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Investigating the Freezing Strength and Durability of Lightweight Concrete With Different Weight Ratios of Nano Montmorillonite and Microsilica

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ABSTRACT: One of the effective ways to reduce the specific weight of concrete is to use mineral pumice instead of aggregate, which can reduce the specific weight of concrete. However, due to the high porosity of mineral pumice, the strength and durability of concrete decrease and increase its permeability. While some of the disadvantages of concrete can be specially corrected by using nanomaterials. Nano montmorillonite quickly swells and increases its volume by absorbing water. This property increases density in lightweight concrete. In this research, to make lightweight concrete from mineral pumice, and to increase its density, nano montmorillonite was used in different weight ratios of 0.5%, 1%, 1.5%, 2%, and 2.5% cement. Also, to increase the quality and reduce the cost of consumable materials, micro silica was used in the amount of 10% by weight of the grade of cement used in concrete. The conducted tests include compressive strength, tensile strength, water absorption in hardened concrete, durability against the freezing cycle, economic index, and examination of concrete microstructure. The results of this research showed that the use of 2.5% nano montmorillonite instead of cement along with 10% micro silica in lightweight concrete can increase the 90-day compressive strength by 65% compared to the control sample. But due to the high cost of preparing nanomaterials, the optimal amount of using nano montmorillonite in lightweight concrete was determined to be 1.5% maximum. Because adding amounts more than that has no noticeable effect on increasing the compressive and tensile strength of concrete and the failure of concrete mainly occurs in the light-grained area.

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1- Introduction

Light grains have a great effect in reducing the specific weight of concrete, but their type has an effect on the characteristics, durability, and strength of light concrete. The specific weight of lightweight concrete is approximately 70% of the specific weight of ordinary concrete. According to the definition of the ACI-213 standard, structural lightweight concrete should have at least 17 MPa compressive strength, and its specific weight should not exceed 1850 kg per cubic meter [1]. It is special for the bottom. According to the ASTM-C33 standard, the maximum specific weight of fine-grained and coarse-grained light stone materials in dry state is 1220 and 880 kg/m3, respectively [2]. One of the methods of making lightweight concrete is the use of porous aggregates and mineral pumice. But the high porosity of these aggregates reduces the compressive strength of concrete. So that it will not be able to be used in structural use [3]. Mineral pumice is a volcanic rock that consists of molten material (magma) with high temperature and has a low weight and many uses. The main property of mineral pumice is its light weight [4].

On the other hand, past research shows that the use of nano montmorillonite in concrete will increase compressive strength and density. This is due to the strong expansion of this material in contact with water. However, the amount of use of nano montmorillonite varies according to the type of concrete. So in some research, they have recommended a ratio of less or more than 1% by weight of cement [1-3]. Therefore, according to the type of concrete and the purity of montmorillonite, before using it in concrete, optimization should be done to determine the optimal and effective amount of this material according to the type of concrete. In this research, with the aim of reducing the specific weight of concrete, Qorveh mineral pumice was used instead of ordinary aggregate. Also, to prevent the reduction of compressive strength due to the use of pumice and increase the density of concrete, nano montmorillonite has been used in different weight ratios instead of part of cement. Therefore, due to the high porosity of mineral pumice and to reduce the use of nanomaterials, micro silica was used in lightweight concrete at the same time. This material in combination with cement increases the adhesion between concrete materials and increases the density and compressive strength of concrete

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Table 1. Physical characteristics of nano montmorillonite

Humidity (%)	Ion exchange coefficient (meg/100gr)	Hardship (mohes)	Electrical conductivity (mv)	Specific surface area (m^2/gr)	Particle size (nm)	Density (kg/m^3)	Name
1-2	48	< 2	25	220-270	2-1	300-370	Nano montmorillonite

Table 2. chemical characteristics of nano montmorillonite

L.O.I	Fe_2O_3 (%)	TiO_2 (%)	CaO (%)	K_2O (%)	SiO_2 (%)	Al_2O_3 (%)	MgO (%)	Na_2O (%)
15.45	5.62	0.62	1.97	0.86	50.95	19.6	3.29	0.98

[4]. In this research, slump tests, compressive strength, tensile strength, durability of concrete against freezing cycle, and microstructure of concrete have been examined and tested. Among the innovative aspects of the current research, we can mention the simultaneous use of nanomaterials with micro silica in lightweight concrete.

