Comprehensive Study on Effect of Partial Replacement of Natural Sand by Artificial Sand and Cement by Rice Husk Ash, on Characteristic Strength of Concrete

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Abstract - *Nowadays there is scarcity of natural sand (River sand) in monsoon season due to complete ban on lease/Permission by district administrative authority/State Government in order to protect the biodiversity of rivers ecosystem because of borrowing of sand from natural resources (River bed).One of the alternatives to natural sand may be artificial sand (Crushed Stone sand) for better option to continue the concrete work without compromising the characteristics engineering strength of concrete. We also use Rice Husk Ash (R.H.A) as a replacement of cement and to increase the strength of cement concrete. By using rice husk ash as a replacement of cement we are supporting the environment by minimizing the pollution caused by traditional burning (disposal of rice husk ash by formers in their open fields) along with reducing the carbon pollution for production of cement which was replaced by rice husk ash in cement concrete mix. In this paper an attempt is made to present a state-of the-art review of papers on replacement of natural sand by artificial sand. This paper aims to deal with the current and future trends of research on the use of Manufactured Fine Aggregate (MFA) in cement concrete. This paper emphasizes on the use of artificial sand and R.H.A as a partial replacement material of natural sand and cement respectively in concrete mix, which will give new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry by economizing the construction cost and enable us to conserve natural resources.*

***Key Words*: Natural Sand, Crushed Sand, Rice Husk Ash (R.H.A), Compressive Strength, Flexural Strength and Tensile Strength, Manufactured Fine Aggregate (MFA) Urbanization**

1. INTRODUCTION

Concrete is main constituent of civil engineering structure work. Rigid pavement of national highway, state highways, major district roads are also made with suitable grade of concrete, according to axle load & V.D.F of commercial vehicles and other important considerations necessary for design of rigid pavement. Conventionally concrete is mixture of cement, sand and aggregate. Properties of aggregate affect the durability and performance of concrete, so fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river or pit sand. Now-a-days good sand is not available it is transported from one place to another so it is need of the time to find substitute to natural river sand. Because of limited supply the cost of natural river sand has sky rocketed and its consistence supply cannot be guaranteed. For the purpose of experimentation concrete mix are designed for M30 grade by replacing natural sand with artificial sand at different replacement levels of 50%, 60% and 70%. For the above purpose, we are going to design concrete mixes of M30 grades by different replacement of natural sand to artificial sand. Its mechanical properties namely cube compressive strength; flexural strength and split tensile strength are study in that experiment. To improve the characteristic strength of concrete we also proposed to used rice husk ash as partial replacement of cement. Rice plant is one of the plants that absorbs silica from the soil and assimilates it into its structure during the growth (Smith et al., 1986). Rice husk is the outer covering of the grain of rice plant with a high concentration of silica, generally more than 80-85% (Siddique 2008). RHA has been used in lime pozzolana mixes and could be a suitable partly replacement for Portland cement (Smith et al., 1986; Zhang et al., 1996; Nicole et al., 2000; Sakr 2006; Sata et al., 2007; etc). RHA concrete is like fly ash/slag concrete with regard to its strength development but with a higher pozzolanic activity it helps the pozzolanic reactions occur at early ages rather than later as is the case with other replacement cementing materials (Molhotra, 1993).

2. EXPERIMENTAL STUDY

2.1 Materials:

2.1.1 Cement: - PPC is manufactured by inter-grinding of cement clinker with appropriate percentage of fly ash and gypsum in a closed-circuit ball mill with a high-efficiency separator to achieve the required fineness. Cement used in this experimental work is Birla gold PPC grades conforming to IS: 1489-2015. The Physical properties of Portland pozzolana Cement obtained on conducting appropriate test as per IS: 4031-1988 are given in Table 3.4

Table 2.1 Physical Properties of Ordinary Portland Cement

S/No	Particulars	Test result
1	Specific gravity	**2.90**
2	Fineness (sieve analysis)	**2.12%**
3	Normal consistency	**30%**

2.1.2 Fine Aggregate:

a) **Natural sand (River sand): -**Fine aggregates are also one of the main ingredients of the concrete which helps to aggregate and cement bond properly. The size of sand is less than 4.75mm sieve. IS:383 1963 defined the fine aggregate which will passes 4.75mm IS sieve and retained on 0.07mm IS sieve is known as fine aggregate. Locally available river sand and which was obtained from river bed, having a lower size of about 0.07mm was used as a fine aggregate.

