Partial Replacement of Cement using Rice Husk Ash and Fly Ash in Non-Autoclaved Aerated Concrete: A Review

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Abstract - *In construction, concrete is the most predominantly utilized substance in the globe. Concrete creates high carbon emission into the environment which contributes to the greenhouse gases. In concrete, cement is used which generate the carbon emission, so in order to reduce the amount of cement in concrete cement can be partially replaced with different waste material such as fly ash and rice husk ash. Approximately 180 million tons of fly ash and 4.4 million tons of rice husk ash are produced in India every year. To have an eco-friendly environment these waste can be utilised in the manufacturing of concrete. In this review paper, more attention is given to the use of the effect of waste materials such as fly ash and rice husk ash on mechanical properties non autoclaved aerated concrete.*

Key Words*: *lightweight concrete, fly ash, rice husk ash

1. INTRODUCTION

In this modern world aerated concrete is used as an innovative construction material. This aerated concrete is lightweight as compared to conventional concrete because of large number of voids present in it. The volume of pores present in concrete is 50% to 60% of the total volume of concrete. Size of these pores will affect the properties such as strength, durability, density, and water absorption etc. in concrete. Due to the pore space in concrete, it also provides good thermal insulation and acoustic insulation.

Aerated concrete is a lightweight concrete. Aerated concrete is also called porous concrete. There are two main types according to production. They are foam concrete (non-autoclaved aerated concrete (NAAC)) and autoclaved aerated concrete (AAC). In AAC, the samples are placed in an autoclave where steam curing of the sample takes place. During steam curing high temperature i.e. 180°c and pressure up to 12bar is maintained. The time period for autoclaving may vary from 8 to 12 hrs. In foamed concrete foam is produced by injecting prefabricated stable foam or adding a special air-entraining agent called foaming agent to the base mixture of cement or mortar (cement + sand + water). In this review paper, more emphasis is on NAAC in which the curing of concrete cubes or blocks is done using water. NAAC is made by adding a predetermined amount of aluminium powder and other additives to the sand, cement and water slurry. In the case of NAAC aggregates having a size greater than sand are not used in making concrete. Foamed concrete is not a particularly new material. The mixture of cement, lime, water, and sand was first discovered in 1914, which was expanded by adding aluminium powder to produce hydrogen in the cement slurry. Prior to these different trails has been made to add air to concrete using egg whites, yeast and other methods.

2. Literature Review:

Saand et.al.,(2019) *studied the effect of partial replacement of cement with rice husk ash at different percentage i.e. 0%,2.5%,5%,7.5%,10%,12.5% and 15% . It was found that up to 10% replacement of cement with rice husk ash the compressive strength and split tensile strength will get increased but further increase in the percentage of rice husk ash beyond 10% the strength starts decreasing. The maximum value of compressive strength and split tensile strength for 10% of cement replacement with RHA obtained is 4.4MPa and 0.53MPa respectively.*

He et.al.,(2019) *used recycled wood fibre and rubber powder in AAC. Researchers used the different percentage of recycled wood fibre and rubber powder in AAC to improve its performance and reduce the negative environmental impact. It is found that 0.4% is optimal wood fibre content for the strength of AAC blocks. No effect is seen at 0.5% and 1% of rubber powder content. At 1% of rubber powder content and 0.4% of wood fibre, high-performance AAC can be obtained.*

Sukmana et.al.,(2019) *used the phosphogypsum in NAAC to study the effect on compressive strength. Taguchi method is used for experimental design. The result shows that the best composition for NAAC is Portland cement with a content of 34%, phosphogypsum 35% and quicklime 10% to achieve the best strength value 20.93 kg/cm² having density 806 kg/m³.*

Fabien et.al.,(2019) *have done experimental work on the replacement of sand with recycling waste perlite and pure perlite. Pure perlite sand and waste perlite sand (30% +30%), which is used to replace sand is characterised by low density, which makes the concrete expand under non-autoclaved condition. The presence of these waste products reduces mechanical strength but improve thermal insulation. It is found that increasing the cement by 2%, we can increase the mechanical strength by 21%. A 100%*

expended material with thermal conductivity of 0.176w/.k was obtained. Therefore non-autoclaved swelling solutions have promoted the development of thermal insulation material based on recycled product.

