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# An Experimental Study On Strength Characteristics Of Ternary Blended Concrete Using Metakaolin , Groundnut Shell Ash And Recycled Coarse Aggregate

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**Abstract:** The implementation of construction ,industrial and agricultural wastes produced by industrial processes has been the subject of waste reduction research for economical aspects , environmental safety and technical sollutions. Presently there is a shortage of concrete materials, so we are in need to come up with The alternative materials to concrete. In this situation we should utilize the larger amount of waste products which is available. For example - construction & demolition waste (recycled Aggregates) agriculture wastages (groundnut shells) , plastic waste etc. In This experimental study,cement was replaced by 0%,5%.10%,15% percentage with (G.S.A.)groundnut shell ash and constant percentage of Metakaolin (15%) by weight. Results show that use of 5% G.S.A. and 15% metakaolin gives as optimum result so 20% use of cement can be reduced . then using optimum mix ,four mixes of concrete with replacement of natural coarse aggregate by (0% ,25%,50%,75% and 100%) recycled coarse aggregates(R.C.A.) were carrid out.Tests were conducted for coarse aggregates , workability of fresh concrete (Slump test), strength of hardened concrete (Compressive strength and Split tensile strength ) for M25 concrete using IS method. Based on present study,definite conclusions have been arrived and suggestions for further works have also been given. Test results indicated that the use of 5% groundnut shell ash and 15% Metakaolin as partial replacement of cement in concrete with use of 25% replacement of natural coarse aggregates with recycled coarse aggregates resulted in improvement in mechanical strengths and can be effectively used in structural concrete . later at 50% , 75% and 100% the compressive strength andsplittensilestrength of the concrete goes on reducing as the recycled aggregate content increases with limiting to control concrete .

**Key Words:**Groundnut shell ash , Recycled Coarse Aggregates , Metakaolin, Concrete Mix Design.

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## I. INTRODUCTION

Huge quantities of construction materials are required in developing countries due to continued infrastructural growth and also huge quantities of construction and demolition wastes are generated every year in developing countries like India.Over the years, many waste materials like fly ash and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, millet husk ash have been tried as pozzalona or secondary cementious materials.

Groundnut shell is an important cash crop produced in large quantity in India. The groundnuts production volume amounted to about 6.5 million metric tons in the country during fiscal year 2017, down from 6.77 million metric tons in fiscal year 2016.Gujarat has top production of groundnut in 2015-16 year which is followed by Rajsthan ,Tamil Nadu , Andhra Pradesh , Karnataka, Madhya Pradesh, Others, Maharashtra, Telangana,, Uttar Pradesh.Gujarat is expected to harvest 29.40 lakh tonnes during kharifseason. The utilization of groundnut husk will promote waste management at little cost, reduce pollution by these wastes and increase the economic base of farmers when the waste is sold thereby encouraging more production.

Supplementary cementing materials (SCMs) have been widely used all over the world in concrete due to their low economic, high strength and good environmental benefits.Er. Mohit&Er. Ravinder Kumar M.tech ( 2015) Concluded that The inclusion of metakaolin as a cement replacing material provides an excellent improvement in the compressive strength of the concrete M25 mix.The utilization of supplementary cementitious material like Metakaolin concrete can compensate for environmental and technical issues.Mix with 15 % metakaolin is superior to all other mixes.

OPC is the typically most expensive constituent of concrete, the replacement of proportion of it with Groundnut Shell Ash(GSA) may improve concrete affordability particularly for low cost housing. The use of

GSA may contribute not only to the production of concrete of higher quality and lower cost but also lead to reduction of carbon dioxide(CO2) emission from the production of cement . Ground nut shell Ash is obtained from Groundnut shell, and is combusted to very high temperature.

In manufacturing of concrete aggregates are generally obtained from natural deposits of sand and gravel, or from quarries by cutting rocks. Nowadays, these sources of natural aggregates are in the state of depletion and their extraction also has harmful effects on the environment. For this reason, it is important to optimize the consumption of natural aggregates as well as to enhance their replacement by other alternative sources as like recycled coarse aggregates.

