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DESIGN AND PRODUCTION OF POLYMERIC STRUCTURAL ULTRA LIGHTWEIGHT CONCRETE WITH ESKANDAN REGION PUMICE

By

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Abstract:

The main objective of this research is to produce structural light weight concrete using natural aggregate and optimization of strength properties. Actually aim is to produce such a light weight which in addition to it's light weight advantages poses construction possibilities as structural concrete in slabs, beams, and columns.

Based on researches done in Eastern Azarbaijan providence in association with E.Azarbaijan geological researches section there was found a rich reserviour of mineral aggregate mine with desired strength properties(Eskandan region pumice), and this kind of aggregate was used in above mentioned concrete mixes.

In current research various samples of this mine have been investigated as light weight aggregate in light weight structural concrete mixes.

In addition to above not only it was important to produced concrete but also it was essentially necessary for researchers that produced mix designs to be practical in concrete practices and has economical benefits.

Tests done on the aggregate in this research include followings:

Identifying the aggregate from geological point of view measurement of water absorption in varieties of time-Density in air dried and saturated dry surface states(SSD)-defining aggregate water content from dried in air state to oven dried state and aggregate compressive strength.

Tests done on concrete samples: Measurement of compressive strength-tensile strength-slump test.

Keywords:

Light Weight Structural Concrete-Pumice-Natural aggregate-Compressive strength

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Introduction

One of the major problems in design and execution of buildings is the considerable weight of dead load, which mainly results from the weights of ceilings and divider walls. Using lightweight natural and artificial materials is of interest as an effective solution in order to reduce the dimensions of the supporting structure, minimize the earthquake force on the building and finally to increase the speed, facilitate the execution and economize the project.

In order to decrease the amount of losses and damages resulting from earthquake besides observing the correct principles and criteria of designing, it is necessary to design and execute the buildings with possible lowest weight. In this regard, it is necessary to carry out special studies in the field of using suitable lightweight materials, which allow the execution of buildings with lower weights.

Different kinds of lightweight concretes can be classified in three general groups including non-fine concrete, cellular concrete and lightweight aggregate concrete according their production methods.

Lightweight concretes can be classified in three groups including structural lightweight concrete, semi-structural lightweight concrete and non-structural lightweight concrete according to their application purposes. [1]

In this paper, this kind of concrete is being analyzed in terms of structural uses and conformity with code requirements on the basis of results obtained from production of lightweight concrete using pumice of Eskandan region.

Methodology:

Laboratory program to determine physical and mechanical properties of produced lightweight concretes is as follows:

- Producing lightweight concrete using pumice lightweight aggregates (fine aggregates & coarse aggregates pumice)
- Producing concrete samples using three ratios of water and cement (W/C= 0.35, 0.4, 0.48)
- Determining the properties including density of concrete in different states, compressive & tensile strength on 3rd, 7th and 28th days.
- Using silica fume in order to increase compressive strength of lightweight concrete in case that the code requirements related to compressive strength of structural lightweight concretes are not fulfilled.
- Offering the optimum mix design

Materials

- Cement: The consuming cement is Portland type II produced in Soufian cement co.

- Aggregate: The consuming aggregate including pumice coarse aggregate, fine aggregate and mineral clinker were prepared from pumice mines of Eskandan affiliated to Omran Pumice Tabriz Company.
- Silica Fume
- Super plasticizer: From Degussa construction chemical

- Study of petrography of lightweight aggregates

Study of petrography of lightweight aggregates shows that the texture of consuming aggregates (about %75) is mainly of glassy texture and their quartz quantity is less than %10, feldspathic index is below %40 and its alteration is less than %25.

Its altered minerals include zeolite and feromanganezine. This stone is classified as average stones in terms of acidity and alkalinity on the basis of its contents of Sio2. Based on their minerals, glass quantity, crystallization manner and chemical analysis these aggregates were determined as pumice.

Chemical analysis of aggregates is illustrated in table 1.

Table 1: Chemical Analysis of Pumice of Eskandan

Compositions		Sio2	Al2o3	Fe2o3	CaO	MgO	L.O.I	Na2O	K2O
	Coarse Aggregate	62.77	17.12	4.88	4.90	1.11	1.88	3.32	1.36
	Fine Aggregate	58.98	17.13	4.48	1.35	1.11	3.97	3.12	1.44

- Amount of water absorbed by Lightweight Aggregates

Average of water absorbed by the aggregates is illustrated in table 2 in different grain sizes.

