The Possibility of Produce Self Compacted Polystyrene Concrete

Lect. Manolia Abed Al-wahab Ali
Al-mustansiriya University
College of Engineering
Material Eng. Dep.

Abstract

The aim of this study is to produce one types of self-compacted lightweight concrete which is known as self-compacted polystyrene concrete (SC-PC) . The SC-PC was produced by using expanded polystyrene beads as a partial replacement by volume of sand,(Glenium 51) as a superplastisizer and styrene butadiene rubber (SBR) as a viscosity modifying agent to prevent the segregation of beads .Also studying the fresh and hardened properties of (SC-PC) (density, compressive, strength, flexural strength and tensile strength).

The results indicated that it is possible to use polystyrene beads for producing (SC-PC) with density ranging from (1660-1895)kg/m^3 and a 28-days compressive strength ranging from (10.23 – 14.65) MPa .

The results also showed that the properties of (SC-PC) are mainly influenced by the content of polystyrene beads and decrease with the increase of polystyrene content . The density of (SC-PC) decreases to (12.4%) when the percentage of sand replacement with polystyrene beads increased from (16.7% to 50%) .While the compressive , tensile and flexural strength decrease to (30.17, 37.93 and 43.3%) respectively when the polystyrene content increased from (16.7% to 50%) by volume of sand .

إمكانية إنتاج خرسانة البوليستايرين الذاتية الرص

الخلاصة

تهدف هذه الدراسة إلى إنتاج احد أنواع الخرسانة الخفيفة الذاتية الرص والتي هي خرسانة البوليستايرين الذاتية الرص ، تم إنتاج هذه الخرسانة باستخدام حبيبات البوليستايرين المتمددة كاستبدال جزئي من حجم الرمل مع (Glenium 51) كملدن متفوق و(styrene butadiene rubber) (SBR) كعامل مساعد للزوجة لمنع انعزال حبيبات البوليستايرين . كما تم دراسة الخواص الطرية والصلبة لخرسانة البوليستايرين الذاتية الرص و هي (الكثافة ومقاومة الانضغاط والشد والانثناء) .

لقد دلت النتائج على إمكانية استخدام حبيبات البوليستايرين في إنتاج خرسانة البوليستايرين ذاتية الرص بكثافة تتراوح بين (1660 – 1895)كغم/م3 ومقاومة انضغاط بعمر 28 يوم بين (10,32 – 14,65) ميكا باسكال .

كما أشارت النتائج إلى أن خواص (SC-PC) تتأثر بشكل كبير بمحتوى البوليستايرين حيث تقل بزيادة محتوى البولستايرن. كثافة (SC-PC) تقل بمقدار (12,4%) عندما تزداد نسبة استبدال الرمل بالبولستايرين من (16.7% - 50%) . بينما مقاومة الانضغاط والشد والانثناء تقل لحد (30,17% و 37,93% و 43,3%) على التوالي عندما محتوى البوليستايرين يزداد من (16,7% - 50%) من حجم الرمل .

Introduction

Lightweight concrete (LWC) is one of the important materials in construction industry because of the practical and economic advantage of it. The essential characteristic of (LWC) is its porosity , which results in low apparent specific gravity .In concrete construction self weight represent a very large portion of the load on the structure , and there are considerable advantages in reducing the density of concrete . Furthermore , (LWC) reduces the cost of form work and steel and it also increases productivity . Concrete which has lower density also gives better thermal insulation than ordinary concrete[1,2,3] .

Many production of LWC had been designed and among them are by the use of lightweight aggregates (LWA) and artificial aggregate such as fly ash , slag and porcelinite rocks and most the process of manufacturing (LWC) is very costly as complex machinery or expensive (LWA) are used . This has lead to a search for substitute for expensive LWA by using the polystyrene beads, which is chosen due to its lightweight properties with density between (16-27)kg/m^3,good thermal energy absorbing characteristic and good thermal insulator leading mainly to non-structural application .

Several researchers[3,4,5] , studied the structural, physical and mechanical behavior of polystyrene concrete . They avoided vibration compaction during the manufacturing of (PC) and compacted their mixes by hand tamping to minimize the segregation of polystyrene beads because of it's low density. Therefore the main aims of this investigation is to use polystyrene beads to produce (SC-PC) which is a special type of concrete mixture characterized by high resistance to segregation that can be cast without compaction or vibration , because it becomes leveled and compacted under its self-weight . So that it is very important to study the mechanical properties (density, compressive, tensile and flexural strength) of (SC-PC) .