In the present investigation Ternary Blended concrete of groundnut shell ash and metakaolin has been used. The binary blend of concrete using groundnut shell ash has the advantage of producing better workability but there is a late development of strength. When metakaolin is used in the binary blend of concrete, there is an early gain of strength but the concrete produced is lesser workable. So, when the groundnut shell ash and metakaolin are used, the ternary blend of concrete gives good workability as well as there is an early gain in strength. Ternary blended Concrete is that which has the inclusion of two different pozzolanic materials with the Portland cement. Then after getting optimum proportion in cement replacement , natural coarse aggregates are replaced with recycled coarse aggregates with that proportion.

## II. MATERIAL AND METHODOLOGY

### 2.1 Materials Used : -

**Cement:** The term cement is used to designate many different kinds of substances that are used as binder or adhesives. In the experimental study, we used "ULTRATECH Cement" OPC of 53 Grade. It is locally available in Rajkot city of Gujarat. properties of the cement tested according to Indian Standards procedure confirms to the requirements of IS: 122-69.

**Table 1:-** Properties of Cement,GSA and Metakaolin.

| Chemical composition | Cement % | GSA% | Metakaolin % |
|---|---|---|---|
| Silica (SiO2) | 21.04 | 22.52 | 47.00% ± 0.50% |
| Alumina Al2O3 | 6.02 | 3.55 | 49.00% ± 0.50% |
| Calcium oxide CaO | 62.93 | 5.88 | 0.39 ± 0.05% |
| Ferric oxide Calcium oxide (Fe2O3) | 3.77 | 2.4 | 0.85 ± 0.10% |
| Magnesium oxide (MgO) | 2.49 | 2.74 | 0.11 ± 0.50% |
| Sodium + Potassium oxide ($Na_2O$ + $K_2O$ ) | - | 8.12 + 4.15 | 0.35 ± 0.05% |
| Sulphuric anhydride (SO4) | 1.72 | 2.4 | - |
| Titanium dioxide ( $TIO_2$ ) | - | - | 1.25 ± 0.10% |
| LOI | 1.63 | 14.96 | 0.80 ± 0.05% |
| Specific gravity | 3.15 | 1.55 | 2.5 |
| Physical Form | Fine Powder | Powder | Powder |
| Colour | Grey | Dark grey | Off white |

**Fine aggregate:** The sand mentioned here is confirming to zone III as per IS: 383-1970 from Aji-Dam, Bhogavo sand used for making concrete and its specific gravity and other data was found out.

**Coarse aggregate**: Coarse aggregate was obtained from locally available crushed stone aggregate about 20 mm maximum of single lot size has been used trough out the experiment. Specific gravity and other tests perform on the coarse aggregate as per IS: 383-1970.

**Recycled coarse aggregate**: Recycled coarse aggregates are derived from broken concrete cubes of concrete laboratory in R.K.University. Crushing of waste was done manually. Specific gravity and other tests perform on the recycled coarse aggregate as per IS: 383-1970. after performing sieve analysis and some tests we use in concrete mix.

**Metakaolin:**
WhiteMetakaolin used in this experimental investigation was obtained from sindhu chemicals supplier Bedi village, Rajkot-Morbi highway. company also provide physical and chemical properties of metakaolin which are as shown in table 1 .

**Groundnut shell :**Groundnut shell ash is the residue powder that is left after the combustion of Groundnut shell. The groundnut shell is obtained as a agricultural waste , the nuts inside the shells used to get vegetable oil which is used in households. Groundnut shell has to be burn 500 to 600°C to get the ash in boiler at Kirti industries, Rajkot. The ashes are sieved through 75 microns sieve to obtain the size of the cement particles.

**Water:** Mostly water for drinking purpose is suitable for mixing concrete as well as curing .the water used for both curing and mixing was potable water. On addition of higher percentage of demolished waste, the requirement of water increases for the same workability. Thus, a constant slump has been the criteria for water requirement, but the specimens having 0% demolished waste, W/C of 0.50 has been used for the study.

