Green Concrete- A need for the future

Sneha J P[1], Rakshaa V[2]

[1,2] *B. Tech Student, Department of Civil Engineering, Vellore Institute Of Technology, Chennai, India*

Abstract - *Concrete has been the most popular construction material and it is the second most devoured entity after water. Though concrete has contributed much to our built environment, it has a massive carbon footprint and consumes huge amount of non-renewable resources which takes a toll on our environment. The conventional cement contributes about 8-10% of world's total CO_2 emissions, and the non-renewable resources are almost exhausted. The optimal solution to mitigate this effect and to attain sustainable development is 'Green Concrete'. Green concrete is the green innovation that uses renewable resources and other substitutes that emits less co2. This paper will give us a brief description about green concrete along with its merits and demerits.*

***Key Words*: Green concrete, Conventional cement, Carbon footprint, Recycled aggregate.**

1. INTRODUCTION

The world is facing multiple challenges every minute, climatic change is the predominant one. Over the past century, the surface temperature of the earth has increased at a rate of 0.6^0C/century. This is due to the emission of greenhouse gases like carbon dioxide, methane, etc. Concrete was found to contribute a significant amount of these gases into the atmosphere. Construction sector contributes a major part in economically developing nations. This industry uses concrete at large amount as it is the most dominant building material. Concrete consists of cement, natural aggregates and water. Cement is the prominent ingredient in concrete, during the manufacturing stage of cement, few raw materials like limestone, clay are crumbled and heated at a temperature of 1500^0C, and this leads to the emission of CO_2 at large amount [1]. Also natural resources are getting exhausted at an alarming rate. Likewise, this industry produces a large amount of wastes.

Construction and demolition wastes are produced around 2 to 3 billion tons/year in which 30-40% of wastes consist of concrete [2]. The majority of the wastes are simply dumped in the landfills whereas only a small percentage of wastes are recycled or reused. As each day passes by, it is difficult to find the perfect area to dump all the wastes. It is necessary to find a way to dispose the wastes and make use of the potential ones.

The predominant way for a sustainable development is to find an alternative: Green concrete. Green concrete was invented in Denmark in 1998 by Dr WG. Green concrete uses waste material as its constituents in its production process that leads to zero depredation. It is possible to achieve sustainable development through green concrete. It contains 3Rs (Reduce, Reuse and Recycle) in its technology. Studies show that green concrete emits 80% less CO_2 than that of normal concrete. Green concrete uses renewable resources as its components, hence depleting of fossil fuels is also controlled.

2. OBJECTIVES OF GREEN CONCRETE

The key objectives of green concrete is to

- Lower the emission of greenhouse gases like CO2, methane.
- Reduce the energy consumption in its manufacturing, utilization and disposal processes.
- Reduce the usage of non-renewable resources and to use renewable resources to the maximum extent.
- Use the construction and other suitable wastes as replacement materials for cement and aggregates.
- Counterpart the physical and mechanical properties of the conventional concrete.

3. SCOPE IN INDIA

Construction industry plays a major role in India's economic development. India with a population of 1 billion people requires more built-up structures like buildings, roadways, bridges. At present cement still remains as the main constituent of the concrete and the conventional concrete is used in large amount, which leads to a number of harmful effects on the environment. The construction waste generated during the process poses great threat to the environment. In order to establish new structures, old and damaged buildings are demolished. There are no proper guidelines to dispose these wastes. The imperative solution to all these issues is Green concrete. Inadequate technology, lack of researches and poor awareness leads to minimal use of green concrete in India. If proper guidelines were created, green concrete would become an active material in India in the mere future.

4. ADVANTAGES /SUITABILITY OF GREEN CONCRETE IN STRUCTURES

a) Using eco-friendly concrete in fresh phase has many advantages such as it improves the flow of matter in the mix, making the concrete ready to pump, workability and absence of cold joints.

b) On the other hand, using Green concrete in hardened phase also has benefits such as the cover quality used for reinforcement is improved, corrosion can be highly reduced by shielding the penetration of chloride ions into concrete, Alkali-Silica reaction can be sheltered, and due to lower heat of hydration thermal cracks will be dwindled.

c) It cuts down the dead weight of the façade from 4535 kg to approximately 3175 kg [31].

d) Green concrete has good heat and fire resistance compared to conventional concrete.

e) Overall construction time is decreased and it improves damping properties of the building.

f) It assists the country in energy conservation by decreasing the emission of CO2 and by creating an environment friendly atmosphere. If green concrete is used, then the disposing of waste in the ground will be reduced, thus reducing the risks to the environment and clearing many hectares of land used for disposal.