Polystyrene Concrete (PC)

Polystyrene is vinyl polymer produced by free radical vinyl polymerization. While expandable Polystyrene (EPS) is polystyrene in raw beads being steam-heated, causing it to expand and forming a cellular structure. This process is best carried out when the aggregate is required, since this minimizes transport costs. Polystyrene has so many commercial names such as "styropor", and it is used mainly as insulating materials. The expanded beads have an apparent density of about (16-27)kg/m^3 . The beads are inelastic, and do not recover when deformed, yet they are able to withstand the stresses when the concrete is mixed. The thermal

conductivity of polystyrene is very low which improves the thermal characteristics of concrete when used as a substitute for the aggregate[3,4,6].

Polystyrene concrete is a lightweight concrete made with expanded polystyrene beads, it is known for its good thermal and caustic insulation properties, it has also been considered for use as a core material in sandwich panels , beams and slabs . Some researchers[5,7,8], studied the properties of polystyrene concrete like density , compressive and flexural strength, dynamic modulus of elasticity and thermal conductivity . Their results showed that these properties are affected by the polystyrene concrete and decrease with increase the polystyrene cement ratio. While Sussman[9] concluded that the mechanical properties of (PC) increase with the increase of its density and these properties are controlled by the water to cement ratio.

Maura[10], also produced (PC) with densities between (220-460)kg/m^3 and compressive strength between (0.7-2.3)MPa, while modulus of rapture was between (0.3-0.36)MPa.

Ismail[4] studied the properties of hardened concrete bricks containing polystyrene beads and he found that (PC) is very prone to segregate where placing and compacting can be quite difficult using vibratory compaction techniques .Also he found that the (PC)bricks with densities less than 1800kg/m^3 have very low strength which can be used as a non-load bearing internal wall while the (PC) with density of (1646)kg/m^3 have compressive strength of (14MPa) which is suitable to use as a load bearing internal wall .

Kuhail[3], studied the characteristics of (PC) and he proved that the proposed mix is very reliable giving strength of up to 200kg/cm^2 with low density. Also he found very high mix workability at a very low water/cement ratio (down to 0.35).

Experimental Work

Materials

Cement

Type (1) ordinary Portland cement was used, its chemical and physical properties are conformed to the Iraqi specification NO.5/1984.

Fine aggregate

Natural siliceous desert sand is used as fine aggregate and it is conformed to requirement of the Iraq specification NO.46/1984, zone(2) .

Expanded polystyrene beads (EPS)

Polystyrene beads with diameters of (4mm) is used as a partial replacement of fine aggregate with apparent density of 16.5kg/m^3.

Mixing Water

Ordinary tap water is used in this work for all concrete mixes and curing of specimens.

Superplasticizer

For the production of (SCC) a superplasticizer is needed .In this work (Glenium51) superplasticizer is used, it's compositionis based on polycarboxylic ether. It conformed to the requirement of types A and F and of ASTM C 494 standard.

Polymer

Is a styrene-butadiene rubber copolymer (SBR) which is specifically designed for use in application need a significant improvement in the bonding strength to various substrates. Therefore , it is used in this research as a viscosity modifying agent which is needed to prevent segregation of polystyrene beads from mixture and produce self-compacted polystyrene concrete (SC-PC) . The Gulf International Chemicals Company, Oman, manufactured this polymer and the typical properties of (SBR) polymer are shown in Table (1). The polymer (SBR) is used as a ratio by weight of cement of (10%).

Table (1)typical properties of (SBR) polymer*

Properties	Description
Appearance	White emulsion
Specific gravity	1.01 @ 25c
PH value	5.5
Freeze / thaw resistance	Excellent
Chloride content	Nil
Flammability	Non – flammable
Compatibility	Can be used with all types of Portland cement

***** 1 (volume) of SBR mixing with (1) volume of water to produce a liquid polymer which is added to concrete mix.

Experimental Program

The main aim of this research is to produce (SC-PC) .Therefore, the first step was to obtain the polystyrene concrete mix (PC) by using a concrete mix having the proportions of (1:3:0) by volume of (cement: sand: polystyrene) with cement content of 300 kg/m^3 and water: cement ratio of 0.45 as a control mix. Then prepared three different (PC) mixes from the control mix by a partial replacement of sand with polystyrene beads .So, the three mixes differ from each other by the content of polystyrene beads. These mixes were prepared by volume because the beads are very light in weight and density compared with other materials.