**2.2Experimental Work**

**Table 2:-** Experimental work on cubes

| Concrete block mix no. | Compressive strength test on tbc cube | | Split tensile test on tbc cylinder | | Concrete block mix no. | Compressive strength test on rca cube | | Split tensile Test on rca cylinder | |
|---|---|---|---|---|---|---|---|---|---|
| | 150x150 x 150 (size in mm) | | 150x150 x 300 (size in mm) | | | 150x150 x 150 (size in mm) | | 150x150 x 300 (size in mm) | |
| Days | 7 | 28 | 7 | 28 | Days | 7 | 28 | 7 | 28 |
| | | | | | | | | | |
| 1 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 3 |
| | | | | | | | | | |
| | 3 | 3 | 3 | 3 | 6 | 3 | 3 | 3 | 3 |
| | | | | | | | | | |
| 3 | 3 | 3 | 3 | 3 | 7 | 3 | 3 | 3 | 3 |
| | | | | | | | | | |
| 4 | 3 | 3 | 3 | 3 | 8 | 3 | 3 | 3 | 3 |
| Total cubes | 12 | 12 | 12 | 12 | | 12 | 12 | 12 | 12 |
| | 96 | | | | | | | | |

**2.3 Scope Of Work:**

The scope of present study includes the following aspects:

- Whatever may be the type of concrete being used, it is important to mix design of the concrete. The same is the case with ternary blended concrete . The major work involved is getting the appropriate mix proportions.
- In the present work, the concrete mixes with partial replacement of cement with different percentage groundnut shell ash and constant percentage of metakaolin were developed using OPC 53 grade cement. A simple mix design procedure is adopted to arrive at the mix proportions. After getting some trail mix, cubes of dimensions150mm *150mm *150 mm and cylinder of dimensions 150mm*300 mm was casted and cured in the curing tank. Compressive strength and Split tensile strength of concrete were conducted to know the strength properties of the mixes. Initially, a sample mix design was followed and modifications were made accordingly while arriving at the trail mixes to get optimized mix which satisfies both fresh, hardened properties and the economy. Finally, a simple mix design is proposed.
- Then in next stage , after getting optimum result in ternary blended concrete mix , laboratory testing on Recycled aggregate is carried out and then it is used in optimum concrete mix as replacement of natural coarse aggregate with different percentage.
- Then in final stage , Analyze the results and conclude the findings from tests is carried out.

**2.4 Concrete Mix Design :**

Control Concrete mix design for M25 grade is done as per IS 10262-2009.
Cement used = OPC 53 grade
Specific gravity of cement = 3.15
Specific gravity of C.A. = 2.75
Specific gravity of F.A. = 2.50
Zone of F.A. = III
Max.W/C = 0.50

Estimated water content for 25-75mm slump = 191.58 liter
Min. Cement = 300 kg/m3
**Mix proportion:**
Water-cement ratio: 0.5
Cement: 383.16 kg
Water: 191.58 kg
Coarse aggregate: 1077.26 kg
Fine aggregate: 729.28 kg
**The mix proportion is:**
Water : cement : sand : coarse aggregate
191.58 : 383.16 : 729.28 : 1077.26
0.5 : 1 : 1.90 : 2.81

**Table 3:-** Mix Designation

| Mix No. | Designation | Cement (%) | Metakaolin (%) | Groundnut shell ash (%) | Natural coarse aggregates (%) | Recycled coarse aggregates (%) |
|---|---|---|---|---|---|---|
| 1 | Control Concrete | 100 | 0 | 0 | 100 | 0 |
| 2 | GSA5 | 80 | 15 | 5 | 100 | 0 |
| 3 | GSA10 | 75 | 15 | 10 | 100 | 0 |
| 4 | GSA15 | 70 | 15 | 15 | 100 | 0 |
| 5 | RCA25 | 80 | 15 | 5 | 75 | 25 |
| 6 | RCA50 | 80 | 15 | 5 | 50 | 50 |
| 7 | RCA75 | 80 | 15 | 5 | 25 | 75 |
| 8 | RCA100 | 80 | 15 | 5 | 0 | 100 |

## III. RESULTS AND DISCUSSION

### 3.1 Natural And Recycled Coarse Aggregate Tests Results Comparison :

In the following table the results of all primary tests performed on aggregates is compared and the limits for each specific test by Indian standard code is written:

