Production of Lightweight Concrete by Using Polystyrene (cork) waste

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Abstract. There are two important subjects in the local and global areas, the first is the environmental pollution and the second is economic advantages of recycling and reusing of industrial materials. One of the most important industrial materials is cork waste. Because of many good properties of cork, like compressibility and a good ability to mould according to human needs, this material become as an important material in several life categories. This research work includes production of new type of light weight concrete and studies the mechanical and thermal properties. Several proportions of raw materials were used to produce this type of concrete. This study is intended to produce light weight concrete with low thermal conductivity so that it can be used for concrete masonry units. Polystyrene aggregate was added as percentages by weight of cement to improve the thermal properties of this type of concrete. Mechanical, and thermal tests with difference ages were made in this work. For polystyrene concrete with polystyrene cement ratio (p/c) of (2.67 – 6)%, the 28-day compressive strength range is from (4.31 – 2.67) MPa, flexural strength range is from (3.05-1.719) MPa, density range is from (1493-1213) kg/m³, and thermal conductivity range is from (0.91-0.782)% as a percentage by that of reference mix. The study show suitability of this type of concrete to be used in concrete masonry units of non-bearing walls.

Keyword: cork waste, light weight concrete, environmental pollution, low thermal conductivity.

1. Introduction

By the beginning of the twentieth century concrete was struggling to stand among other building materials and was resistant. The pressure that reaches 140 kg/cm is considered a great value and has its consideration. There were no specific methods for designing a concrete mixture, nor were there different design methods. There were also no different types of cement that fit various purposes, and there were no different types of concrete such as light concrete and concrete Air-entrained, precast or pre stressed concrete. In the year 1919 the concrete industry witnessed the first revolution, as Abrams discovered that there is a relationship between the pressure resistance of concrete and the ratio of water to the mixture (w/c).
We know that construction technology is in continuous progress and growth, and every day new discoveries and inventions appear for us with the aim of developing all the means and technologies that it uses in various fields in construction. One of the household resources, known as polystyrene, is considered one of the most important technologies in circulation worldwide, which plays the role of laa age in engineering facilities and works. However, there is not much research on this type of concrete. Although granules of synthetic cork were known since the 1950s, the high cost of cork at that time did not encourage its widespread use. To ensure the quality and efficiency of concrete, tests are required starting from the stage of preparing ingredients, mixing and hardening to obtain high resistance. Concrete tests are also useful for finding solutions to any construction problems that appear in the future, to ensure economic efficiency and reduce future maintenance costs.

1.1. The aim of the research:

Producing lightweight concrete with good thermal insulation that can be used in the manufacture of building, units with emphasis on the economic aspect in producing this type of concrete from available materials, at the lowest possible cost.

By using polystyrene material or granules. Gathering preliminary information on properties of concrete components, their tests, types of additives, and stages Concrete and types of laboratory tests for concrete, making use of available scientific references and previous studies, published research, journals and scientific papers of experiences and experiences from inside and outside Iraq and from scientific sites from the Internet.

Conducting a laboratory test on cubic concrete elements with dimensions (15 * 15 * 15) cm for a concrete mixture designed experimentally according to the British method and using the polystyrene additive with specific proportions (2.5%, 0.5%, 0.25%) of cement weight for different ages (7 - 28). A day to fix the ratio (w / c) and monitor the development of the hardened concrete resistance using a fracture test.

Analyze the results of laboratory tests and compare the extent of the development of the compressive strength of concrete with alum The weight scale additives and the ages indicated above.

1.2. Theoretical study

Concrete is a construction material used in the construction process for various structural elements such as bridges Columns, plinths, foundations, etc. It is a mixture of large rubble (gravel) and fine aggregate (sand) mixed with each other by a welded material such as cement, then it is called cement concrete.

Cement concrete is a material made from a mixture of gravel (large and fine aggregates), cement and water, and sometimes additional materials are added to it to obtain certain properties. Concrete is in a flexible state in the early stages so that it can be poured and placed in molds to form dry solid blocks capable of bearing the loads and forces. on her.

