International Journal of Applied and Natural Sciences
ISSN: 3005-3471
DOI: 10.61424/ijans
Journal Homepage: www.bluemarkpublishers.com/index.php/IJANS

IJANS
BLUEMARK PUBLISHERS

| RESEARCH ARTICLE

An Investigation on the Materials of Lightweight Concrete

Khondoker Rajib Ahmed[1] ✉ Mohammad Dulal Bawali[2] and S M Abu Horayra[3]
[1]BUET, Senior Scientific Officer, River Research Institute
[2]IU, Senior Scientific Officer, River Research Institute.
[3]DU, Director General, River Research Institute.
Corresponding Author: Khondoker Rajib Ahmed, **E-mail**: krahmed147@gmail.com

| ABSTRACT
Lightweight concrete has drawn much interest from the building sector, due to its exceptional characteristics and possible advantages. This article thoroughly analyses the benefits of employing lightweight concrete as a practical substitute for regular concrete. The assessment includes investigating several factors, such as material properties, structural effectiveness, sustainability, and economic factors. Firstly, the types of lightweight concrete and different kinds of aggregates used for this type of concrete are discussed briefly in this article. The main objectives of the article are the primary characteristics of lightweight concrete, such as its decreased dead load and reduced density while maintaining a certain compressive strength. Reviewing several articles found that the compressive strength of lightweight concrete ranges from 2.0 to 37.0 MPa, whereas with the addition of chemicals, the strength rises to 62.0 MPa. The benefits of lightweight aggregates such as expanded clay, shale, and pumice are highlighted in connection with how they contribute to the attributes of lightweight concrete. The article also assesses the environmental features of it and the possibility of using recycled materials and different types of chemicals, such as polypropylene fiber, bottom ash, etc. The advantages of producing lightweight concrete are examined to evaluate the ecological effect of its use. These advantages include reduced shipping costs and reduced building waste. The disadvantages of its concrete are also described shortly. Not only the history of this concrete but also the scope of further research work about it is discussed.

| KEYWORDS

Aggregates, compressive strength, density, normal concrete, recycled plastic.

| ARTICLE INFORMATION

ACCEPTED: 24 September 2025 **PUBLISHED:** 04 November 2025 **DOI:** 10.61424/ijans.v3.i3.530

1. Introduction
Concrete is used in more buildings than any other material (Crow, 2008). In fact, after water, it is the world's most widely employed substance. Concrete is utilized in the construction of nearly every type of structure, from roads and bridges to apartment buildings and garages. Concrete is strong because it does not corrode, decay, or catch fire easily. Lightweight concrete (LWC) has been used for a very long period. Numerous monuments constructed of lightweight concrete have endured the test of time. It is puzzling that lightweight concrete (LWC) has not yet been completely replaced by normal concrete (NC) in all building uses, given its many advantages over NC (Theinei et al., 2020). Pumice, scoria, and other types of volcanic ash are examples of this concrete that are often produced by spontaneous volcanic eruptions. The Sumerians employed this around the third century B.C. to build Babylon. The Greeks and Romans were the first civilizations to use pumice in architecture. The St. Sofia Cathedral, also known as Hagia Sofia, in Istanbul, Turkey, was built by Isidore of Miletus and Anthemius of Tralles, two experts who were

employed by Emperor Justinian in the fourth century A.D. Additionally, they created the Pantheon, a Roman temple that was built over time (Nadh and Muthumani, 2017). After the fall of the Roman Empire, the availability of natural, volcanic resources was limited, which limited the usage of lightweight concrete. The development and use of this aggregate marked an important turning point in the history of material technology in the 19th and 20th centuries (Theinei et al., 2020). Meena et al. (2020) have pointed out that the use of this concrete dramatically decreased following the fall of the Roman Empire as people became acclimated to using different materials and new building techniques. Lightweight concrete would frequently be more advantageous and cost-effective than normal concrete in some circumstances, but NC is frequently employed instead since LWC's mechanical properties are not well understood. By closely examining the impact of several types of lightweight aggregate and other influencing elements on workability, strength, and durability, this study shows it is possible to produce lightweight concrete even below the 1000 kg/m3 density (Chung et al., 2018). The review can be a ground-breaking endeavor to gather information on lightweight self-compacting concrete in advance of its potential future use. The goal of this research is to better understand LWC behavior so that it can be applied anytime there is a definite advantage over NC. In this review, the raw materials of lightweight aggregates, the types of lightweight aggregate, the techniques of producing lightweight concrete, the physical and engineering properties, advantages, and disadvantages of this type of concrete are described shortly.