**Table 4:-** Natural and Recycled Coarse Aggregate Tests Results comparison

| Sr. no. | Name of the test | Natural Aggregate | Recycled Aggregate | IS CODE | IS CODE LIMIT |
|---|---|---|---|---|---|
| 1 | Flakiness Index | 10.73% | 9.13% | 2386(PART -1)-1963 | <10 to 15% |
| 2 | Elongation index | 10.55% | 7.88% | 2386(PART -1)-1963 | <15% |
| 3 | Impact Value Test | 4.55% | 8.27% | 383-1970 | <45% |
| 4 | Water Absorption | 1.15% | 3.8% | 2386(PART-3-1963) | 0.1-3.0% |
| 5 | Specific Gravity | 2.75 | 2.69 | 2386(PART-3-1963) | 2.5-3.0 |
| 6 | Crushing Value Test | 16.33% | 20.09% | 2386(PART-4-1963 | <45% |
| 7 | Abration Value Test | 12.77% | 16.55% | 2386(PART-4-1963 | <50% |

### 3.2 Result Of Compressive Strength Of Concrete Cubes Containing Ternary Blends:

**Table 7:-** % of increasement in strength at 7 and 28 days containing G.S.A.

| Mix no. | M.k. In % | Cement in % | Gsa in % | Compressive strength At 7 days (n/mm$^2$) | % of increase in compressive strength at 7 | Compressive strength At 28 days (n/mm$^2$) | % of increase in compress | Slump value (in mm) |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | days | | ive strength at 28 days | |
| 1 | N | 100 | 0 | 17.11 | - | 26.07 | - | 55 |
| 2 | 15 | 80 | 5 | 23.33 | 36.35 | 34.22 | 31.26 | 35 |
| 3 | 15 | 75 | 10 | 22.96 | 34.19 | 27.10 | 3.95 | 37 |
| 4 | 15 | 70 | 15 | 21.33 | 24.66 | 25.47 | 0 | 40 |

- From above results , there is Increase in compressive strength at 5% of G.S.A with 15% metakaolin at 7 days. Then further increasing percentage of G.S.A with 10% and 15% keeping 15% metakaoline constant , there is decrease in compressive strength at 7 days , but all value are more than control concrete mix . there is gain in initial strength at 7 days due to metakaolin'sproperties.From above results , there is Increase in compressive strength at 5% of G.S.A with 15% metakaolin at 28 days. Then further increasing percentage of G.S.A with 10% and 15% keeping 15% metakaoline constant , there is decrease in compressive strength at 28 days , but all value are more than target strength of concrete mix .
- So 5% G.S.A. and 15% metakaolin gives optimum value for cement replacement with 20%.
- The Slump values increased with respect to the replacement levels, more the replacement of G.S.A. , more is the slump observed and decrease in comparison with control concrete.

