

## Experimental study of lightweight concrete used for the production of canoe

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### Abstract

This study was conducted to investigate the properties of lightweight concrete produced by the inclusions of polystyrene beads and perlite that can be used for production of Canoe. Different percentages of polystyrene (20, 35, 50 and 65%) were used. Besides, the 50% of polystyrene beds with different percentages of perlite (10, 20, 30, 40, 50 and 60%) as partial replacement of sand were used. The fresh density, compressive strength, flexural strength and absorption capacity of the mixes were tested. The results show that the uses of 50% of polystyrene with 50% of perlite as partial replacement of sand exhibit suitable ranges of density, compressive and flexural strengths of lightweight concrete used for canoe production. Thus, the Canoe produced from these inclusions of polystyrene and perlite show a clear success in terms of floating.

**Keywords:** Concrete Canoe, Lightweight concrete, Perlite, Polystyrene.

### دراسة تجريبية للخرسانة الخفيفة الوزن المستخدمة في صناعة القوارب الخرسانية

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### الخلاصة

هذا البحث يتناول دراسة خصائص الخرسانة الخفيفة الوزن المصنعة من قطع الفلين مع البرلايت وذلك لتصنيع قارب خرساني. لذلك تم استخدام نسب مختلفة من الفلين وهي 20 و 35 و 50 و 65%. بالإضافة الى ذلك فان نسبة 50% من الفلين تم استخدامها مع نسب مختلفة من البرلايت كاستبدال جزئي من الرمل وهذه النسب هي 10 و 20 و 30 و 40 و 50 و 60%. الكثافة الرطبة ومقاومة الانضغاط ومقاومة الشد والامتصاص تم اختبارها للخلطات الخرسانية الخفيفة المصنعة. النتائج بينت بان استخدام نسبة 50% من الفلين مع 50% من البرلايت كاستبدال جزئي من الرمل اعطت مديات من الكثافة والمقاومة مناسبة لتصنيع القارب الخرساني. ولهذا فان القارب الخرساني المصنع من هذه الخلطة المحتوية على الفلين والبرلايت اظهرت نجاح واضح في فحص الطفو للقارب.

## Introduction

Numerous researches have been carried out on natural or artificial lightweight aggregates in order to produce lightweight structural concrete. The objectives of mix design are to achieve desired workability, density and most importantly, the strength of concrete with the most economic proportions [1-5]. Expanded polystyrene waste in a granular form is used as a lightweight aggregate for production of lightweight structural concrete that float on water [6]. Polystyrene is a thermoplastic polymeric material initially in the solid form and it can be expanded by the use of steam and expansive agents [7]. By incorporating the polystyrene material for different volumes in the concrete, mortar or in the cement paste, a wide range of concrete densities can be produced [7-9].

On the other hand, expanded perlite can be used for manufacturing lightweight concrete [10]. This material, white or light grey in color, is about 1/10 the weight of sand or gravel. Perlite mixes with about 30% less water than comparable lightweight aggregates [11].

One of the applications of lightweight concrete is the manufacture of concrete canoe. Therefore, this study aimed to investigate using of different percentages of polystyrene as well as perlite as a partial replacement of sand to produce lightweight concrete with acceptable values of density and compressive strength. Such a concrete can be used for manufacturing of canoe.

## 2. Materials and experimental

### 2.1. Materials

Ordinary Portland cement used in this study was manufactured by Badush factory and it conforms to Iraqi standard specifications (IQS 5:1984)[12] as shown in Tables 1 and 2. Normal sand which is called Kanhash sand, was used in this study, the fineness modulus and specific gravity of this sand were 2.7 and 2.63, respectively. The expanded polystyrene beads were obtained as raw materials from the commercial sources and these beads were small in diameter and hard. The beads were modified by boiling water to conform the expanded polystyrene beads. The diameter of such beads ranged from 1.5 to 3 mm. The density of these beads was 15 kg/m<sup>3</sup>. Besides, Perlite with specific gravity 2.2 and absorption 6.3% was used in this study. The max. aggregate size of perlite used in this study was 0.150 mm. Waterproofing materials (Betek-Aquaset) was used for ensuring that the canoe would be protected against penetration of water into the canoe. Lastly, reinforcement mesh distributed of 13 mm×13 mm square mesh with 1.0 mm diameter was used for the canoe production.