Concrete differs from other ready-made materials such as iron, wood, plastic, aluminum and others, because it is made and poured on site in most cases. Its manufacture requires certain conditions based on knowledge of its components and properties and the factors that affect the properties of the resulting materials so that it can be used and control the extent of its suitability to carry out its function in the facilities used in it and its ability to resist the conditions and factors it is exposed to during the use of the facility.

Cement consists of clay materials and lime materials that are burned by special furnaces: The aggregate constitutes about (65-75) of the mixture and gives a degree of ductility in the concrete mixture during mixing, transportation and casting.
1.3. The importance of concrete in construction:

Building materials have evolved since ancient times, humans used to use rocks in the process of building housing, then it used clay as a welded material between rocks and stones, and it also used a mixture of clay and lime until the process of manufacturing carnivorous materials developed until it reached the cement used today in the manufacture of concrete as a hydraulic weft material (reacts with water) able to withstand the forces exposed to it.

1.4 The importance of concrete as a structural material lies in the following:

* Availability of raw materials: where the aggregates and raw materials necessary for the manufacture of cement can be obtained from crushers at low costs and in most regions.

* Easy to manufacture and shape.

* High compressive strength: concrete has a high resistance to compressive forces while being weak relatively to the tensile strength, for this reason, rebar is added to concrete to resist the tensile strength of concrete contain reinforcing iron called reinforced concrete. Whereas concrete that does not contain steel reinforcement is called normal concrete.

* Weather resistance: concrete has good weather resistance compared to other materials.

* Fire resistance: concrete has good fire resistance compared to other materials such as wood, iron and others.

1.5 Its shortcomings:

* Its tensile strength is relatively weak.

* Movement resulting from shrinkage by drought or moisture, which causes fine hair cracks, which need to be placed in appropriate armature or connections on separate areas.

* They allow fluids and gases to permeate to varying degrees because they are not solid.

The concrete mixture:

The concrete mixture usually contains:

1- Cement. 2- Aggregates. 3- Water 4- Additions.

2. Cement:

It is that soft, dark-colored substance that, upon interaction with water, forms the cement mortar that works the gravel grains bond and bond with each other to form a solid, cohesive body called concrete. Cement and water are called the broiler which provides resistance to concrete. Cement consists of clay materials and calcareous materials that are burned by special furnaces, so that these components are reconstituted after burning to form a substance called clinker, and after it is cooled, it is crushed and gypsum is added to it to delay solidification (the time of doubt).

2.1. types of cement:

* Ordinary Portland cement:

It is used in construction works in general, and there are different varieties of this type, such as which contains a lower percentage of ferric oxide, petroleum well cement used for lining oil wells, quick-set cement, and other items with special uses.
* Portland cement that is hardened at high temperature and resistant to sulfates: It is used in concrete constructions exposed to moderate influences from sulfates.

* Fast hardening cement:

Ratio of limestone to silicate and ratio of tricalcium silicates in quick hardening cement It is greater than its counterparts in ordinary cement, and is characterized by a degree of smoothness greater than regular cement, which leads to rapid hardening and rapid heat generation.

* Low temperature Portland cement: This type has a low content of tricalcium sulfate and tricalcium aluminate; This leads to a decrease in the heat generated.

* Sulfate resistant cement: -

This type of cement is low in Tr-Calcium aluminate and has a high strength Greater than the resistance to sulfates because of its components »or because of the processes used in its manufacture, therefore, it is used in cases that require high resistance to sulfates.

2.2. Natural and mechanical properties of cement: -

* Cement smoothness: -

The smoothness of cement affects the velocity of hydration, the increase in softness leads to an increase in the speed of the cement reaction, as well as the speed in the growth and increase of cement strength, especially for the first days of reaction and smoothness is one of the reasons for the increase in the strength of fast-hardening Portland cement. Because the process of interaction with water stops to a large extent with the size of cement grains, and that the inner core of coarse grains of cement takes years to interact with water and it may reach that these coarse grains may not interact at all with water and the greater the fineness the greater .

