Usage Possibilities of Diatomite in the Concrete Production for Agricultural Buildings

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Abstract: Construction materials evidently affect economy, strength, durability, safety and expediency of constructions. Selecting locally available material will bring a cost-advantage to structures built in rural parts. Such a case is especially valid for agricultural structures. In present study, effects of a natural pozzolan, diatomite admixture on concrete workability characteristics, setting duration and behavior under axial loading were investigated and possible use of diatomite-blended concrete as a light-weight construction material in agricultural structures was evaluated. This research was carried out in Tokat/Turkey in 2012. Concrete samples were prepared by using different admixture ratios of diatomite as a light-weight aggregate with standard sand and crashed sand aggregates. Water/cement ratios of mixtures were determined by taking a constant slump value into consideration. Unit weight, compressive strength and water absorption test were carried out over the samples. According to the results, unit weight, compressive strengths and water absorption in 150, 200 and 250 doses changed with increasing diatomite contents, respectively, from 1470 kg/m^3 to 2210 kg/m^3, from 20.45 MPa to 1.14 MPa, from 6.04% to 23.85%. Results revealed significant cost-savings by using diatomite aggregate to produce light-weight concrete blocks to be used in agricultural structures. It was also concluded that such blocks might provide significant insulative advantages for heat-balance of livestock barns.

Keywords: Agriculture Structures, diatomite, light-weight aggregate, light-weight concrete, pozzolan.

INTRODUCTION

Agricultural structures directly reflect the level of development in agricultural production activities. Desired characteristics in agricultural structures can only be reached by using proper construction materials and structural members. Therefore, a special attention should be paid in material selection, design and construction of these structures. Current properties of construction materials are results of long-term research and experiences of several researchers. However, there is still a need for more economic and safer construction materials.

Light-weight concrete blocks have started to be used in agricultural structures instead of traditional concrete members [1, 2]. The most common method to produce light-weight concrete is to use light-weight aggregate rather than standard fine or coarse aggregate in concrete mixtures. Light-weight aggregate concretes have several advantages over ordinary concrete since they are more economic, able to be served earlier, environment-friendly and open for technical developments. Therefore, light-weight concrete has become multi-functional constructional material of construction world. Light-weight concrete blocks are used in exterior walls and interior partitions of agricultural structures. They not only provide a decrease in dead loads but also provide significant advantages for noise and heat insulation, heat balance, fire-resistance and esthetic purposes [3-5].

Pozzolan alone does not have a cementing characteristic and gains a cementing effect only when grinded and compounded with lime in moist conditions. Pozzolan is a silica or silica-aluminous artificial or natural inorganic material [6]. There are several researches about the use of pozzolanic materials in concrete mixtures. Such materials are mostly used as concrete admixture or cement blend to reduce concrete costs or to improve engineering characteristics of concrete. Beside the artificial pozzolans, already-known natural pozzolans should also be considered for economical purposes in construction industry. Such natural materials should widely be used in concrete production.

Diatomite is highly porous material with low density, low noise, heat and electrical conductance, high melting point around 1400-1600 °C and resistance against chemicals. It is widely used with these physical characteristics as a light-weight construction material, fill material, insulation material, refractor material, cement pozzolana and absorbent material [7-9]. Diatomite is classified in natural light-weight aggregate group of Turkish Standards [10] and added to concrete

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Table 1: Physical and Chemical Characteristics of Diatomite

Physical		Chemical	
Color	Yellowish	SiO_2	92.8%
Dry density	185 g/l	Al_2O_3	4.2%
Moisture	1-5%	Fe_2O_3	1.5%
Firing loss	0.4	CaO	0.6%
pH	6.5	MgO	0.3%
Wet density	390 g/l	Other oxides	0.5%
Flow rate	0.070	S	0.01%

Table 2: Aggregate Chemical Characteristics

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O
82.4	11.4	2.45	2.28	1.02	0.03	0.03

mixtures to provide lightness, insulation, plasticity, resistance and bleeding prevention. Previous researches revealed that diatomite could be used as a light-weight aggregate in concrete blocks to be used in non-load bearing members of buildings and to be used for insulative purposes [11, 12].

