MANTECH Publications

Journal of Ceramics and Concrete Technology
Volume 7 Issue 2
ISSN: 2457-0826 (Online)

# *Rice Husk Ash as Supplementary Cementitious Material*

***Syed Afzal Basha[1], A Vinod Kumar[2], S Akhil Tej[3], C Bala Hussainy[4]***

*Associate Professor[1], Assistant Professor[2, 3, 4]*

*Department of Civil Engineering*

*G Pullaiah College of Engineering and Technology, Kurnool, A.P. India*

***Corresponding Author's Email: -*** *syedafzal74@gmail.com[1]*

***Abstract***

*The current paper addresses the potential use of Rice Husk Ash (RHA) as a cementitious material in concrete mixes. Cement is generally noted to be the costliest constituent of concrete. The whole construction industry is looking for a reasonable byproduct that would limit the utilization of cements and eventually decrease the construction cost. Rice husk ash (RHA) which has the pozzolanic properties is one among the best options. In this experimental work, an attempt is made to utilize rice husk ash as a partial substitute of cement in concrete. M30 grade of concrete is designed as per the guidelines of IS: 10262 – 2009 and IS: 456 – 2000. Ordinary Portland cement (OPC) was supplanted with Rice husk Ash (RHA) by weight at 0%, 5%, 10%, 15%, 20% and 25%. Tests were performed on fresh and hardened concrete. Physical tests carried out were slump test on fresh concrete and Compressive Strength test and split tensile strength tests were performed on hardened concrete at 7, 14 and 28 days of curing. The test outcomes revealed an optimum strength at 20% replacement level beyond which the strength reduced gradually with the replacement of OPC with RHA.*

***Keywords:*** *Concrete, Ordinary Portland cement, Rice husk ash*

## INTRODUCTION

Concrete is the most widely used man-made construction material and is second only to water as the most utilized substance on the planet (Gambhir, 2005). It is obtained by mixing cement, water, coarse aggregate and fine aggregate (and sometimes admixtures) in required


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

proportions. The mixture when placed in forms and allowed to cure hardens into a rock- like mass known as concrete (Telford, 1989). There are numerous high-rise structures all over the world most of which are constructed out of concrete, and many still to be constructed (Ferny & William, 1994).

The major component of concrete being cement (Ordinary Portland cement) which acts as a binderies increasingly getting expensive due to its increasing costs of manufacturing and selling on the market hence making concrete very expensive. People most of whom live below the poverty line cannot afford this high-cost material hence opting for inadequate mixed proportions of cement with other concrete materials during construction and ending up not building durable and decent houses.

Due to increasing cost of the conventional building material (Ordinary Portland cement), there is need for affordable building materials so as to provide adequate housing for the increasing population. One such alternative building material is the abundant paddy rice husk ash. This ash is produced by burning rice husks that are readily available in various districts of Andhra Pradesh state. Production of paddy, a major crop in the Andhra Pradesh, rose to 1.33 crore tons in 2021-22 from 1.30 crore tons in 2020-21. As per the data provided by the Directorate of Economics and Statistics, paddy production in 2019-20 (both Kharif and Rabi) stood at 1.37 crore tons.

Rice husk can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon.RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature. Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash.

Although the studies on pozzolanic activity of RHA, its use as a supplementary cementations material, and its environmental and economic benefits are available in many literatures, very few of them deal with rice husk combustion and grinding methods. The optimized RHA, by controlled burn and/or grinding,


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

has been used as a pozzolanic material in cement and concrete. Using it provides several advantages, such as improved strength and durability properties, and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions. Up to now, little research has been done to investigate the use of RHA as supplementary material in cement and concrete production. The effect of partial replacement of cement with different percentages of ground RHA on some of the mechanical properties of concrete has been examined.