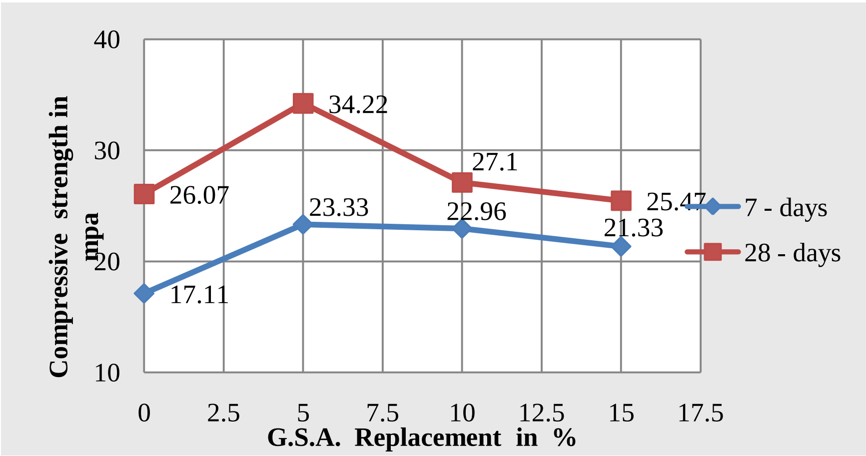


**Figure 1:-** Compressive Strength At 7 and 28 Day Vs % Of G.S.A. Replacement

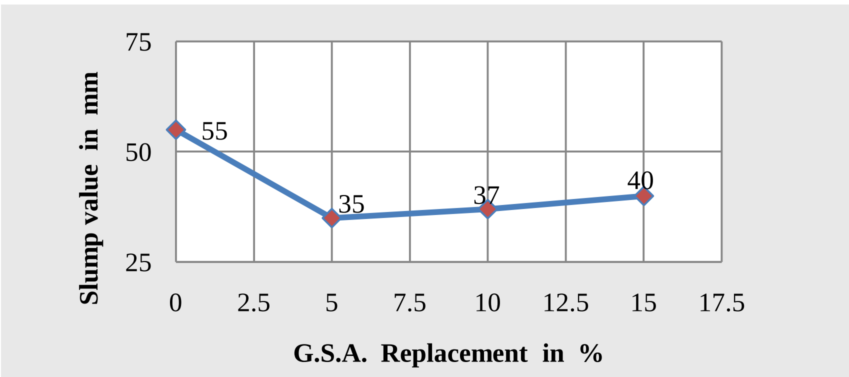


**Figure 2:-** Slump value Vs % Of G.S.A. Replacement

### 3.3 Result Of Split Tensile Strength Of Concrete Cubes Containing Ternary Blends:

**Table 8:-** % of increasement in strength at 7 and 28 days containing G.S.A.

| Mi x no. | M.k. In % | Cemen t in % | Gsa in % | Split tensile strength At 7 days ($n/mm^2$) | % of increase in split tensile strength at 7 days | Split tensile strength At 28 days ($n/mm^2$) | % of increase in split tensile | Slump value (in mm) |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | strength at 28 days | |
|---|---|---|---|---|---|---|---|---|
| 1 | N | 100 | 0 | 1.69 | - | 2.51 | - | 55 |
| 2 | 15 | 80 | 5 | 2.13 | 26.03 | 3.19 | 27.09 | 35 |
| 3 | 15 | 75 | 10 | 1.93 | 14.20 | 2.53 | 0.80 | 37 |
| 4 | 15 | 70 | 15 | 1.74 | 2.95 | 2.12 | 0 | 40 |

- From above results , there is Increase in split tensile strength at 5% of G.S.A with 15% metakaolin at 7 days. Then further increasing percentage of G.S.A with 10% and 15% keeping 15% metakaoline constant , there is decrease in split tensile strength at 7 days, but all value are more than control concrete . From above results , there is Increase in split tensile strength at 5% of G.S.A with 15% metakaolin at 28 days. Then further increasing percentage of G.S.A with 10% and 15% keeping 15% metakaoline constant , there is decrease in split tensile strength at 28 days, but all value are more than control concrete up to use of 10% G.S.A. .
- So 5% G.S.A. and 15% metakaolin gives optimum value for cement replacement with 20%.