In present study, possible use of highly-porous diatomite as a concrete admixture to improve some concrete characteristics was investigated and potential use as light-weight aggregate in light-weight concrete block production was evaluated. In this way, potential use of a natural resource was investigated. The basic objective was set as to produce light-weight concrete blocks to be used in livestock barns and storage structures in which environmental factors and heat-balance play a significant role.

MATERIAL AND METHOD

Material

Diatomite, regular aggregate (sand and crashed gravel), cement, municipal water and light-weight concrete blocks to be produced with these mixtures constituted the materials of present study. Diatomite supplied from Afyon region was used as light-weight aggregate. Physical and chemical characteristics of diatomite are presented in Table **1** [13]. CEM II / B-M (P-L) 32.5 R (Portland Composite Cement) cement [14] was used as cement material of mixtures. Washed river sand and number II-crushed gravel with a maximum grain size of 16 mm were used as regular aggregate. Aggregates were supplied from Taşlıciftlik region of Tokat province and physical-chemical characteristics are provided in Table **2** [15]. Characteristics of cement supplied from Tokat-Artova Cement Facility are provided in Table **3** [16]. Municipal water at 20±2 °C was used as mixture water. Experiments were carried out in laboratories of Biosystems Engineering Department of Agricultural Faculty and construction material laboratories of Tokat Vocational Collage of Gaziosmanpasa University in Turkey in 2012.

Table 3: Physical and Chemical Characteristics of Cement

Characteristics	Value
Initiation of setting (min)	Min 75
Volume expansion (mm)	Max 10
2-days compressive strength (MPa)	Min 10
28-days compressive strength (MPa)	Min 32.5 Max. 52.5
SO_3 (%)	Max 3.5
Cl^- (%)	Max 0.10

Mineral characteristics of diatomite was determined by X-ray diffrection method and presented in Figure **1**. Mineralogical characteristics of diatomite were determined by using XRD (X-Ray Difractometer) method (Bruker AXS D8 Advance Model X-Ray Difractometer, 20-60 KV/6-80 mA).

Method

Diatomite was added as volumetric percentage of total fine aggregate calculated for concrete mixture.

