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Review Paper On Use Of Waste Material In Concrete For Rigid Pavement Construction

Mayank Singh [1], Pushpendra Kumar Kushwaha[2], Mithun Kumar Rana[3]

[1]M. Tech. Research Scholar, Civil Department, RKDF College of Engineering, Bhopal (M. P.),402026 India
[2]Assistant Professor, Civil Department, RKDF College of Engineering, Bhopal (M. P.), 402026 India
[3]Assistant Professor, Civil Department, RKDF College of Engineering, Bhopal (M. P.), 402026 India

ABTRACT :

The goal of the current study is to determine the best approach for replacing cement in highway construction with waste materials generated from various businesses. One of the main environmental, economic, and social challenges in India today is the growing awareness of the vast environmental harm caused by the buildup of waste materials from industrial plants, power houses, colliery pits, and demolition sites. Waste material is anything that is unneeded, undesirable, and regarded as useless by our society as a whole. Discharging waste materials into the air, water, and land is becoming a major environmental issue for materials coming out of industry. However, making appropriate use of these materials in the building sector and for paving roads will significantly contribute to a more pleasant and better-looking society.

Keyword- Cement, Waste material, construction, environment, concrete

1. 1 Introduction :

1.1.1 Introduction: Utilization of Waste Material in Concrete

Concrete is the most widely used construction material globally, forming the backbone of modern infrastructure. However, its production is associated with significant environmental challenges, including the depletion of natural resources, high energy consumption, and the emission of large quantities of carbon dioxide (CO_2). These environmental concerns have spurred a growing interest in sustainable construction practices, particularly the incorporation of waste materials into concrete.

Waste materials, which are often by-products of industrial processes, agricultural activities, or municipal waste, pose a significant environmental burden if not managed properly. Landfills are filling up, and the environmental impact of waste disposal is becoming increasingly unsustainable. By repurposing these waste materials in concrete production, we can address two critical issues simultaneously: reducing the environmental footprint of concrete and managing waste more effectively.

The utilization of waste materials in concrete not only helps in conserving natural resources by reducing the demand for virgin raw materials but also enhances the properties of concrete in many cases. For example, the addition of industrial by-products like fly ash, slag, and silica fume can improve the durability and strength of concrete, while recycled aggregates can reduce the environmental impact of aggregate production.

This review aims to explore the various waste materials that can be effectively utilized in concrete, examining their benefits, challenges, and potential applications. The discussion will cover a range of materials, including industrial by-products, agricultural waste, construction and demolition waste, and municipal waste. Through this analysis, the paper seeks to highlight the opportunities and challenges associated with the use of waste materials in concrete, providing insights into how these practices can contribute to more sustainable construction and waste management strategies.

In summary, the integration of waste materials into concrete represents a promising pathway toward achieving a more sustainable construction industry. By exploring the different types of waste that can be used, understanding their effects on concrete properties, and addressing the challenges associated with their use, this review will contribute to the ongoing efforts to make concrete production more environmentally friendly.

1. 2 Literature survey & background

Al-Jabri (2009 a) examines the effects of replacing sand in excessive overall performance concrete (HPC) dwellings with copper slag. Eight distinct concrete mixtures ranging from zero percent (for the manipulate blend) to one hundred percent had unique quantities of copper slag generated in them. Workability, density, compressive energy, tensile power, flexural strength, and durability of concrete mixtures have all been assessed. The results show that while the workability increased quickly as the percentage of copper slag increased, there was a slight jump in the HPC density of about 5%. Comparable strength to the control mix was achieved by replacing up to 50% of the sand with copper slag. However, increasing the copper slag content beyond this level led to a reduction in compressive strength due to a rise in the blend's free water content. Mixes containing 80% and 100% copper slag showed the lowest compressive strength, around 80 MPa, representing a 16% decrease compared to the control mix. Additionally, the results indicated that surface water absorption decreases as the copper slag content increases up to 40%, but beyond this point, the absorption rate rises sharply.

Jassim (2017) conducted a study to introduce plastic cement by recycling polyethylene waste. Polyethylene, due to its low biodegradability, poses a significant environmental threat. This issue can be addressed by using polyethylene as a partial replacement for sand in concrete mixes. High-density polyethylene waste (HDPW) was partially substituted for Portland cement in various ratios, including 15%, 20%, 25%, 30%, 35%, 40%, 50%, 60%, and 80% by volume. Cube samples were prepared, allowed to dry, and then submerged in water for 3-4 days for curing.

