International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 5 ǁ May 2023 ǁ PP. 280-285

Review on Properties and Microstructure of Flyash and Rubber Incorporated Foam Concrete

Kavya K N[1]
*[*1]PG Student, Department of civil engineering Mar Athanasius College of Engineering, Kothamangalam*

Abstract
Foam concrete is a type of light weight concrete can be either mortar or cement paste in which air voids are artificially entrapped into the mortar matrix. It possess low self weight, high flowability, controlled low strength, minimal usage of aggregate and excellent thermal insulation properties. While reducing the strength of the foam concrete, its durability should not be compromised. Normally density of foam concrete ranges between 400-1850 kg/m3. The density is normally controlled by substituting fully or part of the fine aggregate with foam which is manufactured by pre-foaming process or mixed foaming process. Use of different supplementary cementitious materials and fillers as replacement has proven effective. In this study flyash is used to replace cement and rubber powder is used as fillers. The project is intendented to optimize the quantity of materials used for replacement of cement and fine aggregates and to analyse different properties of foam concrete such as density, compressive strength, thermal conductivity, water absorption. Apart from it, microstructure study on the specimens will conduct to analyse the effect of addition of each material in detail.

Keywords: *Supplimentary cementitious materials, Thermal insulation, Thermal conductivity, Flowability.*

Date of Submission: 01-05-2023 Date of acceptance: 10-05-2023

I. INTRODUCTION

Insulation of buildings is crucial to lowering energy use, particularly in emerging nations where rapid urbanization is taking place. Many researchers have been inspired to produce various types of lightweight materials because of characteristics including fire resistance, affordability, and durability. However, their utility as thermal insulators has been constrained by their comparatively high density (300–1800 kg m–3) when compared to comparable porous organic materials as polyurethane board and expanded polystyrene. By making these materials' porosity higher, lightweight concrete's thermal insulation capabilities can be enhanced. [1]No matter the water/powder ratio, the yield stress and viscosity of all pastes containing just cement were the highest. Consequently, it is advised to add mineral powders to minimize the admixture content while maintaining the same fluidity. [2]. Due to its unique properties, foam concrete has low density and good thermal insulation properties and have good workability thus it can be used in construction works. Considering that foam concrete (FC) which contains high-volume cement and supplementary cementitious material (SCM) has been largely used in building engineering owing to its low density and good thermal insulation performance [3].

The Density of Foamed Concrete is inversely proportional to the percentage of foam that is added to the slurry/mortar. The Compressive Strength and Density of Foam Concrete increases with age. The Compressive Strength of Foamed Concrete increases with increase in the Density. Fine aggregate had a beneficial effect on significantly increase in Compressive Strength of Foamed Concrete. De-moulding of higher density foamed concrete panels is possible after 24 hours but it requires minimum 3 days for lower density foamed concrete panels. The starting of Strength gain for foamed concrete is on higher side than that of normal weight concrete and Strength gain beyond 28 days is faster than normal weight concrete. The addition of fly ash of equal amount of cement makes it possible to gain the target strength with Age. [4].

The demand for novel technology for manufacturing lightweight concrete has increased in the global construction industry. Fine silica fume and polypropylene fibre considerably promoted the hardened strength of the foamed concrete. the addition of polypropylene fibre significantly enhanced the tensile strength and increased the creep resistance and drying shrinkage. Therefore, structural fibered foamed concrete can be used as a substitute lightweight concrete material for the production of structural concrete applications in the construction industries today. [5].

The properties of lightweight foamed concrete (LFC) make it an excellent material for use in construction and civil engineering. It flows readily and doesn't need to be compacted to fill moulds or cavities that are confined or uneven. Porosity and microstructural properties are intimately related to strength and thermal conductivity when density falls. [6].

II. MATERIALS USED

Superplasticizer (SP) is widely used in foam concrete industry to improve rheological properties since compaction and vibration adversely affect the stability of foam bubbles. Content of w/c and SP had a significant impact on the performancve of the foam concrete. In the concrete industry, superplasticizer is a widely used addition. It is mostly used to decrease the amount of water and enhance the rheological characteristics. use of certain substitutes such as fly ash, silica fume, granulated blast slag as a cement or filler replacement; and the use of certain additives such as SP, foam stabilizer and fibres can significantly improve the strength of the foam concrete [7].

