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INVESTIGATION OF MECHANICAL PROPERTIES USED FOR INTERLOCKING CONCRETE PAVE OF FLY ASHES GATHERED FROM DIFFERENT THERMAL POWER PLANTS

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Abstract

In this study, tree different fly ashes (FA) provided from Orhaneli thermal power plant (OTPP), Çayırhan thermal power plant (ÇTPP) and Kangal thermal power plant (KTPP) have been used as a replacement to cement in 10-20-30-40 % ratios, and the mechanical properties of interlocking paving stone (IPS) have been investigated. The mixtures containing ordinary Portland cement were designed to have 28 days compressive strength of approximately 45 MPa. Specimens were subjected to splitting tensile strength test, water absorption test, abrasion resistance testing in accordance with TS 2824 EN 1338, TS EN 1097-6 and ASTM C 944, respectively. Tests on splitting tensile strength test, water absorption test, abrasion resistance were performed up to 90 days. Experimental results show that splitting tensile strength test, abrasion resistance test and compressive strength test the best result was taken replacement %10 of FA obtained from OTPP. According to, finally, in addition to this finding, it was also determined that water absorption and abrasion resistance values have increased as the FA replacement ratio increased.

Keywords: Interlocking concrete pave, Fly ash, Splitting tensile strength, Abrasion resistance, Water absorption

1. Introduction

The usage of the interlocking concrete pave has been increased recently. It is used in the areas in local roads and pavements, parking sites, commercial centers and industrial areas, which are exposed to intensive usage. The usage of the FA in the production concrete pave is a more high quality production, more economical and a more environmentally friendly approach [1,2].

Decreasing the amount of energy used in the production of cement is a significant factor considering environmental pollution and economical factors [3-4]. Taking into consideration the fact that 40% of energy used for the production of cement is decreased during the grind and baking stages, one can easily realize the damage created during various stages of cement production to the environment [5].

In the thermal power plants that utilize low calory lignite during the electricity production, micro particles that are exhausted through the chimney are stored and filtered by electro-static filters [5].

Release of the micro level ash particles accumulated in the filters to the environment by inadequate methods creates broader environmental problems [6-7]. In this aspect, extensive research is being performed in order to provide alternative material usage to prevent excessive utilization of natural energy resources [3]. Today, cement is being replaced by puzzolanic materials in order to provide more economic and higher quality concrete [8, 9].

In our study, fly ash supplied from three different thermal power plants is preferred. Parquet road construction is a superstructure that has been used for a long time. Prior to the usage of hydrocarbon binding such as asphalt or bitumen, implementation of stone parquet casing used to be respected as the main solution to provide endurance, and an adequate surface for wheel rolling [9]. As a result of higher aesthetic

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expectations, IPS started to be used, widely. However, production cost of IPS supplied by natural resources increased sharply because of high labor effort requirement and increased demand. Cost could be slightly decreased by producing IPS by using concrete. Moreover, IPS show elastic behavior in terms of transferring the load to the lower layer due to the rigid materials and the surfaces touching the lower layer. For that reason, parquet casings applied by concrete IPS, sometimes resembling asphalt casing or concrete casing, are regarded to be a type of rigid and flexible casings. [10].

Utilizing fly ash for producing concrete interlocking paving stone leads to an economic and nature friendly approach. According to the literature review performed, fly ash decreases the level of bleeding and the hydration temperature [11-13]. It is stated that cement could be replaced by fly ash of 20-25% for mass concrete, yet in case of significantly low usage, it could cause alkali-aggregate reaction [14,15] 11. Furthermore, as a result of addition to the cement some volume extension occurs and that leads reduction of shrinkage. With regular cure methods, using high accuracy and low carbon fly ashes with equal weight of cement, leads to a 90 days period of lower pressure resistance compared to regular cement, but creates higher pressure resistance afterwards [16].

A study conducted on fly ashes shows that pressure resistance of fly ash added concrete shows a decreasing trend depending on the amount of fly ash. However, fly ash usage of around 15% gives similar results with reference concrete [17-19].

In our study, IPS's were investigated in the 90th day by replacing cement with fly ash in levels of 10%, 20%, 30% and 40% at the Orhaneli Thermal Power plants (OTPP), Çayirhan Thermal Power plants (ÇTPP), and Kangal Thermal Power plants (KTPP). Mechanical properties such as tensile strength, wearing and water absorption were observed.