5. TYPES OF GREEN CONCRETE

5.1 Fly ash concrete

Fly ash is a by-product of coal power plants. Heating of pulverized coal emits 80% fly ash. Fly ash particles are smooth and spherical in shape. Grey to black indicates the increase in the percentage of CO_2 in the fly ash particles. Fly ash is an industrial waste capable of polluting air and water. It lowers the yield of agricultural crops/leaves when it settles on them. Fly ash can be used as a replacement material in concrete [3]. Fly ash is a pozzolan, which contains aluminium and siliceous material that forms cement when it is mixed with water. On the other hand, When the Fly ash is mixed with $Ca(OH)_2$ and H_2O, a compound similar to Portland cement is formed. Fly ash can be used in 2 ways, by blending it with cement clinker and gypsum during the process of manufacturing of Ordinary Portland Cement (OPC) or by adding it to OPC in construction site. In 1980, American Society for Testing and Materials (ASTM) developed the standards for using Fly ash in concrete. Fly ash is classified into 3 classes – N, F and C [4] based on the chemical composition.

Generally, fly ash is used in minimal amounts (15-20% of cementitious material) in concrete. It is also found that when fly ash is used in fewer amounts, the resultant concrete has good durability and workability. The rate of substitution specified is 0.45 to 0.68 kg of fly ash to 0.45kg of cement. For high sulphate resistance, 25-35% of fly ash is used [5]. When more than 50% fly ash is used, the concrete is known as High Volume Fly Ash Concrete (HVFAC). Chemical activators and Super Plasticizers (SP) are required when fly ash is used in larger amounts.

HVFAC performs better at a later stage, its strength and other properties are enhanced at later stages. Resistance towards corrosion is higher when compared to conventional concrete. HVFAC is a futuristic material. HVFAC can be used in mat foundations, retaining walls, road pavements, dam structures, L columns and walls. There are certain limitations in using HVFAC, It cannot be used in cold weather concreting and it acquires strength slowly during the early stage.

Smaller builders and housing contractors are unfamiliar with fly ash concrete and it is difficult for them to replace the standard concrete.

5.2 Geopolymer concrete

Geopolymer concrete is an inorganic polymer that consists of alkali activated Alumino Silicates (SiO2, Al2O3) and industrial wastes. The polymerization process contains a chemical reaction that takes place under a highly alkaline medium in which Al-Si minerals produce polymeric Si-O-Al-O bonds. When compared to the conventional concrete, it emits 80% less CO2 [6]. Curing time of Geopolymer is less than PC. Geopolymer has high Resistance to fire and corrosion. The tensile and compressive strength of this concrete is comparatively higher than the standard concrete. Reaction between the chemical compounds plays a major role during the production process of Geopolymer concrete. It is necessary to understand the alkali-activated technology for the production of this concrete. Strength of Geopolymer concrete depends upon the molarities of the alkaline liquid (NaOH or KOH) and ratios of SiO2and Na2O, H2O and Na2O, Si and Al, water to Geopolymer solids by mass in the total alkaline solution [40].

The compressive strength of dry cured Geopolymer concrete is found to be 15% more than the steam cured Geopolymer concrete. Geopolymer concrete has excellent properties as discussed earlier so it can be very useful for rehabilitation and retrofitting works. Lack of technology and researches related to this area is the major obstacle that restraints countries from using the Geopolymer concrete.