The air void structure in FC is the most important factor on the compressive strength and dynamic modules of elasticity. As a natural result of the changes in the air void system, there may be significant effects on the micro/macro structure and mechanical properties of FC. With the decrease in the density of FC, decreases in compressive strength occur. In addition, protein-based and two different synthetic-based foaming agents were used to produce FC. Therefore, the type of foaming agent used in FC production also affects the mechanical properties of FC.[8]

2.1 SUPPLIMENTARY CEMENTITIOUS MATERIALS

Nowadays, several materials are used as a substitute to cement worldwide. The replacements are used to impart economy, improved durability, different colors, and most importantly, a lower impact on nature than using ordinary Portland cement [11].

2.1.1 Fly Ash

Fly ash is the finely powdered residue produced from the combustion of powdered coal, floats out of the combustion chamber with exhaust gases, and is collected by emission control such as electrostatic precipitator and scrubbers. It is considered the most used pozzolanic material. The application of fly ash in concrete has impacted the technical properties and contributes to environmental pollution control [13]. The primary influence of Fly ash on the fresh properties of concrete is water demand and workability. The reduction in water demand of concrete in the presence of Fly ash usually is about 5 and 15 % compared to the control mix for steady workability. The studies revealed that after 20% of replacement, there is a considerable effect on the mechanical properties. Fly ash is broadly classified into Class F and Class C, and this classification is based on its calcium content [15].

By removing calcium hydroxide, Class Fly ash improves its sulfate resistance at percentage content between 25 to 40 % of final cementitious material. In the case of air-entrained concrete, almost 60% of cement replacement with Class F Fly ash exhibits good resistance to freezing and thawing at a water-cement ratio of 0.33. The resistance is found to be weakened while using Class C Fly ash [19]. At the water-cement ratio between 0.27 and 0.39, and 60% of cement replacement with Fly ash, the specimen exhibits good resistance to chloride penetration [19].

2.1.2 Ground Granulated Blast Furnace Slag

GGBS in concrete increases workability, but the mix was found to be more cohesive. This is because of the smooth surface nature of GGBS particles and thus absorbs less water during mixing. It is also because of the superior dispersion quality of the cementitious particles found in GGBS. It is also found that the mix leads to retardation at average temperatures [20].

The hydration depends on the breakdown of the glass content present in supplementary cementitious particles resulting in a denser microstructure and long-term strength. That is, about 37 % of GGBS is hydrated at 28 days. Thus, the overall hydration temperature can be brought down by incorporating GGBS in the mix. This temperature reduction is because of the finer particles in GGBS, which can be rectified by using Portland cement with high contents of C3A and alkalis [26]. The average pore size is reduced by 15, 30, and 47%, respectively, at 10, 30, and 50%. Out of this, 0.6 water-cement ratios were found to be more successful. The carbonation rate is increased while replacing with GGBS at 50%. This rate can be brought down by extending the period of water curing. The use of GGBS alters the morphology of cement paste. It exhibits a foil-like morphology, while Portland cement produces C-S-H gel with fibril morphology [29].

2.1.3. Silica Fume

Silica fume is an amorphous, highly reactive ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy. The alloy is from high-purity quartz and coal in a submerged arc electric furnace. The packing density and cohesion of the mix is improved can be improved by using silica fume. Thus the bleeding tendency is reduced. The concrete cohesiveness makes it suitable for underwater concreting and flowing concrete. In air entrained concrete, an increased amount of air-entraining admixture is used while incorporating silica fume. Again, there are some problems with the air void system, even though the entrained air remains stable [17].

2.1.4. Rice Husk Ash

Another category of waste material that can be induced in concrete as filler and additives is rice husk ash (RHA), which will be obtained as a result of incineration under controlled conditions. The formation of supplementary C-S-H gel contributes to the strength development and durability characteristics of concrete. The high porous microstructure itself contributes to the weakest point in the hardened matrix. The $Ca(OH)_2$ reacts with atmospheric carbon dioxide to form calcium carbonate, which improves strength formation [18].