Table 2.2 Physical properties of fine aggregate (IS: 2386-1963)

S/No	Properties	Results	Permission limit as per IS: 2386- 1963
1	Type	Natural	-
2	Shape	Rounded	-
3	Size	> 4.75 µ	Retain on 0.07 mm
4	Organic impurities	Colorless	Colorless /Straw Color /Dark color
5	Silt content	1.15%	<3% for natural sand (as per IS 383)
6	Specific gravity	2.58	-
7	Bulking of sand	7.52%	Should not be more than 40%
8	Bulk Density (Kg/m3)	1570	-
9	Fineness modulus	2.53	Between 1.71 to 2.78 for zone-III
10	Free moisture content	1.52%	-

b) **Artificial sand (Crushed sand): -** Artificial sand (crushed sand) is obtained by crushing natural stone to get sand of desired size and zone which would be free from all impurities. Use of crushed sand has become a good substitute for natural sand. Its physical and chemical properties such as colour, size, shape, surface texture of particles depend upon types of stone and its source. The artificial sand produced by machine can be better substitute of natural sand (river sand) because of better quality control during process of manufacturing of crushed sand. The important properties of crushed sand used in concrete are as below:

Table 2.3 Physical properties of fine aggregate (IS: 2386-1963)

S/No	Properties	Results	Permission limit as per IS: 2386- 1963
1	Type	Artificial	-
2	Shape	Partially angular	-
3	Size	> 4.75 µ	Retain on 0.07 mm
4	Organic impurities	Dark brown color	Colorless /Straw Color /Dark color
5	Silt content	4.35%	<15% for artificial sand (as per IS 383)
6	Specific gravity	2.59	-
7	Bulking of sand	18.2%	Should not be more than 40%
8	Bulk Density (Kg/m3)	1930	-
9	Fineness modulus	3.15	Between 2.71 to 4.00 for zone-I
10	Free moisture content	1.50%	-

2.1.3 Coarse Aggregate: Aggregate are the main ingredient of the concrete which gives the ultimate strength to the rigid pavement of expressway, national highways, state highways constructed for infrastructure development of the country. IS:383-1970 defined the Aggregate which is retained on 4.75mm IS sieve and containing only so much finer material as is permitted by is termed as coarse aggregate. 10mm and 20mm Sizes of coarse aggregate are chosen for the experimental work. Physical and Mechanical properties of Coarse aggregate (IS: 2386-1963) as shown in table 2.5.

2.1.4 Water: Water is an important ingredient of concrete which is actively worked in the chemical reaction with cement. Since it helps to provide the strength to cement, the quantity and quality of water is required to be looked into very carefully. Ordinary potable water is used which is free from salt, turbidity and organic content. Water has been used for mixing the materials and curing throughout the investigation in the project work.

2.1.5 Rice Husk Ash (R.H.A): Rice husk ash is used in concrete construction as an alternative of cement. The types, properties, advantages and uses of rice husk in construction is discussed. The rice paddy milling industries give the by-product rice husk. Due to the increasing rate of environmental pollution and the consideration of sustainability factor has made the idea of utilizing rice husk. About 100 million tons of rice paddy manufacture by-products are obtained around the world. They have a very low bulk density of 90 to 150kg/m3.

Table 2.4 Engineering Properties of rice husk ash (R.H.A) (Provided by Supplier)

Sr. No.	Particulars	Proportion (%)
1	Calcium oxide (CaO)	0.67
2	Silicon dioxide (SiO2)	88.32
3	Aluminium oxide (Al2O3)	0.46
4	Iron oxide (Fe2O3)	0.67
5	Magnesium oxide (MgO)	0.44
6	Ignition loss (LOI)	5.81
7	Potassium oxide (K2O)	2.91

Table 2.5 Physical and Mechanical properties of Coarse aggregate (IS: 2386-1963)

S/NO	Properties of material	Coarse aggregates	Permission limit as per IS: 2386- 1963
1	Type	Crushed	-
2	Shape	Angular	-
3	Size	20 mm & 10 mm	-
4	Specific gravity	2.70	-
5	Fineness modulus	7.25	-
6	Bulk density (kg /m3)	1428	-
7	Impact value	11.37%	Should not be more than 30%
9	Crushing value	13.86%	Should not be more than 30%
10	Loss Angeles Abrasion Value	15.45%	Should not be more than 30%
11	Flakiness Index	19.2%	Should not be more than 30%

2.2 Laboratory Works:

2.2.1 Proportioning: -Concrete mix was designed for M30 with optimum proportion of artificial and natural sand (0%, 50%, 60% and 70%) and after that by using different percentage of Rice Husk Ash (R.H.A). The mix proportions of concrete were arrived according to standard IS-10262-2010.

