Review of materials used in Low density concrete as Eco-friendly

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Abstract. Lightweight concrete is the most popular type in constructional activities to get low density for the concrete just as to diminish the extra weight of the structure. There are different types of lightweight concrete based on the type of lightweight material used. As considering eco-friendly materials like waste tires, waste steel fibres, plastic waste, agricultural waste, waste glass can be utilized in concrete by replacing coarse aggregate and fine aggregate. Lightweight concrete is preferable in constructional activities because of its low warm conductivity and improves fire resistance. In general, lightweight concrete ranges from 1440 to 1840 kg/m³. The main aim is to conclude the high-performance lightweight concrete by using a different type of materials in the same way to achieve low density for the concrete. By this study, we understand that high performance can be achieved by adding steel fibres to improve ductility and for low-density waste tire rubber by partial replacement in coarse aggregate and to improve durability by adding bacillus subtilis JC3 crack formation can be reduced.

Keywords: low-density concrete, high-performance concrete, lightweight concrete materials

1. Introduction

The investigation on lightweight concrete to achieve high-performance as well as low Density for the concrete. There are different ways to achieve low density by using eco-friendly materials. Specialties of low-density concrete are its low density and low warm conductivity. Mainly there are two types of lightweight concrete which are generally known are Air entrained concrete and foam entrained concrete. It is an intentionally entering the air or foam into concrete to create voids. Lightweight concrete is also well known as cellular lightweight concrete or low-density concrete. In many kinds of research proved that lightweight concrete life span is more & it is of about 100 years. Lightweight concretes can also be divided based on strength ranges are 1.low density concrete (0.7 to 2 MPa), 2. moderate strength concrete (7 to 14 MPa), 3. structural concrete (17 to 63 MPa). Mainly lightweight concrete is utilized in the construction of high-rise buildings as shown in Figure.1, shell roofs, manufacturing of precast walls as shown in Figure. 3 and pre-stressed concrete which improves the thermal properties and fire resistance, low thermal conductivity. Light concretes are more durable and less resistant to abrasion. Main utilization of LWC as brick masonry as shown in Figure.2. Many types of research done to achieve only lightweight concrete as eco-friendly. This study states that to achieve high performance with lightweight concrete with the available best materials and with better mix design can be noticed.
2. Literature Review

R. Rashmiya et al conducted research using by replacing fly ash and natural aggregate like volcanic origin, sawdust, and they aim to achieve low density and high durability, and mechanical properties. Mainly the paper presents compressive strength development by fly ash and sawdust. The authors took 53-grade cement, M25 grade concrete, and 10mm size aggregate. Split tensile strength and flexural strength of concrete mixes are investigated at days of curing. Authors conducted different types of tests like workability tests, water absorption tests, compressive strength tested, they found that the compressive strength is increased by replacing cement with fly ash and replacing sand dust that replacing percentages are like 30% fly ash and 10% sawdust. Fly ash replacement makes the concrete mix more workable and improves compressive strength and the usage of sawdust makes the concrete lesser in weight & usage of fly ash in concrete makes eco-friendly and it is also called green concrete [1].

M. Ramali et al author explained about durability performance of lightweight aggregate concrete for housing construction in that durability is defined as the ability of a material to withstand the effects of its environmental attacks like carbonation, sulphate attack, chloride attack etc. & the concrete made with lightweight aggregates exhibit a higher moisture content movement than in case of normal weight concrete & by doing 24 hours absorption test lightweight aggregates absorbs from 5 to 20% by weight of dry aggregates. The durability of lightweight aggregate concrete depends on factors like freeze/thaw behaviour, chemical resistance, water absorption, permeability, carbonation and they concluded that permeability can be reduced by replacing fine aggregate with lightweight fine aggregate and if the permeability is increased in concrete leads to environmental attacks and cause deterioration in concrete which leads to reduction of durability in concrete [2].

