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Alternative Construction Materials to Improve Concrete Characteristics

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ABSTRACT

Determining building materials and their types and determining their effect on concrete properties are consistent with the technical and design variables of buildings. From this point of view, the research came to include theoretical studies and empirical tests for some materials, focusing on the aggregate as a basic material involved in the formation of concrete.

The first part includes the introduction, research problem, assumptions, importance, and purpose of the research. the second part was to conduct practical experiments by designing different concrete mixtures in the mixing ratios and the type of aggregate until results were reached regarding the resistance of the concrete that was produced as a result of the difference in densities between ordinary aggregate concrete and lightweight aggregate concrete. Through that, for example, the lightweight aggregate with an age of (7) days and a mixing ratio of (1: 2: 4) gave strength to the models used (19.58) Mpa, and for the same mixing ratio and at an age of (28) days, it gave durability (22.83) Mpa. When the mixing ratio was changed to (1: 1.5: 3), it was (25.74) MPa and (32.34) MPa at the age of (7) days and (28) days, respectively. These results give an accurate indication that the aggregate is light in weight with similarity to the ordinary aggregate in obtaining concrete with a bearing strength within the approved specifications without guaranteeing the environmental treatments and the resulting loads.

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1. Introduction

1.1: General:

There are many types of concrete in the world and vary depending on the quality of the materials that make up them. The aggregate is one of the materials used in the manufacture of concrete because its properties give concrete good properties. Therefore, all studies and research have adopted this article and given it great attention. These studies and research continued until it begged for lightweight concrete, which was classified based on the materials included in its composition, as well as the place of its use in the facilities. The results of the tests

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indicated a decrease in the mechanical properties of concrete with an increase in the lightweight coarse aggregate respectively.

Concrete is a construction material that is extensively used because of its excellent properties such as durability, workability, satisfactory strength, and the easy availability of raw materials (cement, aggregate, and water)which are used to produce it **((Mehta & Monteiro, 2006))** It may be considered to consist of three phases; a cement paste, aggregate and the interfacial transition zone (ITZ) between them. **(Akçaoğlu, T., M. Tokyay, and T. Çelik. 2004 p. 633-638.).**

1.2: Problem of research :

The problem includes:

1-High costs, which need to cast buildings like foundations, structures, and anthers.

2-There is much need for energy because of high thermal conductivity when which use natural materials in concrete.

3- High loadings on the earth, because increase densities of concrete structures.

1.3: Assuming research:

The researcher assumes the following hypotheses;

1- Giving priority to sustainable development is very important, and it begins by securing the requirements of the environment, which represents one of its main pillars, which is building materials.

2- The presence of building materials that have a high quality in terms of environmental impact and do not cost in terms of extracting or manufacturing them.

3- There is an urgent need to produce concrete with sustainable properties that improve performance in concrete structures and replace the existing conventional concrete.

Considering that the lightweight aggregate is widely available in nature or is made from existing clays.

1.4: Significant research :

This research is important because it will add details, the need for it to continue building a life, and the needs of the environment in the buildings or their open outer space.

To expand the use of lightweight concrete, which has become a staple in facilities. With the presence of lightweight aggregates, the production of concrete of this type has increased.

1.5: The aim of the research:

The objectives of the research consist: - The main objective is to find alternatives with better properties than construction materials such as aggregates, for example, as they are a basic material in the production of concrete that can solve environmental problems. It serves as a platform for other researchers to launch into this new, evolving field.

This paper provides an overview of the characteristics of this type of concrete, which will be a promising alternative to traditional materials, and seeks to achieve sustainable development goals by finding lightweight aggregates with good properties.

2. Construction Materials:

2.1 General:

In the generic alternative, materials are important in improving the characteristics of concrete, because, the concrete depends on it.

Lightweight aggregate is one of the types of aggregates used in the production of lightweight concrete, such as concrete blocks, structural concrete, and concrete pavements. In addition to the presence of natural lightweight aggregates, lightweight aggregates are also made from raw materials such as clay, oil shale or slate, blast furnace slag, natural pumice, vermiculite, and perlite as alternatives. It has similar properties to ordinary aggregate, but is less dense than it and thus produces a lighter concrete product.