2.2 REPLACEMENT TO FINE AGGREGATES

2.2.1 Rubber Particles

The waste rubber particles are another environmental hazard. Billions of tires presently abide in landfills and illegal deposits everywhere throughout the world. The leading cause of these tires is that it releases a large volume of toxic chemicals. The rubber particles can be utilized as fillers as well as replaced with fine aggregates. There are mainly three forms of rubber that can be used for concreting like ash rubber, crumb rubber, and tire chips. The workability of the mix with rubber content has not been significantly influenced. The compressive strength will get degraded as time passes in rubberized concrete, but low density (less than 1000kg/m3) can be achieved [19].

The waste tire can be used in different forms like spheroid and fibers in concrete, which advances sustainability in the construction field by utilizing environmental hazard-causing material without draining natural assets. Fiber-shaped tire particles show a more significant reduction in density (34.6%) than spherical ones (19.2%) at 30% of replacement with fine aggregates due to the higher density of spherical particles. It is widely investigated that the compressive strength reduces (70%), and water absorption (32%) increases due to weak adhesion of tire particles with cement. The less stiffness and poor surface texture of rubber particles promote low adhesion with the cement matrix [20].

2.2.2. Quarry Dust

Quarry dust, which is available in large quantities in onsite and offsite locations, is a by-product of stone cutting, grinding, sieving, and crushing, creates several environmental problems. It results in lower energy consumption and greenhouse gas emissions. About 30% of the total volume of stone waste is rock quarrying. This vast amount is dumped as landfills causing damage to the environment and risk to human well-being. A method of solving the aforementioned issue is to use it as an aggregate in concrete. While using quarry dust, it is observed that there is no bleeding in fresh states because of the elongated shape and high surface area exhibited by quarry dust [21].

2.2.3. Plastic Waste

A billion tons of varieties of plastic wastes are disposed on landfills every year, and recycling it into useful products has proven very difficult nowadays. Because of its wide availability and non-biodegradable characteristics, researches are done to incorporate it into concrete. The common forms of plastic waste used in concrete are polyethylene terephthalate (PET) bottles, scraped PVC pipes, metalized plastic wastes. The magnitude of the PET bottle granules concrete is 4mm, which can either be used as fillers or replacements [22]. The density of PET granules is investigated to be 1390kg/m3, water absorption 0%, bulk density is observed to be 844kg/m3. The fineness modulus is observed to be a little superior to that of river sand that is 4.11, since this is single graded [23].

2.2.4. Glass Powder

Glass is rigid, homogenous, inert, stable, amorphous, and isotropic material. It is manufactured by combining several inorganic raw materials and undergoes a process of controlled cooling. The use of waste glass in different forms can be used in the construction sector and is proved to be advantageous as it saves lots of energy and economy. Glass non-crystalline silica is found to be almost the same elements as ordinary Portland cement. However, it differs in concentrations if alkali content is disregarded. The alkali content in glass is a significant disadvantage while using this for concrete production. But this can be decreased by using certain supplementary cementitious materials like Fly Ash, GGBS, and metakaolin [24]

III. PROPERTIES OF FOAM CONCRETE

Different properties of foamed concrete are described below.

3.1. Density

The water cementitious materials ratio is related to the amount of aeration obtained and thus the density. For a given density, water cement ratio increases with proportion of sand. For foam concrete with pozzolans, water± solids ratio appears to be more important than the water cementitious ratio, irrespective of the method of pore-formation. For gas concrete, a lesser water solids ratio leads to insufficient aeration while a higher one results in rupture of the voids, increase in density being the consequence in both the cases. As many physical properties of aerated concrete depend on the density (300±1800 kg/m3), it is essential that its properties be qualified with density. While specifying the density, the moisture condition (i.e., oven-dry condition or at equilibrium with atmosphere) needs to be indicated. The material as delivered from autoclave may be 15-25% heavier than oven-dry material. This value can be as high as 45% for very low density aerated concrete [39].