5.3 Recycled aggregate concrete

Construction waste constitutes a large fraction of solid waste disposal problem. 48 million tons of solid wastes are annually produced in which 25% is contributed by the construction industry. Concrete debris and construction wastes can be used as an aggregate in the new concrete [7]. Demolished concrete can be made into specific size and quality for reuse purposes. Before using the recycled aggregate, it is necessary to first treat them to remove the impurities on the surface. USA, Australia and Japan are the countries that use Recycled Aggregate Concrete (RAC) frequently. China, Germany and Japan published standards for the use of recycled aggregate concrete. Many researchers claimed that the RA has low workability and compressive strength. Recycled aggregates are finer than the natural aggregates and have low specific gravity. The smooth texture of the aggregates, round shape, and high water absorption are the main reasons for this drawback.

One researcher proved that if the recycled aggregate with a rough surface and angular shape is used in concrete, it leads to increase in compressive strength of the new concrete. This is because the rough surface and the angular shape increase the bond strength between the aggregates and the other constituents in the concrete. RA is oven dried to achieve this property (Poon CS 2004).

RAC has been used since World War II (for stabilizing the base in the construction of roadways). RA has high water-cement ratio when compared to the normal cement. RA can only be used in certain limit replacing the natural aggregate. If it is used in larger amounts, the compressive strength of the resulting concrete will be affected. Properties of the new concrete depend upon the properties of the parent concrete.

6. REPLACEMENT MATERIALS USED IN GREEN CONCRETE

6.1 Silica fume and fly ash

Researchers conducted experiments using fly ash and silica fume with fractional replacement of cement and fine aggregate. A M40 grade concrete was cast as a cube, beam, and cylinder. After casting those for 7 and 28 days with different water-cement ratio the final ratio was opted as 0.4 [25]. Then mix design for partially replaced sample was designed. Then again the cubes, beam, cylinder were cast for 7 days and 28 days (Here 7 days and 28 days are curing period time). Replacement of the cement and fine aggregate with the silica fume and fly ash, respectively with different percentages were done.

From the obtained result, they concluded that with a 15% substitution the result was good, although much lower than normal cubes strength, but with the increase in the time the strength of cubes also increased [25]. In addition, the chloride resistance of concrete is also upgraded.

6.2 Quarry rock dust and marble sludge powder

Quarry rock dust can replace natural sand by 100%.It is known as manufactured sand (m-sand). It has zero silt and impurities. Quarry rock dust used for concrete must be completely inorganic; it should not contain any organic impurities. Quarry rock dust is obtained after extraction and treating of rocks. Quarry rock dust particles with size less than 4.75mm are used in green concrete [8]. Studies have proven that the concrete that contains quarry rock dust has more compressive strength than the standard (about 14%). When quarry rock dust is used below 50% by volume, the resultant concrete has less permeability and high water absorption. They are used as surface finisher, and in hollow blocks, and lightweight concrete prefabricated elements.

Marble sludge powder is an manufacturing waste that contains heavyweight metals. The marble sludge powder is used as a fine aggregate that has high CaO content. It is initially obtained in the wet form from marble factories and then dried up. It is used as a filler, to fill void content in the concrete. The resultant concrete has more compressive, split tensile strength and durability than the normal concrete (about 14%) [9].

The SiO_2 present in the marble powder reacts with $Ca(OH)_2$ present on the concrete to form secondary calcium silicate hydrates which makes it stable, structurally dense and increases the impermeability of concrete. Also the sulphate resistance of concrete has been increased since calcium aluminates in the cementitious material are reduced.

The collective use of marble sludge powder and quarry rock dust as substitutes exhibits brilliant performance due to efficient micro filling ability and pozzolanic activity. If the volume of these substitutes exceeds 50%, the compressive and split tensile strength decreases [10].

6.3 Glass as a cementitious material

When glass a non-decomposer is turned into waste it is disposed as landfills, which create a problem to the environment.

Glass is primarily made of silica. Waste glass is crushed down to micro size particles; they are exposed to pozzolanic activity with hydrate products resulting in calcium silicate hydrate (C–S–H).

A laboratory examination was carried out to find the pros and cons of LCD glass in concrete. Cement was substituted with LCD waste by 10% to 50% in rates. In addition, glass sand was considered rather than natural sand by rates of 10% to 30%. Experimental outcomes projected that the glass enhances the compressive strength of the cement. Furthermore, cement containing glass improves concrete structures by age [26]. The advantage of glass in concrete is that the use of cement and sand is reduced, which helps in conserving the natural resources and carbon emissions is also highly decreased.