2.2 Construction Materials:

2.2.1 What are construction materials:

Materials include manufactured products such as components, fittings, items of equipment, and systems; naturally occurring materials such as stone, timber, and thatch; and backfilling excavations in connection with building work.

Narrower definitions of materials such as physical substances that things can be made from' would seem to exclude manufactured products such as components, fittings, items of equipment, and systems. For example, steel is a material, whereas a steel beam is a product.

Some of the more commonly used construction materials that might be considered to fall within this narrower definition are listed below. For a wider list, including products and components see Products and components. The materials like aggregate, architectural fabrics, alkali-activated binder, asphalt, cement, clay, bricks, concrete, ….ets.

Building materials become of great importance, especially in construction works, which is one of their most important uses. And the building materials industries developed with the development of technology and the human need for it. The building materials industry is also an important contributor to our national economy, as its output controls the rate and quality of construction work. **(Zhu, W., P.J. Bartos, and A. Porro,2004, p. 649-658).**

2.2.2 Types of construction materials:

A) Traditional materials: Like clay, Bricks, timber, gypsum….etc. These materials which used for periods ago. These materials have good properties in terms of low density and available reserve.

B) Modern Materials: These materials are developed by an act of technologies in the world, especially after the industries are developing in any space. After that, the world produced many types of materials.

So, construction materials are divided into; natural materials, and Product materials, but all are used in buildings, infrastructures, and other works. Much of the material, smellers in properties, so that one of them entranced alternative for another's. Therefore, the construction materials, are divided to;

1-Fundamental materials, which are used in all countries in the world, like materials. Any one of them has its properties, which were determined last time in specifications, as an (ASTM).

This research includes in its practical part some of its experiments, showing the properties of sand and gravel for use within the limits of the behavior of concrete.

A) Cement; One of the basic manufactured building materials whose functional performance lies in the fact that it represents a tool for bonding and cohesion between other concrete parts, and it has several types that depend on the type of use, its location, and the type of conditions surrounding the intended origin. New manufacturing processes are being researched for the production of green cement to reduce or even eliminate the production and release of harmful pollutants and gases, especially carbon dioxide **(Murray, A. and L , 2008).**

. Growing environmental concerns and increasing cost of fuels of fossil origin have resulted in many countries' sharp reduction of the resources needed to produce cement and effluents (dust and exhaust gases (**Hasanbeigi, A., L, 2012, p. (6220-6238)).**

It is noted that the presence of cement is essential in terms of controlling construction and research is underway to control the pollution outputs resulting from this industry

Peter Trimble, a design student at the University of Edinburgh has proposed 'DUPE' based on Sporosarcina pasture, a bacterium with binding qualities which, when mixed with sand and urine produces a concrete said to be 70% as strong as conventional materials. **(Monks, K.,.2012).**

B) Aggregates: Both types of aggregate are considered as one the materials used in the production of concrete of all kinds, and it is a filler that does not participate in the chemical reaction processes that occur inside the concrete. It is obtained from igneous, sedimentary, and metamorphic rocks, or it is made from clays or slag from furnaces -- etc**. (B, D., 2004, P. 181).**

Aggregate forms the basic material for the concrete body and reduces shrinkage and increases the cohesion of concrete. The aggregate represents (70-80%) of the concrete volume. It is therefore very important to have the right type and quality of aggregate on site that is clean, solid, strong, and graded in size to achieve maximum cohesion in the mix. Aggregates are chemically inert materials, but the latest research revealed that some of them are chemically active and that certain types show chemical bonds at the interface of the aggregate with the cement paste. To increase the density of concrete, a mixture of aggregates of two different types with volumetric gradation is used - larger sizes known as coarse aggregate (gravel) and smaller ones (sand). Coarse aggregate forms the main matrix of concrete and fine aggregate from the grouting matrix between coarse aggregate, as shown in Figure (1).

According to the grain size, aggregates are classified into coarse aggregate and fine aggregate). A sieve (4,75) mm is the boundary between the two types. Aggregate is obtained naturally from processing areas or by crushing large volumes of it. The control of the size of the granules depends on the type of concrete used, its sections, the method of mixing and use, and the type of concrete.

