# The Benefit of Polystyrene (Ps) Waste for Production of Lightweight Concrete and for Environmental Protection

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**Abstract**

In the last decades of the last century, the researchers of engineer's specialists and those interested about the environment-begun focus conducting studies and research for the disposal of all types of plastic waste, when they discovered that these residues are from one of the most dangerous pollutants to the environment, since they have grave consequences on human and nature. Thus, the remnants of the plastic material are the raw materials could be used in several different applications in the field of civil engineering, such as used in concrete mixtures, for to product lightweight concrete. However, the aim of this study is to get rid of one of these plastic wastes a polystyrene (PS) added to the cement mixture to produce lightweight concrete, as alternative for partial replacement for coarse aggregate ratios volumetric range between (10% to 100%) and fine aggregate (50% to 100%), and to know its impact on some of the engineering properties concrete; such as slump, density and pressure resistance, and compared to the reference concrete mixture. The results showed that the addition of plastic polystyrene waste (PS) as the lightweight aggregate to concrete mix, led to obtain lightweight concrete and good properties most of the ratios used. Where helped to increase slump and reduce the density of the mixture, and led to a reduction of compressive strength in inverse proportion to the resistance with increasing size in the mixture.

***Keywords**: Aggregates, Concrete, Compressive Strength, Ordinary Portland Cement, Polystyrene, Slump.*

## 1. Introduction

Through the large industrial revolution and the increase projects for the exploitation of energy natural sources, for all its forms and manifestations, which drew attention of many researchers to the open field in front of recycling industrial waste process, exploited in other industries for the purpose of improving, to take benefit advantage as the energy alternative source, used for production of other materials as an additive, and or as basic as used in concrete mixtures, in paving the roads, in the production of concrete, brick and others in the civil engineering work, in addition of these operations to get rid of the health and environmental damage caused by this waste, and certainly that plastic residues of the most important waste the most abundant and probably the most serious environmental and health standpoint industrial.

The plastics industry returning to the pre-1875, when it was the preparation of a large amount of nitrate Sulaileod, which are a thermoplastic where discovered by the "Alexander Berkz" at year of 1862. The plastics rigid thermoformed (plastic phenolic) has been discovered by the "Lobakiland and Swinseron "in 1909, which was the first composite material produced in large quantities, and has since discovered many modern types of plastic material. The plastic is made up of long chains called polymers compounds (polymers) are arranged in a specific format and this arrangement gives multiple advantages of plastic, and the hard-plastic replacing metals in many of the tools [1, 2].

In 1950 start the plastic spray in the world. At that time there were 2.5 billion people on earth and the global production of plastic was 1.5 million tonnes. Today there are more than 7 billion people and plastic production exceeds 300 million tonnes annually. And expected the production increase up to 33 billion tonnes in year of 2050 [24].

Plastic may be granulated or chopped into flakes and placed in industrial tote bags for transport.
1. Polyethylene terephthalate (PET)
2. High-density polyethylene (HDPE)
3. Polyvinyl chloride (PVC)
4. Low-density polyethylene (PE-LD)
5. Polypropylene (PP)
6. Polystyrene (PS)
7. Other (O) [25].

Uses of plastic materials in most areas of life, in the food utensils, pharmaceutical packaging, hospital equipments, furniture, some parts of buildings, aircraft, airspace, and automobiles and many other areas, and each area has a negative impact on health, and most plastics familiar types are dangerous on health and the environment as the cause industry and burn significant environmental pollution and use of cause and disposal of poisoning is causing many environmental problems.

many researches proved that some types of plastic materials led and lead to numerous health problems, including various cancers and damage to the immune system, damage to the ozone layer. The dioxin substance since of the strongest toxic chemicals, which this release from plastic during its production and use or burn, showing studies conducted in the United States that a high percentage of dioxin in children and adults and that this ratio is sufficient to induce health problems for them [3, 4].

This problem has led to increased awareness, and the emergence of international attention the need to search for solutions to reduce the negative effects the accumulation of plastic waste. There are several methods used for the disposal of plastic waste, including burning a more roads commonly used today to get rid of waste plastics, although this method greatly harm the environment and human and cause many health problems, the burning of plastic to get rid of it leads to the emission of several highly toxic gases such as hydrogen chloride gas (HCl), dioxin components, carbon dioxide (2CO) and carbon monoxide (CO) in addition to ash and the rise in temperature (more than 1000 $C^o$) [3, 5].

The landfill, which means that by the process of solid waste buried underground, including plastic waste, which proved to be ineffective and cause many hazards and environmental pollution significantly, this is composed of waste from oil chemicals degrade in the heart of the landfill to produce toxic substances that cause contamination of soil and groundwater where tons one of the waste pollutes about 500 cubic meters of underground water and that drink human and cause a different cancers disease [6].