Aesthetic appeal of concrete will be enhanced when recycled glass is used as an aggregate.

Powdered glass could be utilized as a cement substitution material of size beneath 75µm to avert concrete cancer aka Alkali-silica reaction [28].

The percentage of replacement is a key factor; the flexural and tensile strength will decrease if 30% of glass waste is added as an aggregate when compared to normal concrete (Seung Bum Park and Bong Chum Lee, 2004).

Glass debris in the form of a cylinder averts the spread of cracks in concrete structures.

Few merits of using glass in concrete are it is economic, and it provides additional strength when it is in powdered form.

Demerits are:

- When powdered glass size decreases, the strength of concrete increases, but below the 50-micron size, glass powder affects the strength of the concrete [37].
- Converting glass into its powder is a challenging task for this process machines and manpower are required.
- While converting glass into its powdered form the workers should be careful as it can affect eyes, hands and even the respiration system.

6.4 Glass powder and silica fume

Silica Fume is a pozzolanic material, and it upgrades the concrete's durability by filling the voids of cement particle and enhances the strength of concrete by reacting with slaked lime which is obtained during the process of hydration of cement.

Experimental investigation was conducted in two phases to determine the measurement. PHASE-I contains different concentrations of glass powder and silica fume. The PHASE-II comprises of a fixed proportion of glass powder with varying percentage of silica fume. It can be observed that when silica fume and glass powder are used in certain percentages they exhibit more compressive strength than the control concrete in Phase I & Phase II and with further increase in Silica Fume the strength decreases.

It is then concluded that flexural strength has a 100% increase compared to normal 28-day concrete and 27% more than 56-day concrete. The split tensile strength has a rise of 35% when compared to conventional concrete for 56 days [29].

The glass powder should be finely ground to less than 75µm in order to avoid the use of the mineral admixture. Concrete containing powdered glass has more benefits than normal concrete, which includes the increment of compressive, tensile and flexural strength.

6.5 Rice hush ash

Husk is a by-product of rice milling. The husk consists of 75% volatile matter and 25% ash. The ash produced during the firing procedure is known as rice husk ash (RHA). RHA is also known as silpozz and consists of amorphous silica (85-90%). One of the best reason to replace cement, Closer the Chemical Composition of substitute to the cement, better the replacement. When RHA is in the range of 20-25 microns, it increases the compressive strength by 10-20%, decreases the heat of hydration by 30%, and decreases the water penetration by 60% [11]. Sulphate resistance decreases when the volume of RHA increases in the concrete. It is advisable to use RHA in smaller amounts as a replacement to cement.

6.6 Carbon nanotubes

Carbon nanotubes (CNTs) are summarized as the arrangement of carbon atoms in hexagonal array in graphite sheet rolls. This arrangement of atoms is of key importance in denoting the mechanical properties of the nanotubes.

CNTs improve the features of the concrete and steel which helps in endorsing the mechanical properties for a good building material. The CNTs can be eight times more efficient than copper in conductivity [1]. CNTs can be used as a sensing concrete as it possess a current density attainable by any conventional metal-wire. Crack resistant concrete which is durable is feasible if the distribution of the CNT in concrete is uniform and a strong bond should be exhibited.

Yu, Kwon and Han [1] conducted an experiment to find the strength of 10 and 20 micrometre CNTs in cements. Experimental outcomes indicate that compressive and flexural strength is higher in cement composites which have CNTs than the conventional cement particularly at 7 and 28 days. It is also observed via scanning electron microscope that CNTs fill the voids in composites. Outcomes conclude that the electrical resistivity is directly proportional to the compressive stress of the cementitious composite.

It could be easily assumed that the distribution of CNTs in a cement concrete mix would increase the overall strength of concrete (since the interlock between aggregates and the binder is made stronger after adding CNTs to the mix). In contrast to macro or microfibers, CNTs interrupt the creation of cracks at the Nano-level and inhibit their growth and spread to the micro-stage.