Coarse material covering in aggregates, increased smoothness will stabilize size and improve workability because it will reduce the amount of water and reduce the amount of bleeding phenomenon.

* Cement stability: -

The stability of cement means that it is resistant to the increase in volume that occurs in it after hardening and which leads to its increase Damage to mortar or concrete. The reason for this volume increase is due to:

* Aqueous calcium sulfate (gypsum) increases by more than that which reacts with compound C₃A during the freezing period, the excess gypsum expands slowly and causes instability. It is for this reason that standard specifications specify the amount of gypsum to be added to the clinker.

* The raw materials placed in the oven contain more lime than that which binds with acid oxides, so the surplus remains in a free state and burns strongly inside the oven;

\[
\text{CaO} + \text{H}_2\text{O} = \text{Ca(OH)}_2
\]

* Cement instability may result from the presence of free magnesia which are crystalline and react in a manner Similar to the free lime reaction. As for the magnesia in the glass, it does not cause the cement to be unstable Being amorphous and hydrolyzing rapidly, converting to the steady state, the equation clarifies the reaction.

\[
\text{MgO} + \text{H}_2\text{O} = \text{Mg(OH)}_2
\]

Free lime in clinker is present between the crystals with other compounds and is partially exposed to water before the cement paste solidification period.
2.3 Aggregate:

It is the sum of grains of rock or stone materials or natural sand or others, and these are welded together by the cement mixture to form a solid body that forms the aggregate about (75% - 65%) of the concrete components and therefore the properties of the aggregates affect the properties and quality of the concrete. Certain properties of aggregates used in concrete, such as the size and gradation of grains, the ratio of large aggregates to fine aggregates, its absorption of water, the moisture content of aggregates, its density, specific weight, the shape of its grains, etc.

2.3.1. Types of Aggregates: -

* Fine aggregate is a group of granules that pass (95 - 100%) of them through a standard (4.76 mm) sieve called sand.
* Coarse aggregate is the group of granules that (95 - 100%) of them are retained within The standard sieve of (4.76 mm) is called gravel Mixed aggregate, which is a mixture of small and large aggregates.

2.3.2. Characteristics of aggregate:

Characteristics that must be met in the aggregate to be chosen: -

1- Granular gradient.
* Durability.
* The shape of the particles and the texture of the surface of the particles.
* Absorption and surface moisture.
* Weight and voids unit.
* Skid resistance.

2.3.3. Design the concrete mixture: -

It is the process of selecting suitable mixing materials and estimating their relative quantities in order to produce concrete at the lowest cost It has a minimum of certain properties, in particular strength, resistance and durability. It is considered one of the most important factors affecting the quality of concrete and the economics of the project, by using proven ratios from experience and called the position ratio, or it may be by mathematical methods based on a technical basis that include the properties of the materials used and the properties required in concrete; Economy according to the type of construction work required. The components of concrete are calculated by weight or volume ratios of cement, aggregates and water. For the design of high-quality concrete mixes, basic considerations are: -

* Cost: includes the cost of materials and equipment and labor wages.
* Specifications: The concrete specifications specify the proportions of both cement and sand And statistics, and that the modern trends of the specifications are less specific, as they set minimum limits, which may cover a number of characteristics, including:
  * Minimum compressive strength which is important for structural considerations.
  * The upper limit of the ratio ( W / C ) or the minimum content of cement and certain weather conditions.
  * The minimum intended air content for the purpose of giving adequate durability.
* Higher cement content to avoid shrinkage cracks when dry weather affects.
* Higher cement content to avoid cracks caused by heat in jumbo concrete blocks.
* The minimum density for structures consisting of massive concrete blocks.

2.4. Factors affecting the selection of mixing ratios:

1- Resistance . 2- Quality control . 3- Durability . 4- Operability . 5- Maximum aggregate size .
6- Grading and type of aggregate .