M. Kalpana et al researched lightweight steel fiber reinforced concrete they found that steel fiber reinforced concrete could be stuff that can decrease the brittleness of concrete and can increase malleability. Steel fiber reinforced concrete used for repair works, strengthening of various structures, lining tunnels and underground structures & mainly steel fibers adapted for positive environments and adopting the waste steel from steel reinforcement and formworks were mixed with structural lightweight concrete with varied fibre contents. This investigation shows that even little amounts of strands will facilitate in preventing the brittle failure of lightweight combination concrete. The impact of steel fiber on the flexural strength of concrete is way bigger than its influence on direct tension or compression, most strength is gained depend on the quality of fibers added. When added fibers to LWC the mode will changes from brittleness to ductileness subjected to compressive strength and bending. fibers reduce the brittle failure & they also authors say that steel fibers are better than others fibers like glass fiber in improving mechanical properties [3].

R. W. Salim et al mention that a lot of research on the utilization of elective materials in concrete, one of such materials that have acquired a great deal of consideration is the waste tire rubber. In this observation, crumb rubber was utilized partial replacement in concrete at zero to sixteen percent and addressed as M0, M4, M8, M12, and M16 respectively. Sieve analysis was done on the crumb rubber and sand. From the sieve analysis revealed that both the fine aggregate and crumb rubber are poorly graded. The slump test showed that the concrete lost its consistency as more rubber crumb was added. The 28 days compressive strength showed that there was an overall decrease in strength. The work presumed that crumb rubber can be utilized up to 16% in concrete. They inferred that crumb rubber in concrete support the development of voids inside the concrete interface and thus lead to the lightweight attributes for rubber concrete [4].

N. Almesfer et al mentioned that the inclusion of an of a non-natural aggregate produced utilizing plastic waste to foster lightweight concrete was considered. Five separate blends were planned, continuously increasing the amount of non-natural aggregate and measuring the fresh and hardened properties of concrete, and it was tracked down that the slump and density of the concrete diminished as the amount of non-natural aggregate in the concrete is increased. Fifteen percent of the regular aggregate by weight was replaced in this ideal blend, which rises to more than 37% of the volume given the lower density of the manufactured aggregate compared to natural aggregate. In that stage two stress-
strain relationships and modulus of elasticity of the concrete was considered. The results shows that plastic aggregates can be used to obtain low density concrete and also good compressive strength of 20MPa for 28 days. So that they concluded that inclusion of plastic in concrete mix can be utilized in non-structural facades and sound barriers for highways [5].

N Iswarya et al their research says that Concrete broadly used non-renewable material in the construction industry has less period and service period. the new investigation shows that the bacteria of different types heal the cracks that are developed in the concrete over time. This type of concrete tends to repair on its own which results in the lengthening of the service period of the building and the maintenance cost is reduced inconsiderable amount. Microbes develop the calcite layer by the precipitation process developed on the surface of the concrete, due to the actions of the bacteria, the calcite layer forms crystals then the cracks on the concrete surface reduced and protects the reinforcement from environmental attacks. To make the concrete lightweight concrete, a foaming agent is induced in the concrete mix during the batching process. They conclude that the experimental study has proved to be a better way of providing strong and durable concrete. The compressive strength shows that the strengths were decreased proportionately with the increase in the volume of bacteria and aluminium powder. The dead weight of the concrete decreases with the increase in the aluminium content. The compressive strength is increased by 3% when compared to the nominal mix without bacteria and aluminium powder [6].

Habibul Rahman et al mentioned that from the test results as the level of palm oil shell increases strength decreased and also other properties like split tensile strength test, modulus of rupture, density is determined and compared to normal concrete & economic analysis indicates possible cost reduction of up to 15% due to pal oil shell coarse aggregate. concrete compressive strength with 15% OPS substitution is between 17.01 and 17.7 N/mm² at 28 days strength and it satisfies the structural requirement of lightweight concrete and also cost reduced of up to 15% due to palm oil shell as coarse aggregate [7].