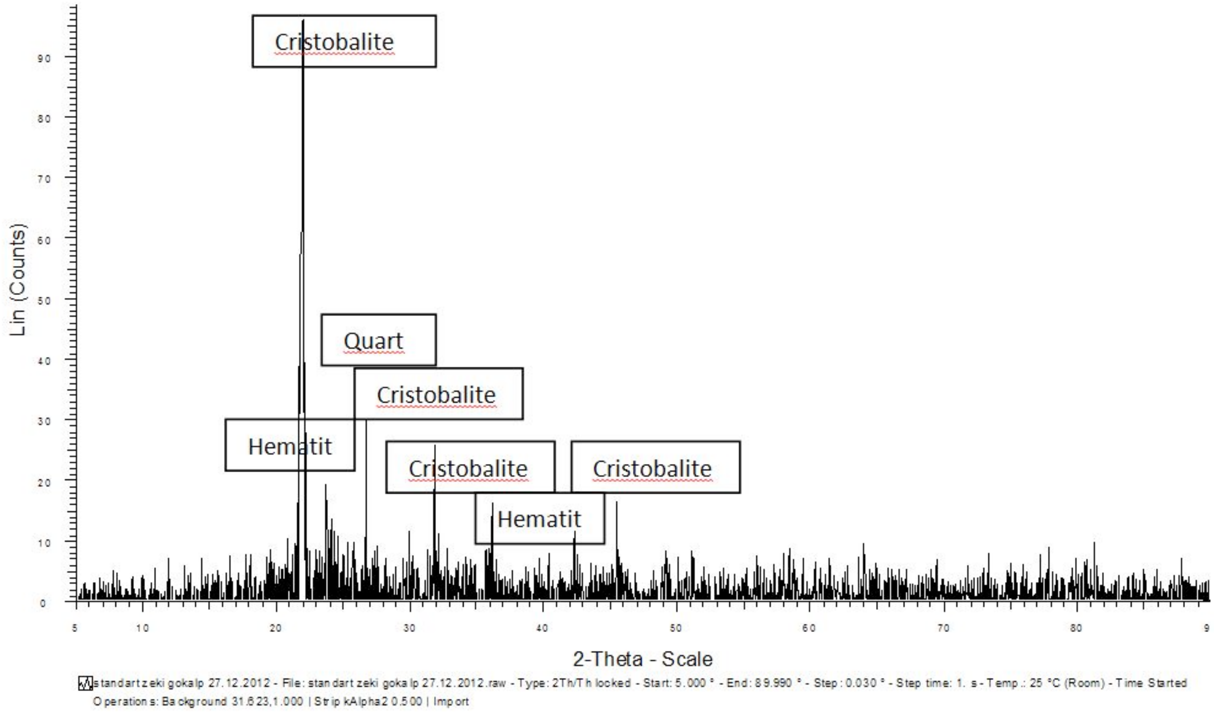

Figure 1: X-ray diffractograms of diatomite used in sample preparation.

The percentages were set as 0, 10, 30, 50, 75 and 100%. Considering the various uses of light-weight concrete in agricultural structures, concrete cement doses were arranged as 150, 200 and 250 kg/m^3. The largest aggregate size was accepted as 16 mm [10] [8]. Weights of mixture materials were calculated in accordance with the relevant Turkish Standard [17]. Materials were weighed with a digital balance and placed into concrete mixer. Following the homogeneous mixture of entire materials, mixture water was added and fresh concrete was obtained.

Since net water/cement ratio of light-weight aggregate concretes are not accurately be determined, series of test mixtures are recommended with concrete samples at specified cement doses and consistency to calculate the amount of remolding water. In present study, series of test mixtures with about 5 cm slump were prepared and amount of remolding water was determined for each cement doses and each mixture [17, 18].

A total of 18 treatments, 6 for each cement dose, were prepared for testing. Each treatment had 3 replications. Compressive strength, water absorption and unit weight tests were performed over the test specimens. A total of 108 cube samples (15x15x15 cm) were tested. Since diatomite light-weight aggregates have high porosities and water absorptions, they were inundated in a water bath for 30 minutes and then added into mixtures as saturated and surface-dry conditions. Fresh concrete was poured into molds in 50 mm layers and each layer was temped 25 times with a temping bar to compact the concrete [19. 12].

The cubes were removed from the molds 24 hours after casting and placed into curing tank with 20±2 ºC water until the day of testing ([19] TS, 2002). Following 28 days curing, compressive strength tests [20], water absorption and unit weight tests [21] were run on cube samples. The equation given in McClune and Moorhouse [22] was used to calculate heat conductivity coefficient of light-weight concrete samples.

RESULTS AND DISCUSSION

Constituents of mixtures with three cement doses and 6 different diatomite contents are given in Table **4**.

Amount of remolding water and thus water/cement ratio of each cement dose increased with increasing amount of diatomite in mixtures mostly because of high porosity and low unit weight of diatomite. The rate of increase in remolding water decreased with increasing cement doses since the amount of diatomite was decreasing in mixtures with high cement doses. Similar results were observed in previous light-weight aggregate researches [23-25].