C) Other materials: Water is an important material in mixing concrete, it helps to workable concrete. So, there are some materials entered in mixing to improve it.

Now, the development in the world, spatially in a structured form, The need to improve the properties of materials continues to control environmental elements to protect their occupants, so research goes to studies of materials to show the extent of their conformity with these environmental elements.

Fig..1: Types of aggregates.

The American Society (ASTM) publishes a comprehensive list of specifications, including (ASTM D 692 and ASTM D 1073), for different types of building materials, including both types of aggregate (gravel and sand) and all its uses, and usually, improvements to its specifications continue**. (ASTM, The American Society for Testing and Material code).**

2-Alternative materials; Concrete is a material used in all structural buildings because it has excellent properties, so that it has good thermal conductivity, and that negative effect on the environment. Therefore, there is a constant need to improve the properties of concrete.

2.2.3 Types of alternative materials:

There are many types of materials, and these materials are different between them. This deferent brought effect on properties and uses location.

1-Lightweight aggregate such as (sand, gravel, limestone, ash, and other lightweight materials.

2-Added materials in concrete to be proved properties of it.

2.2.4 Lightweight Aggregate Concrete:

Conventional cement concrete is a heavy building material. For structures such as multistory buildings, it is desirable to reduce the dead loads. Lightweight concrete (LWC) is most suitable for such construction works. Lightweight aggregate concrete is particularly suitable for use where low density, good thermal insulation, or fire protection are required, but not all of the available aggregate are equally suitable for any particular application. It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following methods:

Ordinary concrete is a heavy building material that generates greater loads on the foundations and thus on the soil, especially for multiple structural buildings. Therefore, it is preferable to use an alternative to this concrete, including Light Weight Concrete (LWC) to reduce dead loads and is most suitable for construction work. Lightweight aggregate concrete is particularly suitable for use in places that require low loads as well as environmental treatments in terms of thermal, sound, and water insulation or to protect against other risks such as fire. Lightweight concrete can be obtained in several ways, including:

1. The Manufacture of concrete using (cement and coarse aggregate) without fine aggregate or replacing it with kiln slag or clinker ---- etc. Thus, voids are formed that give the concrete produced a low density, low weight.

2. The Manufacture of concrete using coarse aggregate cellular (porous) types, called cellular concrete, which is classified as follows:

- Classified as gaseous and foam concrete (Portland cement), gaseous and foam concrete (lime and sand), gaseous slag, and foamed slag (lime and finely divided blast furnace slag or fly ash) (**Mayowa, I.C., A. Chinwuba, and O.P. Gbenro. 2015: p. 145)**. As shown in Figure (2).

2.2.5 Properties of Lightweight Concrete:

Lightweight aggregate is a term for aggregates with a lower density than aggregates of normal density (natural sand, gravel, crushed stone), sometimes referred to as low-density aggregates, which meet the requirements of ASTM C 330, and specify a density less than (1120 kg/m^3) for fine aggregate and less than (880 kg/m^3) for coarse aggregate **(ASTM, The American Society for Testing and Materials code).**

Natural **Product**

Fig. 2: Some types of LWA(ESCSI, 2005)

This includes aggregates prepared by stretching, palletizing, or sintering such as blast furnace slag, clay, fly ash, shale, or slate, and aggregates prepared by treating natural materials such as pumice, scoria, or tuff. Lightweight

stone aggregate that meets the requirements of (ASTM, C 331) with a density of less than (1120 kg/m^3) for fine aggregates and less than (880 kg/m^3) for coarse aggregates**. (ASTM, The American Society for Testing and Material code).**

It is clear from this that this type of aggregate belongs to the types of lightweight aggregates that produce lightweight concrete that meets good environmental requirements, as mentioned above.

-Density; The density of Lightweight Concrete varies from (300–1200) kg/m^3. **((ASTM, The American Society for Testing and Material code)**... Density in general in aggregates or any other material depends on the sizes of the pores and the spaces in them. The more voids, the lower the density. The lightweight aggregate gives little friability for this reason, which results in light concrete as well.