2.4.1. The different (special) types of concrete:

There are many types of them:

1- Ordinary concrete: -

It is concrete without any steel reinforcement, and it is used in the work of concrete beds under foundations and sidewalks and the work of concrete blocks that are not exposed to tensile stresses and work floors and dams, and their resistance ranges between (250-150) kg/cm depending on the purpose for which they are used, and some properties in them can be improved to suit the purpose of use for example to be resistant to sulfates or resistance to erosion and corrosion factors as in the case of marine fenders.

2- Reinforced concrete:

It is an ordinary concrete, with a common reinforcement steel to resist tensile stresses, and this type of concrete is the most common and used in the world due to its ease of implementation and the cheapness of its manufacture. It can be poured directly on the site or poured into the factory to make ready-made concrete units. Balance and compatibility between stresses and strains should be achieved between concrete and iron. Most of the design codes completely neglect the tensile strength of concrete, and therefore the iron bears all the tensile forces affecting as for concrete it bears a compressive force.

3. Pre-stressed concrete: -

It is a normal concrete that is given compressive stresses before it is loaded, and these stresses are enough to evade the tensile stresses resulting from the impact of the loads, and therefore we do not need reinforcing steel, as the final result of the stresses is along the concrete sector after loading (operation), which is often compressive stresses and thus the concrete is able to bear it. Accordingly, concrete must have a high pressure resistance of between (350-600) kg/cm² in order to withstand the stresses of manufacturing pressure and operating stresses. Steel rods used in pre-stressed concrete are called stranded wire cables or ropes from a group of wires or steel rods and are characterized by fewer surface cracks with high resistance to loads and are suitable for use in bridges, water reservoirs and prefabricated units such as railway hooks and telegraph poles.

4- Ready-mixed concrete (precast): -

The concrete is poured and cured until fully solidified in the factory, and then transferred to the origin can be ordinary, reinforced or pre-stressed concrete that includes slabs, columns, walls and concrete blocks Flanges, fences and stairs units.

5- Light Weight Concrete: -

It is the one whose weight is less than 2000 kg/m³ and the purpose of its use is to reduce the weight of the structure and thus reduce the costs of the foundations. The economic and scientific benefits available in
lightweight concrete have made it occupy a high position in recent years in the construction of facilities, and the demand for their implementation is increasing.

6- High strength concrete:
It is concrete with a resistance of more than 600 kg / cm² and may reach or exceed 1400 kg / cm² and can be obtained by using available local materials that are used in the manufacture of traditional concrete (25 kg / cm²) of aggregates, cement and water, but high-strength concrete contains another additional material. (Super plasticizers) plasticizers so that we can reduce the mixing water to the maximum degree while obtaining the same workability and thus obtain a high resistance. As for pozzolanic materials such as silica dust (silica fume) is either or not found in both types of concrete.

2.5. We will talk about one of the types of concrete previously mentioned, namely:

1- Light Weight Concrete
Light concrete that weighs (2500-2200) kg / m³ has been used in America for more than 50 years and its ability to withstand pressure in it is not as strong as in regular concrete, but it performs the required function and its advantages are that it does not need much iron to strengthen the building and requires Smaller foundations and better protection against fire is the most important feature of which makes it an insulating material. It can cost more than concrete mixed with sand and gravel, but the overall construction costs are lower if we take into account the reduction in building weight in addition to less labor and good thermal insulation of buildings.

2- Polystyrene: - (cork)
Polystyrene is produced from the polymerization process of crude styrene, which is a well-known organic compound and from the petrochemical family. This material is classified from the first class insulators in the world that its use is prevalent in most developed countries as it is characterized by several distinct properties. It is a tasteless, odorless, and no crystallization polymer with a long linear chain resulting from the reaction of ethylene and benzene, where the monomer produced by this polymerization is a giant polymer with large side groups of isotactyl form. Scientists continued research on it until they came to produce it in a hard and easy to form crystal form. Fig. (1)
2.6. Properties of Polystyrene:

Among its most important characteristics:

- A heat insulator for its cellular composition that expels heat and solidifies it, and all this according to its density.
- Acoustic insulation absorbs shock and lowers the sound strength of refraction.
- Lightweight material, easy to carry and transport, as it bears compressive strength.
- This material contributes to saving energy consumption and environmental treatment of the building, especially when it is used as panels in the insulation of listening rooms and lectures and preventing the transmission of sound to the interior. In addition, it is used in the roofs as an extra layer of thermal insulation.
- Highly hard, brittle with excellent electrical properties; low absorbing moisture, easy to manufacture, inexpensive, has a smooth and colorless surface so it allows for transparent, semi-transparent and opaque coloring.