3.2. Compressive strength

The specimen size and shape, method of pore-formation, direction of loading, age, water content, characteristics of ingredients used and method of curing are reported to influence the strength of aerated concrete. Pore structure of the air pores and mechanical condition of pore shells have a marked influence on the compressive strength. Density reduction by the formation of large macropores is found to cause a significant strength drop. Compressive strength varies inversely with moisture content. On drying to equilibrium with normal atmosphere, there is an increase in strength and an even larger increase on complete drying out. Hence tests are recommended on materials that have attained equilibrium with the surroundings. A correction factor has been proposed to assess the increase in compressive strength from wet to dry state [26].

3.3. Modulus of elasticity

Most formulae for the modulus of elasticity of foam concrete in compression report it as a function of the compressive strength [27].

3.4. Tensile and flexural strength

The ratio of direct tensile (T) to compressive strength (S) of AAC to be 0.15-0.35. Such variations may be attributed to the fact that the determination of tensile strength is more sensitive to the conditions of the test than that of compressive strength. The ratio of flexural to compressive strength varies from 0.22 to 0.27. For very low density aerated concrete, this value is almost zero [28]

3.5. Drying shrinkage

Drying shrinkage occurs due to the loss of adsorbed water from the material and is significant in aerated concrete because of its high total porosity (40-80%) and specific surface of pores (around 30 m2/g). Decrease in pore sizes, along with a higher percentage of pores of smaller size is reported to increase shrinkage. The capillary tension theory of drying shrinkage of porous building materials states that the water in the pore exists in tension and this creates an attractive force between the pore walls. Drying shrinkage of aerated concrete with only cement as the binder is reported to be significantly higher than that produced with lime or lime and cement. The shrinkage of lime, cement products is the least. With an increasing amount of reactive silica in the paste, shrinkage increases and attains a maximum value at 30-60% silica replacement and then decreases [29].

3.6. Water absorption and capillarity

Foamed concrete being porous, there is a strong interaction between water, water vapour and the porous system and there exists various moisture transport mechanisms. In the dry state, pores are empty and the water vapour diffusion dominates, while some pores are filled in higher humidity regions. Capillary suction predominates for an element in contact with water. These mechanisms make it difficult to predict the influence of pore size distribution and water content on moisture migration. The water vapour transfer is explained in terms of water vapour permeability and moisture diffusion coefficient whereas capillary suction and water permeability characterise the water transfer. The moisture transport phenomena in porous materials, by absorbing and transmitting water by capillarity, has been defined by an easily measurable property called the sorptivity, which is based on unsaturated flow theory[30].

3.7. Durability

Aerated concrete has high porosity, allowing penetration by liquids and gases. This may lead to the damage of the matrix. Freeze-thaw reactions are reported to be significant as far as AAC is concerned at saturation degrees of 20-40%. At higher degrees of saturation, the sample becomes brittle and cracks completely. Protective precautions using bitumen-based materials are necessary when sulphate attack is anticipated. Carbonation can lead to increase in density but it is not very serious unless the exposure to CO_2 is too severe [29].

3.8. Thermal conductivity

Thermal conductivity depends on density, moisture content and ingredients of the material. As thermal conductivity is largely a function of density, it does not really matter whether the product is moist cured or autoclaved as far as thermal conductivity is concerned. The amount of pores and their distribution are also critical for thermal insulation. Finer the pores better the insulation. As the thermal conductivity is influenced by the moisture content (a 1% increase in moisture by mass increases thermal conductivity by 42%), it should not be reported in oven dry condition.[25]

3.9. Fire resistance

In practice, the fire-resistance of aerated concrete is more than or as good as ordinary dense concrete and hence its use does not involve any risk of spread of flames. An important reason for such behaviour is that the material is relatively homogeneous, unlike normal concrete where the presence of coarse aggregate leads to differential rates of expansion, cracking and disintegration. The good fire resisting property of aerated concrete is where its closed pore structure pays rich dividends, as heat transfer through radiation is an inverse function of the number of air-solid interfaces traversed. This coupled with their low thermal conductivity and diffusivity gives an indication that aerated concrete possesses better fire-resisting properties.[14]