Compressive strength, water absorption and unit weight test results of 28-days cured samples are

Table 4: Amount of Materials in each Mixture

Dose	Mixture	Natural Aggregate (kg)		Diatomite (kg)	Water (l)
		Fine	Coarse		
150	150/0.00	827	1329	-	60
	150/0.10	592	1316	164	70
	150/0.30	347	1290	483	80
	150/0.50	515	1275	358	90
	150/0.75	254	1260	531	100
	150/1.00	-	1245	700	110
200	200/0.00	579	1290	-	80
	200/0.10	898	1236	69	100
	200/0.30	691	1221	206	110
	200/0.50	487	1206	339	120
	200/0.75	241	1191	502	130
	200/1.00	-	1176	661	140
250	250/0.00	545	1260	-	100
	250/0.10	870	1196	67	130
	250/0.30	668	1181	199	140
	250/0.50	471	1167	328	160
	250/0.75	233	1147	485	160
	250/1.00	-	1137	639	180

provided in Table **5**. Variation in unit weights of different mixtures is presented in Figure **2**.

Decreasing unit weights were observed with increasing amount of diatomite admixture into concrete mixture. The highest unit weights for 150, 200 and 250 cement doses were respectively observed as 2090 kg/m^3, 2180 kg/m^3 and 2210 kg/m^3 in control treatments of each dose (150/0.00, 200/0.00 ve 250/0.00). The lowest values were obtained from 100% diatomite mixtures of each dose (150/1,00, 200/1,00 and 250/1,00) as 1470 kg/m^3, 1730 kg/m^3 and 1790 kg/m^3, respectively. The inverse relationship between diatomite content and unit weight was because of high porosity and low specific gravity of diatomite compared to ordinary aggregate. Up to 30% lower unit weights than ordinary concrete will definitely decrease the dead loads of buildings. Such a decrease will bring together the savings in materials and decrease also loss of life and property in case of natural disasters.

Water absorption rates for different cement doses and diatomite contents are presented in Figure **3**. The rates in 150, 200 and 250 doses increased with diatomite contents respectively from 6.04 to 15.74%, from 7.42 to 20.76% and from 8.62 to 23.85%. Increasing water absorption rates were observed with increasing diatomite contents because of porous structure of diatomite. Similar results were also observed in studies with light-weight aggregates [12, 24, 26, 27].

Change in compressive strengths of samples with cement doses and diatomite contents were presented in Figure **4**. Compressive strengths in 150, 200 and 250 doses decreased with increasing diatomite contents, respectively from 11.99 to 1.14 MPa, from 12.89 to 1.48 MPa and from 20.45 to 4.18 MPa. The rate of decrease in 150, 200 and 250 doses was calculated respectively as 91, 89 and 89%. Uysal *et al*. [28], Uygunoglu and Unal [12], Sisman and Gezer [29] carried out researches with various light-weight aggregates and observed decreasing compressive strengths with increasing light-weight aggregate contents of mixtures. Negative effect of diatomite content on compressive strength was increasing in lower doses but decreasing in the dose of 250. The lower impact of diatomite content on decrease in compressive strength at high doses was mainly due to high cement content of mixtures. Since the agricultural structures are single-story buildings with low structural loads, light-weight concrete blocks produced with

Table 5: Physical, Mechanical and Thermal Characteristics of Cured Samples

Mixture	Unit Weight (Kg/m^3)	Water Absorption (%)	Compressive Strength (MPa)	Heat Conductivity (kcal/mºCh)
150/0.00	2090	6.04	11.99	1.23
150/0.10	1930	7.53	10.55	1.22
150/0.30	1880	8.58	9.18	1.14
150/0.50	1810	10.30	7.56	1.10
150/0.75	1600	13.21	4.38	0.80
150/1.00	1470	15.74	1.14	0.52
200/0.00	2180	7.42	12.89	1.33
200/0.10	1980	8.38	12.15	1.23
200/0.30	1900	8.39	9.55	1.17
200/0.50	1853	11.82	5.71	1.10
200/0.75	1780	15.21	5.58	1.00
200/1.00	1730	20.76	1.48	0.94
250/0.00	2210	8.62	20.45	1.44
250/0,10	2000	11.51	16.91	1.42
250/0,30	1930	11.43	11.31	1.22
250/0,50	1900	14.15	9.50	1.06
250/0,75	1820	16.20	6.49	0.93
250/1,00	1790	23.85	4.18	0.79