The last method is recycling, a recycling and use of waste, whether home or business process in order to minimize the impact of these residues and accumulation on the environment, the practical experience has confirmed in this area that recycling helps to reduce the cost of raw materials and operating cost, as well as environmental usefulness, previous studies have indicated that recycling some types of plastics rates ranged from 1% to 3% and the rest is disposed of by incineration and land filling [7].

The civil engineering applications requirements of concrete in large quantities in various business, the possible to use plastic waste partial replacement of aggregates in the concrete, and have several researches conducted in this area to useful of plastic waste for to replace the aggregate whether fine or coarse in the concrete mixture [8-12]. Several separate researches conducted as well as to utilize of waste polyethylene terephthalate, polycarbonate, polypropylene, polyurethane and melamine in concrete mixtures [13-18]. Also was studying the use of PVC waste to replace the aggregate of river sand and coarse natural aggregate part in concrete mixtures [19-21]. Venkatesh and his colleagues were studied properties of light weight concrete using expanded polystyrene [22]. Dinesh Sellakutty was working to utilize of waste plastic in manufacturing of bricks and paver block, where concluded that the advantages of these bricks and blocks, light weight, acceptable compressive strength and working as an insulation of water, temperature and voice and also low cost [23].

In addition to the main objective of this research is getting rid of plastic waste, the other goal is probably not as important for the benefit of human, its median permanent need for the production of construction materials and new types of distinct concrete suit different needs of the modern human requirements discovered light weight concrete.

This concrete advantage of several features of the most important light weight, reduce loads hanging over the base and the savings in the size of the foundation, ranged weight per cubic meter of them between (1000 to 1800) kg per cubic meter, fit almost irresistible with a weight and equal resistance to weather conditions ordinary concrete resistance.

In addition to resistance fire, isolate heat and sound, also can be used for industrial and natural waste available locally for their production to meet the urgent need to isolate thermally facilities in cold regions and hot for several reasons, including: the great climate of extremism among the seasons of the year, between day and night, high degrees of intense heat in the summer and fall in the winter, causing a major energy-consuming, especially for the purpose of electric cooling and heating, an important and influential economic factor, and for examples such as plastic waste, especially polystyrene.

In this research was used polymer polystyrene material, and this type of plastic lightweight the density is between 0.96 to 1.04 $gm/cm^3$, the scientific name is N(C8H8), and melting point is $240^oC$. a polymer plasticizing thermoplastic, where the unrelenting heat and solidifies by cooling at room degrees, and it is a plastic rigid, becomes softer at a temperature of 70°C, and melts at point of 240 degrees Celsius. Polystyrene have known in 1839 by German scientist Edward Simon, and in 1939 began using on a large commercial scale in several applications where made into keeping fish boxes, dishes, eggs, cups, saucers, thermal insulator and is also used in maintaining equipment, crockery and glassware from breakage [1].

## 2. Practical plan, Materials and Tests Used

### 2.1 Practical plan

The mixture of reference-free lightweight of aggregates, designed according to the American method for the design of concrete admixtures by simplified steps after the confirmation of the validity of the aggregate especially with regard to gradually coarse aggregate and fine aggregate with water ratio to cement equal to 50% and resistance to compression ranging between (20-40) Mega Pascal,

Therefore, the average valuable for concrete slump ranging has been selected from (5-12 cm), relying on the legal size larger for coarse (20 mm). Also, the coefficient of aggregates smoothness of fine sand which is considered the standard Libyan specifications (49) of sand along Libyan coast is the sand fine gradient, and impose resistance to compression rate ranging between (20-40) Mega Pascal (Mpa) at 28 days. It has been weights account for the components of mixtures all in kilograms per cubic meter, and the water cement ratio was equal to 0.50 for all mixtures. It replaced part of the volume coarse aggregate by lightweight aggregates of proportions volumetric (10%, 25%, 50%, 75%, 100%), followed by the replacement of fine aggregate percentages (50%, 100%) of the type of lightweight aggregates user in this research polystyrene with the stability of the water/cement ratio for all mixes. Table(1) shows the practical program for this search scheme.