***Kunchariyakun et.al.,(2018)** had done an experimental investigation on replacement of sand with two agricultural waste i.e. rice husk ash and bagasse ash in preparation of AAC blocks. These samples are autoclaved at different autoclaving temperature (140^{o}c, 160^{o}c and 180^{o}c) and different time period (4h, 8h and 12h). It was found that the effect of the increase in autoclaving temperature and time is directly related to the increase in strength and microstructural properties. But at 180^{o}c it was found that there is no significant increase in strength with increase in time. The reason for no significant increase in strength is because Si ions from the sand reach its maximum dissolution.*

***Karolina R. And Muhammad F. (2017)** concluded that fly ash and bottom ash can be used in the manufacturing of lightweight concrete to minimize the use of cement and sand. In normal NAAC lightweight concrete, the water absorption is found to be 5.66% which is greater absorption in the study and 2.76% is the smallest absorption by adding 30% fly ash in concrete. For normal NAAC the compressive strength is 8.891Mpa that is the lowest compressive strength in the study and the highest compressive strength is 12.687Mpa using fly ash. The researcher also concluded that the addition of 30% fly ash in concrete gives the highest tensile strength i.e. 1.540Mpa while NAAC gives the lowest tensile strength i.e. 0.801Mpa.*

***Wahane A. (2017)** compared the AAC blocks with red bricks. The researcher concluded that these blocks are more earthquake resistant and safer than red bricks because of the lightweight of AAC blocks. Compared with red bricks, the weight of AAC blocks is almost reduced by about 80% which will lead to reducing a dead load of the structure. Also, it is found that these blocks have an attractive appearance and are easy to adapt to any style of building.*

***Shuisky A. et.al.,(2017)** studied the effect of additive i.e. sodium sulphate on NAAC. In this study, one sample was prepared using 1.54% of sodium sulphate and the extra swelling part is removed from the sample. This removed part is then used to prepare new sample. Three new samples were prepared using 20% off cut with a variation of sodium cement of 1.23%, 2.4% and 3.7%. After analysing these samples they concluded that adding sodium sulphate in the amount of 1.23% and cut-off 20% will produce the best structural properties.*

***Shrivastva and Tiwari (2017)** utilize the different percentage of aluminium in the production of aerated concrete blocks having size 70.6mm*70.6mm*70.6mm. The percentage of aluminium used is 0%, 0.04%, 0.08%, 0.12% and 0.16% of dry weight of material. Researchers observed that with the increase in the percentage of aluminium powder concrete density decreases. It is observed that the compressive strength of sample S1 (when the percentage of aluminium powder used is 0.04%) and S2 (when the percentage of aluminium powder used is 0.08%) of NAAC block is 4.48N/mm^2 and 3.75N/mm^2 respectively which is greater than the third class brick strength.*

***Il'ina and Rakov.,(2016)** studied the effect of grinding of Portland cement clinker with silica, carbonate components and mineral additive on mechanical properties of NAAC. Additives used are wollastonite and diopside to check the compressive strength, thermal conductivity and density of NAAC. Adding additives to NAAC will reduce energy consumption in concrete. It is found that the hardness and elastic modulus of additives diopside is higher. Adding 5% of diopside gives 3.3Mpa compressive strength, 0.131W/m.^{o}c thermal conductivity and 580 kg/cm^3 avg. density.*

***Kunchariyakun et.al.,(2015)** used rice husk ash as partial replacement of sand in autoclaved aerated concrete. Percentage of rice husk ash used for replacement of sand are 25%, 50%, 75%, and 100%. Researchers have checked the mechanical properties of the sample at autoclaving condition having temperature 180^{o}c and pressure 12bar. Samples have been checked for two different time period i.e. 8 hours and 18 hours. The best replacement rate for replacement of sand with RHA is found at 75%. It is found that replacing sand with RHA increases water requirement which negatively impacts the compressive strength of AAC.*