The (SC-PC) that satisfies the criteria on filling ability , flowability , passibility and segregation resistance can be obtained by using a superplasticizer which is (Glenium51) .But with adding it in three (PC) mixes , the polystyrene beads began to float and accumulate at the top surface during mixing . This has lead to add another chemical admixture that prevent the beads from segregation. The idea of using (SBR) polymer as a viscosity modifying agent has been introduced, as the (SBR) improve the bonding strength of the various materials and prevent the beads from floating. The white emulsion (SBR) was used after mixing it with water by volume proportion (1:1) (water: SBR) . After many trails, one (w/c) ratio was used in this research (0.325) with different dosage of (Glenium51) to satisfied the properties of (SC-PC) . The details of the three mixes used throughout this research are given in Table(2) .

Table (2) :-Details of (SC-PC) mixes

Mix symbol	Mix proportions ratio*(C:S:P) by volume	Cement content kg/m^3	W/C** ratio by weight	(SP)*** by weight of cement (%)	(SBR) by weight of cement (%)
R	1:3:0	300	0.450	-	-
A	1:2.5:0.5	300	0.325	10.2	10
B	1:2:1	300	0.325	9.5	10
C	1:1.5:1.5	300	0.325	8.0	10

* C:S:P = cement : sand : polystyrene beads

** W/C = water / cement ratio

*** SP = superplasticizer

Method of mixing

The mixing of (SC-PC) mixes was done by adding the dry cement and sand together in to mixer and mixed for approximate (1) minute . The required amount of (SBR) was then added and mixing continued for a further (2) minutes. After that the water and (SP) were added slowly until the desired consistency is reached. Then the polystyrene beads were added and thoroughly mixed into the mortar.

Testing of fresh concrete

Testing of concrete in its fresh state is a major focus on this study. (SCC) is defined by its behavior when it is in the fresh state, and it is determined whether concrete meats certain requirements while fluid is paramount concrete as SCC or not . The slump flow, L-box and V-funnel are all used for all mixes of this study .The details of these tests could be found in many references[11,12,13]. The test results of the fresh properties of (SC-PC) mixes are given in Table (3) and shown in Fig(1)and Fig (2) .

Table (3):- Fresh properties of (SC-PC) mixes

Mix symbol	Slump flow (mm)	T_{500mm} (Sec)	L-Box	V-Funnel	
			Block ratio	T_V(Sec)	T_{V5}(Sec)
A	700	4	0.88	9	11.5
B	720	3	0.94	7	9.5
C	670	4	0.83	10	13.0

Fig (1)Slump flow test

Fig (2) L-Box test

Testing of hardened concrete

Air dry density

This test was carried out by using 100mm cubes after 28-days of water curing. Three specimens were used for each mix .The tests was conducted according to ASTM C330-82 [(14)].

Compressive strength

The test was carried out according to BS. 1881:part 116:1989[(15)] by using 100mm cube . the concrete compressive strength of each strength of mix represent the average of three specimens . They were tested at 28-days of water curing. See Fig (3)

Splitting tensile strength

This test was conducted in accordance to ASTM C496-68[(16)] .it was carried out on a 100x200mm concrete cylinder tested at 28-days after curing . Three specimens were used for each mix . The tensile strength is calculated according to the following equation.

$$F_{st} = \frac{2P}{\pi Ld} \quad \text{.....(1)}$$

Where:

F_{st}= splitting tensile strength (MPa)

P = maximum load (N)

L = length of the specimens (200mm)

d = diameter of the specimens (100mm)

Modulus of rupture (Flexural strength)

This test was carried out according to ASTM (78-84)[17] by using a (100x100x500)mm prism specimens . The prisms were subjected to two point load and tested at 28days of water curing. The average of three specimens was adopted for each mix. The flexural strength is calculated according to the following equation.