Table (1) show the lab. program of concert mixture.

| plastic type used | Mix. No. | Lightweight aggregate | | | Natural materials | | | |
|---|---|---|---|---|---|---|---|---|
| | | Alternative of Aggregate % | Alternative of sand % | weight (Kg/m$^3$) | Aggregate (Kg/m$^3$) | Sand (Kg/m$^3$) | Cement (Kg/m$^3$) | Water (Kg/m$^3$) |
| Polystyrene | **1** | 0 | 0 | 0 | 1056 | 718 | 377 | 185 |
| | **2** | 10 | 0 | 0.96 | 950 | 718 | 377 | 185 |
| | **3** | 25 | 0 | 2.4 | 792 | 718 | 377 | 185 |
| | **4** | 50 | 0 | 4.8 | 528 | 718 | 377 | 185 |
| | **5** | 75 | 0 | 7.2 | 264 | 718 | 377 | 185 |
| | **6** | 100 | 0 | 9.6 | 0 | 718 | 377 | 185 |
| | **7** | 100 | 50 | 13.6 | 0 | 359 | 377 | 185 |
| | **8** | 100 | 100 | 15.9 | 0 | 0 | 377 | 185 |

Tests conducted for all of concrete admixtures, where it was a test of the slump in the soft condition of the concrete. In addition, to made cubic models with dimensions (15×15×15) cm, which used to test the pressure resistance and dry density of concrete, density tested of the cubes of concrete at one day-old for all mixtures, compressive strength also tested at age 3, 7, 14, 28 days when the samples were wet and dry surface. The weights in the table (1) scaled for sufficient to pour 15 cubic per mixture of mixtures for purpose of conducting laboratory tests.

## 3. Materials used

### 3.1 Cement

Cement used in the laboratory tests and for all mixtures are an Ordinary Portland Cement (OPC) measuring 42.5 Newton, produced by Alkhoms city factory, which located west of the Capital Tripoli city a distance of 120 km, in conformity with Libyan specifications and British specifications (BS EN 179).

### 3.2 Coarse aggregate

Natural coarse aggregate used which supplied from the Wadi Alhira region, with dimensions (0.5cm), (1.0 cm) and (1.5 cm) of diameter and has been mixing with designed proportions shown in Table (2). The amounts of aggregate of the three sizes were natural air-drying and thoroughly mixed. The conformity with Libyan specifications of number (49).

Table (2) show proportions of mixture and size of coarse aggregate in the mixture.

| Aggregate size (mm) | Mix. Proportions (%) |
|---|---|
| 15 | 40 |
| 10 | 40 |
| 5 | 20 |

### 3.3 Fine aggregate

Fine aggregate (sand) used in this research supplied from Sedi Assaih area, which is identical to the standard specifications of the Libyan (49), and where used a natural air-dry inside the lab

### 3.4 Light-weight aggregates (polystyrene (PS)

Material polystyrene (PS) used as lightweight aggregate alternative to natural fine aggregate and coarse aggregates. It is one of the petroleum products where it was assembling stationed in household waste and cut into similar sizes format aggregates used in the mixture of concrete, and its density equal to 1.04 g/cm 3, the name science is N (C8H8), and the melting point of 240° C.

### 3.5 Mixing water

Water used in concrete mixtures in this research obtained from the water network of Zawia city of drinkable water matching the specifications Libyan human construction. Table (1) shows all the weights of concrete admixtures in kg/cubic meter.

## 4. Tests used

### 4.1 Sieve analysis of coarse aggregate and fine aggregate

This test has been conducting for all types of samples coarse and fine aggregates which received from the sites, according to US specification (ASTM-D 422-1966), classification from an engineering standpoint, determine the extent of compliance of specifications, and the natural air drying was in the lab.

### 4.2 Specific weight of the coarse aggregate, fine aggregates and polystyrene

This test conducted for natural aggregates of both types fine and coarse for the waste of polystyrene, according to US descriptors (ASTM-854-1958).

### 4.3 Absorption ratio of coarse and fine aggregates

The determination of the percentage absorption of sand is great importance because when used in dry, it will absorb part of the mixing water for access to the saturated condition, which leads to reduction of the effective mixing water. The share calculated absorption of a sample of sand used in this research. Therefore, its weight at saturated and dry surface (w1) then dried in the oven at temperature of 110° C for 24 hours and weighed after removing from the oven then cooled for two hours (w2) before using, and the ratio of the absorption of the sample under the following equation:

Absorption (ABS %) = (W2 - W1/ W2) 100 (1)

Where: ABS (%) = absorption ratio.

W1 = weight of the sample which is saturated with water.

W2 = weight of the sample is completely dry.

### 4.4 Instrument of compressive strength measuring

It has been measuring the compressive strength of cubes samples at different ages (7, 14, 21, 28 days), according to the US specification (ASTM C39), the samples immersed in the water after 24 hours of prepared by machine of a compressive strength (Lessingstr.73.NEU WULMSTORF) the cubes samples were tested immediately after taken out of water at room temperature. The average of compressive strength of 5 samples recorded for each composition. The following equation used for determination of compressive strength:

Compressive strength = P/A (2)

Where: P = pressure load, and A = face area of cubes sample.