* Benefits of Polystyrene Concrete: *

- Increasing the thermal insulation of the facilities due to their polystyrene thermal insulation compared to the construction materials.
- Reducing dead loads, which leads to lower cost by using design sections and reinforcing steel that are less than those used in regular concrete.
- Consumption of polystyrene or cork from waste, which contributes to reducing environmental pollution.

The physical properties of cork concrete were studied in 1955. (Kohling) conducted a research showing the possibility of using polystyrene in the manufacture of high thermal insulation concrete. In 1978 (Maura) concluded that the compressive strength of this concrete with densities ranging between (460-230) kg / m³ is with a range of (0.7-2.3.) MPs, while the fraction parameters range between (0.36-0.3) MPa. In 1982, Parton noted the properties of this concrete such as density, compressive strength, fracture resistance and thermal insulation. (Sussman-Ritchire) concluded that the compressive and bending strength are directly proportional to the density and a decrease in these properties is observed when the density decreases. This phenomenon has also been discussed before (Cook) where he concluded that the cement bonding material withstands most loads and that the water-cement ratio plays. The most important role in determining the resistance of this type of concrete. The process of adding cork was done as a percentage of the weight of the cement. The effect of this addition on the mechanical properties and density of the produced concrete was studied. This addition had a negative effect on compressive strength and bending and a reduction in density. Al-Hadithi and others added a styrene rubber polymer to cork-containing concrete as a lightweight aggregate in an effort to produce lightweight concrete. The laboratory results obtained from this study indicated that adding cork to regular concrete led to a reduction in density and reduced compressive and bending resistance. By comparison of the reference mixture, the reduction in compressive strength was about 90.7% and the density was 38.9% at 28 days of age. It was also observed that the compressive strength and the rest of the properties of the concrete developed by polymer was increased by 5% increase significantly compared to the rest of the mixtures examined in this study except for the reference. Table (1)
Table (1) shows the density of cork with some aggregates

| Aggregate type | Density kg/m³ |
|----------------|---------------|
| Sawdust        | 320-128       |
| Perlite        | 200-160       |
| Clay           | 1000-800      |
| Rice husks     | 700-500       |
| Polystyrene    | 20-10         |

3. Experimental Work

Material used in this work:

Cement: Portland & standard cement were used in all experimental mixtures in this research.

Water: Drinking water provided by water supply station.

Aggregates

A. Fine aggregate: the fine aggregate supplied from (seventy km) quarry in Al-Basra which lies in the gradient region 2 according to Iraqi standards (45/1984) and the table (3) shows the sieve analysis for the fine aggregate that is used in all of the mixtures in this research.

B. Polystyrene aggregate: polystyrene aggregates locally know as (cork) which is widely available in waste were used in this research where they used in food packaging and household appliance. These aggregates were obtained by crushing the Stayropor into a fine granules with sizes (0.3-4.75) mm, table (3) shows the sieve analysis for these aggregates.

