Comparative Analysis of Green Concrete with Conventional Concrete - A Literature Review

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Abstract— In today's modern world there has been enormous development in the field of "Concrete Technology". With this development, there has also been enormous use of concrete in our day today life. Concrete mainly comprises of cement, sand and aggregate as its main constituents, which when mixed with water in correct proportion gives a byproduct called as "Concrete". The excess use of concrete has led to the environmental impact in terms of resources utilization as well as in terms of pollution. To overcome these impacts the concept of "Green Concrete" came into existence. Green concrete is a recent form to the existing types of concrete which resembles the conventional concrete but its manufacturing or handling of this concrete requires minimum amount of heat energy and causes the lowest harm to the surrounding environment. Since it deals into uses of the recycled aggregates and materials, it also reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO2 emissions are reduced. The reuse of materials also contributes intensively to economy. Green concrete can be considered elemental to sustainable development since it is eco-friendly in nature. One of the methods for manufacturing of green concrete involves reduction of amount of cement in the mix, which added to the reduction the total cement consumption. The use of waste materials also solves the problem of disposing the excessive amount of industrial wastes. Green Concrete is a concrete in which one or more of its constituents are replaced by a resource saving material, which ultimately has reduced environmental impacts in terms of both, resource utilization and pollution impacts together. This paper discusses the importance of Green Concrete in the present day context and highlights its merits over conventional concrete which otherwise posing a serious threat to the environment through global warming.

Keywords: Green Concrete, Conventional Concrete, GGBS – Ground Granulated Blast Furnace Slag, Quarry Dust, Demolised & Broken Brick Compressive Strength, Flexural Strength, Tensile Strength, Workability

I. INTRODUCTION

Green concrete is a concept of using environment-friendly materials in concrete, to finally make the system more sustainable. Green concrete is cheap to produce since waste products or recycled materials are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption while production is quite lower, and durability is much greater. This concrete is often confused with its colour. Waste can be recycled to produce new products or can be used as admixtures to relieve the burden on precious natural resources and also causing minimal negative impacts on the environment. Inorganic residual or tailing products like stone quarry dust, crushed concrete debris, marble waste can be used as green aggregates in concrete. Further, by replacing cement with ground granulated blast furnace slag, fly ash, micro silica in larger amounts, to produce new green cement and binding materials can ultimately lead to the use of alternative raw materials and fuels producing cement with low energy consumption. Considerable research has been carried out on the use of various industrial by-products and micro-fillers in concrete and their impact on concrete characteristics. When we replace one or more constituents of conventional concrete, by environmental friendly materials or recycled materials, the concrete formed is termed as "Green Concrete". As we know the manufacturing process of cement and aggregate causes huge environmental impact, and day by day this increasing demand of concrete materials is ultimately causing impact to our environment. Thus replacing cement and aggregate (conventional constituents of concrete) can in turn help in minimizing the environmental impact caused during manufacturing process of aggregate and cement.

Green concrete name easily gives a illusion of something related to the colour of the substance or the product. But this logic is nowhere in picture as the product has no resemblance to the green colour. Normally in the production of cement there is emission of carbon-di-oxide. The cement industry is also in question to lower its co2 emission as to rising global concerns. The connection between the cement industry and concrete industry is very evident as the latter cannot be produced with the former. So, Green concrete can also be an answer to those concerns. As this world is developing so fast it is next to impossible to replace concrete industry, it is evident from the fact that it is one among the largest industries providing economy, capital and employment. The only way-out is to find an alternative which can bring a balance between the development and the environmental concerns. That is why green concrete is catching eyeballs of various analysts worldwide, "Denmark" being the first among them. Checking the possible ways to get green concrete in work will certainly boost the development process without hampering the current growth rate. The by-products will also get value as they will be ultimately used in the green concrete making process. As green concrete presents various ways for its production that there are many entities of zero or low value which can be used. Dismantled concrete, Fly ash, Use of wasted wooden chunks from fitting can be utilized as aggregate mixture. Green concrete is also comparably cheap to manufacture, as, for example, waste products are used as a partial substitute for cement portion, costing for the disposal of waste are avoided, energy consumption of materials in manufacturing period is lower, while durability is greater. Green concrete is a new form to the existing (regular) types of concrete which resembles the conventional concrete but its manufacturing or usage of this concrete requires minimum amount of heat energy and causes the minimal destruction or damage to the surrounding environment.