Table 2.6 Proportion for M 30 Mix Design of Concrete by using 60% Artificial sand (crushed sand) and 40% Natural sand (river sand)

Grade of Concrete		M 30	
CEMENT		458.14 kg/m3	
Aggregates	Fine aggregates	581.870 kg/m3	1661.910 kg/m3
	Artificial sand	349.662 kg/m3	
	Natural sand	232.208 kg/m3	
	Coarse aggregates	1080.04 kg/m3	
	20 mm aggregates	594.022 kg/m3	
	10mm aggregates	486.018 kg/m3	
Ratio of mix proportion		1:1.27:2.36	
Water/cement ratio		0.43	
WATER		197 lit.	

Table 2.7 Proportion for M 30 Mix Design of Concrete with optimum proportion of artificial and natural sand [60% Artificial sand and 40% Natural sand] by using different percentage (%) of Rice husk ash (R.H.A)

Sr. No.	Mix (%)	Cement (kg/m3)	R.H.A (kg/m3)	Water (lit)	F.A (kg/m3)	C.A (kg/m3)	W/Binder (%)
1.	**Cement**	458.140	0.000	197	581.870	1080.04	0.43
2.	**5% RHA**	435.233	22.907	197	581.870	1080.04	0.43
3.	**7.5% RHA**	423.779	34.361	197	581.870	1080.04	0.43
4.	**10% RHA**	412.326	45.814	197	581.870	1080.04	0.43
5.	**12.5% RHA**	400.872	57.268	197	581.870	1080.04	0.43

Table 2.8 Percentage and Weight of Rice husk ash (R.H.A)

Percentage addition of Rice husk ash (R.H.A)	Amount of Rice husk ash (R.H.A) added by weight of cement (Kg/m3)
5 %	22.907
7.5 %	34.361
10 %	45.814
12.5 %	57.268

2.2.2 Batching and Mixing: - Raw materials such as cement, coarse aggregate, fine aggregate (natural and artificial sand), rice husk ash and water weighted manually according to the design mix. Then materials were mix properly in concrete mixer. Mixing was continued for further 5 to10 minutes or until it develops a uniform mix. After the mixture achieved their homogeneity, first tested for workability by means of Slump Cone Test & then poured into the moulds.

Figure: 2.1 Mixing in concrete mixer

Figure: 2.2 Batching and Mixing of Raw Materials.

2.2.3 Pouring and Compaction of Fresh Concrete Mix: - A Vibrating machine which is used for compaction of fresh concrete at a speed of 3,000 to 10,000 rpm. The samples of concrete were well compacted by vibration of machine. It is used for proper Compaction of concrete during filling in moulds. It is basically an adequate compaction of concrete mix by removal of air voids in fresh concrete to achieve satisfactory strength of concrete.

Figure: 2.3 Pouring and Compaction of Fresh Concrete Mix.

3.4.4 Casting of moulds of Cubes, Cylinders and Beams: -

The fresh concrete is poured, tampered and compressed in moulds. Further compaction was done by vibrating machine. The procedure of mixing and casting is similar for concrete Cubes, Beams and Cylinders. Size of cube is 15 x 15 x 15 cm; beam specimen is 15 x 15 x 70 cm and size of cylinder specimen is 15 x 30 cm.

Figure: 2.5 Casting of moulds of Cubes.

Figure: 2.6 Casting of moulds of Beams.

Figure: 2.7 Concrete Cube, Cylinder and Beam Specimens.

2.3 Hardened Properties of Concrete:

2.3.1 Compressive Strength: - Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Fig. 2.8 Compressive Strength testing in progress

2.3.2 Flexural Strength: -To determine the Flexural Strength of Concrete, which comes into play when a road slab with inadequate sub-grade support is subjected to wheel loads and / or there are volume changes due to temperature / shrinking. Beam mould of size 15 x 15 x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm). Tamping bar (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm). The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens.