-Workability; This characteristic depends on the composition of the materials forming the concrete, as well as their proportions in them. In addition, the external appearance of the porous aggregate, especially in the case of crushing, gives an operation ability that varies from one type to another. Therefore, the operability is not fixed for all types and is variable even for one type by changing the mixing ratios and the (water/cement ratio).

-compressive strength; One of the properties of concrete that are taken into consideration is the strength, which depends on several considerations:

-Percentage of pores and voids in the mixture.
-The gradation of the aggregate used.
-The type of cement used.
-Water/cement ratio.
-Time and method of mixing and use.
-Surrounding factors such as climate factors.

All of this affects the bearing capacity of concrete. As shown in Figure (3).

Ordinary aggregates (particularly fine aggregates) tend to be used to control the hardening properties of concrete and sink through the air trapped inside which is always to improve workability. Most lightweight structural concretes weigh between (16.00 to 17.60) kN/m^3; However, working specifications may allow in special cases more than (18.40) kN/m^3. **(B.E., D., 2004. summary).** This gives an idea of the effect of lightweight aggregates in producing concrete that has good workability and properties that allow it to be widely adopted in construction works.

Fig.3 Lightweight Concrete(Laterlite technical Assistance, 2006)

3. Experimental Work:

3.1 Introduction:

The experimental chapter includes the testing of fundamental materials to improve its results with alternative materials and determine their effect of them in concrete.

The research will focus on tests of basic materials, in the hope that other researchers will adopt the rest of the materials.

3.2 Testings:

Below are some results of tests for our research:

3.3 Ordinary Aggregates:

Mixings of the conventional aggregates were used to produce concrete according to mixing ratios (1: 1.5: 3) and (1: 2: 4) to demonstrate their important properties such as tolerance and density. The aim is to target their behavior and to compare the behavior of concrete manufactured with substrates of structural materials, which must improve the environmental standards and properties of facilities in terms of costs and engineering specifications.

Table -1 [A 7-day test of the concrete mix was tested by mixing 1:2:4], by using ordinary aggregate

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	8.444	2501.9	23.43
2	8.437	2500.1	27.76
3	8.158	2417.18	20.38
4	8.176	2422.5	26.80
5	8.586	2544	25.91
6	8.549	2533.3	28.75

Table -2 [A 28-day test of the concrete mix was tested by mixing 1:2:4], by using ordinary aggregate

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1.	8.585	2543.7	35.14
2.	8.241	2441.5	33.72
3.	8.420	2494.8	34.2
4.	8.752	2592.6	34.17
5.	8.685	2573.3	34.89
6.	8.235	2440	33.2

Table -3 [A 7-day test of the concrete mix was tested by mixing 1:1.5:3], by using ordinary aggregate

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	8.085	2395.6	22.68
2	8.215	2434	21.91
3	8.075	2392.6	20.81
4	8.140	2411.8	23.64
5	8.120	2405.9	22.02
6	8.130	2408.9	25.61

Table -4: [A 28-day test of the concrete mix was tested by mixing 1:1.5:3], by using ordinary aggregate

No.	Weight(Kg)	Density(Kg/m^3)	Strength (MPa)
7	8.180	2423.7	31.23
8	8.205	2431.1	31.19
9	8.135	2410.4	30.79
10	8.175	2422.2	31.23
11	8.155	2416.3	32.49
12	8.145	2413.3	34.15