**Table 1. Physical characteristics of Ordinary Portland cement.**

Test	Results	IQS : 5/1984
Consistency	0.25	0.24-0.32
Initial setting time (minute)	120	Min. 45 minute
Final setting time (minute)	265	Max. 600 minute
Fineness, Blaine, m <sup>2</sup> / kg	275	Min. 230

**Table 2. Chemical properties of Ordinary Portland cement**

Constituent	Component of OPC (%)	Limits of IQS : 5/1984
SiO <sub>2</sub>	21.31	-
Al <sub>2</sub> O <sub>3</sub>	5.89	-
Fe <sub>2</sub> O <sub>3</sub>	2.67	-
CaO	62.2	-
MgO	3.62	≤ 5%
SO <sub>3</sub>	2.6	≤ 2.8%
Loss of ignition	1.59	≤ 4%
Insoluble residue	0.24	≤ 0.75%
Free CaO	1.74	-
L.S.F.	0.8818	-
C <sub>3</sub> S	33.37	-
C <sub>2</sub> S	35.92	-
C <sub>3</sub> A	11.09	-
C <sub>4</sub> AF	8.12	-

## 2. 2 Experimental tests.

In this study the maximum aggregate size for aggregate used in concrete is 4.75 mm. Therefore, the specimens of 50 mm cubes were cast and tested for fresh density, absorption and compressive strength. The test was conducted according to ASTM C642[13] and ASTM C109[14], respectively. On the other hand, the flexural strength was conducted according to ASTM C348[15]. Thus, the prisms 40 × 40 × 160 mm were used for this test. The flow design for all mixes ranged from 100 to 110 %.

## 3. Results and discussion

The properties of lightweight concrete mixes produced by the inclusion of polystyrene beads are shown in this section. However, the optimum mix was selected for the production of canoe. Then, the canoe was produced to examine it for floating test.

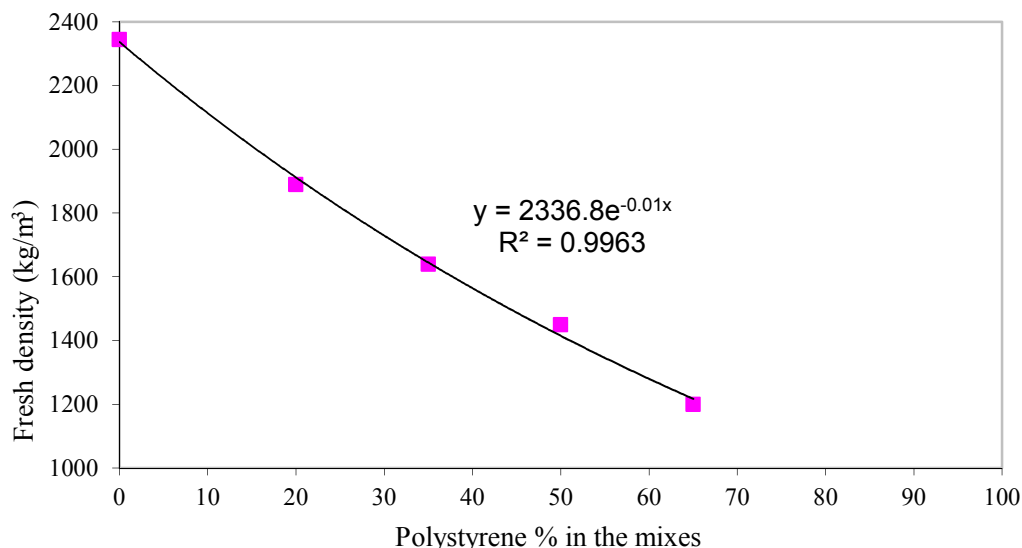
### 3.1. Density

The results of densities obtained from different lightweight concrete mixes are shown in Table 3. The results showed that the concrete is much influenced by the use of polystyrene beads. Therefore, the density of concrete was reduced from 2345kg/m<sup>3</sup> (Ref. mix) to 1200 kg/m<sup>3</sup>. This is obviously related to the specific gravity of the polystyrene beads which affect the density of the concrete [6]. Fig.1 shows the relation between density of concrete and polystyrene percentage. The inclusions of perlite with 50% of polystyrene decreased the density to more extent. The reduction in density also attributed to the specific gravity of perlite [8,12]. Thus, the relationship between density of concrete and perlite inclusions with constant percent of polystyrene 50% is shown in Fig.2.