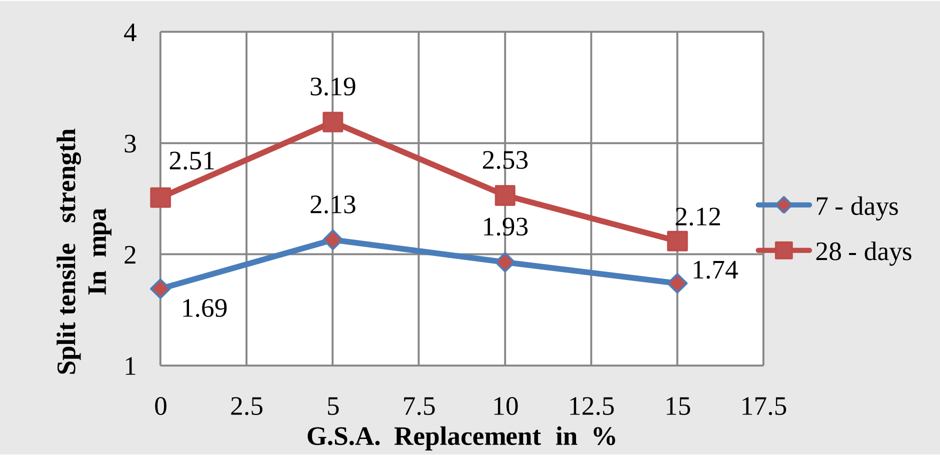


**Figure 3:-** Split Tensile Strength At 7 and 28 Day Vs % Of G.S.A. Replacement

### 3.4 Result Of Compressive Strength Of Concrete Cubes Containing R.C.A. :

**Table 9:-** % of increasement in strength at 7 and 28 days containing R.C.A.

| Mix no. | M.k. In % | Cement in % | Gsa in % | N.c.a. in % | R.c.a. in % | Compressive strength At 7 days (n/mm²) | % of increase in compressive strength at 7 days | Compressive strength At 28 days (n/mm²) | % of increase in compressive strength at 28 days | Slump value (in mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N | 100 | 0 | 100 | 0 | 17.11 | - | 26.07 | - | 55 |
| 5 | 15 | 80 | 5 | 75 | 25 | 19.48 | 13.85 | 31.78 | 21.90 | 33 |
| 6 | 15 | 80 | 5 | 50 | 50 | 17.63 | 3.04 | 29.85 | 14.50 | 30 |
| 7 | 15 | 80 | 5 | 25 | 75 | 16.88 | 0 | 28.96 | 11.09 | 26 |
| 8 | 15 | 80 | 5 | 0 | 100 | 16.15 | 0 | 25.26 | 0 | 21 |

- From above results , there is Increase in compressive strength at 25% and 50% of R.C.A. replacement at 7 days keeping 15% metakaoline and 5% G.S.A. constant , but there is decrease in compressive strength at 75% and 100% of R.C.A. replacement at 7 days . From above results , there is Increase in compressive strength at 25% of R.C.A. replacement at 28 days keeping 15% metakaoline and 5% G.S.A. constant . Then further increasing percentage of R.C.A. , there is decrease in compressive strength at 28 days but all values are more than target strength of concrete mix .
- So 25% R.C.A. gives optimum value for N.C.A. replacement with 20% cement replacement .

- The Slump values decreased with respect to the replacement levels, more the replacement of R.C.A. , less is the slump observed and decrease in comparison with control concrete.