***Narattha et.al.,(2015)** worked on partial replacement of cement with fly ash and silica fumes in NAAC. Thermogravimetric analysis of NAAC is done and it was found that calcium silicate hydrate ettringite, gehlenite, calcium hydroxide and calcium carbonate phases were detected in all mixes. Results showed that the use of silica fumes in NAAC has more compressive strength and thermal conductivity as compared to NAAC made up of fly ash. For silica fumes compressive strength is 23MPa and for fly ash it is 13Mpa. Also found that the specimen cured in water has more compressive strength than the specimen cured in air.*

***Yang et.al.,(2013)** utilized the phosphogypsum for the preparation of non-autoclaved aerated concrete. The result showed that with the increase in Na_2SO_4 the compressive strength increased with the increase in the percentage of Na_2SO_4 from 0 to 1.6% and decreased when the percentage of Na_2SO_4 exceeds from 1.6%. As the aluminium powder increased in the specimen the specimen density decreased. The optimal mixing ratio for preparation of NAAC using phosphogypsum are 15% cement, ground granulated blast furnace slag(GGBFS) 30%, phosphogypsum 55%, quick lime 7%, NA_2SO_4 1.6%, Al powder 0.074% and w/c ratio 0.45.The optimal steam temperature for curing sample is 90^{o}c.*

Xia Y. et.al.,(2013) *have done an experimental investigation on the use of circulating fluidized bed combustion fly ash(CFA) as a raw material in NAAC. The diameter of CFA particle ranges from 9.6μm to 23.9μm which is more suitable for making NAAC because of matching conditions of thickening rate of slurry and reaction rate of aluminium powder and water. Based on physical and mechanical test the optimal proportion of CNAAC was determined to be CFA 63.5 - 65.5%, cement 20-22%, lime 10%, PG 1.5%, Slag-3%. Both cement and lime in CNAAC affect the rheological properties of the paste. Greater the amount of cement, the reduction in relative yield stress is greater. However, relative yield stress and viscosity tend to increase as the number of lime increases.*

Li et.al.,(2011) *used desulfuration residues as aggregate in NAAC. Results showed that with the increase in desulfuration residue content the strength, as well as dry density of NAAC concrete, will get reduced. Gypsum based NAAC has compressive strength less than fly ash based NAAC. Researchers found that the optimal amount of replacement determined as 50%, at this rate the compressive strength obtained is 2.83MPa and bulk density is 543 kg/m^3. XRD pattern shows that the ettringite and calcium silicate hydrated is in such a way that they cover the incompletely reacted desulfuration residue and fly ash.*

My viewpoint: *In future researcher will focus primarily on new science and technology leading to innovative NAAC products. As the NAAC blocks have less compressive strength future research can be done on increasing the strength of these blocks. In NAAC aluminium powder is used as an air-entraining agent and it has high cost so research can be done on finding an alternate solution for the replacement of aluminium powder to make it more economical.*

3. CONCLUSIONS

1. *By utilizing the waste material in concrete disposal problems can be reduced.*
2. *NAAC is a concrete that can cope with the shortage of construction raw materials and can Produce lightweight, energy-efficient and environmentally friendly concrete.*
3. *Fly ash can be utilized to replace cement as well as sand in the production of lightweight concrete and Non-Autoclaved Aerated Concrete.*
4. *In this review paper, it has been found that the largest absorption value of water is 5.66% and smallest absorption of water 2.76% in normal NAAC.*
5. *It has been found while utilizing 30% of fly ash NAAC in concrete the maximum compressive strength obtained 12.687MPa while compressive strength of conventional NAAC concrete i.e. with 0% of fly ash is 8.891MPa.*
6. *It has been found that with the increase in the percentage of aluminium powder the density of NAAC decreases.*
7. *By utilizing fly ash it shows an improvement in tensile strength i.e. 30% of fly ash in NAAC is 1.540MPa while conventional NAAC lightweight concrete tensile strength is 0.801MPa.*
8. *By replacing 10% of cement with rice husk ash maximum compressive strength has been obtained 4.4MPa in NAAC.*
9. *With the increase in autoclaving temperature and time, it was found that compressive strength gets increased up to 180^{o}c.*
10. *AAC blocks are lighter in weight as compare to red bricks and are more earthquake-resistant because of lightweight of AAC blocks.*

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BIOGRAPHIES

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