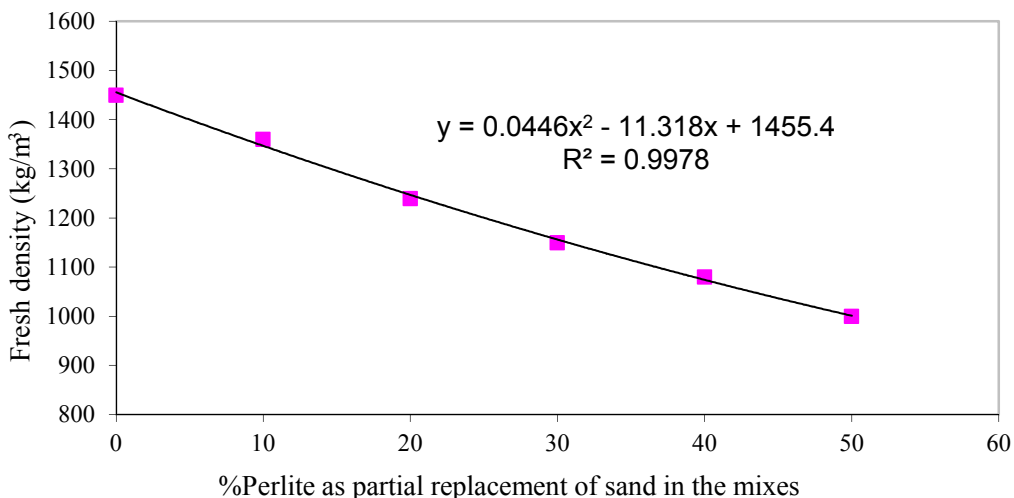
**Table 3. Mix proportion and values of fresh density**

Mix No.	Mix Proportion			Perlite % as partial replacement of sand	Polystyrene %*	Fresh Density kg/m <sup>3</sup>
	Cement	Sand	w/c			
P0	1	2.25	0.6	----	0	2345
P1	1	2.25	0.6	----	20	1890
P2	1	2.25	0.6	----	35	1640
P3	1	2.25	0.6	----	50	1450
P4	1	2.25	0.6	----	65	1200
P5	1	2.25	0.6	10	50	1360
P6	1	2.25	0.6	20	50	1240
P7	1	2.25	0.6	30	50	1150
P8	1	2.25	0.6	40	50	1100
P9	1	2.25	0.6	50	50	1000
P10	1	2.25	0.6	60	50	875

\* Volumetric percentages as addition.



**Fig.1 Relationship between density of concrete and Polystyrene percentage**



**Fig.2 Relationship between density of concrete and perlite percentage as a partial replacement of sand (constant percent of 50% Polystyrene in the mix).**