$F_{bt}= \frac{PL}{bd^2}$ ……(2)

Where:

F_{bt} = Modulus of rupture (MPa).

P = maximum load (N) .

L = distance between the supports (400 mm).

b = the width of the specimen (100 mm).

d = the depth of the specimen (100 mm).

Fig (3)sample of cubes and cylinders of SC-PC (mix A)

Result and discussions

Air dry density

Density is the first indicator if the material can be considered into the lightweight material category or not[4]. Table(3) and Fig(4) show the average density for each mix of (SC-PC)

which produced by using different content of expanded polystyrene beads (EPS) as a partial volume replacement of fine aggregate . The results show that there is a direct relationship between the polystyrene content and the density of the specimens. There is a reduction in these value as the polystyrene content is increased . Because the polystyrene beads responsible about the low weight and low density of the concrete mixes.

Table (3):- density of (SC-PC)

Mix symbol	Percentage of sand replacement (%)	Density (kg/m^3)
R	0.0	2176
A	16.7	1895
B	33.3	1761
C	50.0	1660

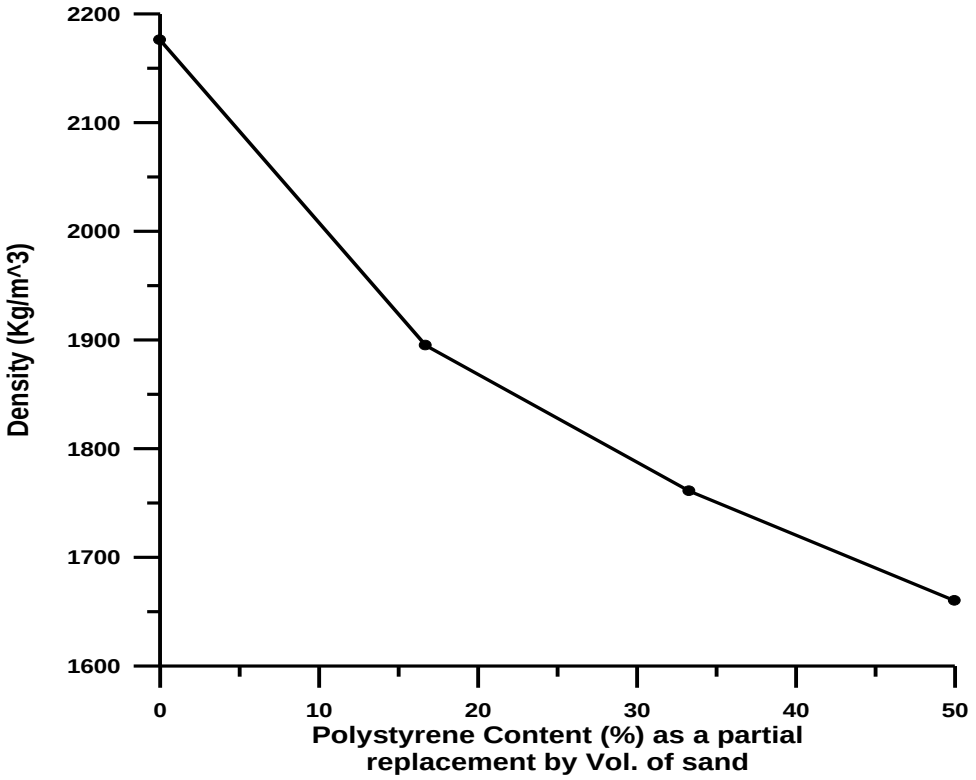

Fig. (4): Density of (SC- PC) with various content of polystyrene beads

Compressive strength

The compressive strength test results are presented in Table (4) and plotted in Fig.(5) . The results show that the compressive strength decreases with increase the polystyrene content . The percentage of reduction in compressive strength increases to (11.26% and 30.17%) for mix (B and C) respectively compared with that of mix (A) when the percentage of sand replacement by polystyrene beads increased by (33.3% and 50%) respectively . That

reduction in compressive strength is due to the beads weakness in compression and also because the polystyrene beads do not react chemically with the mix to contribute strength[3,4] .

