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Investigation of Relationships between Ultrasonic Pulse Velocity and Thermal Conductivity Coefficient in Foam Concretes

M. Davraz[a], Ş. Kilinçarslan[a,*], M. Koru[b] and F. Tuzlak[c]

[a]Süleyman Demirel University, Natural and Industrial Building Materials Application and Research Center, Isparta, Turkey

[b]Süleyman Demirel University, Faculty of Technology, Energy Systems Engineering Department, Isparta, Turkey

[c]Süleyman Demirel University, Faculty of Engineering, Civil Engineering Department, Isparta, Turkey

In this study, using type CEM I 42.5 R Portland cement, limestone powder, polypropylene fibers and super plasticizer, additive foam concrete specimens were produced. 28 days compressive strengths, dry densities, ultrasonic pulse velocities and thermal conductivity coefficient of these samples were determined. Analysing test results, it was noticed that there underlies a strong relationship between ultrasonic pulse velocity and thermal conductivity coefficient in the foam concrete. It is possible to estimate thermal conductivity by ultrasonic pulse velocity method, easy and credible method.

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1. Introduction

Foam concrete is a type of lightweight concrete [1]. It can be obtained by mixing the foam formed by the foaming agent with a mixture consisting of cement, water and aggregate. It contains independent closed pores with a volumetric ratio of 75%–80% within its body [2]. It has an excellent resistance to water and frost. Foam concrete is an environmentally friendly building and insulation material that provides heat and impact sound insulation with its lightweight and non-harmful structure to human health [3]. Foam concrete provides heat, sound and water insulation. Foamed concrete mixture may be poured or pumped into moulds, or directly into structural elements. Ultrasonic pulse velocity, which is the most commonly used non-destructive test method, depends on aggregate characteristics, hydration rate, water–cement ratio and age of the concrete, therefore all parameters affecting the compressive strength [4]. Therefore, ultrasonic pulse velocity (UPV) method is used to determine quality of the concrete for a long time [5, 6].

2. Material and methods

The primary aim of this study is to determine the production of foam concrete within a density of 300–1400 kg/m^3 by mixing cement, limestone powder, polypropylene fiber, super plasticizer (SP) and protein-based foaming agent (see Table I) as well as the relationship between physical and mechanical properties of this foam concrete and its ultrasonic pulse velocity.

TABLE I

The mix designs of foam concretes (kg/m^3).

No.	D_{dry} [kg/m^3]	Limestone [kg]	Water [L]	SP [kg]	Foam [kg]
1	300	0	89	1.48	76.55
2	400	96	119	1.98	70.22
3	500	196	149	2.48	63.85
4	600	296	179	2.98	57.53
5	700	396	209	3.48	51.16
6	800	496	239	3.98	44.84
7	900	596	269	4.48	38.47
8	1000	697	299	4.98	32.04
9	1100	797	329	5.48	25.71
10	1200	897	359	5.99	19.35
11	1300	997	389	6.48	12.98
12	1400	1097	419	6.99	6.65

Cement — 300 kg, fiber — 3.0 kg, water/solid ratio (w/s) — 0.30, saturated-dry surface specific mass of limestone (ρ_k — 2.70 g/cm^3, specific mass of fiber (ρ_{pe}) — 1.90 g/cm^3, density (ρ_{sa} — 1.10 g/cm^3

Firstly, the mixtures were prepared by mixing cement, limestone powder, fibers, water and super plasticizer. Foam with a density of 80 g/L in average was added to the mixtures until theoretical fresh density value calculated was reached according to the mix designs. The compressive strength and splitting tensile strength of air-dried specimens were determined. The productions and experiments of all specimens were conducted in Natural and Industrial Building Materials Application and Research Centre of Suleyman Demirel University. The standards used in the experiments were given in Table II.

*corresponding author; e-mail: seref@tef.sdu.edu.tr

TABLE II

The standards used in the experiments.