**OBJECTIVES**

1. To partially replace the cement used in concrete partially with rice husk ash
2. To investigate the workability of fresh concrete made in which rice husk ash is incorporated fractionally
3. To investigate the compressive strength and splitting tensile strength of concrete made with partial replacement of OPC with rice husk ash

**Previous Studies on Replacement Of OPC With RHA**

Investigation of the influence of 10% RHA inclusion as partial replacement of cement on the compressive strength of concrete was done (Malhotra & Zhang, 1996). Water-to- binder ratio was maintained at 0.40. At 28 days, the RHA concrete had a compressive strength of 38.6 N/mm2compared with 36.4 N/mm2 for the control concrete (100% OPC).At 180 days, RHA concrete exhibited compressive strength of 48.3 N/mm2 compared with 44.2N/mm2 for the control concrete. Investigation of the effect of partial replacement of cement with rice husk ash (RHA) on the porosity and water absorption of concrete was also carried out and cement was replaced with 0, 5, 10, 15, 20, 25, and 30% RHA (Saraswathy, 2007).Proportion of control (without RHA) mix was 1:1.5:3 with w/c ratio of 0.53. Porosity and water absorption test was carried out as per (ASTM C642, 1997).

**It Was Concluded That**

1. Porosity values decreased with the increase in RHA content because small RHA particles improved the particle packing density of the blended cement, leading to are duced volume of larger pores.

2. Coefficient of water absorption for rice husk ash replaced concrete at all replacement levels was found to be less when compared to control concrete.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

A study on the effects of using rice husk ash (RHA), as a cement replacement material, on the workability, rate of workability loss and compressive strength of cementitious materials in a controlled experimental program was performed (Assem, et al., 2003). The possibility of using RHA for producing high strength concrete was also investigated.

Various OPC mortar mixes at0.5 w/c ratio and containing different contents of RHA were prepared and subjected to the mortar flow test at different elapsed periods from mixing. Cubical specimens were taken from these mixes, cured with different curing regimes (air, moist and sealed) and finally tested for compressive strength at age of 56 days. Concrete specimens made with different RHA contents and water cement ratios (0.4, 0.3 and 0.25) were also prepared and tested for compressive strength.

It was found that the incorporation of RHA in OPC mixes led toa notable reduction in the initial flow ability, rate of flow ability loss, and an increase in the compressive strength. In Kenya, an examination of the engineering properties of binder resulting from a mixture of OPC with RHA made from rice husks from Mwea rice mills (Kenya) was conducted and established that the compressive strength of OPC/RHA concrete cubes increases with increased amount of RHA but the compressive strength of OPC/RHA mortar cubes decreases with increased amount of RHA. Workability and setting times were found to decrease with increased amounts of RHA (Dulo, et al., 2002).

In conclusion, the improvement in the compressive strength of cementitious material that is produced as a result of incorporating RHA in OPC is due to the pozzolanic reaction occurring between RHA and free lime in hydrating cement. The presence of free Ca2+ and OH- ions, in hydrating cement is limited and is attributed to the hydration reaction of calcium silicates.

These studies show that due to the high specific surface of RHA, the incorporation of RHA in OPC concrete leads to loss of workability, indicating why most of published studies have used fairly higher water: cement ratios in order to achieve a workable concrete mix. Some of the other early researches have examined the use of rice husk ash (RHA) in concrete.RHA is highly pozzolanic material. The non-crystalline silica and large specific surface area of the RHA is responsible for its high pozzolanic activity. There was an


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

investigation carried out on the effect of rice husk on pozzolanic behavior of rice husk ash (Hana &Moayad, 1984)). The study was aimed at obtaining the actual range of temperature required to burn rice husks so as to get the desired pozzolanic product.

The investigation was done up to 40% replacement of cement with RHA which was realized to be acquired with no significant change in the compressive strength as compared to the controlled mix, if the rice husk is burnt under optimum temperature condition. Some researchers worked hard on the effect of rice husk ash on high strength concrete (Muhammad & Waliudd in, 1996). They studied the effect of rice husk ash (RHA) passing 200- and 325-micronsieves with 10- 30 % replacement of cement on strength of HSC.