2. Methodology

A thorough analysis of literature, papers, and journals published online about lightweight concrete was done. Academic databases, engineering journals, and reliable trade periodicals were used in a methodical search. The following types of publications and articles were reviewed: Case studies and applications of lightweight concrete in construction; Innovations and advancements in lightweight concrete technology; Challenges and limitations related to the use of lightweight concrete; Properties and characteristics of lightweight concrete.

3. Results and Discussions

Important data was methodically gathered from several journals. This data included the following: materials and methods employed in lightweight concrete research. The review was finished with recommendations for further research and development in the field of lightweight concrete (**Fig.** 1).

Fig.1: Lightweight concrete

3.1 Production of lightweight concrete

Lightweight concrete can be produced by three different methods. A vivid description of the three different methods is stated below.

(a) By replacing the typical mineral aggregate with lightweight aggregate: Mainly, lightweight aggregate can be divided into two groups. The first one is a natural lightweight aggregate, and another is an artificial lightweight aggregate.

3.1.1 Natural aggregates

Natural lightweight aggregate can be found in a variety of shapes anywhere. These are only some utilized for lightweight concrete. The lightweight aggregates listed below can be used for structural and commercial LWC (**Fig. 2).**

Fig.2: Lightweight aggregate

1. Pumice: Pumice's acceptable qualities are that it is sufficiently light and peculiar. As a result of a gas explosion from hot molten lava at the time of the eruption from beneath the earth's crest, this rock, which is the result of a volcanic explosion, is light in weight. Its color is pale or almost white, and its texture resembles a cell with a meter connected to it. Pumice has been utilized for a long time, even in Roman architecture. The bulk density of pumice ranges from 500 to 800 kgm^{-3}, while the dry density of concrete ranges from 1200 to 4500 kgm^{-3}.

2. Diatomite: Diatoms, a tiny aquatic plant, are responsible for the formation of diatomite. It is silica that has been hydrated. Aquatic plants eventually die and are dumped beneath the deep ocean floor. When the ocean floor is raised over a long period of time, the diatomaceous earth is then made accessible on land. Pure diatomite typically weighs 450 kgm-3. Diatomite can also sinter synthetic lightweight aggregate in a rotary kiln.

3. Scoria: Compared to pumice, scoria is a little weaker. It is a lightweight aggregate with a dark color that comes from volcanic rock.

4. Saw Dust: Softwood is used in the production of sawdust. This can be prevented by adding lime to the mixture, which will contribute around 1/3 to 1/2 volume of cement and sawdust. This only applies to sawdust made from softwood; while making sawdust from hardwood, tannins were removed using methods such as boiling water and ferrous sulphate solutions. The practical ratio of cement to sawdust in the mixture is 1:2 to 1:3. Uses for sawdust include the production of precast concrete products, joint less flooring and roofing tiles, and concrete blocks that hold nails securely. Wood shavings are combined with Portland cement or gypsum to create wood wool concrete, which is used to make precast blocks. Acoustic wall panels are made with this product. 5. Rice husk: Utilizing rice husk, groundnut husk, and bagasse allows to produce low weight concrete for certain applications.

3.1.2 Artificial aggregates

There are many artificial aggregates for lightweight aggregate, such as brickbats, cinder, clinker, breeze, foamed slag, vermiculite and etc (https://cementconcrete.org). There are various types of Lightweight aggregates. The raw materials of the lightweight aggregates can be of various forms, such as clay, polystyrene, shale, slate, etc. (Yoon et al., 2015). The Dry bulk density (kgm^{-3}) of Clay, Polystyrene, Slate, and Shale are 692, 15.8, 769, and 772, respectively.

(b) By injecting gas or air bubbles in mortar-Aerated concrete: Aerated concrete is formed by adding air or gas to a mixture that contains Portland cement or lime and finely crushed siliceous filler in order to generate an equally cellular structure when the mix sets and hardens. It is made up of sand, cement, and water. Other names for it include gas or foam concrete. A variety of techniques can be used to create aerated concrete. It is possible to produce gas, mix foam, or release a considerable amount of hydrogen gas by mixing a finely powdered metal (typically aluminum powder) with the slurry and forcing it to react with the calcium hydroxide generated during the hydration process. This hydrogen gas creates the cellular structure when it is present in the slurry mixture. In this situation, bleaching powder, zinc powder, and hydrogen peroxide may be employed. (Mulgund and Kulkarni, 2018).