Venu Malagavelli et al. [1] studied on high performance concrete with GGBS and robo sand nd concluded that the percentage increase of compressive strength of concrete is 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

Luo et al. [2] experimentally studied the chloride diffusion coefficient and the chloride binding capacity of Portland cement or blended cement made of Portland cement and 70 % GGBS replacement with or without 5 % sulphate. They found that (i) chloride diffusion coefficient decreased; (ii) chloride ion binding capacity improved in samples of blended cement.

Clear concluded that higher the proportion of GGBS, the slower the early age strength development.

Oner and Akyuz[studied on optimum level of GGBS on compressive strength of concreteand concluded that the optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content.

Qian Jueshi and Shi Caijun studied on high performance cementing materials from industrial slag and reviewed the recent progresses in the activation of latent cementitious properties of different slag. They opined that Alkali-activated slag, such as blast furnace slag, steel slag, copper slag and phosphorus slag should be a prime topic for construction materials researchers.

Ganesh Babu and SreeRama Kumar studied on efficiency of GGBS in Concrete. Wainwright conducted Bleed tests in accordance with ASTM C232-92 on concretes in which up to 85% of thecement was replaced with ground granulated blastfurnaceslag (GGBS) obtained from different sources. They observed that delaying the start of the bleed test from 30 to 120 min reduced the bleed capacity of the OPC mix by more than 55% compared with 32% for the slag mixes. The reduction in bleed rate was similar for all mixes at about 45%.

Soutsos et al. studied on fast track construction with high-strength concrete mixes containing Ground Granulated Blast Furnace Slag. They showed that the existing maturity functions like the Nurse-Saul and the Arrhenius equation may not be suitable for GGBS concretes.

Pavia and Condren studied the durability of OPC versus GGBS Concrete on Exposure to Silage Effluent. This research concluded that PC composites incorporating GGBS are more

durable than those made with PC alone in aggressive environments under the action of acids and salts such as those produced by silage.

Ashish kumar dash et al. researched on different materials like rice husk ash, GGBS, silica fume to obtain the desired needs.

Higgins discussed on the effect of addition of a small percentage of calcium carbonate or calcium sulfate on the sulfate resistance of concrete containing GGBS. Pazhani and Jeyaraj[conducted experimental investigation to assess the durability parameters of high performance concrete with the industrial wastes.

Shariq and Prasad examined the impact of different curing methods on the compressive strength development of cement mortar and concrete incorporating ground granulated blast furnace slag (GGBFS). Their findings revealed that OPC (Ordinary Portland Cement) concrete exhibited higher compressive strength compared to GGBFS-based concrete across all replacement levels and ages. Among GGBFS replacements, 40% proved optimal, significantly improving compressive strength after 56 days, outperforming both 20% and 60% replacements.

Stanley researched the use of iron blast-furnace slag in concrete, either as an aggregate or a cementing material. Hanifi Binici and colleagues investigated blended cements containing corncob ash (CA) and GGBFS, concluding that these blends showed 15% lower compressive strength than control specimens when immersed in a sulfate solution over 24 months. However, blended cements demonstrated better resistance to sodium sulfate with higher percentages of additives.

Puertas and collaborators analyzed the carbonation behavior of water glass- or NaOH-activated slag mortars, finding that alkali-activated slag mortars carbonated more deeply than Portland cement mortars. Barnett et al. focused on strength development in mortars containing GGBFS and Portland cement, concluding that early-age strength in GGBFS mixtures is highly temperature-dependent.

Wang Ling studied the application of GGBFS in China, while An Cheng, Ran Huang, and colleagues investigated the durability of GGBFS concretes and the corrosion behavior of reinforced concrete beams under varying load ratios. Olorunsogo et al. explored the effect of particle size distribution (PSD) on the bleeding characteristics of slag cement mortars, revealing that for slag samples with a similar size range, the bleeding capacity increased with particle size, except for 30% slag mixes with a 0.35 water-to-cement ratio.

Huiwen Wan and co-researchers investigated the geometric characteristics of different GGBFS particles, such as PSD and shape, and their influence on cement properties. These studies indicate that the optimal percentage replacement of GGBFS may vary based on the properties of the materials used. The primary objective of the present study is to assess the strength and durability characteristics of GGBFS concrete using locally available fine and coarse aggregates.