### 4.5 Mold cubes preparation

Mold cubes of concrete dimensions (15×15×15) cm equipped by cast into metal molds. According to British Standards (BS 1881, Part 7) cleaned, and fitted before beginning the mixing process and anoint by very light layer of oil for easily dislodged and prevents the adhesion of concrete on the inner surface of them olds while removed from the mold after 24 hours until gaining firmness and then begin the treatment process.

### 4.6 Method of concrete mixing

Attend weights of cement, water, coarse and fine aggregates. In addition to lightweight aggregate polystyrene (PS) required percentages in each batch and in sufficient quantity to pour cubes 15 each a mixture of mixtures listed in Table (1). The weights put inside mechanical mixer used in the laboratory coarse aggregate. In the first added a little mixing water running in the mixer for half a minute and then add sand, lightweight aggregates and cement, then operates a blender until mixed material well, after that add water and a blender in the case of the rotation for three minutes followed by stopping three minutes and then operating two minutes more.

After casting all the mixture components of mechanical mixer, pour the mixture in a large plastic basin and mix manually thoroughly mixed and filled molds on three layers, each layer compacting by rod of steel cross-section dimensions (2.5×2.5) cm, dedicated for this purpose. At rate of 25 blow each layer or stacked molds by electrical vibrator for a few minutes, and then place the mold smooth surface by an especial leveling equipment (spoon). Moreover, should note that the last layer thickness must be larger on the top of the cube's surface up to 1.0 cm to avoid a decrease in the settlement because it does not permit to increase the sample inside the cube after the completion of the third layer.

### 4.7 The curing

After 24 hours of the process of pouring concrete inside steel moldings, untangled carefully and then put the cubes for all mixtures in the basin of fresh water at degree lab temperature, leave the models in the basins ripening period decision for gaining strength gradually until due date to perform the required testing.

## 5. Concrete Tests

### 5.1 Measurement degrees of workability (slump test)

The slump tested according to the American standard specifications (ASTM C 143-78). Where the vessel cone placed in dedicated on the base, then the concrete poured inside of cone for three layers. The compacting each layer (25) blows by steel rod of compaction, then leveling the concrete surface exactly with the edge of the cone, where the third layer cast into the cone. So that is higher than the edge of the cone bit and take out excess concrete, then lifts the mold and measured value of slump by the ruler, as the value of slump give an indication of the extent of workability of each mixture.

### 5.2 Measuring density of concrete

Three samples concrete cubes weighed for every concrete mixture where indicated in Table (1) by the delicate balance and calculates the rate of weight cubic, then measure the dimensions of one cubes carefully and calculate the volume, after that calculate the density of concrete by following law:

Density: $\rho = W / V$ (3)

Where: $\rho$ = density

W = Weight

V = volume

### 5.3 Compressive strength test

Extracted cubes from the treatment basin, cleaned faces cube, dried by a cloth of excess water and leave for two minutes for to get dry surface of cube. The cubes placed between the jaws of the pressure device with a concentration in the middle of the jaw of the one side face perpendicularly. The load must be centrally on model and rate of velocity is fixed 4kn/sec according to US specifications (ASTM-C39), then registration the load causes failure, and compressive strength is calculated.

## 6. Results and Discussion

### 6.1 Sieve analysis

#### 6.1.1 Sieve analysis of coarse aggregate

Through the results shown in Table (3) and Figure (1), which represents a curved gradient of coarse aggregate after mixed of percentages above-mentioned in the table (2) and compare with the upper and lower limits of the standard specifications Libyan's number (49). Through sieve analysis test of aggregates note that coarse aggregate when mixing ratios of (5, 10 and 15 mm) sizes were obtained gradient is located within the boundaries of the standard specifications Libyan (No. 49) upper and lower except size (10 mm).

Table (3) show the sieve analysis results for coarse aggregate.

| Sieve opening (mm) | Weight retained (gm) | Accumulative of weight retained (gm) | Accumulative of retained proportion (%) | Pass percent (%) | Boundary of Libyan specification |
|---|---|---|---|---|---|
| 37.5 | 0.0 | 0.0 | 0.0 | 100 | 100 |
| 20 | 99 | 99 | 5 | 95 | 90-100 |
| 14 | 792 | 891 | 45 | 55 | 40-80 |
| 10 | 536 | 1427 | 71 | 29 | 30-60 |
| 5 | 378 | 1805 | 90 | 10 | 0-10 |
| Pan | 195 | 2000 | 100 | 0.0 | --- |
| Total | 2000 | | | | |