Table 2: Percentage of water absorption in aggregates in different times

Grain Size (mm)	Soft 0-2.3	Fine 2.36-4.75	Medium 4.75-12.5	Coarse 12.5-25
Water absorption after 30 minutes (%)	24	32.5	29.8	28.2
Water absorption after 24 hours (%)	31	44	41	37.4

- Test of Determining Physical Properties

Physical properties of pumice were determined on the basis of ASTM C 618 and ISIRI 3433 standards that are illustrated in table 3.

Table 3: Physical Properties of Pumice of Eskandan

Item	Properties	Test Results	Requirements of Standards
1	**Softness: Remaining amount on 45 micron sieve**	18	34
2	**Index of strength-based activity With Portland cement in 7 days, minimum, in compare with witness sample (%) With Portland cement in 28 days, minimum, in compare with witness sample (%)**	73 99	75 75
3	**Specific weight g/m³**	0.9-1.3	--
4	**Soundness: Expansion or Contraction, maximum (%)**	0.03	0.8

Grading of Lightweight Aggregates

Coarse materials were selected mainly from lightweight aggregates with maximum size of 1.2 inches (12.5 mm) and lightweight fine aggregates and materials passed from sieve no.4 (about 5 mm). Production of dense concrete has been planned in this study and production of lightweight concrete with spaces between aggregates used in production of concrete blocks are not considered in this program.
Grading of mixed lightweight aggregates was selected as fine aggregates with the size of 0-4.75 mm and coarse aggregates with the size of 4.75-12.5 mm to be placed in permitted limit of determined grading according to ASTM C330 standard.

Quantities of components of mixed lightweight concrete

Ratios of mixtures of components were determined according to ACI 211.2-91.[2]
To estimate the amounts of lightweight aggregates the absolute volume method was used which is more precise than weight method in materials.
Volume of Aggregates = 1- (volume of cement + volume of water + approximate volume of entrapped air)
Weight of aggregates = volume of aggregates $\times \gamma sat$
And
γsat = Aggregate density of lightweight materials saturation
Considering high amount of water absorption in lightweight aggregates in compare with ordinary aggregates, it is difficult to determine humidity state of lightweight aggregates and estimate the amount of water absorption during mixing and finally determining free water in mixing project.

During production of concrete mixtures the lightweight aggregates are leached for 24 hours to reach saturation stage and then used in production of mixtures with saturated-surface dry (SDD).
The amounts of components of produced lightweight concrete mixtures are illustrated in table 4.

Table 4: The amounts of components of lightweight concrete mixture produced with pumice lightweight aggregates of Eskandan

Item	**Water of mixture kg/m³**	**W/C kg/ m³**	**Amount of cement kg/ m³**	**Lightweight coarse aggregate kg/ m³**	**Lightweight fine aggregate kg/ m³**	**Calculated Density Kg/ m³**
A	199	0.48	414.5	258	787	1658
B	199	0.4	497.5	248	755	1700
C	199	0.35	568.6	234	728	1729.5

Tests carried out on concrete samples
Tests of compressive strength were carried out on cubic samples (15×15×15 cm).
Cylindrical samples with dimensions of (15×30) cm were used for tensile strength (Brazilian Test). The amounts obtained for compressive strengths are average strength of features of standard cylindrical samples of (15×30) cm obtained by converting the strength of cubic samples using suggested code coefficients.

- Test Results
Results of conducted tests include the average features of compressive strength for standard cylindrical samples, tensile strength of samples and density of concrete for different ratios of water-cement are illustrated in table 5.

Table 5: Results of conducted tests on lightweight concrete mixtures produced with pumice lightweight aggregates

Number of Project		A	B	C
W/C		0.48	0.4	0.35
Density of Fresh Concrete kg/m³		1663	1713	1738.5
Density of 28-day air-dried concrete kg/m³		1366	1490	1530.5
Density of oven-dried concrete kg/m³		1248	1334	1395
7-days	**Average of Compressive strength f_c kg/cm²**	83.5	106	117

	Average of Compressive strength fc kg/ cm²	126.5	143.4	152.5
	Average of Tensile strength ft kg/ cm²	14.2	20.5	21.6
	% Ft / Fc	11.7	14.3	14.2