The test results indicated that strength of HSC decreased when cement was partially replaced by RHA for maintaining same value of workability. They observed that optimum replacement of cement by RHA was 10 –20 %.A conclusion of burning rice husks at temperatures below 700°C because of producing rice husk ashes with high pozzolanic activity was made. (Mahdikhani, et al., 2010).

**Hydration Mechanism of Concrete with RHA**

Portland cement contains 60 to 65% of lime and upon hydration, a considerable portion of lime is released as free calcium hydroxide Ca (OH)2, which is primarily responsible for the poor performance of Portland cement concretes in acidic environments. Silica present in the RHA combines with the calcium hydroxide and results excellent resistance of the material to acidic environments. RHA replacing Portland cement resists chloride penetration, improves capillary suction and accelerated chloride diffusivity. Pozzolanic reaction of RHA consumes calcium hydroxide present in a hydrated Portland cement paste, reduces susceptible to acid attack and improves resistance to chloride penetration.

This reduces large pores and porosity resulting very low permeability. The pozzolanic and cementitious reaction associated with RHA reduces the free lime present in the cement paste, decreases the permeability of the system, improves overall resistance to CO2 attack and enhances resistance to corrosion of steel in concrete. Highly micro porous structure RHA mixed concrete provides escape paths for the freezing water inside the concrete, relieving internal stresses,


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

reducing micro cracking and improving freeze- thaw resistance.

## MATERIALS

***Cement:*** Cement is the one of the binding materials. The cement used in our project is Ordinary Portland cement of 53 Grade. The cement used is fresh and without any lumps. Portland Cement (PC) is a hydraulic binder and a key ingredient of concrete which acts like glue to stick sand and gravel together.

***Fine Aggregates:*** The sand used in this investigation is ordinary river sand. The sand passing through 4.75 mm size sieve is used in the preparation of specimens. The sand conforms to grading Zone-II as per IS: 383-1970. The properties of sand such as fineness modulus, water absorption and specific gravity were determined as per IS: 2386-1963.

***Coarse Aggregates:*** The physical properties have been determined as per IS: 2386-1963.The course aggregates used in our project is 20mm size aggregates. The specific gravity of coarse aggregates is 2.9.

***Rice Husk Ash:*** Rice Husk Ash used in the present experimental study was obtained from the local furnaces in the outskirts of Kurnool city. The silica content was about 90% with a mean particle size of 25 microns. The ash was grey black in color.

***Water:*** The water used is potable water and it's free from suspended solids and organic materials, which might have affected the properties of the fresh and hardened concrete. The water used for both mixing and curing of concrete should be free from impurities, injurious amounts of acids, alkalis, oils, salts, organic matter or other substances that may be deleterious to concrete or steel. The presence of chlorides and sulphates are injurious to reinforcing bars as they may be corroded. The general required of water for mixing and curing concrete shall be as per IS 456-2000.

***Table 1: Mix proportions***

| Cement ($kg/m^3$) | Fine Aggregate ($kg/m^3$) | Coarse Aggregate ($kg/m^3$) | W/C ratio |
|---|---|---|---|
| 350 | 771.37 | 1140.78 | 0.4 |

### Slump Cone Test

Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

batch to check the uniform quality of concrete during construction. The slump test is the simplest workability test for concrete, involves low cost and provides immediate results.