(c) By avoiding sand fraction - 'No-fines' concrete: Concrete that contains only coarse aggregate, cement, and water is known as no-fine concrete. For no-fines concrete, the aggregates that pass through a 20 mm screen and stay on a 10 mm sieve are required. Because only one size of aggregate is employed, the required voids in this concrete are kept. The void content of concrete can range from 30 to 40%, depending on the level of consolidation. Fine concrete cannot be produced using a cement to aggregate ratio of 6:1 to 10:1. The water to cement ratio in concrete must be in the range of 0.38 to 0.50 to get the desired consistency. The ratios of water to cement, aggregate to cement, and concrete unit weight all affect how strong No-fines concrete is. (Dalvi, 2021). Apart from these three procedures, lightweight concrete can be made by using plastic waste as recycled plastic aggregate (RPA) and red sand as filler. In a research work, an experimental investigation of concrete using recycled plastic aggregate as coarse aggregates was presented. It was noted that 100% replacement of typical lightweight aggregate with recycled plastic aggregate showed about a 13% decreasing in chloride penetration. Compressive strength was decreased; however, the gained compressive strength varied from 12 to 15 MPa, which is useful for non-load bearing structural elements such as low side building, cementitious backfill, pavements, and others (Alqahtani et al., 2015). Some researchers made lightweight concrete by utilising polystyrene foam. The procedures included the following steps. Firstly, cement, sand, water, and concrete additives with gravel and low-density additives, ideally made of polystyrene, were thoroughly mixed. Then the combination was stabilized by adding a substance with an electrical charge the components were thoroughly blended to get a uniform mixture. The mixture was Spooned into moulds and kept it to moulds to be hardened. (Saradhi et al., 2005).

3.2 Properties of Lightweight Concrete

3.2.1 Density of LWC

By replacing either totally or partially with lightweight aggregates instead of dense natural aggregates, lightweight concrete is specified by BS EN 206-1 as having a minimum oven-dry density of 800 kgm^{-3} and a maximum oven-dry density of 2,000 kgm^{-3}. Though concrete is constructed using the most densely natural aggregates possible and furthermore contains extra air, as in no-fines, aerated, or foamed concrete, for example, this range of densities can be reached even though it is not covered by this Standard. According to BS EN 13055, a lightweight aggregate is one that has a dry bulk density of less than 1200 kgm-3 or a particle density of less than 2.0 Mgm-3. These properties are mostly the product of confined pores and surface vesicles in the particle structure. For structural concrete, the optimal aggregates should absorb less water and have a low cement paste content. The best method for achieving this is to compare the particle density of structural concrete to that of typical natural aggregate, such as using a reference particle density of 2.6 Mgm^{-3}. Although the minerals that make up the solid structure of the majority of aggregates, whether lightweight or not, have densities close to 2.6 Mgm-3, air contained inside an aggregate's structure is what allows compacted structural concrete to weigh less than 2,000 kgm-3. Understanding the variations between the two meanings of density is essential. According to BS EN 1097-33, the definition of particle density is the mass of a single aggregate particle per unit volume, while BS EN 1097-64 refers to the mass of dry particles contained inside a certain volume as the dry loose bulk density. It follows that aggregates with the least interstitial empty space make concrete with the lowest densities (Newman and Owens, 2003, Properties of Lightweight Concrete, Advanced Concrete Technology).

Some researchers found that the density of lightweight varies from 300 to 1850 kgm^{-3} (Mulgund and Kulkarni, 2018). Barkha Verma (2022) used coconut shell and fly ash for making lightweight concrete and found density and 28-day compressive strength are 19.75 kgm^{-3} and 19.1 MPa, respectively. Here, 1.0 MPa is equal to 1.0 Nmm^{-2}. In another research paper, the density of lightweight concrete was compared using lightweight aggregate and recycled plastic aggregate, where the results are 697 and 600 kgm^{-3}, respectively (Alqahtani et al., 2015).