Tamilarasan et al. studied chloride diffusion in concrete incorporating GGBFS as a partial cement replacement, with and without superplasticizers. Their results showed that increasing the GGBFS percentage reduced chloride diffusion, with M25 concrete exhibiting **lower chloride diffusion than M20 concrete.**

Wagih et al. studied the aspect regarding the use of reused concrete and demolished concrete waste as the replacement of natural aggregate (NA). Approx 50 sample were made by replacing of NA with RCA of 0%, 25%, 50%, 75%, 100% and by adding super plasticizer from 0% to 1.3%. Silica fume in very small size were added to 10% of cement. By performing various test different properties of concrete like compressive strength etc, were measured.

Ebrahim et al. (2013) provide different factors like gradation, angularity, soundness, and solubility of aggregate were kept in mind to use the recycled concrete as subbase layer of the pavement. On the basis of the findings it was observed that only 70% of required strength can be achieved by mixing of 5% cement with recycle concrete aggregate. However, this value can be increased up to 77%.

Courard et al. (2010) examined the suitability of recycled aggregates for the construction of roller compacted concrete (RCC). It is special types of polymer concrete that do not contain reinforcement while the construction of structure. It has high compressive strength and durability and very less sensitive to shrinkage also. Different test like Los Angeles test, specific gravity test and durability test were conducted in the study. Findings of the study revealed that the recycled aggregates can be used as RCC as overall performance was good

Malagavelli and Paturu (2011) carried out an experimental investigation on the performance of the concrete using solid waste fibers and found that the increase in the load carrying capacity of concrete. It was further reported that the maximum 2% of fibres could be used for strength purpose and that up to 6%, for disposal purpose.

Sultana and Prasad (2012) observed improvements in aggregate properties when coated with waste plastic and identified the optimum plastic content to be 6-8%, based on stability values. Additionally, Pandey (2012) conducted experiments using recycled plastic in the form of cellular networks with cell sizes ranging from 150mm × 150mm to 200mm × 120mm and depths of 50mm to 100mm, placed over a compacted foundation. The study concluded that with minimal maintenance, this construction method could enhance the flexibility of concrete, prevent surface cracking, and extend the lifespan to about 15-20 years.

Ramesh et al. (2003) reported that replacing cement with high-volume fly ash up to 20% has been commonly practiced for enhancing the durability and cost-effectiveness of concrete roads. Basak et al. (2004) indicated that partial replacement of cement with fly ash could save approximately 25% of the total cement volume, reducing construction costs by about 15%, provided fly ash is properly collected. Sagar (2007) studied fly ash concrete with higher flexural strength and concluded that fly ash could be used for constructing semi-rigid pavements using lime-fly ash concrete.

Sharma et al. (2010) found that the fly ash as a filler from different power plants demonstrated good potential for their use in Bitumen Concrete mixes. The optimum performance of mixes with different contents of fly ash was shown at 7% filler content. Prabhakar et al. (2011) emphasized that durability of the concrete structures could be improved by using fly ash as a mineral admixture and further concluded that up to 35% of the cement could be replaced with fly ash without affecting the mechanical properties of the concrete. Kumar (2012) found that Fly ash and fly ash based products have been established for economic, durable and eco-friendly construction and development in rural sector. Suryawanshi et al. (2012) reported that fly ash cement concrete does not gain appreciable strength in the initial 7-14 days'; but in 28-days, the cement constituents and pozzolanic reaction results in rapid hardening properties, with 25% replacement of cement with fly ash. Chaudhary (2012) found that the compressive strength with 50% fly ash as admixture showed the improvement over conventional concrete.

Bindra et al. (2003) reported that up to 15%-20% of recycled aggregates by volume can be used in concrete to achieve properties comparable to normal concrete. Barai (2005) suggested that adjustments in water content are necessary to maintain the desired properties of normal concrete when using recycled aggregates. Dhir and Kevin (2010) found that recycled and secondary aggregates could replace 20%-30% of the total aggregate volume without altering the water-cement ratio, achieving the required characteristics of standard concrete. Desai (2010) highlighted the benefits of using recycled aggregates in construction, recommending a usage limit of 30%-40% by volume without affecting concrete properties. Marius et al. (2011) demonstrated through lab tests that recycled aggregates, up to a maximum of 30%, performed similarly to crushed gravel when used as chipping sand in rigid pavement construction.