II. OBJECTIVES OF THE STUDY

The main objective of this research is to compare conventional concrete and green concrete in terms of its workability and strength. The use of various materials like fly ash, GGBS, quarry dust, broken bricks etc in concrete helps in minimizing the resources consumption used to develop the conventional concrete and provide benefits like improved strength and workability of concrete with useful disposal of by-products. This type of concrete will also used to control the energy consumption and will able to minimize the hazards caused to the environment.

III. LITERATURE REVIEW

There were various studies been conducted on the use of such recyclable materials in concrete which gives adequate strength and its durability? The studies also suggests about the difficulties arise for the use of such by-products in the proportion of concrete. Few of the data from previous studies have been discussed here along with the methodology adopted and conclusions. Many research investigations have been carried out regarding the use of such by-products to minimize the amount of energy consumed and also to reduce the damage to the surrounding environment.

1) In 2018, Sanjay Thakur, et al studies fly ash concrete and the research study of silica fume concrete conclude that:
    1) The use of both silica fume and fine aggregate will be overall beneficial
    2) By the use of these there will be decrease in amount of cement and fine aggregate
    3) The initial property of concrete like bleeding, segregation and slump will improve
    4) There will be increase in the strength of concrete that is high strength performance concrete is formed.
    5) The use of both fly ash and silica fume in concrete will overall enhance all the property of concrete and high strength concrete is achieved with the partial replacement of silica fume and fly ash.
2) In 2016, Praveer Singh, et al studied about the silica fume and comes to the conclusion that cement is becoming a scarce resource all over the world because of increase in demand day by day. The use of silica fume as a pozzolana material has increased in recent years because when mixed in certain proportions it enhances the properties of both fresh and hard concrete. Addition of silica fume in proper proportion improves durability attack by acidic waters and improving concrete conditions.
3) In 2015, Arun Borsaikia, et al studied about the silica fume & its properties and comes to the conclusion that various parameters of both fresh and hardened concrete are getting changed due to silica fume content. Following conclusions can be made.
    1) Workability of concrete improves with addition of silica fume up to certain limit.
    2) Ultimate compressive strength of concrete increases with replacement of cement by silica at certain specified limit.
    3) Ultrasonic Pulse Velocity increases with increase in compressive load initially and the decreases with increase in compressive load due development of micro cracks in concrete. Abrupt decrease in Ultrasonic Pulse Velocity occurs at 70-80% of failure load.
4) Garg and Jain (2014), studied on green concrete: efficient & eco-friendly construction materials. It presents the feasibility of the usage of by product materials like fly ash, quarry dust, marble powder/granules, plastic waste and recycled concrete and masonry as aggregates in concrete. It concluded that, it focuses on known benefits and limitations of a range of manufactured and recycled aggregates. Use of concrete product like green concrete in future will not only reduce the emission of CO2 in environment and environmental impact but it is also economical to produce. Dhoka (2013), carried out "green concrete: using industrial waste of marble powder, quarry dust and paper pulp" The green concrete is prepared by using industrial waste of marble powder, quarry dust with proper proportions". The versatility of green concrete& its performance derivate will satisfy many futureneeds.
5) In 2014, Vishal S. Ghutke, et al studied about the silica fume and comes to the conclusion that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. After performing all the tests and analyzing their result, the following conclusions can be derived:
    1) With the increase in w/c ratio strength of concrete decreases.
    2) The optimum value of compressive strength can be achieved in 10% replacement of silica fume.
    3) As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varies from 10 % to 15 % replacement level.
    4) Workability of concrete decreases as increase with % of silica fume.
    5) Compressive strength decreases when the cement replacement is above 15% of silica fume.
6) In 2014, Umesh Sharma, et al studied about the silica fume & concluded that concrete is the most important engineering material in a construction industry because of its inherent strength properties. Micro silica primarily of very fine smooth spherical silicon is the reason of air pollution. This is a by-product of some Industries. Use of micro-silica with concrete decreases the air pollution. Silica fume also decrease the voids in concrete since of oxide particles with an extremely high surface area. Micro silica particle are 100 times smaller than as that of cement particle. Silica fume is usually categorized as a supplementary cementitious material. These material exhibit pozzolanic properties, cementitious properties and a combination of both properties due to this properties it can affect the concrete behaviour in many ways. Silica fume is a material which may be a a reason of Air Pollution. This is a by-product of some Industries. Use of micro-silica with concrete decreases the air pollution. Silica fume also decrease the voids in concrete.