3.2.2 Strength

Ranjbar et al. produced a set of high-strength lightweight concrete blocks whose strengths were up to 100 MPa with a matching density of 1865 kg/sq m. The strength of the aggregate is the main element regulating the strength of high-strength lightweight concrete. Five different types of lightweight aggregates were analyzed. The elastic modulus, which ranged from 17.8 to 25.9 GPa, is lower than that of normal-weight concrete, and the tensile/compressive strength ratio seems to be lower for high-strength lightweight concrete than for high-strength normal-weight concrete. In comparison to low- to medium-strength lightweight concrete, the form of the ascending section of the stress-strain curve was more linear than for high-strength lightweight concrete.

A study has shown that the addition of polypropylene fiber, at 0.56% by volume of concrete, resulted in a 90% increase in indirect tensile strength and a 20% increase in modulus of rupture when compared with plain sintered fly ash lightweight aggregate concrete (Kayali et al., 2003)

Table 2. Variation of the strength of concrete with the variation of mix type (Ranjbar et al.).

Mixture types	Compressive Strength (MPa)			
	03-day	07-day	14-day	28-day
NC	14.2	19.4	23.3	29
LWC	21	26.8	27	27

In research work, Alengaram (2010 used Palm Kernel shell as a lightweight aggregate to produce lightweight concrete. In the research work, the desired strength of Palm Kernel Shell Concrete was 30 MPa, But the obtained compressive strength was 37 MPa, which is more than the expected strength. According to ASTM C331M, the compressive strength of lightweight concrete is directly proportional to the density of concrete. In research work, Van et al. (2018) used bottom ash and expanded polystyrene in lightweight concrete. For different combinations of bottom ash and expanded polystyrene compressive strength of lightweight concrete varies at different curing ages. The compressive strength of lightweight concrete is directly proportional to expanded polystyrene, inversely proportional to bottom ash. With the increment of Expanded polystyrene, the strength of the concrete was decreasing, and With the increment of Bottom ash, the strength of the concrete was increasing.

Nevertheless, according to Dhawal Desai, the compressive strength of lightweight concrete varies from 2.0 to 7.0 MPa. (https://www.engineeringcivil.com)

3.3.3 Modulus of elasticity

The modulus of elasticity is the slope of the secant to the stress-strain diagram. Many equations for the modulus of elasticity have been developed over the years. One pf them is $Ec = 1000f/c$, here Ec and f/c are in psi. But after a long research, Adrian Pauw arrived at an empirical equation, which is $Ec = 33w^{1.5}\sqrt{f/c}$, here both Ec (modulus of elasticity) and f/c (compressive strength) are in psi, and w (unit weight) is in pcf. In the second equation, the modulus of elasticity is a function of unit weight as well as compressive strength. (Jagtap et al., 2020). Due to the low unit weight of lightweight concrete, it has a lower value of modulus of elasticity than normal concrete.

In concretes with the same volume fraction of aggregate and water-cement ratio, a lower specific energy loss suggests that the aggregate has a higher elastic modulus and is stronger (Nilsen et al, 1994).

3.3.4 Workability

Light Weight Concrete Mix (LWC) made with cement, silica sand, natural coarse aggregates, artificial coarse aggregates, silica fume (SF), fly ash (FA), high-range water reducers, and water with varying mix proportions exhibits a remarkably good degree of workability with less density. After instant mixing, the slump values of above mentioned LWC mixes ranged from 90 mm to 180 mm, respectively. Mix prepared using FA, SF, and blast furnace slag (BS) has good workability with no bleeding and segregation. (Elango et al., 2021).

3.3.5 Durability properties

A study demonstrates that lightweight concrete can be at least as durable and permeability-free as regular concrete. The article's authors employed various mixes to assess the water permeability and resistance to deterioration of lightweight and similar ordinary concretes following freezing, thawing, wetting, drying, and continuous carbonation cycles. Because initial curing significantly impacts paste quality, it is likely also to affect inflow and outflow rates. Lightweight concrete generally performs similarly to conventional concrete in terms of wetting/drying and freeze-thaw performance. These concretes display substantially less carbonation, regardless of the curing circumstances, and have significantly larger cement contents and lower water/cement ratios than standard concrete at the highest nominal strength. The carbonation is reversed wherever the mixed proportions are. According to research, the amount of concrete cover required to safeguard embedded reinforcement needs to be more relaxed and might be loosened. Compared to regular concrete, the carbonation depth for lightweight concrete ranges from less to slightly more (usually less than 5mm). If appropriate curing is not ensured, the advantage of specifying a higher degree of concrete is lost (Dhir et al., 1989). Many researchers have determined the mechanical properties of lightweight concrete containing Pumice aggregate. *Effects of polypropylene fiber on lightweight concrete:* The addition of 0.25% and 0.50% volume fraction of polypropylene fiber in lightweight concrete reduces its slump value and density, and the addition of 0.75% and 1.0% volume fraction of polypropylene fiber in lightweight concrete reduces its compressive strength (Prakash et al., 2019).