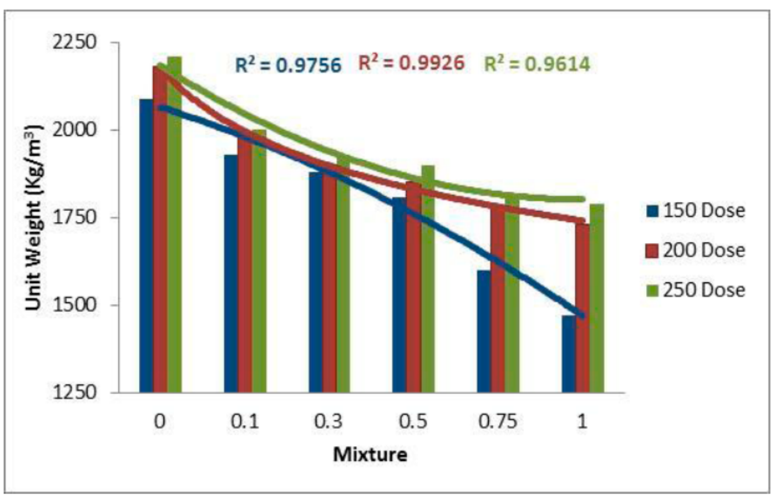

Figure 2: Variation in unit weight with cement dosage and diatomite content.

diatomite can comfortably be used in agricultural structures.

Although specified differently in various standards, the concrete with unit weights between 300 and 2000 kg/m^3 and compressive strength of over 16 MPa is classified as light-weight concrete [17, 19, 30, 31]. The concrete produced with diatomite in present study may be classified as light-weight insulation concrete with regard to strength and heat conductance values.

Heat conductivity coefficients of different cement doses and diatomite contents are presented in Figure **5**. The coefficients for 150, 200 and 250 doses varied respectively between 1.23-0.52, 1.33-0.94 and 1.44-0.79 kcal/hmºC. While heat conductivity of an ordinary concrete varies between 1.20 and 3.09 kcal/m°Ch based on unit weight, such value is between 0.17 - 0.860 kcal/m°Ch in light-weight concrete. These low heat conductance values largely depend on type of

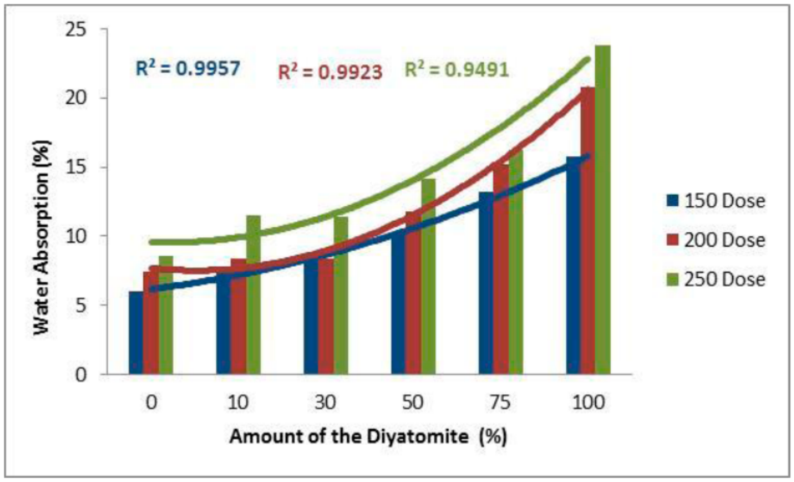

Figure 3: Water absorption rates of different cement doses and diatomite contents.