7) Wangchuk et.al. (2013), studied that green concrete for sustainable construction. It is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Replacement of materials over nominal concrete is what makes green concrete more environmental friendly concrete. Marble sludge powder, quarry rocks, crushed concrete and fly ashes are some of the materials used for making green concrete, a sustainable construction. With green concrete technology we can save the natural materials.
8) In 2013, Debabrata Pradhan, et al studied about the silica fume and comes to the conclusion that the optimum compressive strength is obtained at 20% cement replacement by silica fume at all age levels (i.e. at 24 hours, 7 and 28 days). Slump value may be increased by increasing the dosages of superplasticizer without hampering the strength for further investigation but the ranges of compacting factor from 0.82 to 0.88 and slump value from 20 to 50mm are also good for using concrete in the field in control system. Higher compressive strength resembles that the concrete incorporated with silica fume is high strength concrete (HSC) as per IS code recommendations. It is reported that improved pore structures at transition zone of silica fume concrete led to it as high performance concrete but durability tests are yet to be surveyed. During the testing of cubes at 28 days the failure plane of cubes cut the aggregates but not along the inter facial zone which is concluded that the interfacial zone attained much higher strength than control concrete i.e. concrete without silica fume.
9) In 2012, N. K. Amudhavalli, et al concluded that Portland cement is the most important ingradient of concrete and is a varsetile and relatively high cost material. Large scale production of cement is causing enviornmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementatious material in making concrete. This paper represents the detail experimental study on compressive strength, flexural strength and split tensile strength. Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases.
10) In 2012, Ajay Verma, et al concluded in there paper that concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. With increase in a trend towards the wider use of concrete for high rise buildings there is a growing demand of concrete with higher compressive strength. There are two types of materials crystalline and noncrystalline. Micro silica or silica fume is very fine non crystalline material. Silica fume is produced in electric arc furnace as a by-product of the production of elemental silicones or alloys, containing the silicon. Silica fume was initially viewed as cement replacement material and in some area it is usually used as replace by much smaller quantity of silica fume may be used as pozzolanic admixtures. Silica fume increases the strength of concrete more 25%. Silica fume is much cheaper than cement therefore it very important from economical point of view.
11) Mr.Vardhan Nagarkar, et al publishes a paper on green concrete in 2010. In which they conclude that green concrete is a very low energy and resources consuming material. And it is also reduces environmental pollution. This method is useful for saving natural resources for future generations. He also studied about the silica fume and conclude that cement is a scarce resources all over the world because the demand of cement increases day by day. At recent time the use of silica fume increases because when it mixes with cement its enhance the hardness and freshness of cement.
12) Mr.Vardhan Nagarkar, et al also studied about the emission of carbon dioxide from conventional cement and concluded that concrete is most common material used in construction field and it emits a large amount of environmental wastes. And carbon dioxide produced from concrete affects the global warming, etc.
13) Mr. Abhijeet Baikerikar studied about the factor affect on environment due to concrete from which he concluded that at recent time approximately one ton of carbon dioxide are emitted from one ton of cement. Carbon dioxide is one responsible gas for global warming. Without aggregates concrete cannot be produced.
14) WANG, H.-Y., ZENG, H.-H. & WU, J.-Y. - An experimental investigation was undertaken specifically concentrating on the mechanical and durability properties of polymer concrete. Recycled glass sand, fly ash (FA) and meta kaolin (MK) were used as fine aggregates in the concrete mix design. Five concrete mixes were prepared from which one was the control mix (no FA or MK content). The mixes were cast into moulds from which specimens in form of cylinders and prisms were prepared. These specimens were then tested to evaluate the performance of polymer concrete [3]. It is perceived that MK and FA mixes exhibited higher compressive strengths compared to the control mixes. After 28 days, the strength started to increase significantly. Mixes containing 15% FA attained the highest compressive strength after 28 days [10].
15) ZHAO, H., SUN, W., WU, X. & GAO, B - Another experimental investigation was carried out to study the properties of self-compacting concrete (SCC) comprising FA and ground granulated blast furnace slag (GGBFS) admixtures. Portland cement was replaced with FA and GGBFS by rates of 20%, 30% and 40%. One control mix mixture, three FA mixtures and three GGBFS mixtures were prepared [1]. The results shows that the compressive strength of FA mixes were slightly lower than the control mixes. After three days, the strength of 20% FA dropped by 5MPa. However, after 90 days the strength of all mixes was almost the same as the control mix [4].
16) KHALIL, E. A. B. & ANWAR - A laboratory investigation was performed to examine the properties of concrete comprising FA and SF. Cement was substituted with SF at portions ranging between 0-10%. Mixtures comprising both FA and SF were found to be effective in improving the strength properties of concrete. In