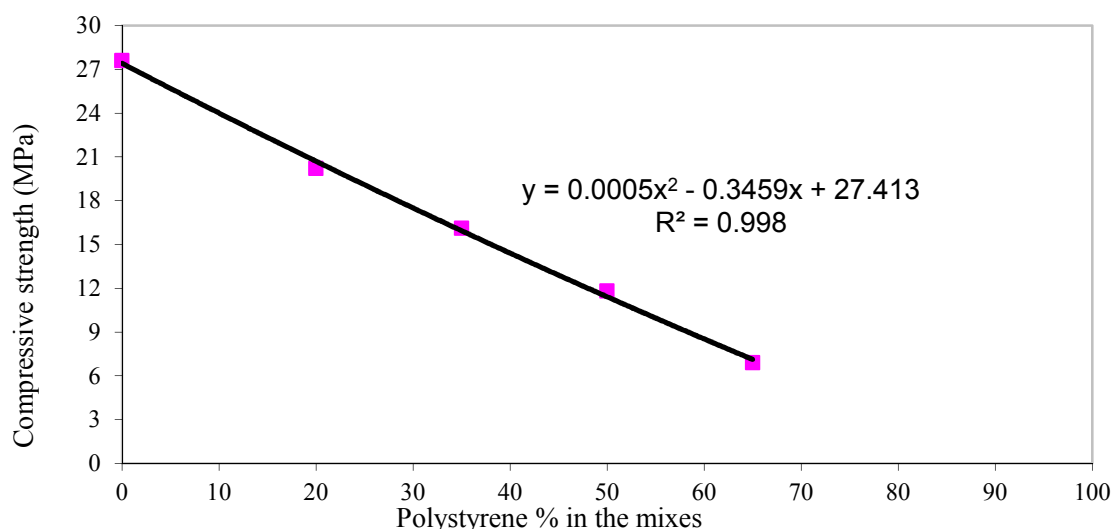
### 3.2. Compressive strength

The results of compressive strength at 28 days for lightweight concrete mixes are shown in Table 4. The reduction in compressive strength of concrete with the inclusion of polystyrene beads was found in this regard. Therefore, a significant reduction was recorded by the inclusion of polystyrene as 65%. Such inclusion, decreased the compressive strength from 27.6 MPa (Ref. Mix) to 6.9 MPa due to the stiffness of polystyrene beads which affects the properties of concrete [6-8]. The relationship between compressive strength of concrete and polystyrene beads is shown in Fig.3.

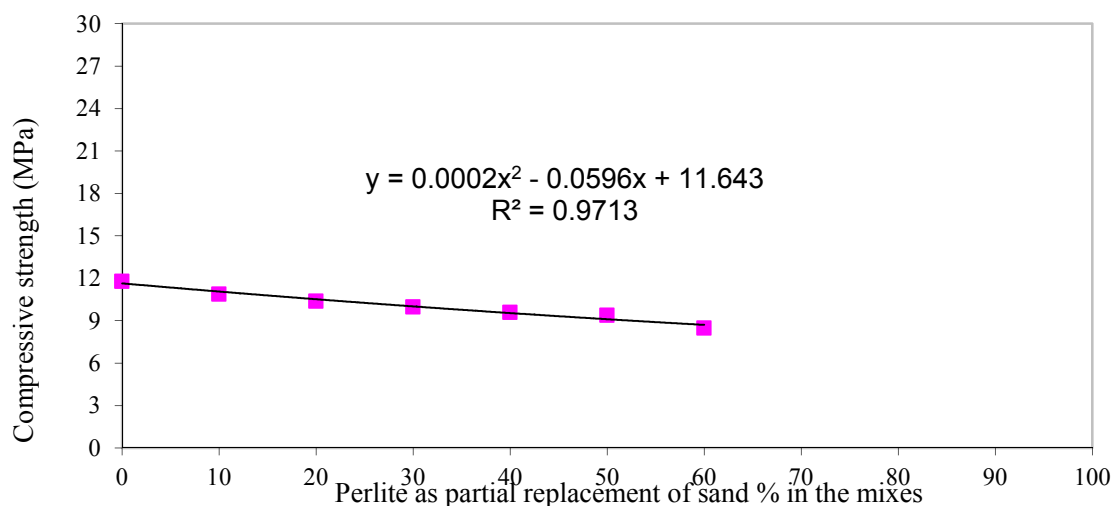
Besides, the inclusion of perlite with 50% of polystyrene decreased slightly the compressive strength of lightweight concrete. In this regards, a significant relationship is shown in Fig.4.

**Table 4. Mix Proportions and values of compressive strength, flexural strength and absorption.**

Mix No.	Mix Proportion			Perlite, %a prtial replacement of cement	Polystyrene, %	Compressive strength,28days (MPa)	Flexural strength 28days(MPa)	Absorption %
	Cement	Sand	w/c					
P0	1	2.25	0.6	----	0	27.6	4.85	5.65
P1	1	2.25	0.6	----	20	20.2	4.30	11.45
P2	1	2.25	0.6	-----	35	16.1	3.25	12.60
P3	1	2.25	0.6	-----	50	11.8	2.75	13.40
P4	1	2.25	0.6	-----	65	6.9	1.75	15.30
P5	1	2.25	0.6	10	50	10.9	2.45	13.80
P6	1	2.25	0.6	20	50	10.4	2.30	14.60
P7	1	2.25	0.6	30	50	10.0	2.25	15.50
P8	1	2.25	0.6	40	50	9.6	2.20	15.80
P9	1	2.25	0.6	50	50	9.4	2.10	16.40
P10	1	2.25	0.6	60	50	8.5	1.75	16.70