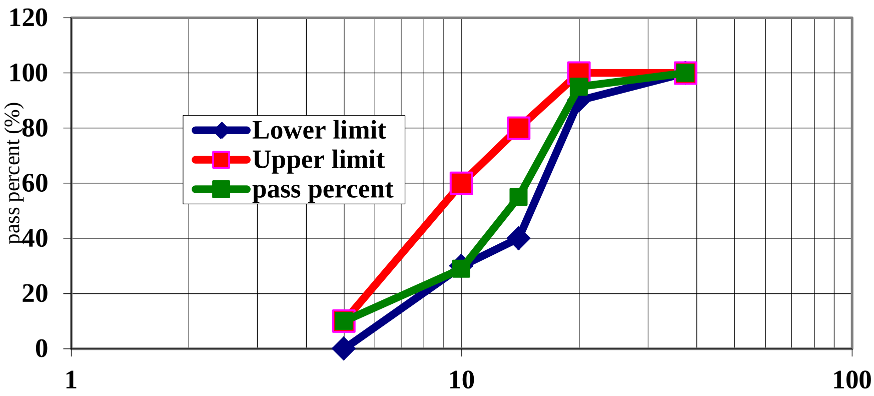


Figure (1) show sieve anylisis of coarse aggregate, upper and lower limits of libyan specification.

### 6.1.2 Sieve analysis of fine aggregate

After tested the sieve analysis of fine aggregates, the results shown in Table (4) and Figure (2), which represents a curved of grain size distribution of fine aggregates with upper and lower limits of the standard specifications Libyan's number (49). After result and comparing, it is clear that the sand used the soft sand of gradient and within the boundary of Libyan specification. It also noted the fine aggregate user approaching the upper limits of the standard specifications Libyan (No. 49) of the third gradient as observed which conforms to specifications only in size (0.15 cm). More than the upper limit of the specification, and it is a very fine sand and most particles confined within the dimensions of (0.3 cm) and (0.15 cm).

Table (4) show the sieve analysis results for fine aggregate.

| Sieve opening (mm) | Weight retained (gm) | Accumulative of weight retained (gm) | Accumulative of retained proportion (%) | Pass percent (%) | Boundary of Libyan specification |
|---|---|---|---|---|---|
| 5 | 0.0 | 0.0 | 0.0 | 100 | --- |
| 2.36 | 0.0 | 0.0 | 0.0 | 100 | 80 - 100 |
| 1.18 | 0.0 | 0.0 | 0.0 | 100 | 70- 100 |
| 0.60 | 11 | 11 | 2 | 98 | 55 -100 |
| 0.30 | 197 | 208 | 42 | 58 | 5 - 70 |
| 0.15 | 164 | 372 | 75 | 25 | 0- 15 |
| Pan | 125 | 497 | 100 | 0.0 | --- |
| Total | 497 | | | | |

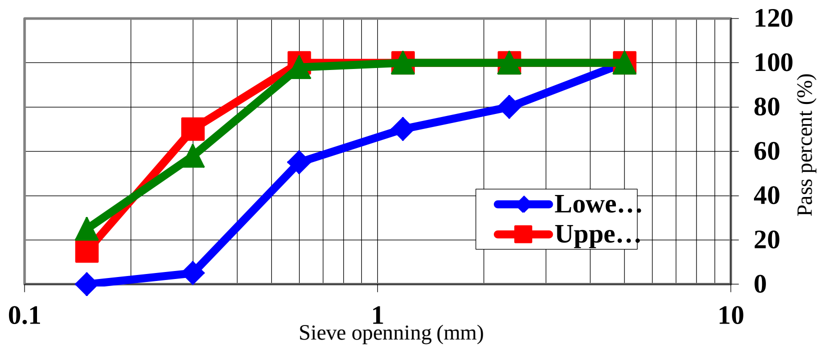


Fig. (2) show the sieve anylisis of fine aggregate and Upper and lower limits of Libyan specifications.

### 6.1.3 Specific weight and absorption

From tests conducted on natural course, fine aggregates and lightweight aggregates the results of specific weight and the ratio of absorption shown in the table (5). An observed from the table that considerable variation in the value of the specific weight of the natural course, soft and lightweight aggregates used in this study. Therefore, has been replaced quantities of natural aggregates by the lightweight of aggregate based on volumetric ratios for to get a fixed size for all concrete mixtures listed in table (1).