addition, chloride resistance of concrete was also improved [5, 6].

17) ÇAKıR, Ö. & SOFYANLı, Ö. Ö. - An experimental research was performed to study the effects of SF on mechanical and physical properties of recycled aggregate (RA) concrete. Portland cement was replaced with SF by rates of 0%, 5% and 10%. Moreover, RA was replaced with natural aggregates (NA). The compressive strength results suggested that SF recycled aggregate concrete experienced reductions in early age compressive strength. However, after 28 days the strength of these mixes increased when compared to the control mix. Concrete mixes comprising 10% SF exhibited better performances in terms of mechanical and physical properties [7].
18) LONG, G., GAO, Y. & XIE, Y. - The relationship between mixing proportion parameters of self-compacting concrete (SCC) were examined in a further research. In that same research, the environmental impacts of SCC were also examined. Sixteen portions of SCC mixtures incorporating various by-products such as FA, slag and meta kaolin were created. The test results suggested that the addition of by-products reduced CO2 emissions. Furthermore, adding three mineral mixtures into SCC was more operative in reducing the environmental impact compared to the addition of single or two mineral admixtures. Therefore, addition of by-products such FA, slag and meta kaolin not only reduced CO2 emissions but also reduced environmental impacts [1].
19) RASHAD, A. M. - Laboratory study was performed to study the effects of concrete containing a combination of high volume fly ash (HVFA) and slag. Four different mixtures with various contents of HVFA and slag were prepared. After the mixes were prepared, specimens were constructed and tested. The test results suggested that the compressive strength of HVFA concrete was lower than PC concrete. Moreover, addition of slag to the concrete mix further reduced the strength. However, HVFA concrete displayed better fire performance compared to PC concrete. It was recommended not to mix slag with FA as it reduced the strength of concrete [8].
20) PANDA, K. C. & BAL, P. K. - A study was performed to examine the properties of self-compacting concrete using RA. NA was replaced with RA by rates of 10%, 20%, 30% and 40%. Six different mixes were prepared. Thereafter, specimens were created and tested. Test results suggested that an increase in RA content lead to a reduction in compressive strength, flexural strength and split tensile strength. Moreover, the properties of concrete in terms of strength were not improving when RA were used in the mix. Additionally, 30% replacement of RA helped to achieve the required compressive strength [9].
21) WANG, H.-Y., ZENG, H.-H. & WU, J.-Y. - A laboratory investigation was performed by towards macro and micro properties of concrete containing liquid crystal glass (LCD) glass. Cement was replaced with waste LCD by rates of 10%, 20%, 30%, 40% and 50%. In addition, natural sand was replaced with glass sand by rates of 10%, 20% and 30%. Various tests were performed to evaluate the performance of LCD glass. The test results suggested that addition of glass sand enhanced the compressive strength. Moreover, glass sand provided higher resistance and it improved properties of concrete with age. By utilizing glass in concrete, usage of cement and sand could be minimized which could help preserve the natural resources and reduce carbon emissions [10].
22) (Nielsen & Glavind, 2007) - In one research, the properties of concrete tactile blocks prepared with recycled tire rubber were studied. Sand was replaced with waste tire rubber by proportions of 10%, 20%, 30%, 40% and 50%. Six concrete mix designs were prepared, out of which one was the control mix. From each concrete mix, three specimens of sizes 150 x 150 x 500mm were prepared for flexural and compressive strength test. The test results revealed that rubber modified concrete obtained the same consistency as the control mix. The highest compressive strength was achieved when 10% rubber was cooperated in the mix design. This strength was also found to be higher than the control mix. It was concluded that 10% recycled tire mix could be used to make tactile paving blocks [11].The reduction in CO2 emissions can be done through: (a) the substitution of cement with flay ash, (b) the use of ground granulated blast furnace slag from steel plants, (c) use of micro silica, (d) the use of pozzolanic materials and limestone powder, (e) various kinds of ash from the burning of domestic waste and bio-fuels, and (f) crushed waste glass [12]
23) Uzal, Turanli, and Mehta reported that their initial research results with the concrete containing natural pozzolana high volume (50% of the mass of cementious material), which was named the High Volume Natural Pozzolana (HVNP) indicates achievement that promises to structural applications, reaching 14 MPa strength(aged 3 days) and 38 MPa (age 28 days). Natural pozzolana used is a low-calcium fly ash and granulated blast furnace slag. The larger portion of the fly ash can be used to substitute cement the reduction of CO2 emissions in the cement manufacturing process will also be reduced.
24) Glavind & Jepsen has prioritized taking 4 steps to go green concrete in Denmark, namely: (a) improving the utilization of residual products such as fly ash in large scale, (b) the use of residual products from concrete plant, such as: stone dust, and concrete slurry, (c) the utilization of residual products of other industries, such as fly ash from bio-fuels and combustion of sewage sludge ash in waste processing installations, and (d) the use of a new type of cement that is more environmentally friendly, such as mineralized cement, the addition of limestone, and waste derived fuels.The comparison of CO2 emissions generated in the service life cycle of a bridge pillar located in aggressive environments (50 years, as a special case) by 4 kinds of different design principles, namely: (a) Reference column, made of conventional reinforced concrete, (b) A column made of green concrete (containing 40 ~ 50% fly ash), (c)B column made of green concrete (containing 40 ~ 50% fly ash) with stainless steel reinforcement, and (d) column C is made of green concrete (containing 40 ~ 50% fly ash)