2. Materials and Methods

2.1. Materials

Three different types of fly ashes (FA) are supplied from OTPP, ÇTPP and KTPP. In the cement mixture, coarse aggregate 0-4 mm class, CEM I 42.5 R cement (OPC) and Ankara network water are used. The physical properties of aggregate are given in Table 1, OPC and FA TS EN 450-1/A1 [20], TS EN 197-1 [21], TS 639 [22]ve ASTM C 618 [23] within comparative chemical properties are provided in Table 2.

Table 1. Physical properties of aggregates

Physical properties	0-4 mm.
specific gravity (kg/dm^3)	2,574
Water absorption rate (%)	2,2

Fly ash supplied from OTPP and ÇTPP is categorized in V class due to the reactive lime level under 10% [11]. Since levels of SiO_2, AL_2O_3, Fe_2O_3 are lower than 70%, and CaO percentage is below 10%, it is classified as F [21]. At the same time, S+A+F> %70 constraint required under TS 639 is satisfied. Limestone of KTPP fly ask is classified as W due to its reactive lime over 10% [23]. Even though levels of SiO_2, AL_2O_3, Fe_2O_3 do not satisfy TS 639 requirement of >70%, since S+A+F > 50% constraint is satisfied; its fly ash is determined as class C [20].

Table 2. According to standard and chemical characteristics of FA and OPC

	FA			Standartlara uygunluk sınırları					
	OTPP (%)	ÇTPP (%)	KTPP (%)	TS EN 450	TS EN 197-1		TS 639	ASTM C 618	
					V	W		F	C
SiO_2	48,45	50,88	37,85						
Al_2O_3	24,75	14,00	14,23						
Fe_2O_3	7,65	9,63	4,25						
S+A+F	80,85	74,51	56,33				>70,0	>70,0	>50,0
CaO	9,11	11,75	29,14						
MgO	2,30	4,11	1,68				<5,0		

SO_3	2,51	3,96	7,12	<3,0			<5,0	<5,00	<5,00
K_2O	2,65	1,85	1,02						
Na_2O	0,42	2,65	0,65						
KK	1,72	0,74	3,56	<5,0	<5,0	<5,00	<10,0	<6,00	<6,00
Cl^-	0,005	0,017	0,007	<0,1					
Serb. CaO	0,12	0,57	7,58	<1,0					
Reak. SiO	35,1	40,15	28,04	>25,0	>25,0	>25,0			
Reak. CaO	7,86	7,84	24,02		<10,0	>10,0			

2.2. Methods

Units storing IPS mixture elements are produced in a laboratory containing measuring device, and adequate mixer. Cement mixture is prepared according to TS 802, and water/cement (w/c) ratio is determined to be 0.50 (Table 3) [24]. By decreasing the weight of cement in IPS by rates of 0%, 10%, 20%, 30%, and 40%, fly ashes supplied from OTPP, CTPP, and KTPP are produced by replacing. IPS's are produced by applying 6 seconds of vibration by interlocking paving stone machine under 20 ± 2°C temperature. Samples taken from the cast were watered by sprinkling system twice a day for a week (morning and evening) and then once a day.

Table 3. The ratio of interlocking paving stone

Materials	Reference	FA contribution percentages			
		10 %	20 %	30 %	40 %
Aggregate 0-4 mm. (kg.)	1041	1041	1041	1041	1041
Cements (kg.)	260	234	208	182	156
FA (kg.)	0	26	52	78	104
Water (Lt.)	130	130	130	130	130

Splitting tensile strength experiment was performed by following TS 2824 EN 1338 [25] standards. The experiment was conducted through the section, which is parallel to the sides of IPS, symmetric and the longest cleavage section. Therefore, the fact that "perpendicular distance from any point of the cleavage section to the side surfaces must be at least 0.5 times of the IPS width on at least 75% of cleavage section area" is satisfied (Figure 1).