Ashish S Moon et al discussed that foam concrete is one of the most popular type of concrete. Because of its flexibility and its usage, many structures around us build with concrete. A green building is an environmentally conscious building, designed, constructed, and operated to minimize the total environmental impacts. Carbon dioxide is a greenhouse gas emitted by human activities. It is claimed that 5% of the world's carbon dioxide emission is attributed to the cement industry, which is the vital constituent unconcreted to CO₂ the environmental pollution will occur, there is a need for finding an optimal solution along with satisfying the civil construction needs. Foam concrete is a new technology for sustainability which fulfils the criteria of being a Green Material. This paper says that foam concrete can be a sustainable material for construction and also focuses on the cost-effectiveness of using foam Concrete as a building material in replacement with Clay Brick or other bricks. Authors mentioned that foam concrete rating as per GBRS is water required is less from foam concrete compared to normal concrete & also foam concrete is best in thermal insulation, sound insulation, fire resistance [8].

M.Priyanka et al done on research about the development of mix proportions of geopolymer lightweight aggregate concrete with lightweight expanded clay aggregates give lightweight and different mix proportions are made to get approximate mix design. lightweight expanded clay aggregate can be utilized in the production of lightweight geopolymer concrete as the % of lightweight expanded clay aggregate increases, compressive strength decreases but due to geo polymerization in concrete the strength is more compared to conventional concrete. Density is decreased by increasing expanded clay aggregates. Strength gained at 60% of lightweight expanded clay aggregate at1550kg/m³ is more than 25MPa, hence we can utilize this as a structural lightweight concrete [9].

D.Oreshkin et al studied about properties of lightweight extruded fine-grain cement concrete with hollow glass microspheres & it is provided that extrusion reduces the water requirement of concrete mix with hollow glass microspheres, significantly increases the compressive strength and reduces the
formation of cracks, reduces water vapor permeability and heat conductivity. They concluded that lightweight extruded fine-grained with hollow glass microspheres are used for the production of window lintels from the extruded mix was developed as well & also the experimental batch of reinforced window lintels was produced in cities of Izhevsk and narrow-forming, the produced units were successfully applied in process of cottage construction of these cities [10].

Kim hung Mo et al researched agricultural waste materials as a lightweight aggregate for reinforced concrete construction. mostly palm oil shell and coconut are widely using as agricultural waste in concrete to produce structural lightweight concrete. This paper deals with the use of agricultural-based lightweight aggregate concrete as reinforced concrete structural member such as beam, slab which were carried out by researchers in past behaviour of structural members under flexural, shear and the torsional load was also summarised. From this review, it was proved that one of the main usages with lightweight concrete as reinforced concrete member which enhanced ductility compared to conventional concrete & this was observed in all types of agricultural wastes such as op, POC concretes and another interesting conclusion is that bond strength of reinforced LWC to normal weight concrete as observed by smaller crack spacing and crack width of reinforced concrete members[11].

K.Naveen Kumar et al explained that Lightweight concrete block finds a wide range of application within the construction industry. A concrete block having a dry density of approximately 300 to 2000 kg/m³ is deliberate to be lightweight concrete. By using lightweight concrete can reduce the self-weight of the structure. Thereby it reduces the price of construction. During this study the combination of cement, water, and coarse aggregate with fines omitted. The concrete mix contains cement, coarse aggregate, and vermiculite. Fine aggregate is completely neglected. Three trial mixes are prepared. The cubes are casted and tested within the compressive strength testing machine. The results of compressive strength at 7, 14, 28 days gives reliable results and densities are 1866, 1943, 2010kg/m³. By the results says that 1:1.5:15 gives the best results and this proves that vermiculate can be implemented in construction as brick masonry [12].

A.Mohammed Hameed et al done research on the employment of plastic waste to produce lightweight concrete. The usage of plastic waste as aggregate to lower the environmental influence of both concrete and waste of plastics. Recycle polyethylene terephthalate flake aggregates are presented & making five batches of concrete are manufactured with different PET contents (1,3,5,7,10%) by weight of Portland cement. Results show that usage of 1% gives increase in compressive strength and flexural strength by the usage of PET at 1,3% increases flexural strength and ratio of 1% of PET gives the optimum value of split tensile strength. Density values decreased with an increase in PET content, decreasing the ratio of density up to 14% especially at 10% of PET [13].