IV. CONCLUSIONS

- Foamed concrete is typically subjected to an accelerated hardening process in order to prevent the aforementioned coarsening and collapse.
- The Density of Foamed Concrete is inversely proportional to the percentage of foam that is added to the slurry/mortar.
- The Compressive Strength and Density of Foam Concrete increases with age.
- The Compressive Strength of Foamed Concrete increases with increase in the Density.
- Fine aggregate had a beneficial effect on significantly increase in Compressive Strength of Foamed Concrete.
- De-moulding of higher density foamed concrete panels is possible after 24 hours but it requires minimum 3 days for lower density foamed concrete panels.
- The starting of Strength gain for foamed concrete is on higher side than that of normal weight concrete and Strength gain beyond 28 days is faster than normal weight concrete.
- The addition of fly ash of equal amount of cement makes it possible to gain the target strength with Age.
- Both the foamed concrete mixed proportions can be used for making partition walls in buildings.

REFERENCES

[1]. Jun Jiang, Zhongyuan Lu, Yunhui Niu, Jun Li, Yuping Zhang (2015), "Study on the preparation and properties of high- porosity foamed concretes based on ordinary Portland cement", S0264-1275(15)30919-9.

[2]. Rudiele Aparecida Schankoski, Ronaldo Pilar, Luiz Roberto Prudêncio Jr., Raissa Douglas Ferron (2016), "Evaluation of fresh cement pastes containing quarry by-product powders", Construction and Building Materials 133 (2017) 234–242.

[3]. Dingyi Yang, Miao Liu, Zhibin Zhang, Pengpeng Yao, Zhiming Ma (2021), "Properties and modification of sustainable foam concrete including eco-friendly recycled powder from concrete waste", Case Studies in Construction Materials- https://doi.org/10.1016/j.cscm.2021.e00826.

[4]. Maheshkumar H. Thakrele (2014), "Experimental Study On Foam Concrete", Construction and Building Materials, Vol. 4, Issue 1, Feb 2014, 145-158.

[5]. Y.H. Mugahed Amran, Rayed Alyousef, Hisham Alabduljabbar, M.H.R. Khudhair, Farzad Hejazi, Abdulaziz Alaskar, Fahed Alrshoudi, Ayesha Siddika (2019), "Performance properties of structural fibred-foamed concrete", Results in Engineering 5 (2020) 100092.

[6]. Alassane Compaor, Moustapha Sawadogo, Youssouf Sawadogo (2023), "Preparation and characterization of foamed concrete using a foaming agent and local mineral resources from Burkina Faso", Results in Materials 17 (2023) 100365 Available.

[7]. Alassane Compaor´e, Moustapha Sawadogo, Youssouf Sawadogo (2023), "Preparation and characterization of foamed concrete using a foaming agent and local mineral resources from Burkina Faso", Results in Materials 17 (2023) 100365 Available.

[8]. Burçin S¸enol S¸eker, Murat G¨okçe, Kenan Toklu, (2022), "Investigation of the effect of silica fume and synthetic foam additive on cell structure in ultra-low density foam concrete, Case Studies in Construction Materials 16 (2022) e01062.

[9]. A Peter and Claisse (2016), "Cement and cement replacement materials. Civil Engineering Materials", 18:163–176, 2016.

[10]. Ameer A. Hilal, Nicholas Howard Thom, and Andrew Robert Dawson (2018), "On void structure and strength of foamed concrete made without/with additives", Construction and Building Materials, 85:157–164, 2015.

[11]. R Helmuth (2020), " Fly ash in cement and concrete, Portland Cement Association", Journal of Cement and Concrete Research, 30:201–204, 1987.

[12]. V Bilodeau, K E Sivasundaram, V M Painter, and Malhotra (2019), "Durability of Concrete incorporating High Volumes of Fly Ash from Sources in the U. S.A", Materials Journal, 91(10):3–12, 2019.

[13]. H.T.Cao, L Bucea, B.Wortley, V. Sirivivatnanon (2020), "Corrosion behaviours of steel embedded in Fly ash blended cements", ACI special -145,215-228(2020).