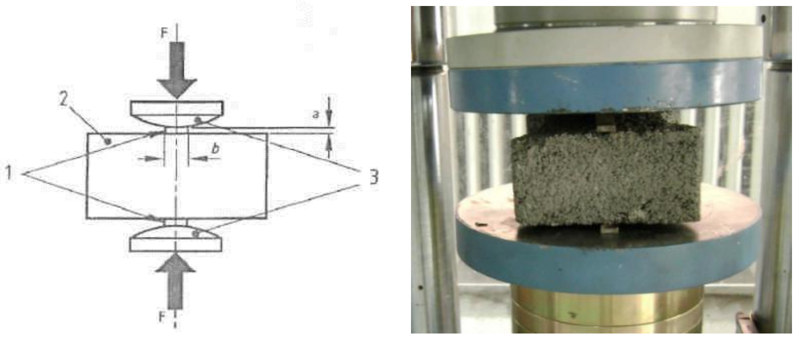

Figure 1. Splitting tensile strength test

Abrasion resistance is performed under ASTM C 944 [26] standards. It is conducted by abrading the upper surface of the parquet stone by an abrader propeller. Abrading machine is performed by a device providing the horizontal movement of abrading propeller that creates 200 turns per minute. Water absorption experiment is conducted by following TS EN 1097-6 standards [27] (Figure 2).

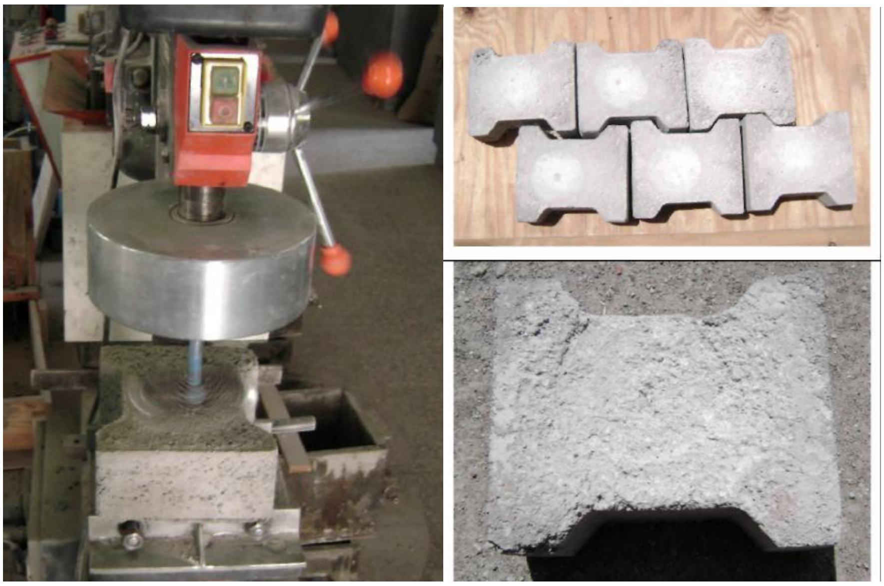

Figure2. Test of abrasion

3. Results and Discussion

The 90 days values of splitting tensile strength are provided in Figure 3. Interaction of thermal power plant-replacement percentage is found to be important statistically ($p<0.05$) according to the repeat measure factor analysis result, which is based on time factor (90th day), three factors of Thermal Power Plants (OTPP, ÇTPP ve KTPP), and four levels of replacement percentage (0%, %10, % 20, % 30 ve % 40). Duncan test, which is one of the multiple comparison methods, was used to determine the difference between means. There was no difference except the replacement values of 30% and 40% FA according to the Duncan test results.