Surajit et al. (2005) found no significant improvement in the strength of concrete at 7 and 28 days but reported a substantial increase in compressive strength at 90 days for blast furnace slag aggregate concrete (a 10.71% improvement compared to stone aggregates).

Raju et al. (2003) discovered that concrete cubes containing 10% silica fume showed better performance when exposed to 0.1%, 1.0%, and 5% sulfuric acid concentrations for M50, M60, and M70 grade concrete.

Huang et al. (2004) noted limited progress in rubberized concrete research at that time but found that rubberized concrete has high toughness, although its strength decreases significantly with increased rubber content. Zheng et al. (2008) confirmed that both strength and modulus of elasticity declined as the rubber content in concrete increased. Rosa et al. (2009) recommended that rubber content in concrete should not exceed 10% due to resistance losses. Mavroulidou et al. (2010) found that using 0-10% rubber in concrete improved workability, density, and 28-day cube compressive strength, but beyond this limit, rubber negatively affected concrete performance. Sara et al. (2010) concluded that incorporating rubber aggregates from waste tires is an effective solution to reduce the weight of concrete for specific engineering applications, but further research is needed to assess the durability and toughness of rubberized concrete.

Based on these studies, various researchers have extensively explored the use of waste materials in pavements and construction activities. Numerous investigations in India have focused on utilizing waste materials as construction materials, with a wide range of findings summarized in the reviewed literature.

Wan et al. (2018) examined the usage of waste materials in definite proportion to make light weight self compacting concrete. Different samples were made by using perlite, scoria, and polystyrene lightweight aggregates in varying proportion. After conducting different tests of compressive and tensile strength it was concluded that more waste is added to mix will result in the lesser compressive strength of concrete

Rao et al. (2006) recommended the utilization of aggregate obtained from C & D waste in concrete. Aggregate used in concrete should be free from salts and other rubbish materials which destroyed during demolish building. Workability of RAC in concrete was found to be decreased when the 50% of natural aggregate get replaced with RA

Few yew year before Robayo et al. (2016) investigated the behavior of RCBW as alkaline and admixture of Na_2SiO_3 and OPC. Five samples were made during the study. Out of which one sample consisting 100% RCBW and remaining samples were contained OPC in different proportion i.e. 5%, 10%, 15%, 20%. It was observed that 10 % of OPC sample mixture shows utmost compressive strength of 41.39 MPa. It was also found that addition of corroborates increase the compressive strength of the mix.

Poon et al. (2005) investigated the use of recycled concrete aggregates (RCA) and crushed recycled clay brick waste (RCBW) as sub-base materials for pavement construction. They created three mixtures of RCA and crushed clay brick in varying ratios, specifically maintaining the percentage of clay bricks at 0%, 25%, and 50%. The study found that sub-bases composed of crushed clay bricks were less susceptible to moisture. The analysis concluded that using 100% recycled concrete aggregates instead of natural aggregates resulted in increased optimum moisture content, while maximum dry density decreased.

Jaroslav et al. (2017) examined the impact of incorporating concrete powder on the mechanical properties of cement paste. They created five samples with varying percentages of recycled concrete powder (RCP) ranging from 0% to 50%, along with one sample of Portland cement for comparison. All tests conducted were based on a curing period of 28 days. An impact resonance test was performed to determine Young's modulus for each sample.

Mohammadinia et al. (2017) studied the effect when fly ash is mixed with crushed brick (CB) and reclaimed asphalt (RAP) in the subbase layer of flexible pavement. Aggregates of CB and RAP having size of 20 mm were accumulated from factory where recycling is done. Fly ash (FA) is added in different proportions. A number of compaction tests were conducted on CB and RAP to determine the OMC and MDD.

Wang et al. (2017) examined the effect on concrete when fly ash is added to mix. Fly ash was added to mix in replacement of cementitious material like cement. While preparing sample for testing w/c ratio have to kept .35 and .25 and replacement of cement from 8% to 15% can be done. Test to find compressive strength, chloride permeability and shrinkage of new concrete mix. After analyzing result it was found that 15% substitution give the optimum result

Bahurudeen et al. (2015) examine the performance of bagasse ash as a alternative supplementary cementitious material in concrete. Due to high composition of silica (SiO_2) in bagasse ash, formation of CSH gel was more by reacting with calcium hydroxide in cement. By performing different test for compressive strength, heat of hydration, drying shrinkage and durability it was concluded that 25% of replacement can be done.