M.A.B.Emon et al [14] talked about that Brick chips, delivered from burning of clay, are very normal in Bangladesh and different nations of the southeast locale of Asia and have been utilized as coarse aggregate for a long time. These brick chips are viewed as lightweight total (LWA) as a result of their lightweight and permeable design. Brick chip concrete is a type of lightweight aggregate concrete (LWAC) and has lower mechanical properties and higher weakness than traditional typical weight concrete. Working on this part of LWAC with brick chips is vital since brick chips are exceptionally mainstream in the nation because of their minimal expense and wide accessibility. For the improvement of ductility for concrete by utilizing locally produced low cost galvanized mild steel wire fibre as an alternative to conventional steel fibres was considered. Steel fibres are not available in markets in many countries. Compressive and tensile strength of cylinders as well as load-deflection and cracking behaviour of beams with variable fibre contents have been evaluated. Improvement has been observed for compressive and tensile strength of concrete through GI wire fibres addition. Ultimate strength and toughness showed maximum increment up to 30% for a certain range of fiber content. Results of the experiments and cost comparison reveal that GI fibre can be utilized as a low-cost alternative to steel fibres for improving the performance of brick chips in concrete [14].
Victor Vaganov et al mentioned that Lightweight concrete is a more and more popular material in modern building construction. Foamed concrete (FC) is the most prospective kind of lightweight concrete. The solution for achieving low density, low water absorption, and localization of shrinkage is the application of lightweight aggregate-foamed glass grains. However, due to the high silica content in foam glass aggregate, using this one in cement-based composites creates a risk of alkali-silica reactions. This study mentioned that high-performance lightweight concrete with foamed glass and to localize alkali-silica reactions using different admixtures, including carbon nanotubes in the mix. The main advantage of foamed glass grains decreases their density and decrease the density and decrease the surface water absorption in such a way using carbon nanotubes with foam concrete may be supposed it improves foam concrete durability [15].

Murthi Palani Swamy et al researched permeability properties of lightweight self-consolidating concrete produced with coconut shell aggregate. Replacing the coarse aggregate with coconut shell from 0 to 100%. Rice husk and silica fume were considered for developing binary and ternary blended self-consolidating concrete with total powder 450 kg/m$^3$ and 550 kg/m$^3$. Coconut shell aggregate satisfies workability requirements. Compressive strength for 28 days for 75% replacement of coconut shell aggregate by coarse aggregates gives 21.72MPa which is quite above the strength required for structural lightweight concrete [16].

Zunaithur Rahman et al have studied waste tire rubber in concrete. Here the waste tire is partially replaced with coarse aggregates to produce rubberized concrete mix & the replacements are done at different percentages. comparing slump value for conventional and rubber concrete, slump value of fresh concrete decreased due to an increase in replacement of tire chips. The density of concrete also decreased by increasing in replacement. they concluded that compressive strength increases nearly 15% in water curing & in acid curing compressive strength increased nearly 20%. Mainly strength decreased with an increase in waste tire rubber due to poor bonding strength between cement and tire chips for both 14,28 days[17].

B Samali, G Adam et al did the research on waste tire rubber treatment to use as aggregates in concrete. Rubber particles of 1 to 4mm size were treated in three different chemical solutions to result in an optimized method to create a surface consisting of reactive functional groups hydroxyl, carboxyl, and amino groups. The rubber firstly undergoes an oxidizing process by KMnO$_4$ for providing sufficient oxidation, later KMnO$_4$ removed by rinsed with distilled water later rubber undergoes with NaHSO$_3$ sulphonation reaction then final treated rubber improves the contact angle between water reduced and improves the contact angle with cement and this leads to improvements in bond formation and compressive strength [18].

![Figure 1](image1.jpg) **Figure 1.** Low density CLC blocks used in Hyderabad for IBM office building.

