, INDIA) for 5 hours at7000C.The volatile matter is removed and 8grams of CSA content is left behind. CSA thus obtained is subjected to chemical treatment to recover silica nano particles. This chemical treatment is the procedure of extraction of silica from CSA and The formed silica nano particles were characterized by FTIR, XRD and SEM.[9]

## IV. RESULTS AND DISCUSSION

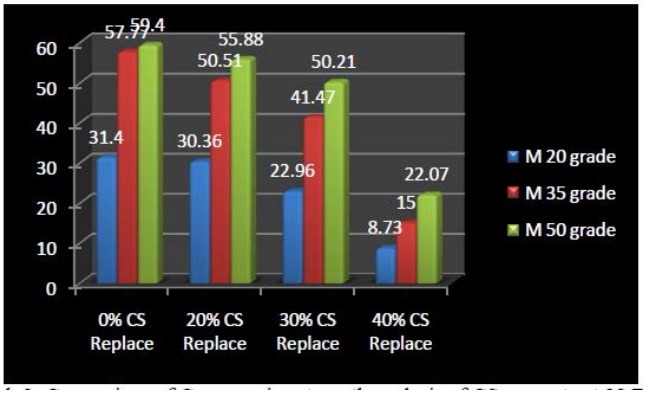
***Table1. Properties of Concrete with Coconut Shells as Aggregate Replacement [1]***

| Mix name | Slump, mm | Density, kg/m3 | Compressive Strength, MPa | | | Split Tensile Strength, MPa | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 day | 7 day | 28 day | 1 day | 7 day | 28 day |
| M1 | 25 | 2365 | 6.84 | 11.11 | 22.33 | 0.38 | 0.76 | 2.39 |
| M2 | 23 | 2186 | 3.2 | 5.16 | 13.56 | 0.19 | 0.95 | 1.51 |
| M3 | 22 | 2117 | 3.56 | 7.29 | 12.56 | 0.45 | 0.95 | 1.35 |
| M4 | 20 | 2061 | 3.91 | 7.82 | 9.33 | 0.25 | 0.76 | 1.15 |
| M5 | 23 | 2027 | 2.22 | 3.47 | 7.22 | 0.19 | 0.64 | 0.8 |
| M6 | 26 | 2023 | 3.40 | 5.56 | 9.67 | 0.32 | 0.57 | 1.08 |

With CS percentage increase the 7 day strength gain also increased with corresponding 28 day curing strength. However, the overall strength decreased with CS replacement when compared to control concrete. Furthermore, fly ash as cement replacement had negative influence when compared to corresponding CS concrete and fly ash as aggregate replacement had similar performance as that of corresponding CS replaced concrete. Similar to compressive strength, the split tensile strength also decreased with increase in CS replacement. Furthermore, for 28 days of curing addition of fly ash as cement replacement reduced overall split tensile strength of CS concrete and fly ash.[1]




***Graph1. Comparison of Compressive strength analysis of CS concrete at 7 Days [2]***




***Graph2. Comparison of Compressive strength analysis of CS concrete at 28 Days [2]***

For M20 grade concrete cubes with 30% replacement of CS aggregates had given requisite strength of 23 Mpa at 28 days. Hence, it can be used with proportions varying from 0-30%. for M35 grade concrete cubes with 30% replacement of CS aggregates had given strength of 42 Mpa at 28 days and for M50 grade concrete cubes with 30% replacement of CS aggregates had given requisite strength of 51 Mpa at 28 days. Further replace CS up to 40% which gives M20 grade concrete strength so; we can use it as M20 grade concrete up to 40% CS replaced for low cost housing & the places where it is easily available. [2]

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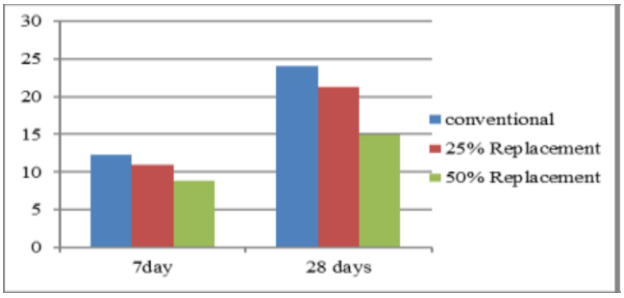


***Fig3. Comparison between compressive Strength of Conventional Concrete And 25% and 50% Replacement Coconut Shell Concrete [3]***

The 28 days compressive strength of coconut shell concrete was found to be 21.31 for 25% replacement by coconut shell aggregate it satisfies the requirement for structural lightweight concrete. And compressive strength of coconut shell concrete was found to be 14.88 for 50% replacement by coconut shell aggregate under full water curing and it can be used for less important work.[3] CSA contains 37.97% SiO2, 24.12% Al2O3 and 15.48% Fe2O3. This gives 77.57% of SiO2+ Al2O3+Fe2O3which is in line with ASTM C 618-78 requirement of 70% minimum for pozzolanas. Thus, CSA meets the requirement for a pozzolana. The LOI of 11.94 and SO3 of 0.71 all fall within agreeable limits. [5]