Due to this fact, it has been widely used for workability tests since 1922. Generally concrete slump value is used to find the workability, which indicates water-cement ratio, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value. When the slump test is carried out, following are the shape of the concrete slump that can be observed:

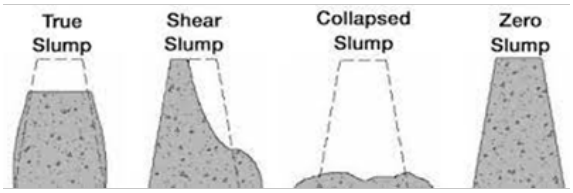



***Fig: 1 Types of slumps***

**TYPES OF CONCRETE SLUMP TEST RESULTS**

- **True Slump –** True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in figure-1
- **Collapsed Slump –** This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate
- **Shear Slump –** The shear slump indicates that the result is incomplete, and concrete to be retested
- **Zero Slump –** Zero slumps is the indication of very low water-cement ratio, which results in dry mixes. This type of concrete is generally used for road construction.

**Table 2: Slump Test Results**

| S.No | Percentage replacement of OPC with RHA (%) | Slump(mm) |
|---|---|---|
| 1 | 0 | 91 |
| 2 | 5 | 88 |
| 3 | 10 | 81 |
| 4 | 15 | 77 |
| 5 | 20 | 72 |
| 6 | 25 | 61 |

**Compressive Strength Test**

Compressive Strength was tested on cubical specimen of size 150mm X 150mm X 150mm and Split tensile strength was tested on cylindrical specimens of dimensions of 150mm


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

diameter and 300mm in height for all mixes. The principal properties of hardened concrete which are of practical importance are those concerning its strength; stress-strain characteristics; shrinkage and creep deformation; response to temperature variation; permeability and durability. Of these, the strength of concrete assumes a greater significance because the strength is related to the structure of hardened cement paste and gives an overall picture of the quality of concrete.

Concrete must be proportioned & produced to carry imposed loads; resist deformation & be dimensionally stable. The quality of concrete is characterized by its mechanical properties & ability to resist deformation. Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPA to 30 MPA and higher in commercial and industrial structures. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc. Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for compressive strength of cylindrical concrete specimens. Compressive Strength Definition Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. Compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied. As noted from the strength values mentioned in Table 3, the compressive strength was found to increase gradually from 5% to 20% replacement levels and the maximum strengths were obtained at 20% substitution levels. RHA can be considered as suitable replacement material for cement in concrete composites with respect to compression attributes. Compression strength is one of the key strengths for all concrete related composites' because concrete should be strong in compression and however this material is weak in tension which is compensated by the addition of steel reinforcement.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Journal of Ceramics and Concrete Technology
Volume 7 Issue 2
ISSN: 2457-0826 (Online)

***Table 3: Compressive strength test results***

| S. No | Percentage Replacement Of OPC With RHA (%) | Compressive Strength (N/Mm$^2$) | | |
|---|---|---|---|---|
| | | 7days | 14 Days | 28 Days |
| 1 | 0 | 17.28 | 23.58 | 31.26 |
| 2 | 5 | 18.86 | 23.93 | 32.21 |
| 3 | 10 | 18.91 | 24.23 | 32.85 |
| 4 | 15 | 19.22 | 25.35 | 33.89 |
| 5 | 20 | 20.01 | 25.89 | 34.58 |
| 6 | 25 | 16.74 | 20.334 | 28.23 |



***Fig: 2 Ttesting of Cube specimen***

**Split Tensile Strength Test**

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence it is not expected to Resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. This procedure based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which is similar to other codes like IS 5816 1999.As observed from the test results of split tensile test, the strength was found to increase gradually from 5% to 20% replacement levels and the maximum strengths were obtained at 20% substitution levels. Hence 20% replacement level is considered to be an optimum percentage with respect to these two mechanical properties of concrete.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

***Table 4: Splitting tensile strength test results***

| S.No | Percentage replacement of OPC with RHA (%) | Split Tensile Strength (N/mm$^2$) | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| 1 | 0 | 1.12 | 1.78 | 2.06 |
| 2 | 5 | 1.31 | 1.80 | 2.95 |
| 3 | 10 | 1.65 | 1.98 | 3.33 |
| 4 | 15 | 1.72 | 2.06 | 3.76 |
| 5 | 20 | 1.91 | 2.56 | 4.56 |
| 6 | 25 | 1.38 | 1.98 | 3.01 |