Liu and Guo (2018) check the performance of high strength concrete which was made up of steel slag powder. When the 10% replacement of cement was done with pores less than 50nm their will be no change in the strength of concrete. Steel slag was reacting like admixture, which improve the workability and fluidity of mixed concrete.

Liu and Wang (2017) studied the influence on plain concrete by adding steel slag silica fume in it. Silica fume and steel slag were used in a ratio of 92:8 and 84:16 after mixing for 10 min in mixture. Sample was tested for compressive strength, splitting tensile strength, chloride ion permeability, carbonation and drying shrinkage. Examine the results it was concluded all the property was better than the plain concrete.

Das et al. (2015) conducted a study to use GGBS contain concrete to marine environment. Cylindrical 16 sample were made and some are exposed to water contain NaCl and $CaCl_2$and some to normal water. Result concluded that by adding GGBS to concrete permeability of concrete get decreased so that possibility of chloride penetration will decrease to 36%.

Marinho et al. (2017) conducted study to use ladle furnace slag (LFS) as a binder in cement concrete mix. Ladle furnace slag (LFS) is a by-product of low carbon steel production, obtained from the process of secondary refining in ladle furnaces The main components of the LFS are calcium, silicon, magnesium, aluminum oxides, and calcium silicates under various allotropic forms. LFS is obtained in a slow cooling process and presents a large content of fine particles, with 20–35% below 75 μm. Calcium oxide and calcium magnesium silicates are the 88% of total mix. After lots of tests it was concluded that utilization of LFS instead of lime for cement composite based material. It is the best suitable material for the partial alternate of cement.

Sathiparan et al. (2018) measures the effect on cement block by partially replacement of sand by some agricultural waste. Open dumping of agriculture waste causes various health hazards and also pollute the environment. Cement block were made up of agricultural waste like rice husk. Cement, sand and waste materials were mixed in different proportion like (1:5:1), (1:4:2), (1:3:3) to make 400 sample.

Jassim (2017) conducted a study to introduce the plastic cement based on the recycling of polyethylene waste. In now days, polyethylene is the most dangerous material that is harmful for our environment due to its low biodegradability. This problem can be resolved by using polyethylene in replacement of sand in mix. The partially replacement of high density polyethylene waste (HDPW) with portland cement was used in different ratio like 15%, 20%, 25%, 30%, 35%, 40% 50%, 60% and 80% by volume.

Maddalena et al. (2018) examined the suitability of low carbon waste material as the replacement of Portland cement. A comparison was made with the properties of OPC by investigating physical, thermal and mechanical properties of silica fume and in small form nano-silica in order to remove some elements and to add some green binders.

Ashish (2018) conducted the study to attain sustainable growth check the feasibility of waste marble powder in concrete as a replacement of cement and sand. Waste that was generated by marble was about 3Mt per year and the country which producers largest of marble waste is India. After studying some past studies it was found that 10% of diatomite and 5% marble powder mix is the perfect replacement of concrete.

Patil et al. (2021 investigated a study by replacing some percentage ratio of cement by adding volcanic ash into the concrete mixture. Different sample were casted in different ratio of 10 to 50%. It was examined that up to 40% OPC can be partially replaced by volcanic ash. After that reduction in strength and rusting of the reinforcement will take place due to the presence of various chlorides in volcanic ash which decreases the durability of concrete

Rajput et al. (2023) conducted a study on Waste crete bricks by using recycled paper waste and cotton. Sixty sample were made by using paper waste (PW), cotton waste (CW) and Portland cement in different proportion of 85-89% PW + 10% Cement + 1-3% CW. By performing various test compressive strength,

1.3 Conclusion :

The integration of waste materials into concrete presents a significant opportunity for advancing sustainable construction practices. This approach not only addresses the pressing issue of waste management but also contributes to the reduction of the environmental impact associated with traditional concrete production. Through the incorporation of various waste materials—such as industrial by-products, agricultural residues, recycled aggregates, and municipal waste—concrete can be engineered to achieve enhanced properties while simultaneously conserving natural resources and reducing carbon emissions.