Table 2 - sieve analysis for polystyrene and standard aggregates

| Sieve size | Polystyrene aggregate | Standard fine aggregate | Iraqi standards (45/1984) for fine aggregate(1) for gradient region 2 |
|------------|-----------------------|-------------------------|---------------------------------------------------------------------|
| 4.75       | 100                   | 100                     | 90-100                                                               |
| 2.36       | 50.97                 | 86.16                   | 75-100                                                               |
| 1.18       | 15.31                 | 73.84                   | 55-90                                                                |
| 0.6        | 5.81                  | 42.4                    | 35-59                                                                |
| 0.3        | 1.74                  | 9.36                    | 8-30                                                                 |
| 0.15       | 0                     | 1.6                     | 0-10                                                                 |

Experimental mixtures:

A. First mixture: (control mixture) mixing ratios (1 cement : 3 sand) weight, while water to cement ratio was (0.5)

B. Second mixture: mixing ratio (1 cement : 3 sand) weight with addition of (2.5%) percentage polystyrene aggregate form the cement weight with keeping the water to cement ratio (0.5)
C. Third mixture: mixing ratio (1 cement : 3 sand) weight with addition of (0.5%) percentage polystyrene aggregate form the cement weight with keeping the water to cement ratio (0.5)

D. Forth mixture: mixing ratio (1 cement : 3 sand) weight with addition of (0.25%) percentage polystyrene aggregate form the cement weight with keeping the water to cement ratio (0.5)

### Table 3 - the weight of used material for each cubic meter

| Mixture Number | Mixing ratio | Cement ratio (kg) | Gravel ratio kg | Sand | Water ml | Polystyrene |
|----------------|--------------|-------------------|----------------|------|----------|-------------|
| 1              | Control      | 7.52              | 30.08          | 15.04| 3760     | 0           |
| 2              | 2.5          | 7.52              | 30.08          | 15.04| 3760     | 1.88        |
| 3              | 0.5          | 7.52              | 30.08          | 15.04| 3760     | 0.376       |
| 4              | 0.25         | 7.52              | 30.08          | 15.04| 3760     | 0.188       |

Mixing procedure for concrete:

The materials were mixed by hand to guarantee good homogeneous mixture where using electrical mixing device will lead to dispersal polystyrene aggregates due to its low density when compared to the other ingredients. The mixing procedure can be listed as follow:

1. Adding cement to water with continuous mixing until a homogeneous color is appeared for the mixture.
2. Adding a suitable portion of water to moisturize the mixture
3. Adding polystyrene aggregates with continues mixing.
4. Adding the left amount of mixing water with continuous mixing until a homogeneous color is appeared for the mixture.

Casting and compaction of concrete:

1. Coating the inner face of the iron mold with layer of oil
2. Inserting the concrete mixture with two equal thickness layers
3. Compacting the mixture by hand by using a metal bar due to inability to use electrical vibrator which leads to separation of polystyrene aggregates.
Fig. 2 Curing: After finishing the casting, the specimen left in the molds for 24 hour, and then the mold were removed and the specimen immersed in water till the test time.

Fig. 3 The used molds: Cubic iron mold with dimensions of (50*50*50) mm were used for specimen casting to investigate compressive strength, density and absorption rate, and iron prisms shape molds with dimensions (40*40*160) mm were used to prepare the required specimen for flexural strength test, meanwhile cylindrical plastic molds with dimensions (30 mm height*30 mm diameter) were used to prepare specimen for thermal coefficient tests.

4. Analyze and discuss the results:

Using a pressure device to find out the compressive strength as shown in the figure (5).
4.1. Analysis of fracture results for concrete without additives. Fig. (5).

![Figure 5](image1)

Figure (5) shows the breakdown results for additive free concrete over 7 and 28 days.

It was found that the compressive strength of concrete without adding cork within 28 days was less than the design resistance by (19.9%).

4.2. Analysis of the fracture results of 2.5% cork-added concrete. Fig. (6).

![Figure 6](image2)

Figure (6) shows the results of the fracture of the concrete with cork added by (2.5%)

It was found that the compressive strength of concrete with cork added by (92.5) within 7 days was less than the resistance. The design ratio is (84.4%) and is less than the compressive strength of the concrete without...
adding cork by a percentage (80.5%) During 28 days, it is less than the design resistance by (79.6%) and less than the compressive strength of concrete from Other than adding cork by (74.5%).