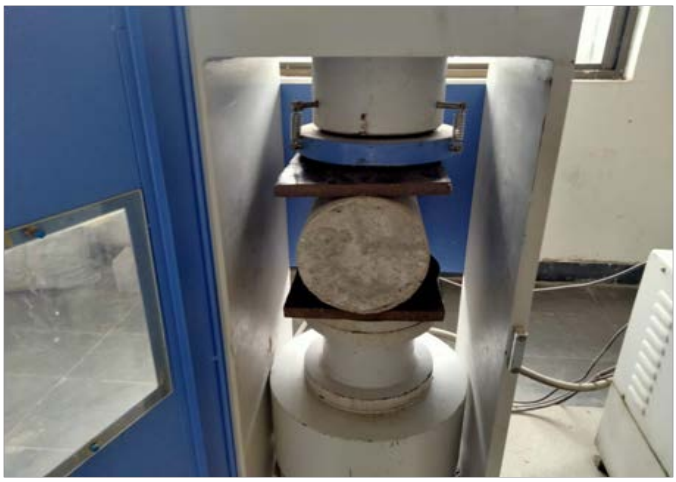


***Fig: 3 Testing of Cylindrical Specimens***

## CONCLUSIONS

Based on experiments and test results on fresh & hardened concrete the following conclusions are drawn:

Due to addition of rice Husk ash, concrete becomes cohesive and more plastic and thus permits easier placing and finishing of concrete. It also increases workability of concrete.

Due to addition of RHA, it is observed that early strength gain is slightly increasing with addition of 5%, 10%, 15% &20% RHA in normal concrete at 7 days.

But in 28 days tests results it is found that with addition of 20% RHA in normal concrete strength is running parallel or more than of normal concrete. Thus 20% RHA is the optimum content for getting nearly equal strength at 28 days.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

As the replacement of cement by RHA in concrete increases, the workability of concrete decreases. Replacement of cement with Rice Husk Ash leads to increase in the compressive strength and split tensile strength.

The optimum replacement level of Rice Husk Ash is found to be 20% for M30 grade of concrete.

The utilization of RHA holds promising prospects in the country because it softens the impact on the environment & capital cost of the structure. As the Rice Husk Ash is cheaper material, it reduces the cost of construction. It helps in reducing the pollution in environment.

**REFERENCES**

1. Abubakar, H. A. R., 2010. Malaysian rice husk ash - Improving the durability and corrosion resistance of concrete. Concrete Research Letters, Volume I.

2. Anon., 1988. Cement and Concrete Terminology. Detroit, Michigan.

3. Assem, A., Gamal, A. E. &Ramy, Z., 2003. Fresh and Mechanical properties of thecementitious materials containing rice husks ash. Cairo: Zagazig University.

4. A.A. Boateng and D.A. Skeete, “Incineration of Rice Hull for use as a Cementitious Material: The Guyana Experience,” Cement and Concrete Research, Vol.20, 1990, pp.795-802.

5. Arpana, “Rice Husk Ash-Admixture to concrete,” 2nd National conference on Advances in concrete Technology, February 26-27, 2004, pp.93-98.

6. Deepa G. Nair, K.S Jagadish, Alex Fraaij, “Reactive Pozzolanas from Rice Husk Ash: An alternative to cement for rural housing,” Cement and Concrete Research 36(2006)1062-1071

7. G.V.Rama Rao and M.V.SheshagiriRao,”High performance Concrete with Rice Husk Ash as Mineral Admixture, ”ICI Journal, April-June 2003, pp.17-22.

8. H.B.Mahmud, B.S.Chia and N.B.A.A. Hamid,” Rice Husk Ash-An Alternative material in


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

producing High Strength Concrete," International Conference on Engineering Materials, June 8-11, 1997, Ottawa, Canada, pp.275-284.