Fig.4.1: Instruments and Materials

Fig.4.2 Cube Molding

Fig.4.3 cubes out of molds

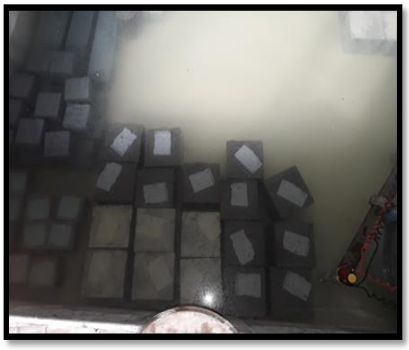

Fig.4.4 Curing the Cubes

Fig.4.5 Compressive strength device

4. Lightweight Aggregate

Coarse and Fine are the main materials used in the manufacture of concrete and concrete blocks, which have been developed to be widely used in the construction of installations worldwide, despite different climatic environments, which have adversely affected the overall use of building materials. This has necessitated research into new ways of obtaining alternatives to building materials in which environmental treatments are available. One alternative is Lightweight Aggregate, which is available in different parts of the world. (This type is of importance in modern facilities and is used in the construction of single and multi-story residential buildings and other structures. In addition, it is used in the production of light concrete blocks (LWA Concrete Blocks), which are important in that they have good thermal insulation compared to the usual concrete. It is also lightweight, making it more economical to use because of the energy consumed to run the building as well as reducing the cost of reducing the loads on the foundations and walls of the building. These reasons prompted many engineers and

researchers to study them and work to improve their quality and expand their use. **(Ismail, Nadia Salem, and Daoud, Da'ad Muhammad,. 2010. P. 10-12).** .
The available varieties are found in the low-lying cow and Tarifawi (west and south of Rutba City)

5. Structural LWA Concrete

Several experiments and research have been conducted to produce a variety of lightweight concrete depending on the type of light aggregates used. This has given an added property to concrete, a property of abundant materials by reducing dead loads and energy-saving thermal insulation. For example, concrete is of the following types: **(FIP Manual, 1983, p.233-245).**

(A) Structural LWA. Concrete:

It is a highly efficient structural concrete, made from lightweight, with its density (1400-2000 kg / m3) and the lowest compressive strength (15) N/ mm2. **(Laterlite technical Assistance, "General Catalogue 2006", Edition (2006), Italy, P.6)**...and figure (3) shown it.

(B) (Insulation LWA Concrete):

The type of light concrete used for thermal insulation purposes. With a density of (600-1000) kg / m3 and a carrying capacity (25-100) kg/cm^2**.((Laterlite technical Assistance, ""General Catalogue 2006"", Edition , 2006, Italy, P.6).**

These properties were granted by the nature of use in the ceilings and walls which few thicknesses.

The properties of concrete (endurance, density, heat insulation, and sound) depend on the materials that are in their manufacture and vary from region to region. This difference resulted in different densities and thermal insulation (K-coefficient of thermal conductivity ranging from 0.13-0.24 W/m) with a mass and pressure between 0.48- 5,17 N / mm^2 **(Ismail, Nadia Salem, and Daoud, Da'ad Muhammad,. 2010. P. 10-12).**

Table -5:[A 7-day test of the Lightweight Concrete mix was tested by mixing 1:2:4]

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	6.34	1987.9	20.32
2	6.67	2011.23	20.65
3	6.21	1956.67	15.03
4	6.27	1973.65	19.11
5	6.87	2045	21.08
6	7.06	2078	21.28
Rate			19.58

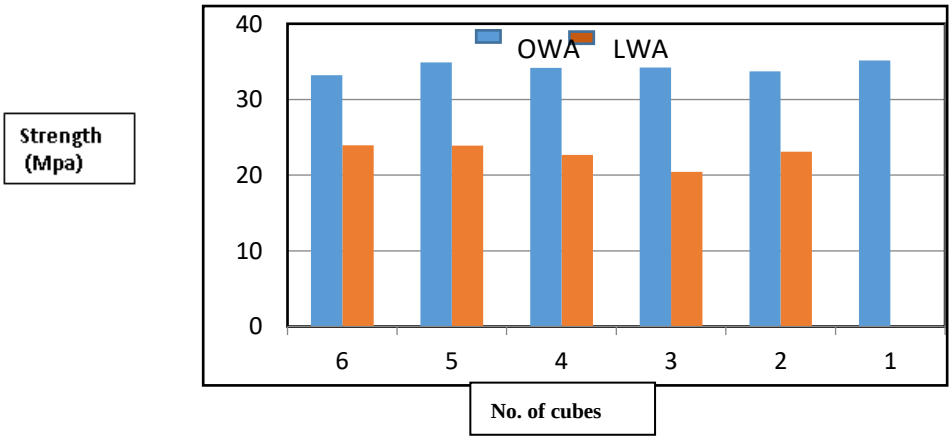

Fig.4.6 Strength between OWA & LWA in concrete mixed by (1:2:4) in (7) days
OWA=Ordinary Aggregate, LWA=Lightweight Aggregate