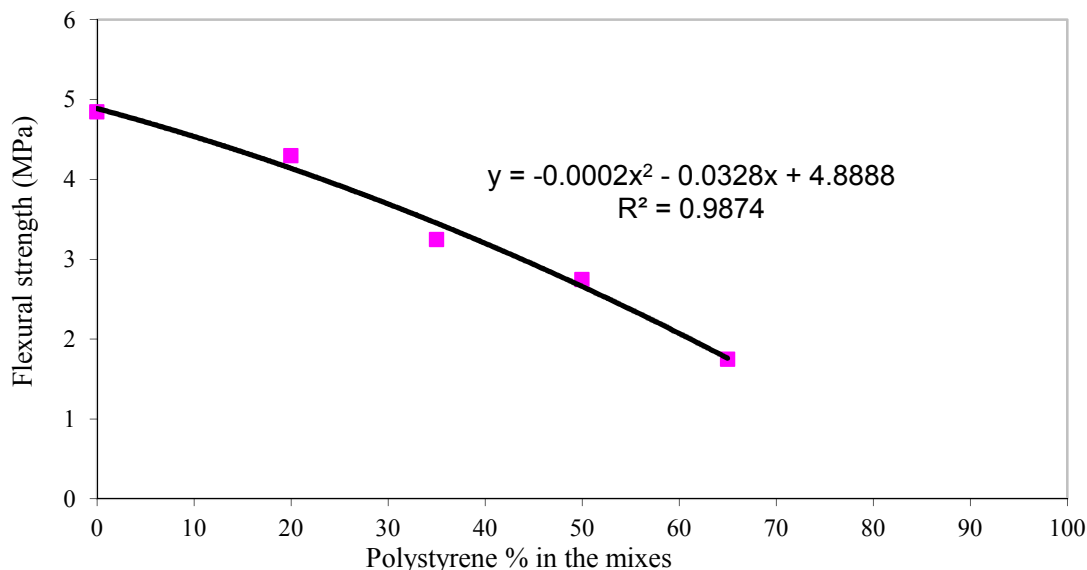
**Fig.3 Relationship between compressive strength of concrete and Polystyrene percentage.**



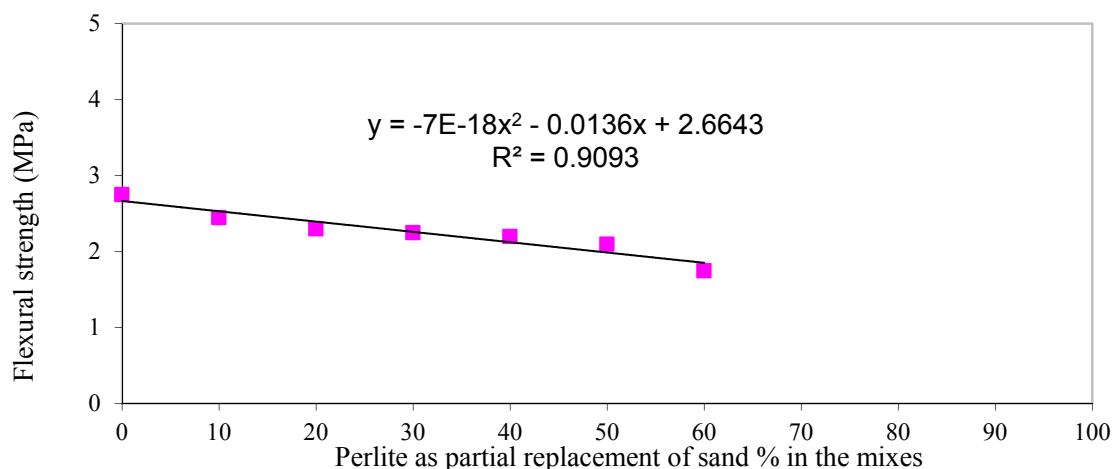
**Fig.4 Relationship between compressive strength of concrete and perlite percentage as a partial replacement of sand (constant percent of 50% Polystyrene in the mix).**

### 3.3. Flexural strength

The results of Flexural strength at 28 days for lightweight concrete mixes are shown in Table 4. A significant reduction in flexural strength of concrete with the inclusion of polystyrene beads is observed in Fig.5. Therefore, the highest reduction was recorded by the using of polystyrene as 65%. Thus, the flexural strength of concrete was decreased from 4.85 MPa (Ref. Mix) to 1.75 MPa due to such use. This behavior can be attributed to the mechanical properties of polystyrene which affects the properties of concrete [6-8]. Besides, the inclusions of 50% of polystyrene with different percentages of perlite decrease the flexural strength in the similar manner to that of compressive strength. The relationship between flexural strength of concrete and different percentages of perlite with constant percent of polystyrene "50%" is shown in Fig. 6.