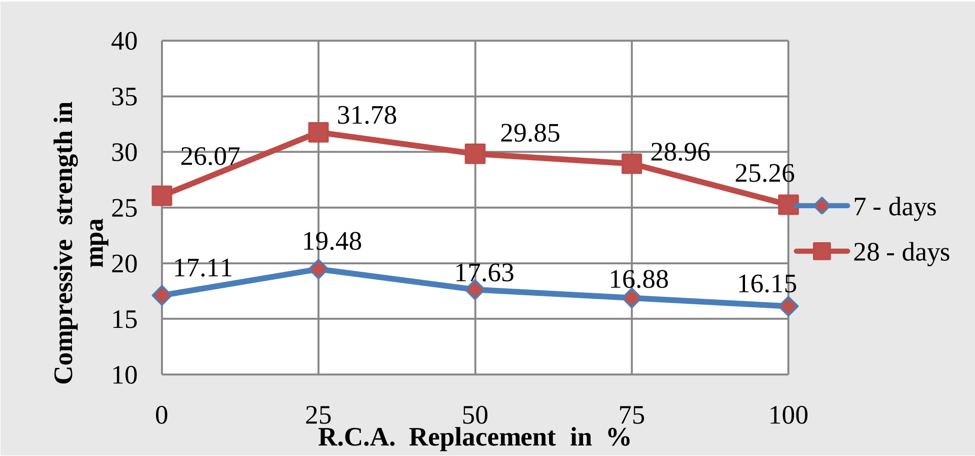


**Figure 4:-**Compressive Strength At 7 and 28 Day Vs % Of R.C.A. Replacement

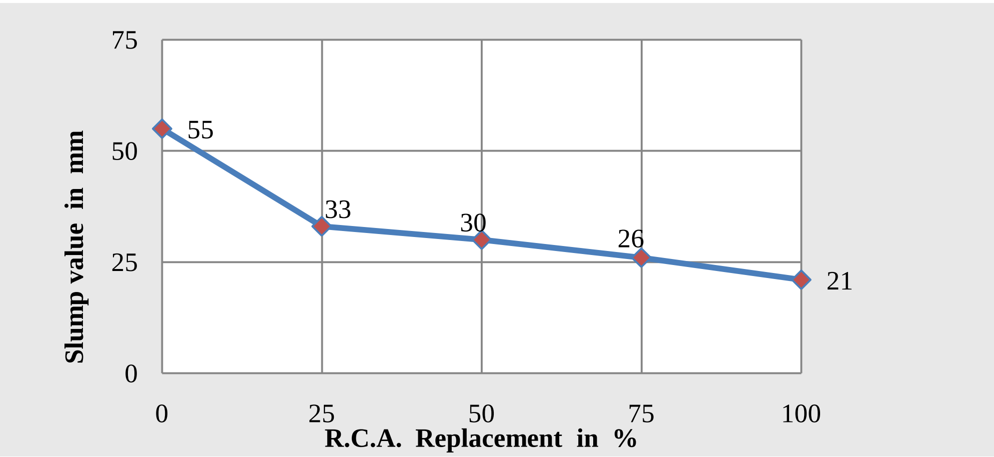


**Figure 5:-**Slump value Vs % Of R.C.A. Replacement

**3.5 Result Of Split Tensile Strength Of Concrete Cubes Containing R.C.A. :**

**Table 10:-** % of increasement in strength at 7 and 28 days containing R.C.A.

| Mix no. | M.k . In % | Cement in % | Gsa in % | N.c. a. in % | R.c. a. in % | Split tensile strength At 7 days (n/mm$^2$) | % of increase in split tensile strength at 7 days | Split tensile strength At 28 days (n/mm$^2$) | % of increase in split tensile strength at 28 days | Slump value (in mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N | 100 | 0 | 100 | 0 | 1.69 | - | 2.51 | - | 55 |
| 5 | 15 | 80 | 5 | 75 | 25 | 2.12 | 25.44 | 3.16 | 25.90 | 33 |
| 6 | 15 | 80 | 5 | 50 | 50 | 2.08 | 23.07 | 3.00 | 19.52 | 30 |
| 7 | 15 | 80 | 5 | 25 | 75 | 1.95 | 15.38 | 2.90 | 15.54 | 26 |
| 8 | 15 | 80 | 5 | 0 | 100 | 1.86 | 10.05 | 2.66 | 5.98 | 21 |

- From above results , there is Increase in split tensile strength at 25% of R.C.A. replacement at 7 days keeping 15% metakaoline and 5% G.S.A. constant. Then further increasing percentage of R.C.A. , there is decrease in split tensile strength from 50% , 75% and 100% of R.C.A. replacement at 7 days but all values are more than control concrete . From above results , there is Increase in split tensile strength at 25% of

R.C.A. replacement at 28 days keeping 15% metakaoline and 5% G.S.A. constant. Then further increasing percentage of R.C.A. , there is decrease in split tensile strength from 50% , 75% and 100% of R.C.A. replacement at 28 days but all values are more than control concrete .

- So 25% R.C.A. gives optimum value for N.C.A. replacement with 20% cement replacement .