9. Badogiannis, E., Chaniotakis, E., Papadakis, V. G. & Tsivilis, S., 2004. Exploitation of poor Greekkaolins: strength development of met kaolin concrete and evaluation by means of K-value. Cement and Concrete Research, Volume 34, pp. 1035-1041.

10. Berntsson, L., Chandra, S. & Kutti, T., 1990. Principles and Factors Influencing High Strength Concrete Production. Concrete International, pp. 59-62.

11. Bleszynski, S. H. M. & Thomas, 1999. The effect of fly ash composition on the chemistry of pore solution in hydrated cement pastes. Cement and concrete research, Volume XXIX.

12. Brooks, J. & Neville, A. M., 2006. Concrete Technology. New Dehli: Dorling Kindersley Limited.

13. Bui, H. J. & Stroeven, 2005. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and Concrete Composites, Volume XXVII,pp. 357-366.

14. Chand rasekar S, R. N. P. S. K. G., 2003. Processing properties and applications of reactive silica from rice husk. Journal of Materials Science.

15. Cui, L. T. Y. & Tang, 2007. The effects of aggregate properties on lightweight concrete. Building and Environment, pp. 3025-3027.

16. Dulo, K. G. N., P, S. M. & S, W. B., 2002. Rice husk ash cements alternative pozzolana cement for Kenyan building industry. Journal of Civil Engineering JKUAT, Volume VIII.

17. Edward, N. G., 2008. Concrete Construction Engineering Handbook. 2nd Ed. New Jersey: CRC Press.

18. Farny & William, 1994. Production of concrete using natural pozzolana.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

19. Gambhir, M. L., 2005. Concrete Technology. 3rd ed. New Dehli: McGraw Hill Publishing.

20. Hana, A. & Moayad, A. N., 1984. Use of Rice huks ash in Concrete. International Journal of Cement Composites and Lightweight Concrete, Volume VI.

21. Jayanti, R., K, Y. R. & R, C., 2013. The Effect of Rice Husk Ash Used as Supplementary Cementing Material on Strength of Mortar. International Journal of engineering research and applications, III (3), pp. 133-136.

22. Kosmatka H, 1988. Designing and Control of concrete mixtures in Portland cement Association. pp. 17, 42, 70,184.

23. KS 02-1263, 1994. Kenyan standard for manufacture of Portland pozzolana cement. KEBS Kenya.

24. Maeda, 2001. Development of a new furnace for the production of rice husk ash. ACI International Conference on fly ash, silica fume, slag and natural pozzolans in concrete, Volume II.

25. Mahdikhani, M., Moodi, P. & Ramezanianpour, A., 2010. Mechanical properties and durability of concrete containing rice husks ash as supplementary cementing material. International Journal of Civil Engineering, VII (2).

26. Malhotra, M. V. & Zhang, H. M., 1996. High performance concrete incorporating rice husk ash as a supplementary cementing material. ACI Material Journal, Volume 93, pp. 629-636.

27. Mehta, K. P. & Monteiro, J. M. P., 2006. Concrete: micro structure, properties and materials. 3rd Ed. New York: McGraw- Hill.

28. Moral, O. N. O. & Tasdemir, 1996. Factors determining the correlations between concrete properties. Cement and Concrete research, pp. 1629 - 1637.

29. Muhammad, I. S. &Waliuddin, A. M., 1996. Effect of rice husk ash on high strength concrete.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Construction and Building Material, X (7), pp. 521-526.

30. Saraswathy, S. H., 2007. Corrosion performance of rice husk ash blended concrete. Construction and building materials, Volume XXI.

31. Tsivilis, 2000. Properties and behavior of limestone cement concrete and mortar. Cement and Concrete research, pp. 1679-1633.


Page 73-86 © MANTECH PUBLICATIONS 2022. All Rights Reserved