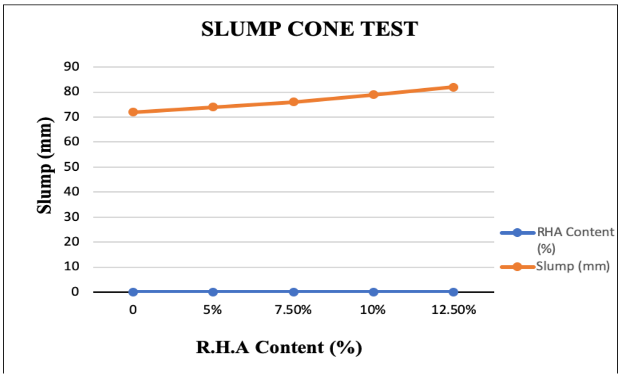
Fig. 2.9 Flexural Strength testing in progress

2.3.2 Split Tensile Strength: -This method covers the determination of the splitting tensile strength of cylindrical concrete specimens. Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ± ½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients. Number of Specimens – At least three specimens, preferably from different batches, shall be made for testing at each selected age.

Fig. 2.10 Tensile Strength testing in progress

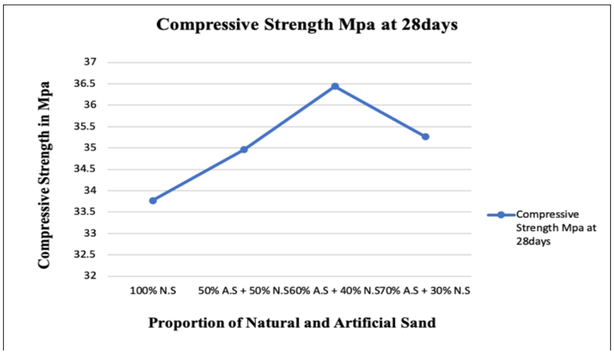
3. RESULTS AND DISCUSSION

3.1 Workability: - Slump test was carried out on each mix to ascertain workability of Concrete with Rice Husk ash as well as control mixtures. The results of slump tests for M-30 grade concrete with and without R.H.A are shown in given graph 3.1.

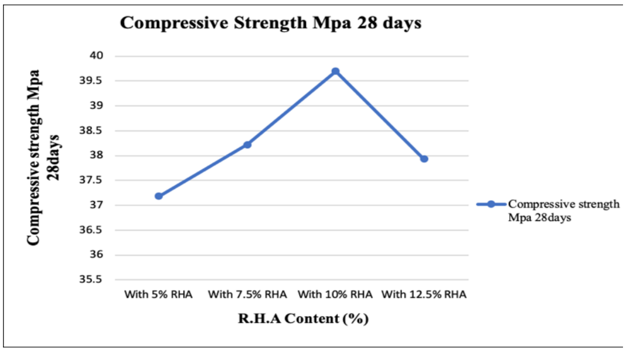


Graph 3.1 Slump Cone Test Values with Different Percentage of RHA

3.2 Compressive Strength: - Total 24 cubes were casted for natural and artificial sand and 24 cubes with R.H.A of different percentage (5%, 7.5%, 10% and 12.5%). All the specimens were cured at 28 days. In present study average compressive strength of concrete with different % of R.H.A is slightly increased up to 10% of Rice Husk ash.

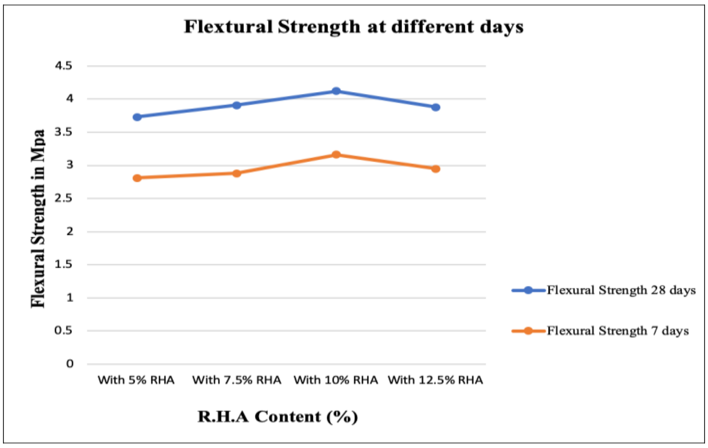


Graph 3.2 Average Compressive Strength of Concrete cubes with different proportion of RHA at 28days