with stainless steel cladding have been investigated. It appears that the use of the three green concrete could reduce CO2 emissions by up to less than 30% compared to conventional concrete.

25) According to Mehta there are 3 structural engineer's tools for sustainability of the cement industry or reducing CO2 emissions: (a) consume less concrete for new structures, by developing innovative architectural concepts and structural design, using highly durable concrete, and using prefabricated elements for easy assembly,(b) consume less cement in concrete mixtures by using super plasticizer instead of more mixing water and cement to obtain the required consistency of fresh concrete, and optimizing the size and grading of aggregates, and (c)consume less clinker in the cementing material by selecting blended portland cements and concrete mixtures that contain high volume of coal fly ash, granulated blast-furnace slag, natural or calcined pozzolanas, silica fume, and reactive rice-husk ash.

IV. CONCLUSION

It was important to note that the quantity of by-product or waste replacement played a vital role to the properties of concrete. From all the previous studies, following points have been concluded:

- There is significant potential in waste materials to produce green concrete.
- To use GGBS as a replacement of cement in concrete.
- To use stone quarry dust as a replacement of fine aggregate in concrete.
- To use broken and demolished bricks as a replacement of coarse aggregate in concrete.
- To conduct experimental analysis for the strength of different grades of concrete.
- To compare the economic feasibility of conventional concrete and green concrete made with recyclable materials.
- To check the suitability of such materials in higher grade of concrete.
- To conduct durability tests on high-performance concrete.

REFERENCES

[1] Chirag Garg and Aakash Jain, Department of Civil engineering, BITS-Pilani, Hyderabad Campus, Andhra Pradesh, India "Green concrete: efficient and eco-friendly construction materials", ISSN(E):2321-8843; ISSN (P):2347-4599, Vol.2, Issue 2, Feb 2014,259-264.

[2] Md. Nuruzzaman, Md. Saiful Islam, M. Salauddin, Md. Saiful Islam, Department of civil engineering, Chittagong University of Engg. and Technology, Chittagong, Bangladesh, Strength aspect of concrete using stone dust as a partial replacement of sand International Journal of Advanced Structures and Geotechnical Engineering, Vol.4, October 2015.

[3] Sumit L. Chauhan, Raju. A Bondre, Assistant Professor P. I. G. C. E. Nagpur, Partial Replacement of Sand by Quarry Dust in Concrete, International Journal of Scientific and Research Publications, Volume 5, Issue 7, July 2015 1 ISSN 2250-3153.