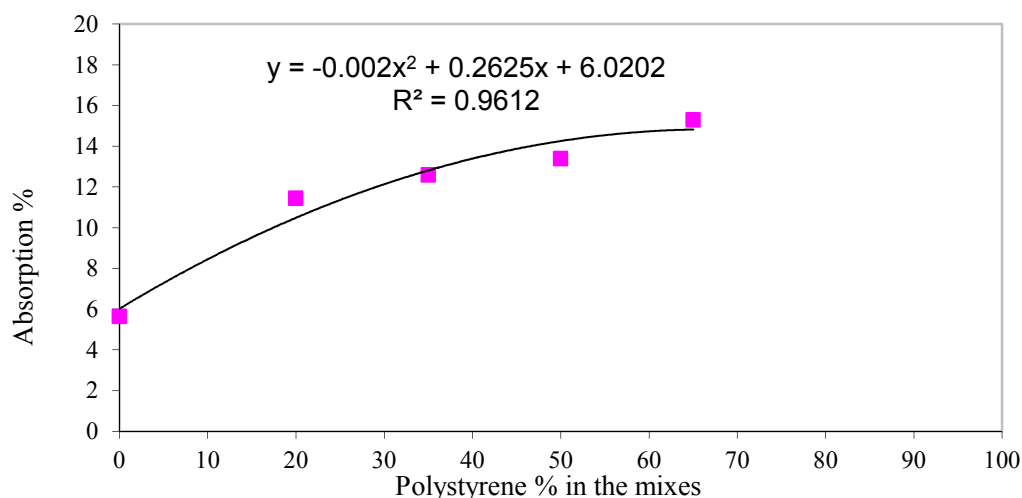
**Fig.5 Relationship between flexural strength of concrete and Polystyrene percentage**



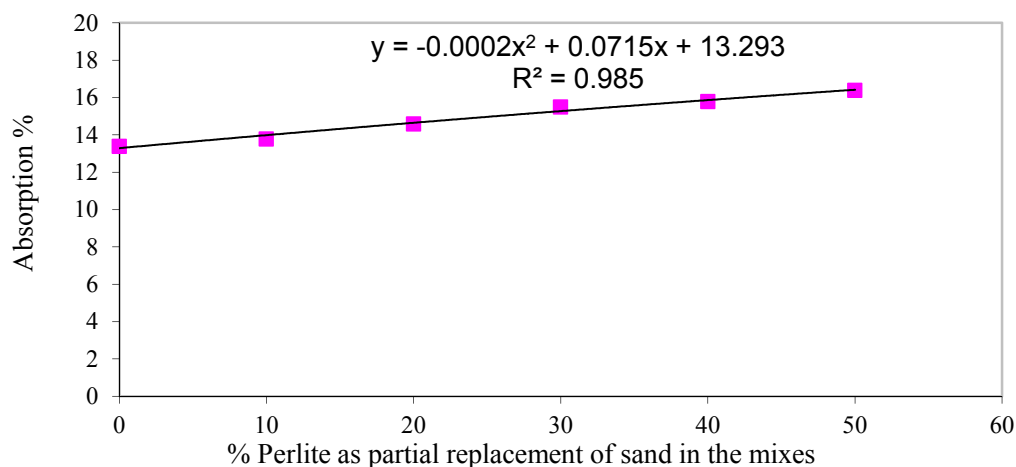
**Fig.6 Relationship between flexural strength of concrete and perlite percentage as a partial replacement of sand (constant percent of 50% Polystyrene in the mix).**

### 3.4 Absorption

The results of absorption at 28 days for lightweight concrete mixes are shown in Table 4 . The using of polystyrene beads increased the absorption of such concrete. Therefore, the inclusion of 65% polystyrene increased the absorption from 5.65% (Ref. Mix) to 16.7%. The relationship between absorption of concrete and polystyrene percentage is shown in Fig.7. The inclusions of 50% of polystyrene with different percentages of perlite exhibit higher ranges of absorption of the concrete. This behavior can be attributed to the incremental pores in the lightweight concrete mix which are the spaces for the absorbed water [16]. Thus, the relationship between absorption of concrete and different percentages of perlite with constant percent "50 %" polystyrene beads is shown in Fig. 8.