Table (5) show the results of specific gravity and Absorption proportion

| Type of aggregate | Specific gravity | Absorption proportion (%) |
|---|---|---|
| **Coarse aggregate** | 2.64 | 1.63 |
| **Fine aggregate** | 2.61 | 0.36 |
| **Polystyrene** | 0.024 | 0.0 |

### 6.1.4 Workability (slump test)

In the beginning it is worth noting that the water / cement ratio equal to (0.5), and all mixtures mentioned in table (1) Special properties of concrete mixtures, has been observed in general of the table (6) and figure (3) following the slump values:

Through, the investigation clear that the amount of slump for all groups of mixture (1, 2, 3, 4, 5, 6, 7, 8) and for the replacement of natural aggregates by textured pumice (polystyrene),it is less than the limits of the design requirements for blends concrete of normal course and which have acceptable slump (50-120 mm). It main approximately that almost dry mixes, because natural coarse aggregate user which is grit crushed in addition to the grading of sand used very fine as the smoothness coefficient of less than 2 approximately.

Table (6) show result of slumps for concrete mixtures at polystyrene added

| Groups | Value of slump (cm) |
|---|---|
| 1 | 0.0 |
| 2 | 0.3 |
| 3 | 0.7 |
| 4 | 0.5 |
| 5 | 0.5 |
| 6 | 2.0 |
| 7 | 2.0 |
| 8 | 2.7 |

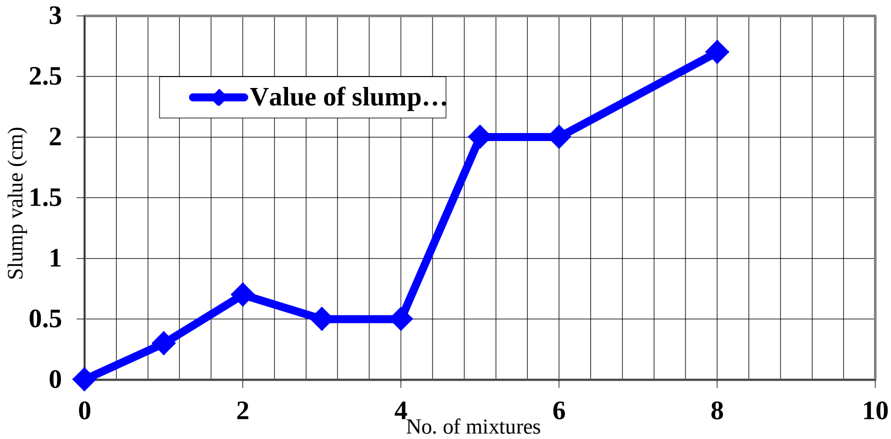

Fig. (3) show the slump of concrete mixtur at added of light wieght ggregate

It also noted from table (6) and figure (3) that the amount of slump is directly proportional to increase the proportion of lightweight aggregates in the mixture of concrete, and decrease the proportion of natural aggregates contrast as increasing the value of slump of 0.0 cm in the reference mixture No. 1 to 2.7 cm, in the mixture No. 8, which is free from natural course and fine aggregates, where is caused due to untie absorption polystyrene (plastic properties) of water mixture compared to natural aggregates.

### 6.1.5 Gravimetric density (weight density)

The table (7) shows the results obtained from the measurement at least three cubes for each of mixture to used polystyrene material group as a lightweight aggregate, and has been calculate the density of concrete admixtures of divided of the rate cubes weight of each calculated mix by (kg) on a per cubic volume calculated per cubic meter.

Through studying the table (7) and figure (4) for mixtures of constant water cement ratio equal (0.5) and all mixtures, it was note that the density of reference mixes free from lightweight aggregate replaced by natural aggregates equal to (2331) kg/cubic meter and is within the scope of concrete moderate density which ranges from (2100-2500) kg/cubic meter.

As for mixtures group (2, 3, 4, 5, 6, 7, 8) container proportions of light-weight pumice (polystyrene) and as mentioned in the table (1) special properties of mixtures, note that the density inversely proportional with increase the proportion of volume polystyrene in the mixture, it decreased density to 1266 kg/cubic meter of No.(6) free mixture of natural course aggregate, and to 532 kg/cubic meter for the mixture No.(8), from natural course and soft aggregates.