[4] Dr. A.D. Pofale1, Syed Raziuddin Quadri2, Professor in Civil Engineering, Visvesvaraya National Institute of Technology, South Ambazari Road Nagpur 440010 ** M.Tech(Thesis): Student, Construction Technology and Management, Civil Engineering Department, Visvesvaraya National Institute of Technology, ,South Ambazari Road Nagpur 440010,Effective Utilization of Crusher Dust in Concrete Using Portland Pozzolana Cement, International Journal of Scientific and Research Publications, Volume 3, Issue 8, August 2013 1 ISSN 2250-3153.

[5] K. Karthika, G. Snekha, R Sinduja, S Priyadharshini, Assistant Professor, Final year students Department of Civil Engineering, PSVPEC Chennai, Tamil Nadu, India, Experimental Analysis of Quarry Dust and Metallic Dust as a Partial Replacement of Fine Aggregate in Concrete, International Journal of Engineering Research and Technology, ISSN: 2278-0181,Vol.6,Issue 7,July 2017.

[6] Dr. P. B. Sakthivel, C. Ramya, M. Raja International, Innovative Method of Replacing River Sand by Quarry Dust Waste in Concrete for Sustainability Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013.

[7] Engr. Muritala Ashola ADIGUN, B.Eng; M.Sc Civil Engineering Department, Lagos State Polytechnic, Ikorodu, Lagos State, Nigeria, Cost-Effectiveness of Replacing Sand with Crushed Granite Fine (CGF) In the Mixed Design of Concrete, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 1 (Nov. - Dec. 2013), PP 01-06.

[8] D.B. Desai, A.K. Gupta And Pradeep Kumar,(2013) "Green Concrete: Need Of Environment", International Journal Of Advanced Science, Engineering And Technology, ISSN 2319-5924, Vol 2, Issue 2, pp. 134-137.

[9] M.S. Kakamare, V.V. Nair, (February 2015) "Sustainable Construction Materials and Technology: Green Concrete", International Journal of Advanced Technology In Engineering And Science. Volume No.03, Special Issue No. 02, ISSN: 2348 – 7550, Pp. 310-314.

[10] M. Shahul Hameed And S. S. Sekar, (June 2009) "Properties Of Green Concrete Containing Quarry Rock Dust And Marble Sludge Powder As Fine Aggregate", ARPN Journal Of Engineering And Applied Sciences , ISSN 1819-6608 Vol. 4, No. 4, pp. 83-89.

[11] Prof. Chetna. M. Vyas, Prof. (Dr.) Darshana R Bhatt, (July 2013) "Concept Of Green Concrete Using Construction Demolished Waste As Recycled Coarse Aggregate", International Journal Of Engineering Trends And Technology (IJETT) – ISSN: 2231-5381, Volume 4, Issue 7, pp. 3160-3165.

[12] Chirag Garg and Aakash Jain, (Feb 2014) "Green Concrete: Efficient & Eco-Friendly Construction Materials", Impact: International Journal of Research In Engineering & Technology (Impact: IJRET), ISSN: 2321-8843, Vol. 2, Issue 2, pp. 259-264.

[13] U.R.Kawade, P.A.Salunkhe, S.D.Kurhade, (April 2014) "Fly Ash Based Geopolymer Concrete", International Journal of Innovative Research In Science, Engineering And Technology, Volume 3, Special Issue 4, pp. 135-138.
[14] Shivaji S. Bidwe and Ajay A. Hamane, "Effect of different molarities of sodium hydroxide solution on the strength of geopolymer concrete", American journal of engineering research, e-ISSN : 2320-0847, Volume 4, Issue 3, pp-139-145..
[15] Swapnil Wanjari and Jerril Sebastian, (March 21, 2015) "Partial replacement of cement in geopolymer quarry rock dust concrete under different curing conditions", Proceedings of international conference on transportation and civil engineering, ISBN: 978-93-84468-19-4, pp 12-19.
[16] Garg Chirag & Jain Akashi, "Green Concrete Efficient& Eco Friendly Construction Material", International Journal of Research in Engineering and Technology (Vol 2)
[17] Krishnamurthy, "Properties of Green Concrete Mix by Concurrent use of Fly Ash and Quarry Dust" IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021.
[18] IS CODE: 516-1956 (Tests for Strength of Concrete).