**Fig.7 Relationship between Polystyrene percentage and absorption capacity of lightweight concrete**



**Fig.8 Relationship between perlite percentage as partial replacement of sand + 50% Polystyrene percentage in the mix with absorption of lightweight concrete**

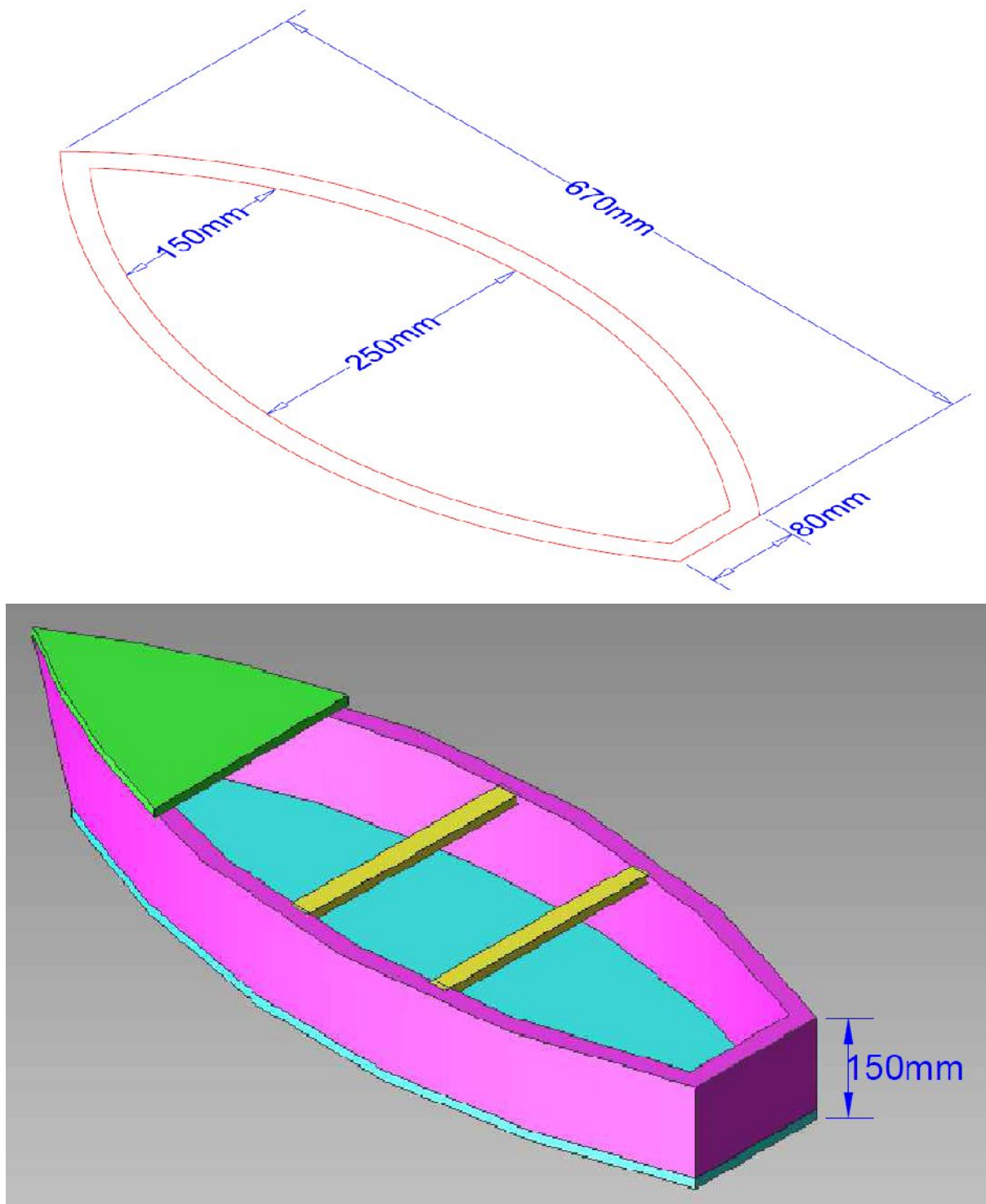
### 3.5. Canoe production

It should be mentioned that the use of 65% polystyrene was found to be hard to use in concrete mixes. This may be attributed to the disability of the mortar (cement + water + sand) in the mix from maintaining a homogenous mix. In another word, the segregation of polystyrene beads from the mix may occur at this rate of inclusion. However, from the results obtained from different lightweight concrete mixes, it can be found that the mix “P9” with 50% perlite as partial replacement of sand and 50% polystyrene as addition in the mix gives the suitable results to produce the canoe from such mix. However, the result of absorption shows that this percentage is 16.4 %. This range of absorption is accepted for lightweight concrete when such concrete is not exposed to aggressive salts existed in water. But in case of canoe production, it should be remembered that such canoe may face deteriorations due to chlorides and sulfates found in water. Therefore, the use of water-proofing materials may solve this problem and the result of absorption is reduced to 1.4 % only.