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Table (7) show result density of concrete mixture at Polystyrene added.

| Mixture No. | Density (kg/m3) |
|---|---|
| 1 | 2331 |
| 2 | 2202 |
| 3 | 2051 |
| 4 | 1775 |
| 5 | 1500 |
| 6 | 1266 |
| 7 | 931 |
| 8 | 532 |

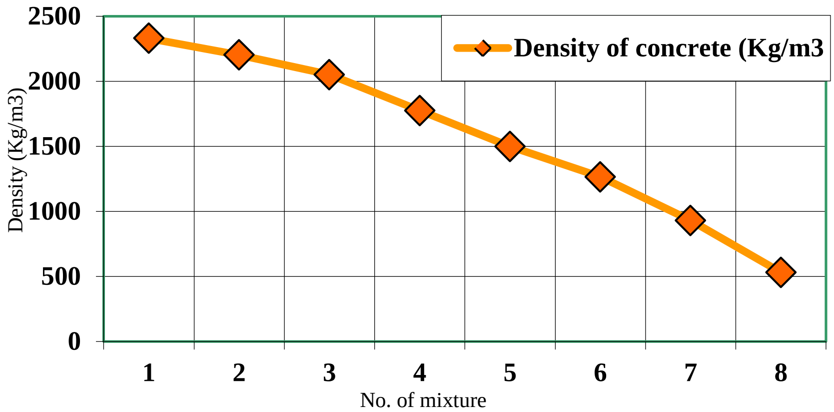

Figure (4) show the density of all mixture with additional light weight aggregate

## 6.1.6 Pressure resistance

Table (8) shows the results of compressive strength of cubes mixtures group of (1 to

results. Pressure resistance measured at ages (3, 7,14, 28) days for to investigate the development of pressure-resistant all mixtures, Figure (5) and Figure (6) illustrate the results of the group.

Through studying the figures (5) and (6) of the group mixtures at the proportion of (water/cement) = 0.50 and installed in the table (8) of stress resistance results. It is clear that the pressure resistance increases with increase the age and for all mixtures, and note that the pressure resistant suit in reverse with increase the proportion of lightweight aggregates in the concrete mixture.

The mixture considered the reference number (1) high pressure resistance, reaching a value of (45.3 Mpa) at 28 days, either mixtures (2, 3 and 4), which container portions of polystyrene (pumice) (10%, 25% and 50%) respectively, replacing the volume of coarse aggregate in concrete mixture, shall be considered acceptable resistance to limit extent and commensurate with the located proportion of lightweight aggregates where was valued at 28 days (10.7, 22.8 and 24.0 Mpa) respectively. For the mixtures (5 and 6) which contain the proportions of pumice (50% and 100%) respectively, replaced the volume of coarse aggregate in the concrete mixture, where are considered weak compressive strength compared to reference mixture (1) which has reached the limits (3.7and 5.9 Mpa) respectively at the age of (28) days.

The mixtures (7and 8) completely free of gravel, and which was also sand rate replacement (50% and 100%) respectively with pumice, and were the pressure resisting is very weak, despite the homogeneity of the mixture of the concrete has reached resistance (0.0 and 1.4 Mpa) on respectively at 28 days.

Table (8) results of compressive strength at period time

| Mixture No. | Compressive strength (Mpa) at period time store | | | |
|---|---|---|---|---|
| | 3 days | 7 days | 14 days | 28 days |
| 1 | 24.4 | 32.1 | 33.8 | 45.3 |
| 2 | 5.6 | 16.6 | 21.9 | 24.0 |
| 3 | 12.8 | 15.7 | 20.7 | 22.8 |
| 4 | 5.7 | 7.7 | 10.7 | 10.7 |
| 5 | 3.4 | 5.3 | 5.4 | 5.9 |
| 6 | 1.5 | 1.8 | 3.6 | 3.7 |
| 7 | 0.9 | 0.9 | 1.2 | 1.4 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 |

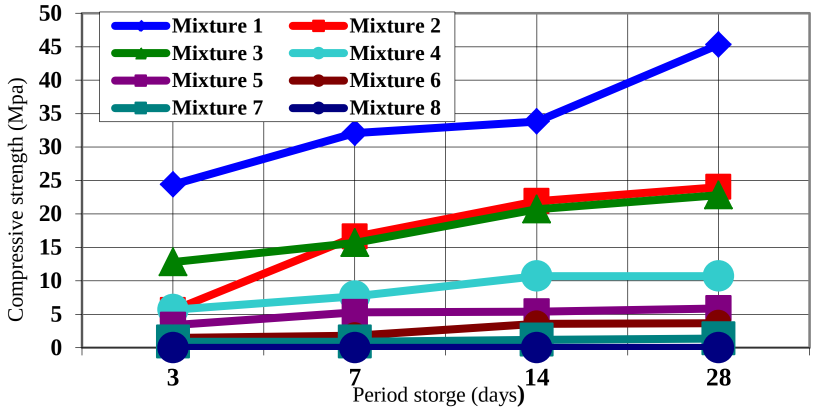


Fig. (5) show relation ship between the period of storge and compressive strength for all mixtures with addetional light weight aggregate