The review of existing literature and case studies demonstrates that many waste materials can effectively replace or supplement conventional concrete components. Materials like fly ash, slag, and silica fume have proven to improve the mechanical and durability properties of concrete, while recycled aggregates offer a viable alternative to natural aggregates, contributing to a circular economy. Additionally, the use of unconventional waste materials, such as plastic waste and tire rubber, shows promise in developing innovative concrete solutions with specialized applications.

However, the utilization of waste materials in concrete is not without its challenges. Issues such as the variability in waste material properties, technical and economic feasibility, and the need for standardized regulations must be addressed to ensure the widespread adoption of these practices. Furthermore, ongoing research is essential to optimize mix designs, understand long-term performance, and explore new waste materials that could be utilized in concrete.

In conclusion, the utilization of waste materials in concrete represents a forward-looking approach to achieving sustainability in the construction industry. By embracing this practice, we can significantly reduce the environmental impact of concrete production, extend the life cycle of waste materials, and promote a more sustainable and resilient built environment. Continued research, innovation, and collaboration among industry stakeholders will be crucial in overcoming the current challenges and fully realizing the potential of waste material utilization in concrete.

REFERENCES :

[1] Anupam, A.K., Kumar, P., Ransinchung, G.D. and Shah, Y.U., 2017. Study on Performance and Efficacy of Industrial Waste Materials in Road Construction: Fly Ash and Bagasse Ash. Airfield and Highway Pavements 2017, p.45.

[2] Amin NU., 2010. Use of bagasse ash in concrete and its impact on the strength and chloride resistivity. Journal of materials in civil engineering. Nov 8;23(5):717-20.

[3] Appiah, J.K., Berko-Boateng, V.N. and Tagbor, T.A., 2017. Use of waste plastic materials for road construction in Ghana. Case studies in construction materials, 6, pp.1 7.

[4] Ashish DK., 2018. Feasibility of waste marble powder in concrete as partial substitution of cement and sand amalgam for sustainable growth. Journal of Building Engineering. Jan 31;15:236-42.

[5] Bahurudeen A, Kanraj D, Dev VG, Santhanam M., 2015. Performance evaluation of sugarcane bagasse ash blended cement in concrete. Cement and Concrete Composites. May 1;59:77-88.

[6] Al-Hadidy A.I. and Yi-qiu T. (2009), "Effect of polyethylene on life of flexible pavements", Journal of Construction and Building Materials, volume 23, India

[7] Awwad M. T. and Shbeeb L (2007), "The use of polyethylene in hot asphalt mixtures", American Journal of Applied Sciences, India

[8] Barai,S.V. and Rakshvir. 2005. Experimental studies on recycled aggregates based concrete, Proc. In International Conference on Structural and Road Transportaion Engineering, IIT,Kharaghpur, India, 225-233

[9] Marik,S. and Roy, D.K.S. 2005. Performance of Blast Furnace Slag as a coarse aggregate in Concrete, International Conference on Structural and RoadTransportationEngineering,Jan,2005,IIT,Kharagpur, Indi ,244-251

[10] Marius, T.M. and Tadu, A. 2011. Use of recycled aggregates in Rigid Pavement construction, GheorgheAsach i Technical University of Lasi Bulletin, 70-78

[11] Mavroulidou, M. and Figueiredo,J . 2010. Discarded tyre rubber as concrete material:A possible outlet for used tyres, Global NEST Journal,Vol.12,No.4, 359-367

[12] Sagar,A.K. 2007. Use of locally available materials: Fly ash for road construction works, India Infrastructure Report, New Delhi

[13] Sar,S.,Giuseppe, C.M,Massimo,B. and Marcello,M. 2010. Use of Rubber particles from recycles tires as concrete aggregates for Engineering Applications,Proc. In Second Int. Conf. on sustainable construction materials and technologies, University of Wisconsisn Milwaukee Center, ISBN 978, 1.4507.1490.7

[14] Zabihi SM, Tavakoli H, Mohseni E., 2018. Engineering and Microstructural Properties of Fiber-Reinforced Rice Husk–Ash Based Geopolymer Concrete. Journal of Materials in Civil Engineering. May 31; 30(8):04018183.

[15] Mindess, S., Young, J.F. and Darwin, D., 1981. Concrete Prentice-Hall. Englewood Cliffs, NJ, 481.

[16] Indian Bureau of Mines "Indian Minerals Yearbook 2015, (Part- III : Mineral Reviews) ,54th Edition", Ministry of Mines.