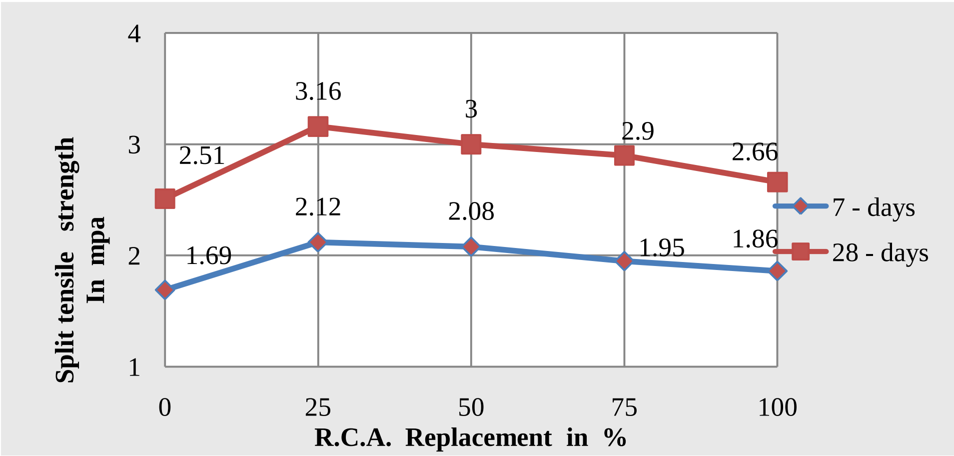


**Figure 6:-**split tensile strength at 7and 28 day vs % ofr.c.a. replacement

## IV. CONCLUSION

The experiment is based on two types of material replacement i.e. cement replacement by using groundnut shell ash and metakaolin , natural coarse aggregate replacement by using recycled coarse aggregates. Total eight type of mix are to be used for study . i.e. one control concrete , three mix containing G.S.A. with 5% , 10%, 15% and keeping 15% Metakaolin in all mix as ternary blends , then after another four mix containing recycled coarse aggregates with 25 % , 50% , 75% and 100% . after performing compressive strength test and split tensile strength test at 7 and 28 days with its slump value and getting results as discuss in previous chapter some conclusion are made which are as follows :

### A. Conclusion from test results : -

- It is observed that the compressive strength at 7 days of concrete increases by using 5%, 10% ,15% G.S.A. and keeping 15% metakaolin constant as replacement of cement with respect to control concrete mix .It is observed that the compressive strength at 28 days of concrete increases by using 5%, 10% ,15% G.S.A. and keeping 15% metakaolin constant as replacement of cement with respect to target mean strength for M25 Grade of concrete.There is decrease in workability with respect to control concrete but , increase in percentage of G.S.A. there is increase in workability of concrete mix.It is observed that the split tensile strength at 7 days of concrete increases by using 5%, 10% ,15% G.S.A. and keeping 15% metakaolin constant as replacement of cement with respect to control concrete mix.It is observed that the split tensile strength at 28 days of concrete increases by using 5% and 10% of G.S.A. and decreases by using 15% of G.S.A. by keeping 15% metakaolin constant as replacement of cement with respect to control concrete mix .
- It is observed that the compressive strength at 7 days of concrete increases by using 25% and 50% of R.C.A. with using optimum value of cement replacement with respect to control concrete mix.It is observed that the compressive strength at 28 days of concrete increases by using 25%, 50% ,75% and 100% of R.C.A. with using optimum value of cement replacement with respect to target mean strength for M25 Grade of concrete.By using R.C.A. in concrete , There is decrease in workability with respect to control concrete and optimum mix ,with increase in percentage of R.C.A. there is decrease in workability of concrete mix.It is observed that the split tensile strength at 7 and 28 days of concrete increases by using 25%, 50% ,75% and 100% of R.C.A. with using optimum value of cement replacement with respect to control concrete mix.

### B. Overall conclusions : -

- 5% of G.S.A. and 15% of metakaolin is best combination which gives optimum value for compressive and split tensile strength of concrete. 20% cement replacement can be done by this combination with increase in concrete strength which is very good for reduction of cement production with reduction of carbon dioxide and also utilize groundnut shell ash as agro waste.Naturalcoarse aggregate need to mine but recycled coarse aggregate can ignore this process. This on-going research project is to determine the strength characteristics of recycled coarse aggregate for potential application in the high concrete structural concrete. According to the results which are obtained that workability is been decreasing byincreasing R.C.A. ,It is possible to achieve strength by using R.C.A. up to 75% . Further replacement above 50% can be done by introducing some admixtures to maintain the workability.From the observation of the results we can conclude that the replacement of natural coarse aggregate by recycled coarse aggregate about 50% is been recommended since it attains more strength compared to normal concrete with using ternarly blends containing G.S.A. as agro waste and metakaolin .

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