Table (4):- compressive strength of (SC-PC)

Mix symbol	Percentage of sand replacement (%)	Compressive Strength(MPa)
R	0.0	19.70
A	16.7	14.65
B	33.2	13.00
C	50.0	10.23

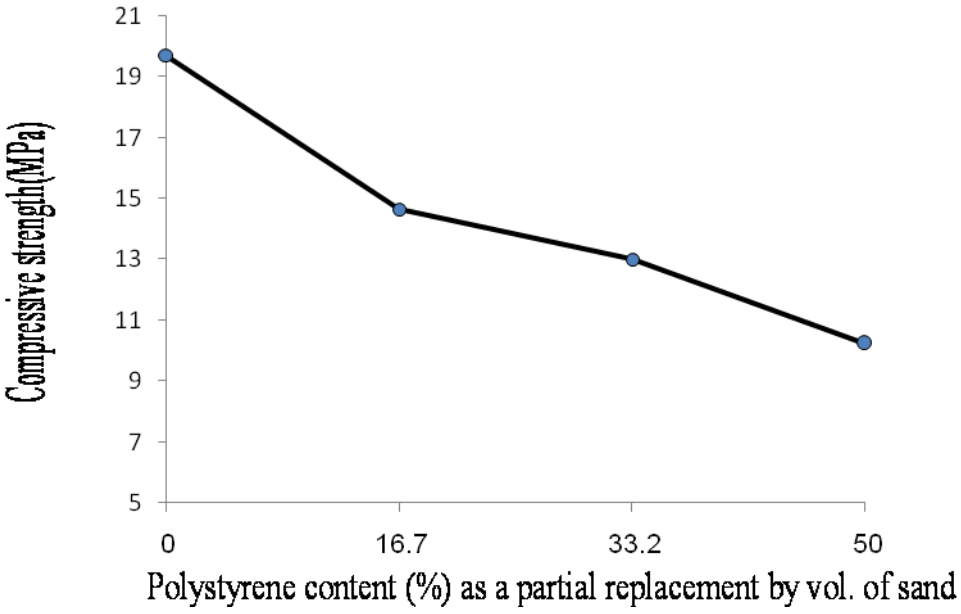

Fig.(5): Compressive strength of (SC- PC) with various content of polystyrene beads

Splitting tensile strength

The splitting tensile strength for the three mixes of (SC-PC) cured in tap water up to 28-days are shown in Table (5) and represented in Fig.(6) and Fig (7)

Table (5):- Tensile strength of (SC-PC)

Mix symbol	Percentage of sand replacement(%) by volume	Splitting Tensile strength (MPa)
R	0.0	1.77
A	16.7	1.45
B	33.3	1.21
C	50.0	0.90

The results show that the tensile strength decrease with adding the polystyrene beads and the amount of reduction depends upon the polystyrene content in the concrete specimens. The percentage of reduction in tensile strength increases to (16.55% and 37.93%) compared with mix (A) when the percentage of polystyrene beads is increased to (33.3% and 50%) , respectively .