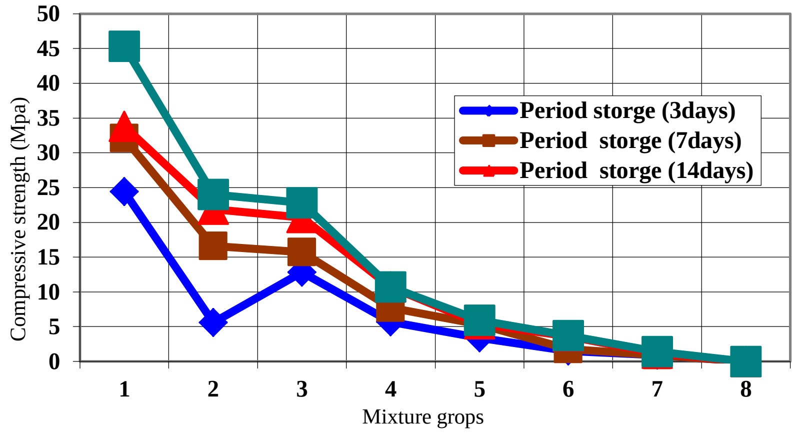


Figure (6) show progress of compressive strength for every grop at period storge for all mixtures with addetional light weight aggregate

## 7. Conclusions

### 7.1 Sieve analysis

1. When mixing coarse aggregate ratios listed in the table (2) of the sizes of (0.5, 1.0 and 1.5 cm) can be obtain gradient appropriately located within the boundaries of the Libyan standard specifications No. (49), upper and lower.
2. Sand used is fineness grading where almost size particles located at within Sizes (0.15 mm) and (0.3 mm).

### 7.2 Specific weight and absorption

1. The results of the specific weight and the proportion of the absorption of natural course and fine aggregates within range of normal limits.
2. The lightweight aggregates have been observed from the table (5) significant disparity in the value of the specific weight of the natural course aggregate, soft aggregate and lightweight aggregate. Therefore, it replaced the quantities of natural aggregate by lightweight aggregate, based on volumetric ratios, and not by weight ratios for to get ensure the stability of the size of the concrete mixtures.

### 7.3 Slump test

1. The water/ cement ratio is constant and equal to (0.50) for all mixtures mentioned in the table (6)
2. The amount of slump for the reference mixture is (0.0 cm) which is less than the boundary of the design requirements because of gravel and crushed softness of the sand used in the mixture.
3. The amount of slump for all mixture of first group (2, 3, 4, 5, 6, 7, 8) which is containing pumice (polystyrene), it located less than the boundary of the design requirements for concrete mixes regular business as well.
4. In general, the amount of slump is direct proportional to increase the proportion of lightweight aggregates in concrete mixture, where caused due to the lack polystyrene of water absorption mixture, and in other hand decrease the proportion of natural aggregates in return.
5. 

### 7.4 Density

1. The reference mixtures of free from lightweight aggregates at density (2331) kg/cubic meter within the boundary of normal concrete and moderate density.
2. For mixtures group which user pumice as lightweight aggregate observed that the density inversely proportional to the increase of size proportions in concrete mixture.
3. The first group mixtures (2, 3, 4, 5, and 6) which replaced the coarse aggregate to pumice proportions (10%, 25%, 50%, 75%, and 100%) respectively, the density moderate mixtures ranged between (1266 kg/cubic meters to 2022 kg/cubic meter) .
4. The Mixture (7, 8) which replaced the fine aggregate and coarse aggregate to pumice percentages (50%, 100%) respectively, were the density of mixtures very low, which ranged from (532 kg/cubic meters to 931 kg/cubic meter), where the final mix cubes floating in the water treatment basin.

### 7.5 Compressive strength test

1. The compressive strength of the reference mixtures at ratio (water/cement) = (0.5) is good and within the design ranging where was reaching (45.3 Mpa) at 28 day.

2. For mixtures user group of pumice is clear that the compressive strength increases with age store, and also for all mixtures note that the compressive strength inversely proportional with the increase the proportion of lightweight aggregates in the concrete mixture.
3. The mixture (2, 3, and 4) containing ratio of pumice (10%, 25%, and 50%) respectively, replacing the volume of coarse aggregate in the concrete mixture, shall be consider acceptable resistance to some extent and commensurate with found proportion of lightweight aggregates.
4. The mixture (5, 6) container the percentage of pumice (50%, 100%) respectively, replacing the volume of coarse aggregate in the concrete mixture, the compression resistance was weak compared to the reference mixture.
5. The mixtures (7, 8) which were completely free from gravel, and were sand replacement rate (50%, 100%) respectively by pumice, were compressive strength is very weak despite the homogeneity of the concrete mixture.

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