Table (4.6): [A 28-day test of the LW Concrete mix was tested by mixing 1:2:4]

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	6.89	1994.3	22,87
2	7.08	1997.7	23.12
3	6.47	1898	20.46
4	6.79	1991.8	22.67
5	7.09	1998.6	23.89
6	7.18	2020.4	23.96
Rate			22.83

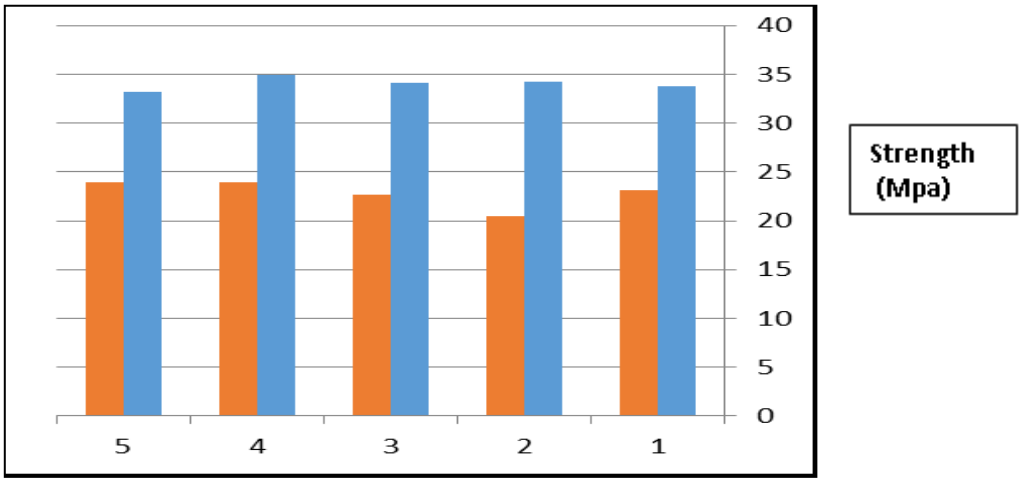

Fig.4.7 Strength between OWA & LWA in concrete mixed by (1:2:4) in (28) days

Table (4.7): [A 7-day test of the Lightweight Concrete mix was tested by mixing 1:1.5:3]

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	7.12	1798	**29.2**
2	6.88	1754	**21.65**
3	6.97	1816	**28.7**
4	6.93	1760	**23**
5	7.02	1758	**29.23**
6	6.95	1774	**22.65**
Rate			**25.74**

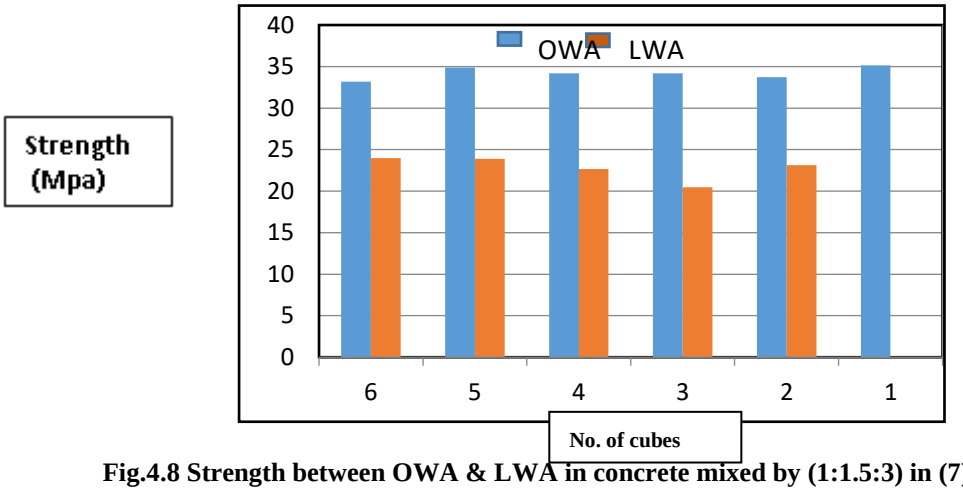

Fig.4.8 Strength between OWA & LWA in concrete mixed by (1:1.5:3) in (7) days

Table (4.8): [A 28-day test of the Lightweight Concrete mix was tested by mixing 1:1.5:3]