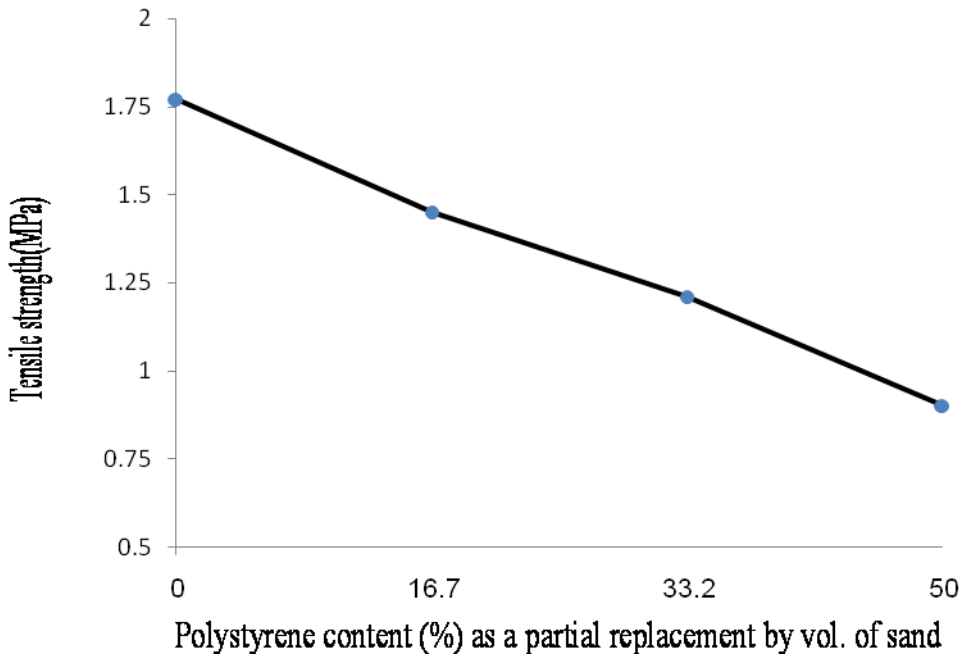

Fig. (6): Tensile strength of (SC-PC) with various content of polystyrene content

Fig(7) shows the good distribution of polystyrene beads through the concrete mix, which is due to the effect of (SBR) for preventing the polystyrene beads from segregation and floating to the top surface.

Mix (A)

Mix (C)

Fig(7)The failure in tensile strength for mixes (A and C)

Modulus of rupture (Flexural strength)

The test results of modulus of rupture for the three types of (SC-PC) (A, B and C) are shown in Table (6) and plotted in Fig(8). It was observed that the flexural strength test at 28-days show similar behavior, compared with compressive and tensile strength, where the modulus of rupture decreases with increase of polystyrene content .For example, the amount of reduction in flexural strength for mixes (B and C) compared with mix (A) increases to (19.9% and 42.3%) when the polystyrene content was increased to (33.3% and 50%) , respectively .

Table (6):- Modulus of rupture (SC-PC)

Mix symbol	Percentage of sand replacement (%) by volume	Modulus of rupture (MPa)
R	0.0	3.85
A	16.7	3.12
B	33.3	2.50
C	50.0	1.80

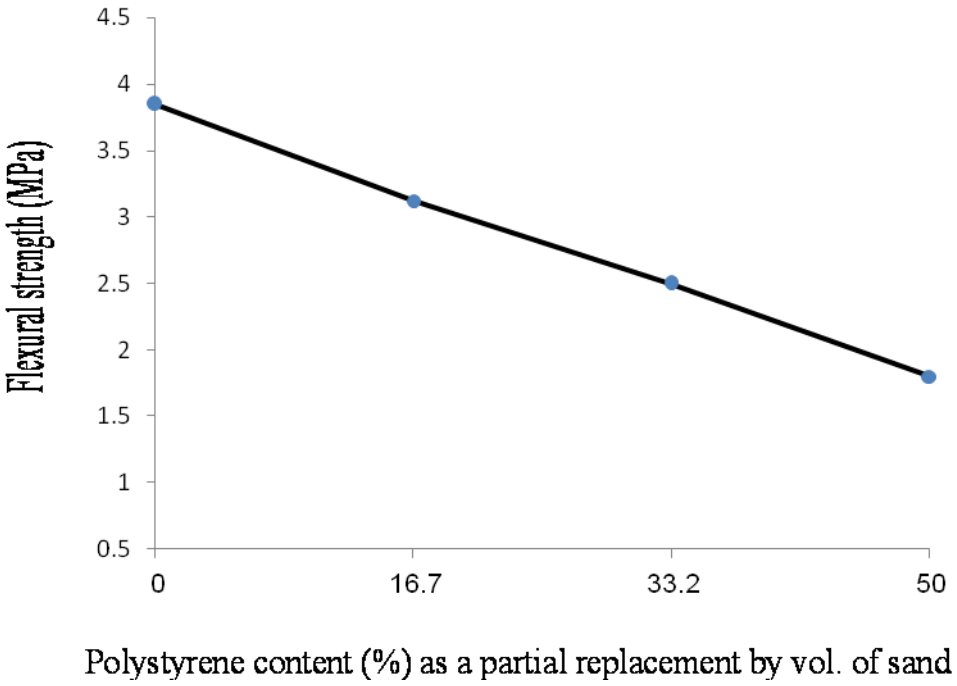

Fig. (8) Modulus of rupture of (SC- PC) with various content of polystyrene content

Fig (9) failure in modulus of rupture of SC-PC (mix B)

Conclusions

1 – It is possible to produce various type of self-compacting polystyrene concrete (SC-PC) by the addition of polystyrene beads as a partial replacement of fine aggregate and using (SBR) polymer with ratio of (10%) by weight of cement and superplastisizer which is (Glenium 51) .