***Table 2: Oxide composition of CSA and OPC respectively [5]***

| Oxide | Percentage composition (%) | |
|---|---|---|
| | CSA | OPC |
| Sio2 | 37.94 | 20.70 |
| Al2O3 | 24.12 | 5.75 |
| Fe2O3 | 15.48 | 2.50 |
| CaO | 4.98 | 64.0 |
| MgO | 1.89 | 1.00 |
| MnO | 0.81 | 0.20 |
| Na2O | 0.95 | 0.60 |
| K2O | 0.83 | 0.15 |
| P2O5 | 0.32 | 0.05 |
| SO3 | 0.71 | 2.75 |
| LOI | 11.94 | 2.30 |

The 7 days strength decreases from 13.78N/mm2 for OPC to 6.43N/mm2 for 30% replacement with CSA. The strength after 28 days curing decreases from 34.22N/mm2 for OPC to 13.11N/mm2 30% replacement with CSA. The optimal 28 days strength for OPC-CSA mix is recorded at 10% replacement (31.78N/mm2).

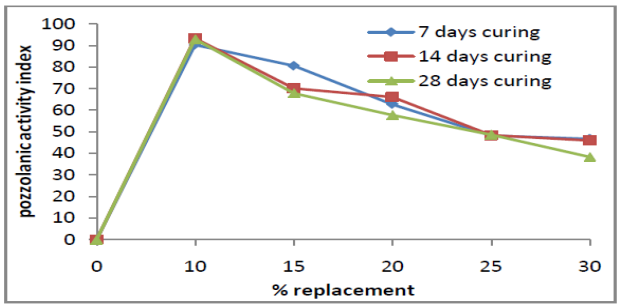


***Fig4. Compressive strength at various percentage replacements 0-30%[5]***

Decrease in pozzolanic activity with increasing percentage replacement, which is expected, since the strength decrease with increasing percentage replacement of OPC with CSA. The compressive strength decreases with increase in percentage replacement of OPC with CSA. The 7 days Strength decreases from 13.78N/mm2 for OPC to 6.43N/mm2 for 30% replacement with CSA. The strength after 28 days curing decreases from 34.22N/mm2 for OPC to 13.11 N/mm2 30% replacement with CSA. The optimal 28 days strength for OPC-CSA mix is recorded at 10% replacement (31.78N/mm2).[5]

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***Table 3: Results of the test carried out on the concrete mix for Palm Kernel Shell Ash (PKSA)[7]***

| Replacement (%) | Slump (mm) | Fully compacted concrete (fc) | Partially compacted concrete | Compacting factor (pc/fc) | Air entrainment (%) | Pressure | Water cement ratio |
|---|---|---|---|---|---|---|---|
| 0 | 55 | 17.2 | 15.2 | 0.90 | 1.5 | 1.5 | 0.55 |
| 10 | 35 | 17.2 | 15.6 | 0.90 | 0.5 | 1.5 | 0.61 |
| 20 | 50 | 17.1 | 16.4 | 0.95 | 0.5 | 1.5 | 0.63 |
| 30 | 38 | 17.1 | 16.0 | 0.93 | 1.2 | 1.5 | 0.55 |
| 40 | 33 | 17.2 | 15.8 | 0.91 | 0.8 | 1.5 | 0.63 |
| 50 | 35 | 17.1 | 16.8 | 0.98 | 0.6 | 1.5 | 0.55 |

***Table 4: Results of the test carried out on the concrete mix for CSA.[7]***

| Replacement (%) | Slump (mm) | Fully compacted concrete (fc) | Partially compacted concrete | Compacting factor (pc/fc) | Air entrainment (%) | Pressure | Water cement ratio |
|---|---|---|---|---|---|---|---|
| 0 | 60 | 17.6 | 16.5 | 0.94 | 1.2 | 1.5 | 0.5 |
| 10 | 65 | 17.58 | 16.4 | 0.93 | 1.0 | 1.5 | 0.55 |
| 20 | 65 | 17.8 | 16.65 | 0.94 | 0.8 | 1.5 | 0.6 |
| 30 | 55 | 17.75 | 16.8 | 0.93 | 0.6 | 1.5 | 0.61 |
| 40 | 40 | 17.63 | 16.61 | 0.94 | 0.61 | 1.5 | 0.64 |
| 50 | 55 | 17.5 | 16.1 | 0.92 | 1.0 | 1.5 | 0.64 |