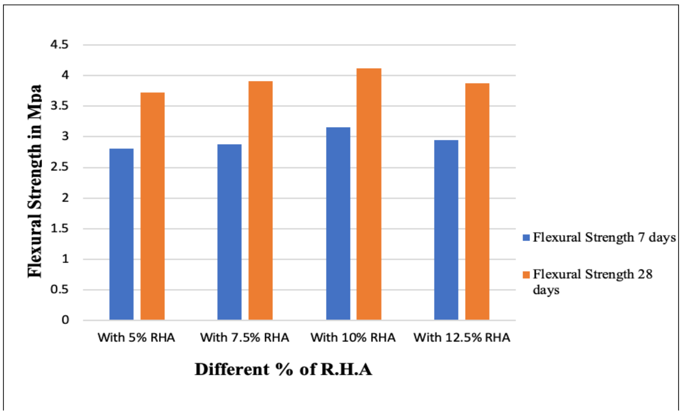


Graph 3.3 Average Compressive Strength of Concrete cubes with different proportion of RHA at 28days

3.3 Flexural Strength: -Total 08 beams were casted of Concrete with R.H.A of different percentage (5%, 7.5%, 10% and 12.5%). 8 beams were also casted with Concrete having different proportion of natural and artificial sand. All the specimens were cured at different curing intervals 7 and 28 days. In present study average flexural strength of Concrete with R.H.A is increased up to 10% of Rice Husk ash.

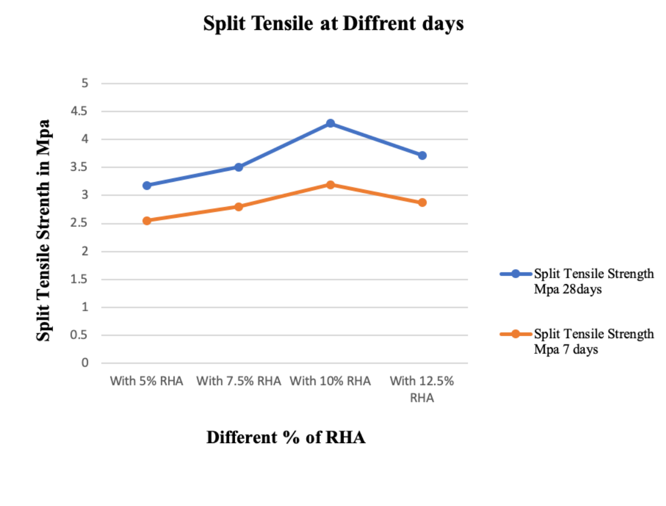


Graph 3.4 Average Flexural Strength of Concrete Beams with different proportion of RHA at 7 and 28 days

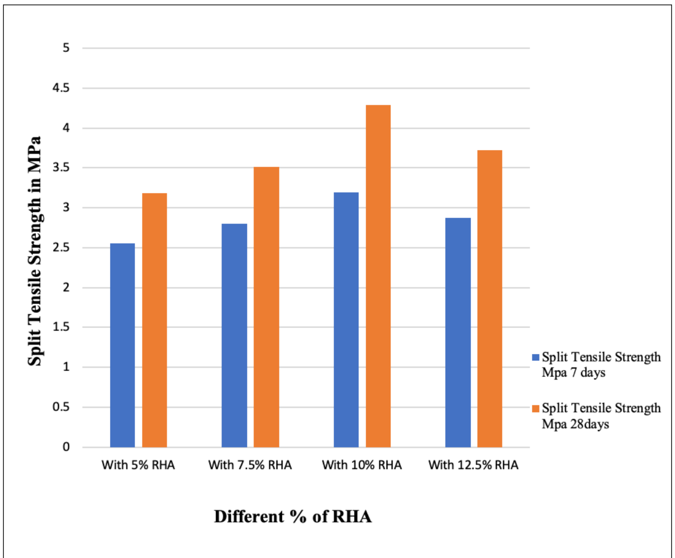


Graph 3.5 Bar chart of Average Flexural Strength of Concrete Beams with different proportion of RHA at 7 and 28 days

3.4 Split Tensile Strength: - Total 16 cylinders, were casted with R.H.A of different percentage (5%, 7.5%, 10% and 12.5%). 16 cylinders were also casted with Concrete having different proportion of natural and artificial sand. All the specimens were cured at different curing intervals 7 and 28 days. In present study average split tensile strength of Concrete with R.H.A is increased up to 10% of Rice husk ash.