For example, if CNT reinforcement is made along with traditional steel reinforcement, and given that the concrete will not crack under the designed load, then we are talking about almost no corrosion to steel.

After reinforcing concrete with CNTs, an exceptional characteristic in the hardened concrete was detected: piezoresistivity [38]. This feature means that CNT reinforced concretes possess an electric resistance to some extent, to the compressive load applied on them.

Few applications of CNTs-Reinforced Concrete are they have been successfully utilized as self-sensing materials, in order to thoroughly monitor the health of structural members and measuring stresses in concrete under load, to detect unnoticeable flaws in concrete, and identifying vehicle flow in roads and highways [47].

6.7 Coconut shell

Coconut shell is a lightweight aggregate. Dried coconut shell can be utilized as coarse aggregate in concrete in partial amounts.

As per the experiment conducted by research scholars, they determined that the strength of the concrete is inversely proportional to amount of coconut shell replaced. As the number of coconut shell rises, the surface area also upsurges; therefore additional cements are needed to bond. Meanwhile the percentage of cement should be same, hence there can be no further bonding and thus strength is diminished.

If coconut shell replacement percentage increases, workability of concrete also increases [43]. Compared to crushed granite, coconut shell shows greater abrasion resistance.

7. POTENTIAL BARRIER TO USE GREEN CONCRETE

(a) The mind-set of the consumer who is afraid to take a new innovative step.

(b) The industries are reluctant to follow a new method for production of concrete. The fast-growing and established concrete industries need to change due to environmental problems which are majorly caused by concrete construction, defining, manufacturing, transport, printing, demolition, and recycling.

(c) Out-dated building codes don't explain about the green materials so a new code should be established considering the recycled materials.

(d) Buildings made of green concrete have comparatively less mechanical strength to normal concrete when an uncertain amount is used.

(e)Water absorption is high in particular substitute product.

(f) Shrinkage value of green concrete is higher than the normal concrete in some cases or when an uncertain amount is used.

8. CONCLUSION

It is significant to note that the amount of waste replacement plays an important role in deciding the final properties of concrete. Moreover the substituting product should be selected in such a way it attains the properties of concrete. Concrete containing green cement or aggregates had improved mechanical and durability properties. It was clinched that sorptivity rates for few green concrete was decreasing, this implies that Green concrete requires less water content compared to the standard concrete. Green concrete is cost effective and eco-friendly. Utilizing green concrete helps in reducing the extraction of river sand. Furthermore, carbon emissions that are generated during the manufacturing process of cement, crushing of aggregates and other similar processes can be reduced. Green concrete has a wide range of applications. It can be utilized in both structural and non-structural aspects considering their rate of strength. Henceforth it can be concluded that green concrete helps in the advancement of a sustainable environment by minimizing the carbon emission rate and the waste disposal rate.

REFERENCES

[1] BambangSuhendro," Toward green concrete for better sustainable environment", 2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials (SCESCM), 2014.

[2] Sandeep Shrivastava, Abdol Chini,"Construction Materials and C&D Waste in India", 2010.

[3] DR. ARUP SAHA CHAUDHURI,"High Volume Fly Ash Mixed Green Concrete For CivilEngineering Purposes",Techno india main college,Kolkata,2019 .

[4] Ahmed Al-Mansour Cheuk Lun Chow,"Green Concrete: By-Products Utilization and Advanced Approaches",Structural Upgrading Systems for Sustainable and Resilient Concrete Infrastructure, special Issue,2019.

[5] AnanthKamath K & Mohammad Suhail Khan," Green Concrete", Imperial Journal of Interdisciplinary Research (IJIR) Vol-3, Issue-1, 2017.

[6] PeterDuxson,John L.Provis,Grant C.Lukey "The role of inorganic polymer technology in the development of 'green concrete", Cement, Volume, December 2007, Pages 1590-1597.

[7] Neeraj Jain, MridulGarg, and A. K. Minocha," Green Concrete from Sustainable Recycled Coarse Aggregates: Mechanical and Durability Properties", Hindawi Publishing Corporation Journal of Waste Management Volume 2015.