According to Iranian concrete code, the 28-day compressive strength of lightweight concrete (standard cylindrical samples) should be more than 160 kg/ cm². The ASTM C330 standard limits the minimum compressive strength up to 170 kg/cm² and the specific weight up to 1850 kg/m³ [3]. The results of conducted tests show that the compressive strengths of concretes produced with lightweight aggregates (fine aggregate & coarse aggregate pumice) are less than the code compressive strengths. In this case, the produced concretes cannot be used as structural lightweight concrete [2]. So in order to obtain the 28-day compressive strength of lightweight concrete at the amount of 270 to 300 kg/cm² to use in structural applications, the following actions were taken:

In order to decrease the density of concrete, different samples of pumice aggregate with different grain sizes, different water-cement ratios and also different weights of cement and silica fume were prepared. The obtained results showed that if the sizes of pumice aggregates are larger the compressive strength of concrete samples will be low because of low strength of aggregates and in case of using fine aggregate pumiced, the compressive strength of samples will be increased but the density of concrete will be closer to density of ordinary concretes, so we cannot say that this concrete is a lightweight concrete. To solve this problem, lightweight materials of mineral clinker are used and a lightweight concrete was produced using clinker materials. The ratio of water-cement is increased in these concretes because of high amount of water in clinker and it is not possible to choose water-cement ratio lower than 0.4 because of low efficiency of concrete.
So in order to solve this problem, the water-cement ration should be increased in these concrete. By increasing the ratio of water-cement, the obtained strength will be very low in these samples and it will not be possible to use them as structural concretes. Therefore, in the next step, we will try to produce concrete samples with dimensions of (15×15×15) cm, different weights of coarse aggregate and fine aggregate pumice, crinkle with different ratios of water-cement, different weights of cement and silica fume together with super plasticizer.
As crinkles are used in these samples, the density of concrete decreases and the weights of the samples decreases because of the existence of pumice aggregates, while the compressive strength of the concrete increases.
Using pumice in concrete mixture solved the creeping problem of concrete samples produced with crinkle.

Among different kinds of produced concrete mixtures, the mixture that obtained 28-day compressive strength in 270 to 300 kg/cm² and has the lowest density was selected for continuing the examination.
In table 6, the consuming materials and their weights are illustrated.

Table 6: Weights of Consuming Materials in Optimum Mix Design

		Pumice Aggregate						
		Coarse Aggregate Kg/m³	**Fine Aggregate Kg/m³**					
420	50.4	300	800	350	189	12.6	0.45	0.37

Curing the Samples

After selecting the optimum mix design, the concrete samples were prepared according to table 6 with dimensions of (15×15×15) cm. After 24 hours, the samples were taken out of molds and were placed in saturating environment and then the test of compressive strength was carried out for 3-day, 7-day and 28-day concretes. The results of this test are illustrated in table 7.

Table 7: Compressive Strength (kg/cm²) & Average Density of Concrete Samples

Time	**3-days**	**7-days**	**28-days**	**Density (kg/cam²)**
Strength	198	231	293	1762

Conclusions

- The studies showed that the consuming aggregates are mainly of pumice.
- By using Eskandan pumice with 12 % silica fume instead of cement it is possible to obtain the compressive strength close to structural strength.
- Studying the results of tests conducted on samples containing lightweight coarse aggregates and lightweight fine aggregates with cement at the amount of more than 400 kg/m³ showed that resulted compressive strength in this case is between 125-152 kg/cm² while the density of dried samples were variable between 1365-1530 kg/m³. So, there concretes don't fulfill the code requirements of structural concretes.
- Density of lightweight concrete produced with pumice aggregates, crinkle and 12 % Silica Fume instead of cement is about 1762, while the resulted compressive strength is

between 270-300 kg/cm². The code requirements are fulfilled in this case (ASTM C330) and the produced samples will be suitable to be used for structural applications.
- Lightweight structural concrete will be about 25 % lighter than ordinary concretes.
- By using lightweight structural concrete with pumice, the dead load and as a result the weight of the building will be considerably decreased. So it is possible to minimize the expenses of molding and transportation of concrete and reinforcement. Also when these concretes are used to construct the ceilings and beams of tall buildings, dimensions of columns (specially) in lower story's will be considerably decreased.

References

Josefh J.waddell, Joseph A.dobrowolski, *Concrete construction handbook*, Third edition, 2001
Hormoz Famili, *Concretology*,, university of science and technology, 2006
Hormoz Famili,, Research project of lightweight aggregate concrete, *university of science and technology.2008*