2.3. Analysis of the fracture results of (0.5%) cork-added concrete. Fig. (7).

Figure (7) shows the results of the fracture of concrete with cork added by (0.5%)

It was found that the average characteristic resistance of concrete with cork added by (0.5%) within 7 days is less than the designed resistance by (55.4%) and less than the average resistance of concrete without adding cork by a percentage (44.3%) Within 28 days, it was less than the design resistance by (51.4%) and less than the average resistance of concrete without adding cork by (39.3%).

2.4. Analysis of the fracture results of (0.25%) cork-added concrete. Fig. (8)

Figure (8): shows the results of the fracture of concrete to which cork was added by (0.25%)
It was found that the compressive strength of concrete to which cork was added by (0.25%) within 7 days was less than the design resistance by (45.3%) and less than the compressive strength of concrete without adding cork by a percentage (31.6%). And within 28 days, it is less than the design resistance by (33.4%) and the compressive strength of concrete without adding cork by (16.8%).

Comparison of fracture results for cork-added concrete (2.5%, 0.5%, 0.25%) with additive Free Concrete (Cork).

![Figure (9): shows a comparison of the weights of the cubes](image)

It was found that the cubes of concrete with cork added (60.25%) are lighter than the cubes of concrete without the additive and give higher resistance than the cubes with cork added at rates (0.5%, 2.5%). The more processing days, the weight decreases. The higher the cork percentage, the thinner concrete becomes, and the lower the characteristic resistance.

5. Results and discussion:

By comparing the tests results we can notice the strong connection between density and polystyrene to cement ratio (p/c), where the density decreases with (p/c) ratio increase as in figure (10), and it is known that density has a direct impact on all mechanical and physical properties of concrete.

1- Compressive strength: figure (11) shows compressive strength increasing corresponding to density decreasing (p/c).

2- Flexural strength: figure (12) shows flexural strength increasing corresponding to (p/c) decreasing.

3- Absorption ratio: figure (13) show absorption rate increasing corresponding to (p/c) ratio increasing and that is due to increase of voids in concrete with (p/c) ratio increasing.

4- Thermal conduction: figure (14) shows the relation between thermal conduction and (p/c) ratio where thermal coefficient increase with corresponding to (p/c) ratio decreasing which present voids decreasing in concrete which leads to thermal coefficient increasing.

6. Conclusion:

Many tests have been done in order to obtain the thermal and mechanical properties of fine aggregate, cement and polystyrene aggregate concrete. And through this study we can conclude that:
1- Polystyrene aggregation employment into the concrete as one of this consistent has a direct impact on density which has a solid connection with all concrete properties, where the density decrease with the increasing of polystyrene to cement ratio (p/c), and in this research a light weight concrete was produced with densities (1213-1493) Kg/m³ by using (p/c) ratio between (2.67-6) %-of cement weight in the mixture.

2- Compressive strength in the range of (2.67-4.31) MPa with age of 28 days can be obtained (p/c) ratio within the range of (2.76-6) % and with comparing these values with values of compressive strengths of concrete cells that defined by standard Iraqi specifications (1441/2000) where this specification defines the minimum value of compressive strength about (0.7) MPa and this shows that the concrete produced can be used to manufacturing of masonry units of non-bearing walls.

3- Flexural strength for polystyrene concrete at the age of 28 days is about (1.179-3.05) MPa by using (p/c) ratio of the range (2.67-6) %.

4- The addition of polystyrene aggregate leads to increasing of absorption rate, where the values of absorption was (10.75-15.38) % by using (p/c) between (2.76-6) %.

5- Thermal insulation for the concrete can be improved by the addition of polystyrene aggregate to the constituent of concrete where through this research a value of thermal conduction coefficient about (0.782-0.91)% as a ratio for thermal conduction for the standard mixture and that was done by using (p/c) ratio of (2.67-6)%.

![Figure (10)](image-url) Relationship between density and ratio of polystyrene to cement (p / c)
Figure (11) Compressive strength

Figure (12) Flexural strength

Figure (13) Absorption ratio
Figure (14) Thermal conduction

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