Advantages and disadvantages of lightweight concrete

Lightweight concrete has many kinds of advantages. Some of them are given below.

1. Reduced density of concrete results in reduced deadload of the whole structure.
2. Reduction in thermal conductivity.
3. Increase fire and free thaw resistance and sound absorption.
4. Increase nailing and sawing properties than conventional concrete (Agarwal, 2021).

The goal of a study was to employ lightweight concrete to estimate the seismic response of a six-story reinforced concrete structure. When bending moments and shear forces were taken into account for both NWC and LWC, it was found that the latter had decreased to 15 and 20 percent, respectively (Vandanapu and Krishnamurthy, 2018).
The only disadvantage of lightweight concrete is that, in certain situations, corrosion can occur almost twice as deeply as it can with NC. Therefore, more caution must be used to ensure that the lightweight concrete structures' reinforcing has enough cover to prevent corrosion.

4. Conclusions

Lightweight concrete is a beneficial option for building lighter structures while still solid and long-lasting. The main goal of employing it is to make structures lighter, which has benefits including less transportation costs, better handling, and less stress on foundations. One of its noteworthy qualities is the versatility of the materials that can be used as aggregates in lightweight concrete. The use of materials that might not have substantial environmental effects or that might otherwise be difficult to dispose of properly is made possible by this adaptability. Waste can be reduced, and a more sustainable approach can be promoted in construction by using these materials as aggregates in this concrete.

The environment is particularly at risk from the rising concern over technological waste and medical waste. Electronic and medical waste should be disposed of properly to prevent contamination, harmful leaching, and threats to human and animal health. Since these waste streams will only increase, these issues must be addressed quickly. Using medical and electronic waste as aggregates in lightweight concrete is a smart and timely idea. In this way, experts can efficiently divert these materials from landfills and possibly dangerous disposal techniques, turning them into priceless resources for construction. This method not only assists in reducing environmental risks but also lowers the demand for conventional concrete aggregates, which may benefit the preservation of natural resources. Moreover, adding electronic and medical waste to this type of concrete can improve the material's overall performance. These wastes frequently have valuable materials that can enhance certain concrete features, such as enhanced acoustic absorption or increased thermal insulation.

References

[1] Agrawal, Y., Gupta, T., Sharma, R., Panwar, N. L., Siddique, S. (2021), A Comprehensive Review on the Performance of Structural Lightweight Aggregate Concrete for Sustainable Construction, Constr. Mater. 1: 39-62.

[2] Alengaram, U. J., Mahmud, H., Jummat, M. Z. (2010), Development of lightweight concrete using industrial waste material, palm kernel shell as lightweight aggregate, and its properties. 2nd International Conference on Chemical, Biological, and Environmental Engineering.

[3] Alqahtani, F. K., Ghataora, G., Khan, M. I., Dirar, S., Kioul, A., Al-Otaibi, M. (2015), Lightweight Concrete Containing Recycled Plastic Aggregates. International Conference on Electromechanical Control Technology and Transportation (ICECTT, 2015), doi: 10.2991/icectt-15.2015.101.

[4] Bicer, A., Kar, F. (2017), The effects of apricot resin addition to the light weight concrete with expanded polystyrene. *Journal of Adhesion Science and Technology*. 31, 2335–2348.

[5] Chung, S Y., Elrahman, M, A., Stephan, D., Kamm, P, H. (2018), The influence of different concrete additions on the properties of lightweight concrete evaluated using experimental and numerical approaches, Construction and Building Materials, 189(314-322).

[6] Crow, J M (March 2008). The concrete conundrum, Chemistry World: page 62–66.

[7] Dalvi, V. R., Pawar, D. L., Walekar, A. M. (2021), A REVIEW PAPER ON NO-FINES CONCRETE, *International Journal of Creative Research Thoughts*.Vol 9, Issue 06, page 518-520.