[8] Nikhil Chhipa, Divyank Jain, Jeeya Ram, "A Review Paper on Green Concrete",International Journal of Engineering Research,Volume.7, Issue 4,March 2018.

[9] Dhiraj Kumar Tiwari, Ankur Rai, Jagrit Dewan, Rohit Mathew,"ComparativeStudy on Green Concrete",Volume 2, Issue-4,2015.

[10] M. Shahul Hammed and A.S.S Sekar. "Properties of Green Concrete Containing Quarry Dust and Marble Sludge Powder as Fine Aggregate", APRN Journal of Engineering and Applied Sciences, June 2009.

[11] Mehta Neeraj, SehrayaAashish and Malik Aman," GREEN CONCRETE: AN INNOVATIVE APPROACH TO SUSTAINABLE DEVELOPMENT", International Journal of Advances in Engineering & Scientific Research, Vol.2, Issue 9, Nov-Dec – 2015.

[12] K.M.Liew,A.O.Sojobi,L.W.Zhang,"Green concrete: Prospects and challenges",Construction and Building Materials,Volume 156, Pages 1063-1095,15 December 2017.

[13] Maria Criado, Susan A. Bernal," Sustainable and Nonconventional Construction Materials using Inorganic Bonded Fiber Composites", 2017.

[14] M Jolin,D Burns,"Understanding the pumpability of concrete", Engineering Conference International,2009.

[15] A.Mujahid and A. Zaidi, "Assessment of recycled aggregate concrete," Modern Applied Science, vol. 3, no. 10, pp. 47–54, 2009.

[16] M T Gumed*e*,S O Franklin"Studies on Strength and Related Properties of Concrete Incorporating Aggregates from Demolished Wastes: Part 2—Compressive and Flexural Strengths",2015.

[17] Malhotra V.M and A.A.Ramezanianpour, "Fly Ash In Concrete",CANMET, Natural Resources Canada, 1994.

[18] Arpit, Harsh, Abhishek, Asad"A Review on the Comparison of Compressive Strength of Green Concrete",International Journal of Advanced Research in Science and Engineering, Vol 07,Issue 10,2018.

[19] S. P. Mukherjee, Dr Gaurang Vesmawala,"Literature Review on Technical Aspect of Sustainable Concrete",International Journal of Engineering Science Invention,Vol 2,Issue 8,2013.

[20] R V Silva,"Fresh-state performance of recycled aggregate concrete: A review",Construction and Building Materials,Volume 178,pages 19-31, 2018.

[21] Sang-Woo Kim,Bum-Sik Lee,Young-Seek Kim,"Structural Performance of Recycled Aggregate Concrete Confined by Spiral Reinforcement",Journal of Asian Architecture and Building Engineering, Volume 17, Issue 3,2018.

[22] S. Manasa, M. UdayBhaskar, G. Naveen Kumar,"Performance of Recycled Aggregate Concrete for M25 Grade Concrete",International Journal of Engineering and Advanced Technology (IJEAT), Volume 9, Issue 2.

[23] Krishan Pareek,Srishti Saha, Nayan Gupta, Purnachandra Saha, "Effect of Recycled Aggregate on Mechanical and Durability Properties of Concrete International Journal of Structural and Civil Engineering Research,Vol. 8, No. 2, May 2019.

[24] Pandurangan S,Vimalanandan G,Dr.S Senthil Selvan,"Performance of High Volume Fly Ash Concrete",International Journal for Innovative Research in Science & Technology Volume 1, Issue 11,April 2015.

[25] Sanjay Thakur &Harpreet Singh "A Review on Effect of Silica fume and Fly Ash on Concrete by Some Partial Replacement of Cement and fine aggregate", International Research Journal of Engineering and Technology (IRJET),2018.

[26] ManikGoyal and Harish Kumar,"Green Concrete: A Literature Review",special issue,2018.

[27] Mehta, P. K. "Sustainable Cements and Concrete for the Climate Change Era – A Review". Proc. 2nd International Conference on Sustainable Construction Materials and Technologies. Ancona, Italy, June 28-30, 2010.