Experiment	Standard	Sample shape
dry density	TS EN 678	unit volume
compressive strength	TS EN 1354	15 cm cubic
splitting tensile	TS EN 12390-6	15 cm cubic
thermal conductivity	TS EN 12667	30*30*5 cm
UPV	TS EN 12504-4	15 cm cubic

3. Results and discussion

The tests of compressive strength, splitting tensile strength and UPV were applied on foam concrete specimens, after 28 day curing period. Compressive strength (f_c), splitting tensile strength (f_{ct}), ultrasonic pulse velocities (V_p), thermal conductivity coefficient of foam concrete samples were determined according to arithmetic mean of three measurement results for each density set; the results depending on ρ_{gk} of specimens were given in Table III.

TABLE III

The test results of compressive strength, splitting tensile strength and UPV of foam concrete specimens at 28 days (av).

No.	ρ_{gk} [kg/m^3]	f_{c-28} [MPa]	f_{ct-28} [MPa]	V_p [m/s]	k [mW/mk]
1	364	0.85	0.10	1494	0.09
2	510	1.93	0.19	1795	0.14
3	563	2.15	0.32	1900	0.14
4	715	3.66	0.65	1979	0.16
5	837	4.41	0.79	2010	0.22
6	851	4.96	0.98	2016	0.24
7	965	5.76	1.01	2041	0.27
8	1100	6.77	1.09	2088	0.30
9	1272	7.51	1.22	2152	0.32
10	1321	8.77	1.27	2225	0.36
11	1429	9.02	1.38	2263	0.43
12	1531	10.94	1.43	2317	0.50

In foam concrete specimens, the change of actual dry density depending on UPV was given in Fig. 1, the thermal conductivity coefficient depending on UPV was given in Fig. 2.

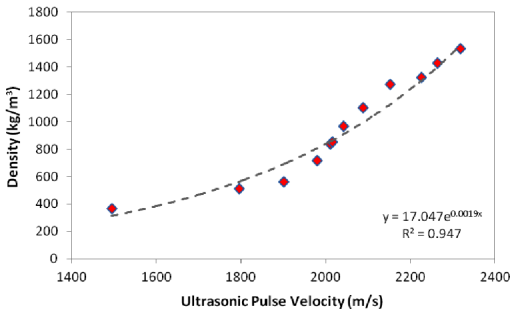

Fig. 1. UPV change depending on actual dry density.

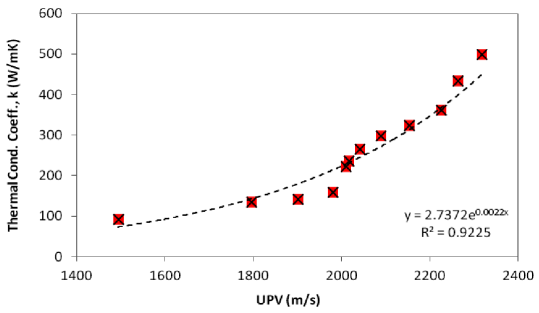

Fig. 2. Thermal conductivity coefficient depending on UPV (V_p).

4. Conclusion

As a result of the study, the relationships regarding the estimations of dry density, compressive strength and thermal conductivity coefficient values depending on UPV values were proposed for foam concretes with fine limestone aggregate, the cement dosage of 300 kg/m^3 and water/solid ratio of 0.30. It was observed that there is a strong relationship between UPV — dry density, UPV — compressive strength and UPV — thermal conductivity coefficient in the foam concrete. For the foam concrete samples produced in this study:

— Dry densities changed between 350 and 1500 kg/m^3;

— Compressive strengths ranged between 1 and 11 MPa;

— Thermal conductivity coefficients were between 90 and 500 mW/mK;

— UPV values changed between 1500 and 2320 m/s.

In foam concretes, since it is required a long time to obtain test results of dry density, compressive strength and thermal conductivity, it is possible to estimate density, compressive strength and thermal conductivity by UPV method, which is a non-destructive, easy and confidential method.

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