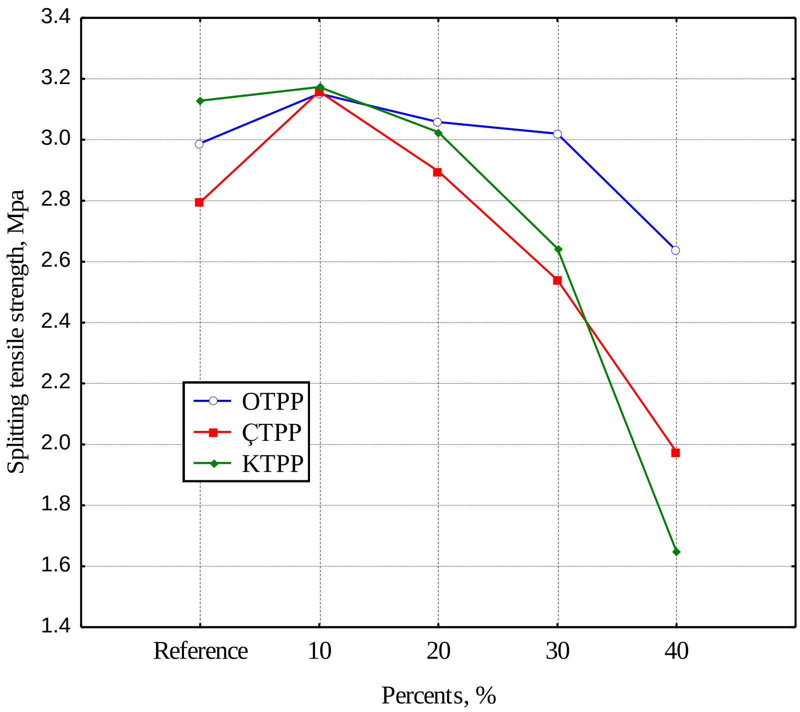

Figure 3. The results of splitting tensile strength test

As illustrated in Figure 3, 10% of FA obtained from OTPP increases 55%, 20% increases 2.3%, and 30% increases 1.1%, and 40% decreases 11.8% than to reference concrete. 10% of FA obtained from ÇTPP increases 5.7%, 20% decreases 3.1%, 30% decreases 15%, and 40% decreases 34% than to reference concrete. Furthermore, 10% of FA obtained from KTPP increases 6.2%, 20% decreases 1.2%, 30% decreases 11.5%, and 40% decreases 44.5% than to reference concrete. According to these results, FA obtained from KTPP with 10% replacement gives highest results than to the other ones.

Regression analysis was performed in order to determine the interaction of replacement values depending on the splitting tensile strength. As a result of regression analysis, the relationship between splitting tensile strength and replacement values can be explained by a quadratic equation $Y = b_0 + b_1X + b_2X^2$ model. The statistics related to the regression model prepared according to the power plant change are provided in Table 4.

Table 4. The regression analysis between the splitting tensile strength values with the percentage substitution

Factor		Regression coefficient	Regression Equation	Significant level
Thermal power	Day			
OTPP	90.	0,943	$Y=2.7043+0,3615*X-0,0742*X^2$	0,05
CTPP	90.	0,991	$Y=2,723+0,4062*X-0,112*X^2$	0,05
KTPP	90.	0,993	$Y=2,362+0,7904*X-0,1852*X^2$	0,05

The relationship between plant type values and percentage values gave good results according to regression coefficient as shown in Figure 4. It is possible to calculate the slices of percentage between 0-40% values by using the equations in Figure 4.

The 90 days values of abrasion resistance are provided in Figure 4. Interaction of thermal power plant-replacement percentage is found to be important statistically ($p<0.05$) according to the repeat measure factor analysis result, which is based on time factor (90th day), three factors of thermal power plants (OTPP, ÇTPP ve KTPP), and four levels of replacement percentage (0%, %10, % 20, % 30 ve % 40). Duncan test, which is one of the multiple comparison methods, was used to determine the difference between means. There was no difference except the replacement values of 30% and 40% FA according to the Duncan test results.

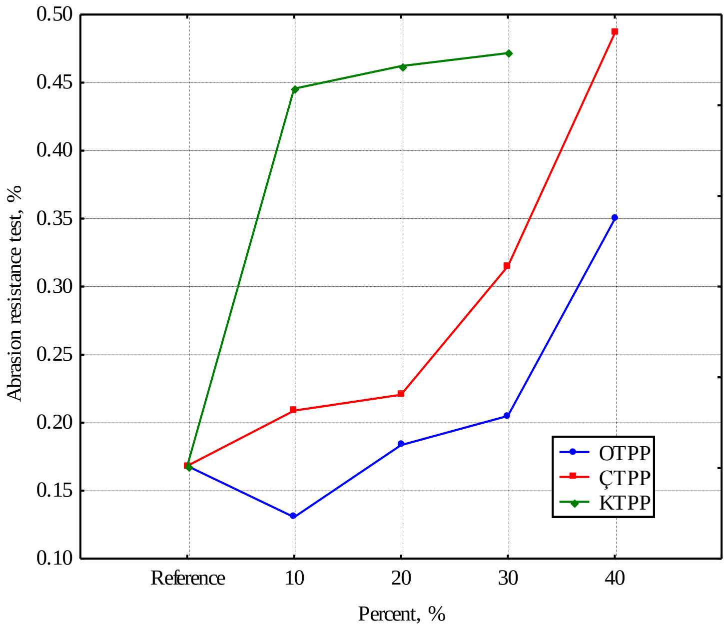

Figure 4. The value of abrasion resistance test

According to abrasion resistance results shown in Figure 4, three different thermal power plants are different from each other, and FAs obtained from OTPP gave best results.