No.	Weight (Kg)	Density (Kg/m^3)	Strength (MPa)
1	7.28	1760	**36.9**
2	6.45	1736	**27.35**
3	6.84	1714	**36.7**
4	6.77	1719	**31.6**
5	7.08	1753	**36.05**
6	6.87	1728	**25.43**
Rate			**32.34**

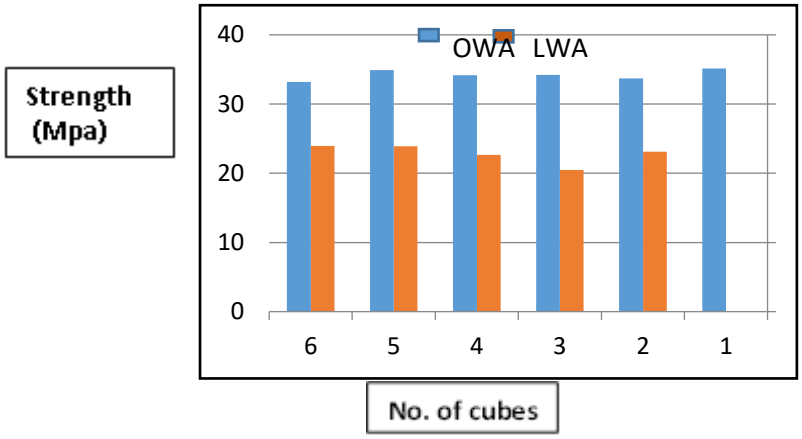

Fig.4.9 Strength between OWA & LWA in concrete mixed by (1:1.5:3) in (28) days

6. Analysis of the results:

Forms 4-6 and 4-7 show the behavior of concrete in terms of durability. It is shown that the effect of aggregates on durability is evident through the results recorded in the tables with the difference in the age of the concrete and the stability of the mixing ratio. A more accurate indication of the behavior of the concrete in operation has changed the mixing ratio, resulting in a change in the bearing strength of the concrete. This gives an impression that supports the possibility of a shift towards structural alternatives to the manufacture of lightweight concrete with sustainability.

The results obtained in the laboratory concerning the compressive strength of light concrete, are as shown in Tables (4-5), (4-6), (4-7), and (4-8), and they were, respectively, as a summary of the models used (19.58)Mpa at the age of (7) days and (22.83) at the age of (28) days for the mixing ratio (1:2:4) Mpa. When the mixing ratio was changed to (1:1:5:3), it resulted in the strength of materials of (25.74) at an age of (7) days and (32.34) Mpa at an age of (28) days. It is clear from the obtained results that the aggregate is light in weight, and can give excellent resistance when the proportion of cement is increased to the other components.,

When looking at the figures (4-6), (4-7), (4-8), and (4-9), they give closeness in the values of the compressive strength, with the difference in density between the two types of aggregates (ordinary and lightweight aggregates)

So, and through what was mentioned above, it is possible to adopt lightweight aggregates to produce light concrete that meets the requirements of the environment and increases its thermal comfort levels to protect humans from its many negative effects.

7. Conclusions

1. Concrete improvements can be made by using alternatives that yield results close to the normal concrete specifications.

2 - The results of our research leads us to good solutions to the problem of dead loads.
3 - The alternatives to building materials used in concrete have given good solutions to the problems of thermal and sound insulation, which save energy, especially in the field of air conditioning for buildings.
4- Reducing the economic costs of implementing concrete structures from Hira by reducing the quantities of light concrete and steel reinforcement.

8. Recommendations

Through the results of the research, the following recommendations were adopted:
1 - increase research in this aspect to complete access to sustainable formulas in the environment.
2 - the use of light materials to improve the characteristics of concrete and the disposal of the use of amounts of energy affecting the environment
3- Use of lightweight building materials to reduce densities and thus reduce sluggishness on foundations and soil.

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