![Figure 2](image2.jpg) **Figure 2.** Lightweight concrete brick house construction.
3. Conclusions

- From this investigation on materials is to conclude the best structural lightweight concrete and low density by a different type of naturally available materials are replaced in concrete for different constructional purposes.
- All types of the above-mentioned materials can able to get lightweight for concrete but there will be a variation in compressive strength compared to normal weight concrete.
- So, to get high performance and more durability for concrete using materials like rubber chips, steel fibres, sawdust and maintaining proper mix design. The main point which is observed above is Bacillus subtilis JC3 can add to concrete either internally or externally for the concrete to reduce the crack formation.
- Further investigation is needed and experiments need to be done for the above-concluded materials in concrete that have the potential to get the high performance or not.

References

[1] Rashmiya R, Praveenraj M, Vennila R, Arivazhagn R, Mageshwari R and Ash F 2018 A COMPARATIVE STUDY ON DURABILITY AND PROPERTIES OF LIGHTWEIGHT CONCRETE 268–75

[2] Zulkarnain F and Ramli M 2008 Durability of Lightweight Aggregate Concrete Panel for Modular Housing Construction 2nd Int. Conf. BUILT Environ. Dev. Ctries. (ICBEDC 2008) 541–51

[3] Kalpana M and Tayu A 2020 Light weight steel fibre reinforced concrete: A review Mater. Today Proc. 22 884–6

[4] Akinyele J O, Salim R W and Kupolati W K 2016 Production of Lightweight Concrete From Waste Tire Rubber Crumb Eng. Struct. Technol. 8 108–16

[5] del Rey Castillo E, Almesfer N, Saggi O and Ingham J M 2020 Light-weight concrete with artificial aggregate manufactured from plastic waste Constr. Build. Mater. 265 120199

[6] Iswarya N, Adalarasan R, Subathra Devi V and Madhan Kumar M 2019 Experimental investigation on strength and durability of light weight bacterial concrete Mater. Today Proc. 22 2808–13

[7] Rahman Sobuz H, Hasan N M S, Tamanna N and Islam M S 2014 Structural Lightweight Concrete Production by Using Oil Palm Shell J. Mater. 2014 1–6

[8] Moon A S, Varghese V, Waghmare S S, Moon A S and Engineering C 2015 Foam Concrete as A Green Building Material 25–32
[9] Priyanka M, Karthikeyan M and Chand M S R 2020 Development of mix proportions of geopolymer lightweight aggregate concrete with LECA Mater. Today Proc. 27 958–62

[10] Oreshkin D, Semenov V and Rozovskaya T 2016 Properties of Light-weight Extruded Concrete with Hollow Glass Microspheres Procedia Eng. 153 638–43

[11] Mo K H, Alengaram U J and Jumaat M Z 2014 A review on the use of agriculture waste material as lightweight aggregate for reinforced concrete structural members Adv. Mater. Sci. Eng. 2014

[12] Naveen Kumar K, Vijayan D S, Divahar R, Abirami R and Nivetha C 2020 An experimental investigation on lightweight concrete blocks using vermiculite Mater. Today Proc. 22 987–91

[13] Hameed A M and Ahmed B A F 2019 Employment the plastic waste to produce the lightweight concrete Energy Procedia 157 30–8

[14] Emon M A B, Manzur T and Yazdani N 2016 Improving performance of lightweight concrete with brick chips using low cost steel wire fiber Constr. Build. Mater. 106 575–83

[15] Vaganov V, Popov M, Korjakins A and Šahmenko G 2017 Effect of CNT on Microstructure and Minearological Composition of Lightweight Concrete with Granulated Foam Glass Procedia Eng. 172 1204–11

[16] Palanisamy M, Kolandasamy P, Awoyera P, Gobinath R, Muthusamy S, Krishnasamy T R and Viloria A 2020 Permeability properties of lightweight self-consolidating concrete made with coconut shell aggregate J. Mater. Res. Technol. 9 3547–57

[17] Rahman Z 2017 Study on Waste Rubber Tyre in Concrete for Eco-friendly Environment Eng. Technol. India 1 167–76

[18] Pourmohammadimojaveri S 2017 An Investigation on Waste Tyre Rubber Treatment to Use as Aggregates in Concrete Material Curr. Trends Biomed. Eng. Biosci. 6 24–6