2- Materials and method

In this research, to reduce the specific weight of concrete, mineral pumice with a maximum size of 19 mm was used instead of sand. Despite its very low weight, the pumice stone has good resistance [2]. The sand used for making concrete was obtained from mines in the Kharameh region of Fars. Consumable sand has a maximum nominal size of 0-4.75mm and has a saturated specific weight with a dry surface (SSD state) of 2350kg/m^3. Aggregate grading was done by classified sieves according to ASTM-C136 standards. Also, micro silica was used in concrete with the aim of reducing the porosity of cement paste and improving the quality of the transition zone between cement and aggregate, as well as increasing the compressive strength. In this research, a fixed amount of 50 kg of micro silica was added per cubic meter of concrete. The cement used was type 2 of Fars. The consumable super lubricant is based on polycarboxylate ether model LK-PC8020, which is part of the newest generation of super lubricants. Nano montmorillonite is sodium-containing and its physical and chemical characteristics are in accordance with table no. 1 and 2.

3- Result

The results of this research show that the use of nano montmorillonite in concrete can significantly improve the mechanical properties of concrete. However, the optimal amount of using nano montmorillonite in concrete depends on various factors such as the type of concrete, the purity of nano montmorillonite, environmental conditions, and the type of use. Nano montmorillonite swells in contact with moisture and due to the absorption of water, the increase in its volume causes the porosity of concrete to decrease. This feature will increase the density and strength of concrete. Also, the results of the experiments showed that the use of nano montmorillonite in lightweight concrete increases the density due to the high porosity of mineral pumice. As a result, due to the increased density, the amount of water absorption and permeability of concrete decreases, and its compressive strength and durability against the freezing cycle increases. In this research, the optimal amount of using nano montmorillonite in lightweight concrete was between 1% and 1.5% by weight of cement grade along with 10% microsilica. While the results of other past research show that the optimal and effective amount of nano montmorillonite in ordinary concrete is about 0.5%, in self-compacting concrete it is about 0.75% and in cement composites, it is about 1% by weight of the grade of cement used. [5-7]. Also, using more than 1.5% of nanomontmorillonite along with 10% of micro silica in light concrete does not make a noticeable change in the results or in some cases causes weakness in the concrete. Therefore, the use of high amounts of nano montmorillonite will not be justified due to its high price and limited availability. Also, in order to increase the durability of light concrete against the freezing cycle, taking into account other economic criteria and the specific weight of concrete, it is recommended to use foaming additives in concrete.

4- Result

1. The use of at least 1.5% by weight of montmorillonite along with microsilica in light concrete will cause a weight loss of less than 5% and a strength loss of less than 10%, which is durable against the freezing cycle according to ASTM-C666-B standards. It is within the allowed range.

2. The final compressive strength (90 days) in plans is 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control plan,

a. Qorve mineral pumice b. Microsilica c. Nano montmorillonite d. super lubricant

Fig. 1. Some materials used in the experiment

respectively, by 13.9%, 32.3%, 57.1%, 62.4%, 65.8% increased.

3. The amount of slump in plans is 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control plan, respectively, by 15.9%, 26.1%, 31.8%, 34.1%, 37.5%, decreased.

4. Tensile strength in designs 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control design by 11.5%, 19.2%, 34.6%, 3% respectively. 42% has increased by 46.2%.

5. The amount of final water absorption (72 hours) in plans is 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control plan, respectively, by 0.26%, 48.5%, It has decreased by 69.7%, 83.5% and 92.0%.

6. The amount of concrete resistance after exposure to 300 freezing cycles in the designs is 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control design, respectively, by 28.1%. 51.4%, 77.4%, 80.8% and 82.2% have increased.

7. The amount of concrete weight loss after 300 freezing cycles in designs 0.5%, 1%, 1.5%, 2%, 2.5% compared to the control design by 17.1%, 9.9% respectively 32%, 47.4%, 59.2% and 67.1% decreased.

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