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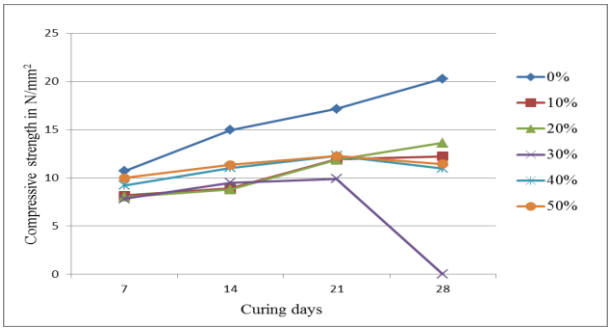


*Fig 5. Compressive strength with Partial Replacement of Cement with PKSA*

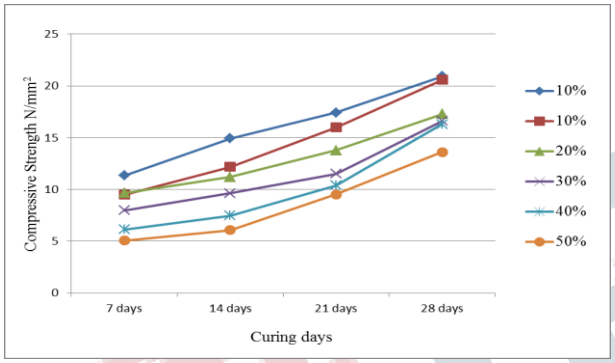


*Fig 6. Compressive strength with Partial Replacement of Cement with CSA*

This work has shown that partial replacement of cement with 20% palm kernel shell ash and coconut shell ash in concrete gives an average optimum compressive strength of 15.4 N/mm2 and 17.26 N/mm2 respectively at 28 days.[7]

Extraction of silica from the coconut shell ash gives following test results: Thermal gravimetric analysis of coconut Shell gives the proximate analysis of the coconut shell shows high quantity of volatile matter, then fixed carbon, moisture content and least amount of ash content are as shown below.

*Table 5 .Proximate analysis results of coconut shell [9]*

| | |
|---|---|
| Fixed carbon (wt. %) | 21.75 |
| Volatile matter (wt. %) | 71.06 |
| Sample Moisture (wt. %) | 8.53 |
| Ash (wt. %) | 0.66 |

The thermal gravimetric analysis of coconut shell shows that the weight loss accelerates from 200 °C, which can be attributed to the release of H2O and CO2 resulting from the decomposing of cellulose and lignin in coconut shell.

*Table 6 : Elemental composition of silica nanoparticles by EDAX [9]*

| Element | Percentage by weight |
|---|---|
| C | 0.301 |
| O | 0.867 |
| Na | 0.76 |
| Si | 98.01 |
| S | 0.062 |
| Total | 100 |

CSA contain high content of silicon and some impurities like sodium, potassium, calcium, iron, copper, magnesium, lead and manganese.

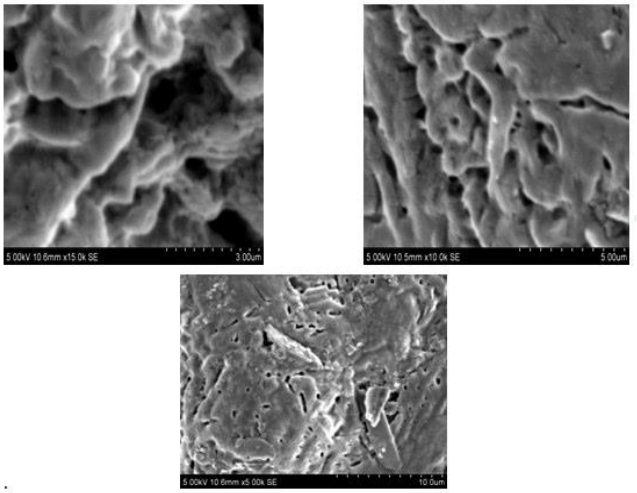

*Fig 7. SEM of nanosilica obtains from chemically treated CSA at 3µm, 5µm and 10µm.*

The SEM of nanosilica provides further insight of the morphology and size details of the silica nano particles. The silica nano particles were non uniform as shown in Fig 5. This might may be due to the to the fact that, in coconut shell the silica form rigid caves that surround the organic matter.

## V. SUMMURY AND COMMENTS

A brief review of recent research and technology based, we conclude that, Coconut shell has potential as lightweight aggregate in concrete. Also, using the coconut shell as aggregate in concrete can reduce the material cost in construction Replacement of CSA does not give adequate strength to cement so we can use CSA as a admixture it will help in accelerating strength of concrete or mortar.. By observing literature we come to know coconut shell ash has properties like cement it will defiantly help to enhance the compressive strength of concrete.

The need for well-defined SiO2 nano particles is becoming increasing now a day. Coconut shell is a common household waste burnt at controlled temperature produces large amount CSA. The CSA can be subjected to chemical treatment to recover SiO2 nano particles.

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