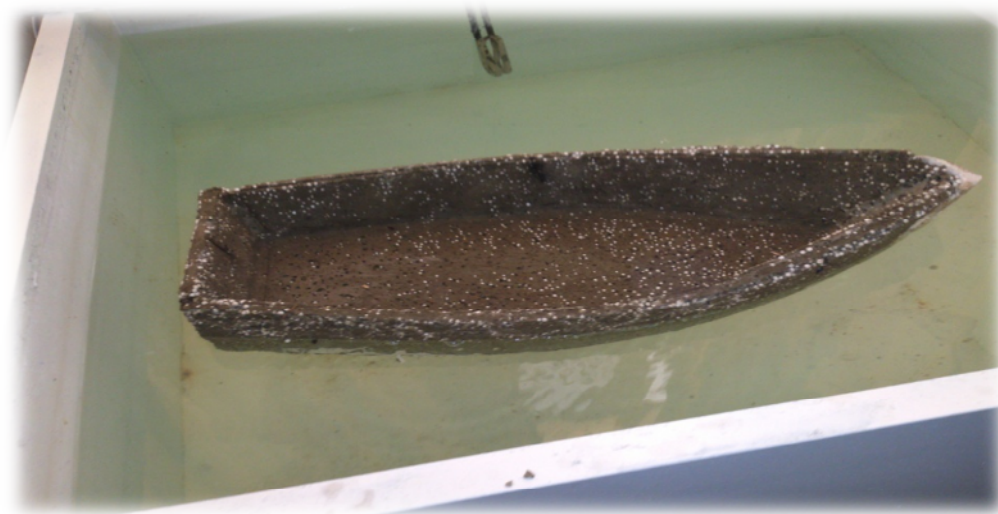
The design of canoe was used depending on some previous researches [17-18]. Thus the details of the dimensions of canoe are shown in Fig.9.

However, a Canoe was produced using the mentioned mix (P9) and the floating of such canoe was observed clearly as shown in Fig.10.





**Fig.9 Details of Canoe model and its dimensions.**



**Fig.10. Floating test of produced Canoe.**

#### **4. Conclusions**

Some conclusions can be drawn from this study:

- 1- The density of lightweight concrete decreased by the inclusion of polystyrene beads in the mix. The use of 65% of polystyrene reduced the density of the concrete by about 50%.
- 2-The compressive strength of lightweight concrete was influenced due to polystyrene beads inclusion. The addition of 65% polystyrene reduced the compressive strength from 27.6 MPa to 6.9 MPa.
- 3- The use of 65% of polystyrene beads makes the homogeneity of the mix is elusive. Therefore, the use of 50% of polystyrene as well as, the partial replacement of sand with perlite as 50% may solve this problem.
- 4- Using of 50% polystyrene with 50% perlite as partial replacement of sand were found to be suitable for the production of canoe.

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**The work was carried out at the Technical College of Mosul, Mosul-Iraq.**