The 90 days values of water absorption are provided in Figure 4. Interaction of thermal power plant-replacement percentage is found to be important statistically ($p<0.05$) according to the repeat measure factor analysis result, which is based on time factor (90th day), three factors of thermal power plants (OTPP, ÇTPP ve KTPP), and four levels of replacement percentage (0%, %10, % 20, % 30 ve % 40). Duncan test, which is one of the multiple comparison methods, was used to determine the difference between means. There was no difference except the replacement values of 30% and 40% FA according to the Duncan test results.

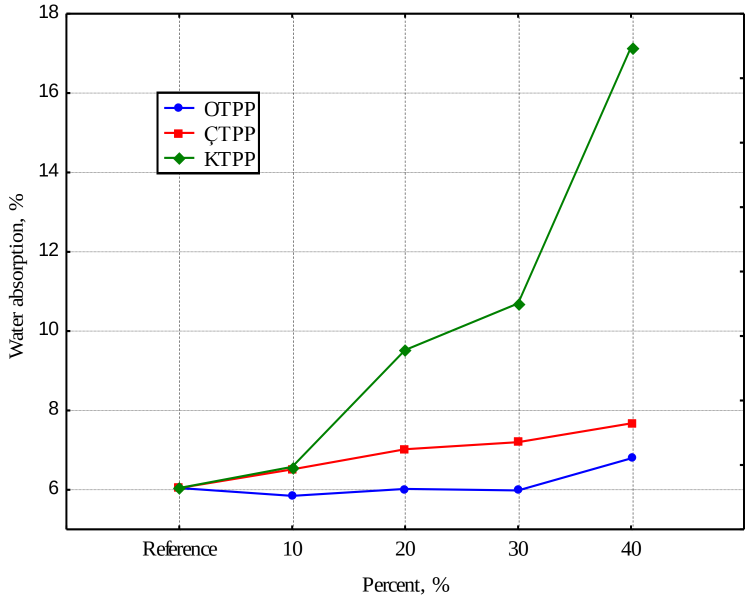

Figure 5. The value of water absorption test

According to water absorption percentage results shown in Figure 5, three different thermal power plants are different from each other, and FAs obtained from OTPP have least water absorption percentage. When percentages considered, water absorption percentages increase as replacement percentages increase in every thermal power plant.

4. Results

FAs obtained from OTPP, ÇTPP and KTPP were used for IPS production. Splitting tensile strength, abrasion and water absorption tests were performed for IPSs.

Three plants were conformable to TS EN 450, TS EN 197-1, TS 639 ve ASTM C 618 standards according to the results of chemical analysis performed on FAs obtained from OTPP, ÇTPP and KTPP. The FAs obtained from OTPP and ÇTPP are classified as V class, and similarly the FAs obtained from KTPP are as W class.

According to splitting tensile strength test, there is no difference between 10% and 20% values of FAs obtained from OTPP, ÇTPP and KTPP, but there is difference between 30% and 40% values. Besides, FAs obtained from OTPP give best results in every percentage.

According to abrasion resistance test, FAs obtained from OTPP give best results in every percentage however FAs obtained from KTPP gave worst results. Besides, abrasion resistance values increase as FA replacement percentage increases.

According to water absorption test, FAs obtained from OTPP and ÇTPP give similar results in every percentage, however FAs obtained from KTPP is dissimilar from the others. FAs obtained from OTPP give best results in every percentage. Besides, water absorption values increase as FA replacement percentage increases.

Minimum value of splitting tensile strength of IPS should not be under 2 MPa, and water absorption ratio should not be over 7 % as recommended in TS 2824 EN 1338. 30% value of FAs obtained from OTPP conform with this limit however 30% value of FAs obtained from ÇTPP and KTPP don’t conform.

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