2 – The densities of (SC-PC) mixes were between (1660-1895)kg/m^3 with a 28-days compressive strength ranging between (10.23-14.65)MPa . Mix(A) with density of (1895)kg/m^3 and compressive strength of (14.65)MPa is the most suitable mix to be used for the production of masonry units which are used for load bearing internal wall. While mix(C) with density and compressive strength of 1660kg/m^3 and 10.23MPa is suitable to be used for non-structural purpose and mainly for thermal insulation purpose

3 – The density of (SC-PC) mixes decrease with increase the polystyrene content as a partial replacement of fine aggregate . The percentage of reduction in density was (7.1 and 12.4%) when the percentage of sand replacement with polystyrene beads was (33.3 and 50%) , respectively compared with their density at 16.7% replacement .

4- The mechanical properties of (SC-PC) mixes (compressive tensile and flexural strength) decrease with increase the content of polystyrene beads . for example , the reduction in (compressive , tensile and flexural strength) increase to (30.17% , 37.93% and 43.3%) , respectively when the percentage of sand replacement with polystyrene beads increased from (16.7 to 50%) .

References

1 – Neville, A.M., "**properties of concrete**" , long man group limited, London, fourth and final edition, 2000, p.831.

2 – Spratt, B.H., **"An introduction to lightweight concrete**", cement and concrete association, fifth edition, 1975, pp.1-17.

3 – Kuhail, Z., "**polystyrene lightweight concrete (poly concrete)**", An-Najah university. J. Res, vol.15, 2001, pp.41-61 .

4 – Ismail, I., Saim, AA. And Saleh, A.L., "**properties of hardened concrete Bricks containing expanded polystyrenebeads**", 5th Asia-pacific structural engineering and construction conference (APSEC 2003), Aug. 2003, Johor Bahru, Malaysia, pp. 171-179 .

5 – الجيلاوي ، ندى مهدي، **"خواص الخرسانة خفيفة الوزن مع دراسة العزل الحراري والمعاوقة الصوتية"**، اطروحة ماجستير، جامعة بغداد، كلية الهندسة، 1997، 107صفحة .

6 – BASF, **"A polystyrene manufacture",** Technical Reports, Germany, 1997, www.(After Ref.3).

7 – Parton, G.M., "**polystyrene beads concrete properties and mix Design"**, Magazine of concrete research, vol. 44, No.3 1982, pp.153-161), (after Ref. 4).

8 – Baun, G., **"styropore concrete technology properties and application**", beton information, 1974 .

9 – sussman, V. , **"lightweight plastic – aggregate concrete",** ACI, Journal proceeding, vol. 27, No.7, July 1975 .

10 – Maura, G. **, "Lightweight concrete made with expanded polystyrene**" , IL. Cement, 75, part 1 , 1978, pp. 21-29 .

11- Al –jabbri ,L.A., **"The influence of the mineral admixtures and steel fibers on the fresh and hardened properties of SCC"**, M.Sc. Thesis, Al-Mustansiriya University,Iraq,2005,p.135.

12- Ali ,M.A., **"Effect of shape and size of specimen on some mechanical properties of (20-80)MPa self –compacting concrete** "M.Sc., Thesis, Al-Mustansiriya University,Iraq,2007.

13- Hussian, Z.M.A, **"The effect of grading of aggregate on the properties of self compacting concrete"** M.Sc. Thesis, Al-Mustansiriya University, Iraq, 2008, p.124.

14- ASTM C330-82 **,"Lightweight aggregate for structural concrete "**, Annual book of ASTM standards , vol. 04-02, 1984 , pp. 243-246 .

15 – B. S. 1881, part 116, "**Method for determination of compression strength of concrete cubes"**, British standards institution, 1989, 3pp.

16 – ASTM C496-86, "**standard test method for splitting tensile strength of cylindrical concrete specimens"**, Annual book of ASTM standards, vol. 04-02, 1989, pp. 32-34.

17 – ASTM C78-84, "**standard test method for flexural strength of concrete (using simple beams with third point loading)",** Annual book of ASTM standards, vol.04-02, 1989, pp. 32-34.