[8] Dhir, R. K., Munday, J., Cheng, H. T. (1989), Lightweight Concrete: Durability, https://trid.trb.org/view/313268

[9] Elango, K. S., Sanfeer, J., Gopi, R., Shalini, A., Saravanakumar, R., Prabhu, L. (2021), Properties of light weight concrete – A state of the art review. Materialstoday. Vol 6, part 9, page 4059-4062. https://www.engineeringcivil.com/development-of-lightweight-concrete.html. (accessed on 25-7-23). https://cementconcrete.org/cement-concrete/lightweight-concrete/2413. (accessed on 25-7-23). https://www.nevadareadymix.com/concrete-tips/structural-lightweight-concrete. (accessed on 25-7-23)

[10] Jagtap, P J., Rathod, M, R., Murtuja, S, S, S., (2020). A Review Paper on Comparative Study of Lightweight Concrete and Reinforced Concrete. Vol. 7(3).

[11] Jo, B. W., Park, S K., Park, J. B. (2007), Properties of concrete made with alkali-activated fly ash lightweight aggregate (AFLA). Cement and Concrete Research. Vol 29, Issue 4, page128-135.

[12] Kayali, O., Haque, M N., Zhu, B. (2003). Some characteristics of high strength fiber reinforced lightweight aggregate concrete, Cement and Concrete Composites. Volume 25, Issue 2, February 2003, Pages 207-213.

[13] Meena, R., Sharma, S., Sharma, A., Kumar, M. (2020), Study on Lightweight Concrete- Review*, International Journal of Engineering Research and Technology*. Vol 9 issue 7, page 786-787.

[14] Mulgund, A. A., Kulkarni, D K. (n.d) LIGHT WEIGHT CONCRETE, *International Research Journal of Engineering and Technology (IRJET)*, vol 05, Issue 05, Page 2592-2593.

[15] Nadh, V, S., Muthumani, K. (2017). Critical Review on Structural Lightweight Concrete. 2017, *International Journal of Civil Engineering and Technology* 8(2):252-263.

[16] Newman, J., Owens, P. (2003), Properties of Lightweight Concrete, Advanced Concrete Technology.

[17] Nilsen, A. A., Monteiro, P. J. M., Gjorv, O. E. (1994) Cement and Concrete Research, Vol. 24, No. 8, pp. 143-1427, 1994.

[18] Oreshkin, D., Semenov, V., Rozovskaya, T. (2016). Properties of Lightweight Extruded Concrete with Hollow Glass Microspheres. Procedia Eng. 153, page 638-643.

[19] Prakash, R., Thenmozhi, R., Raman, S. N., Subramanian, C. (2019). Fibre reinforced concrete containing waste coconut shell aggregate, fly ash, and polypropylene fibre. DOI: 10.17533/10.17533/udea.redin.20190403.

[20] Ranjbar, M. M., Beygi, M. H., Nikbin, I. M., Rezvani, M., Barari, A. (n.d). Evaluation of the Strength Variation of Normal and Lightweight Self-Compacting Concrete in Full-Scale Walls.

[21] Saradhi, D., Ganesh, K., Tiong-Huan, W. (2006), Effect of polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete. Cement and concrete composites, vol 28 issue 6, page 520-527.

[22] Standard Specification for Lightweight Aggregates for Concrete Masonry Units; (2017) ASTM C331M-17, ASTM International, West Conshohocken, PA, USA, 2017

[23] Thienel, K. C., Haller, T., Beuntner, N. (2020), Lightweight Concrete—From Basics to Innovations, Materials, vol 13. doi:10.3390/ma13051120.

[24] Van, L T., Dinh, T. V., Kim, D. V., Bulgakov, B., Aleksandrova, O. (2018). Combined Effects of Bottom Ash and Expanded Polystyrene on Lightweight Concrete Properties, MATEC web of conferences, 251, 01007, https//doi.org/10.1051/matecconf/201825101007

[25] Vandanapu, S N., Krishnamurthy, M. (2018) Seismic performance of lightweight concrete structures, Adv. Civ. Eng. 2018 (2018) 1–6.
[26] Verma, B. (2022), Experimental Study on Light Weight Concrete Using Coconut Shell and Fly Ash. *International Journal for Research in Applied Science and Engineering Technology,* vol 10, issue 01, page 752-758.