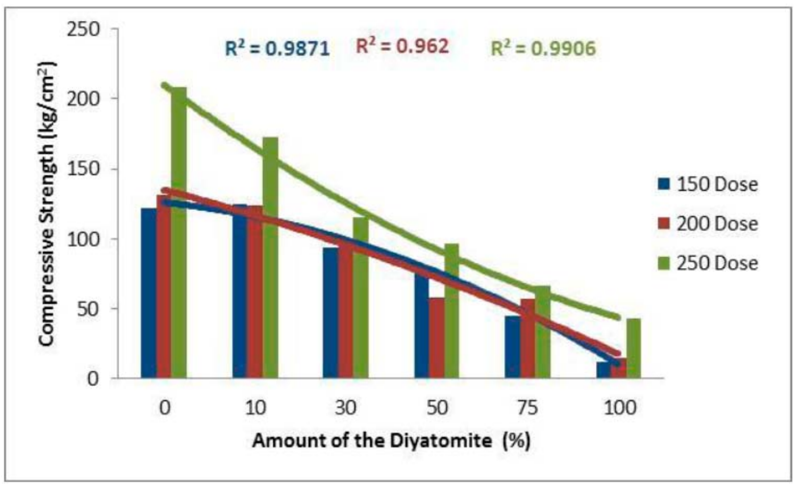

Figure 4: Compressive strengths of different cement doses and diatomite contents.

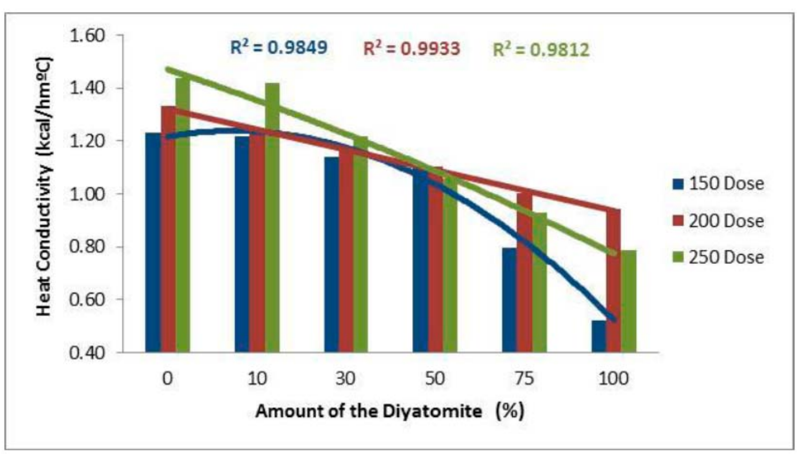

Figure 5: Heat conduction coefficients of different cement doses and diatomite contents.

light-weight aggregate used in production of light-weight concrete [7]. Similar to unit weights, heat conductivity coefficients also decreased with increasing diatomite contents (Figure **5**). The decrease rate was especially distinctive in 150 dose since the amount of fine material and displacing diatomite and consequently void ratio are higher in this dose. Increasing cement doses increased density and decreased porosity and consequently increased heat conduction coefficient.

CONCLUSION

Indoor environmental conditions play a vital role in agricultural structures. Heat-loss through structural members has significant impacts in heat-balance calculations. Such losses can be reduced by using construction materials with low heat conductance.

Results revealed that diatomite could be used to produce light-weight concrete blocks with sufficient strength and low heat conductance. Diatomite may provide almost 55% decreases in heat conductance, thus significantly reduce the heat loss through structural members. The diatomite content can be arranged as between 10 and 50% based on the purpose of use and cement dose. Higher diatomite contents significantly decrease strength characteristics and lower contents increase heat conductance. However, water permeability measures should definitely be taken when using such materials in contact with water. Finishing plaster and moisture insulation should be provided over structural members. Otherwise, excessive moisture transmission negatively affects mechanical and thermal characteristics of structural members and may covert the advantages of using light-weight concrete blocks into disadvantages. As a conclusion, diatomite can be used as a light-weight aggregate in production of light-weight concrete to be used in non load-bearing members with high heat insulation. In this way, raw material resources may be converted into economical benefit for individuals and the country and significant energy-savings may be provided through heat insulation.

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