[14]. D. Etrodedroit D, Michigam, ACI 2026 IR 67. (2006), "GGBS as a cementatiois consitunt in concrete; ACI manuel of concrete practice", Part –I-Materials and general properties of concrete, 2006.

[15]. Sakai K, Watanabe H, Suzuki M, Hamazaki K.(1992), "Properties of granulated blast-furnace slag cement concrete, Proceedings of fourth international conference on fly ash, silica fume, slag, and natural pozzolans in concrete. Istanbul, Turkey: American Concrete Institute Publication", ACI-SP132, p. 1367–383, 1992.

[16]. Paulo J P Kumar Mehta and Monterio.(2020), "Concrete, microstructure, properties and materials, 4th Edition", McGraw Hill Education (India) Private Limited 2020

[17]. Gruszczyński, M., & Lenart, M (2020), "Durability of mortars modified with the addition of amorphous aluminum silicate and silica fume", Theoretical and Applied Fracture Mechanics, 107, 102526, 2020

[18]. Le.H. T, Siewet, K Ludwig H M (2014), "Synergistic effects of rice husk ash and fly ash on properties of self-compacting high-performance concrete", Proceedings of symposium on ultra-high performance concrete and nano technology for high-performance construction materials, Kerssel, Germany,187-195,2014.

[19]. Sara Sgobba, Giuseppe Carlo Marano, Massimo Borsa, and Marcello Molfetta (2010), "Use of rubber particles from recycled tires as concrete aggregates for Engineering Applications", In Proceedings of Second International Conference on Sustainable Construction materials and technologies, 2010.

[20]. Andressa F. Angelin, Rosa C. Cecche Lintz, Luísa A. Gachet-Barbosa, and Wislei R. Osório (2017), "The effects of porosity on mechanical behavior and water absorption of an environmentally friendly cement mortar with recycled rubber", Construction and Building Materials, 151:534–545, 2017.

[21]. Schankoski, R. A., Pilar, R., Prudêncio, L. R., & Ferron, R. D (2017), "Evaluation of fresh cement pastes containing quarry by-product powders", Construction and Building Materials, 133, 234-242, 2017.

[22]. Johannesson, B., & Utgenannt, P (2001), "Microstructural changes caused by carbonation of cement mortar", Cement and Concrete Research, 31(6), 925-931, 2001.

[23]. Semiha Akçaözog˘lu, Cengiz Duran Atis¸ and Kubilay Akçaözog˘lu (2010) "An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete", Waste Management, 30(2):285–290, 2010.

[24]. Matos, A. M., & Sousa-Coutinho, J (2012), "Durability of mortar using waste glass powder as cement replacement", Construction and Building Materials, 36, 205-215, 2012.

[25]. Abhishek Thakur and Saurav Kumar (2022) "Mechanical properties and development of light weight concrete by using autoclaved aerated concrete (AAC) with aluminum powder" , Materials Today: Proceedings 56 (2022) 3734–3739

[26]. Najim, K. B., and Hall, M. R. (2010), "A review of the fresh/hardened properties and applications for plain- (PRC) and self-compacting rubberized concrete (SCRC)." Journal of Construction and Building Materials, ELSEVIER, 24, 2043-2051.

[27]. Mohammad Reza sohrabi, Mohammad Karbalaie (2019), "An experimental study on compressive strength of concrete containing crumb rubber" Journal of Cement and Concrete Research, ELSEVIER, 44, 2309-2358.

[28]. Yunping Xi, Yue Li, Zhaohui Xie, and Lee J.S.(2003), Utilization of Solid Wastes (Waste Glass and Rubber Particles) as Aggregates in Concrete, Colorado, 2003.

[29]. Gintautas S., Audrius G. and Benjaminas C (2007), Deformation Properties of Concrete With Rubber Waste Additives, Lithuania: Kaunas University of Technology, 2007.

[30]. A. Mohammad Mustafa al bakri, S.A. Syed Nuzul Fadli, M.D. Abu bakar and K.W leong, Comparison of rubber as aggregate and rubber as filler in concrete. Journal of Cement andConcrete Research, ELSEVIER, 84, 2309-2323