[28] Dr. G.Vijayakumar , Ms H. Vishaliny , Dr. D. Govindarajulu," Studies on Glass Powderas Partial Replacement of Cement in Concrete Production", International Journal ofEmerging Technology and Advanced Engineering, Volume 3, Issue 2, February 2013.

[29] Dr. D. V. PrasadaRao ,G.YashvanthSai"An Experimental Investigation on the StrengthProperties of Concrete by Partial Replacement of Cement with Glass Powder and Silica Fume", Vol. 6, Issue 11, November 2017.

[30] Tae Hyoung Kim , Chang U Chae , Gil Hwan Kim &Hyoung Jae Jang "Analysis of CO2 Emission Characteristics of Concrete Used at Construction Sites", 2016.

[31] Anantha Lekshmi M L," Green Concrete-for the Future-A Review", International Journal of Engineering Research & Technology (IJERT), Special Issue – 2016.

[32] GopinandanDey and Joyanta Pal, "Use of Brick Aggregate in Standard Concrete and Its Performance in Elevated Temperature", IACSIT International Journal of Engineering and Technology, Vol. 5, No. 4, August 2013.

[33] Aggregate Concrete at High Temperatures", Journal of Materials in

[34] Fernando Pacheco Torgal, J.P. de Castro Gomes, Said Jalali," Using mine waste mud to produce environmentally friendly new binders" International Congress Sustainable Construction, Materials and Practices, January 2007.

[35] M.D. Lepech& G.A. Keoleian, S. Qian& V.C. Li," Design of green engineered cementitious composites for pavement overlay applications", Life-Cycle Civil Engineering – Biondini & Frangopol (eds) Taylor & Francis Group, London,2018.

[36] NH Jun,MMABAbdullah,TSJin,AAKadir,CATugui and AV Sandu," Use of Incineration Solid Waste Bottom Ash as Cement Mixture in Cement Production" ,International Conference on Innovative Research — ICIR EUROINVENT 2017, IOP Publishing.

[37] Neeraj Agarwal, NikhilGarg,"A RESEARCH ON GREEN CONCRETE",JIRMPS, Volume 6,Issue 4,2018.

[38] Rashad Al Araj, Adil K. Tamimi," Sustainability of Carbon Nanotube-Reinforced Concrete", International Journal of Structural and Construction Engineering Vol: 11, No: 7, 2017.

[39] Manmohan, D. & Mehta, K. "Heavily Reinforced Shearwalls and Mass Foundation Built with Green Concrete". Concrete International. Vol. 24, No. 8, August, 64-70, 2002.

[40] ÇAKıR, Ö. &SOFYANLı, Ö. Ö." Influence of silica fume on mechanical and physical properties of recycled aggregate concrete". HBRC Journal, 11, 157-166, 2015.

[41] Vishal S. Ghutke&PranitaS.Bhandari "Influence of silica fume on concrete", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 2014.

[42] Mageswari.L.M and B.Vidivelli, " The use of Sheet Glass Powder as Fine Aggregate Replacement in Concrete", the open Civil Engineering Journal, vol:4,65-71, 2010.

[43] DewanshuAhlawat, L.G.Kalurkar "Coconut Shell as Partial Replacement of Coarse Aggregate in Concrete," International Conference on Advances in Engineering & Technology, 2014.

[44] Vishwas P. Kukarni, Sanjay kumar B. Gaikwad," Comparative Study on Coconut Shell Aggregate with Conventional Concrete", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 12, June 2013.

[45] S.S. Jamkar, Y.M.Ghugal and S.V.Patankar, Effect of Fly-ash Fineness on Workability and Compressive Strength of Geo-polymer Concrete, The Indian Concrete Journal, pp: 57-62, 2013.

[46] Uzal, B., Turanli, L. and Mehta, P.K. "High-Volume Natural Pozzolan Concrete for Structural Applications". *Materials Journal.* 104 (5), September, 2007.

[47] M. S. Konsta-Gdoutos and C. A. Aza, "Self sensing carbon nanotube (CNT) and nanofiber (CNF) cementitious composites for real time damage assessment in smart structures," Cement & Concrete Composites, vol. 53, p. 162–169, 2014.