Graph 3.6 Average Split Tensile Strength of Concrete Cylinder with different proportion of RHA at 7 and 28 days



Graph 3.7 Bar chart of Average Split Tensile Strength of Concrete Cylinder with different proportion of RHA at 7 and 28 days

4. COST BENEFIT ANALYSIS

4.1 Cost Benefit Analysis (CBA):- It is a systematic approach to estimate the short and long term consequences, measuring all costs and all possible profits and benefits from an investment project proposal, taking into account both quantitative and qualitative factors, sometimes called benefit–cost analysis (BCA).CBA is the social evaluation of marginal projects, correcting for a potential market failure, Environmental impacts of projects/policies are often externalities, both negative and sometimes positive, and CBA seeks to attach monetary values to external effects so that they can be taken account of, along with the effects on ordinary inputs and outputs.

4.2 CBA Analysis in Present Study:-In this research work, the maximum strength achieved by Replacement of Natural sand (at optimum percentage - 60% artificial sand + 40% natural sand) of M-30 grade concrete at 10% addition of Rice Husk Ash (R.H.A) content by weight of cement. If we want to continue the Highway construction work at project site in three months of rainy season, during which there is scarcity of natural sand (River sand) due to complete ban on lease/ Permission to borrow sand from natural resources, artificial sand (Crushed Stone sand) is better option to continue the concrete work without compromising the characteristics engineering strength of concrete. By using artificial sand at optimum percentage (60% artificial sand + 40% natural sand) we get enhanced strength of cement concrete for construction of Rigid Pavement of the project. We also use Rice Husk Ash (R.H.A) @10% (by weight of cement) as a replacement of cement and also get increase in strength of cement concrete. By using rice husk ash as a replacement of cement we are also supporting the environment by minimizing the pollution caused by traditional burning/disposal of rice husk ash by formers in their open fields and also reducing the carbon pollution for production of cement which was replaced by rice husk ash in cement concrete. By mix designing with artificial sand and rice husk ash in optimum proportion as explained above we get enhanced strength of concrete i.e., Compressive strength, Flexural strength & Split tensile strength. It is also observed that there is cost benefit by using artificial sand with rice husk ash in production of cement concrete of M30 grade for construction of Rigid Pavement of project Highway.

5. CONCLUSIONS

Analysis of the results on the effect of using Artificial sand as a partial replacement of natural sand (by weight of sand) in addition to use of Rice Husk Ash as partial replacement of cement (by weight of cement) on the strength of concrete leads to the following conclusions-

- The incorporation of Artificial sand in concrete causes gradual increase in Compressive strength up to optimum percentage 60% artificial sand + 40% natural sand and further decreases with the increase in proportion of artificial sand.
- The incorporation of Artificial sand in concrete causes gradual increase in Flexural strength up to optimum percentage 60% artificial sand + 40% natural sand and further decreases with the increase in proportion of artificial sand.
- The incorporation of Artificial sand in concrete causes gradual increase in Split tensile strength up to optimum percentage 60% artificial sand + 40% natural sand and further decreases with the increase in proportion of artificial sand.
- The incorporation of Artificial sand in concrete causes gradual decrease in workability.
- With optimum percentage of artificial sand we analyse the use of rice husk ash and replace cement

by 5%, 7.5%, 10% and 12.5% and found that with increase in percentage of rice husk ash in cement concrete characteristic strength of M30 grade concrete gradually increases up to 10% and then decreases.

- The incorporation of Rice Husk Ash in concrete causes gradual increase in Compressive strength up to 10% of R.H.A and further decreases with the increase in proportion of R.H.A.
- The incorporation of Rice Husk Ash in concrete causes gradual increase in Flexural strength up to 10% of R.H.A and further decreases with the increase in proportion of R.H.A.
- The incorporation of Rice Husk Ash in concrete causes gradual increase in Split tensile strength up to 10% of R.H.A and further decreases with the increase in proportion of R.H.A.
- By using rice husk ash as a replacement of cement we are also supporting the environment by minimizing the pollution caused by traditional burning/disposal of rice husk ash by formers in their open fields and also reducing the production of carbon for production of cement which was replaced by rice husk ash in cement concrete.

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