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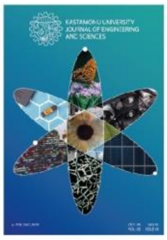

Usability of organic wastes in concrete production; Palm leaf sample

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Abstract: Palm leaves are vegetal waste that are not widely used by the society, only piled up and causing odors that mix with the environment. Channeling this waste material into the construction industry helps to overcome waste disposal problems as well as promote sustainability. The most important features expected from the buildings are the creation of the most suitable environmental conditions for the products to be stored or the creatures that will live in them, and they can be used safely for a long time. In the construction of the buildings, materials that are the cheapest possible, safe and capable of creating the optimum environmental conditions should be used. The materials to be selected should have sufficient strength and durability, high heat and sound insulation and lightness. Since single-storey buildings are not subject to excessive load, it is important that the thermal insulation is high and light in material selection. Since the widespread use of concrete as a building material in the world, efforts to make concrete light, cheaper and better insulating have gained importance. Lightweight concrete, which is easy to apply, has been an important building material in recent years. With the use of lightweight concrete as a building material, benefits such as economy in terms of material, earthquake resistance, and the elimination of a second insulation material for heat and sound insulation can be achieved. In this study; Experimental study using Portland cement (CEM I), Palm Leaf, CEN standard sand and water mortar production; sample production, curing, some physical and mechanical experiments were carried out in four stages. The usability of palm leaf, which is a vegetable waste, as aggregate in concrete production by replacing it with CEN standard sand at 0, 5, 10, 20, 30 and 40% as well as 10% with cement has been investigated. The study results show that the addition of both ground palm leaf and palm leaf aggregate significantly altered almost all properties of concrete. These changes are at different levels in terms of physical properties. As a result of the study, it was determined that as the amount of foam increased, the spreading diameter increased, whereas palm leaf addition decreased the spreading diameter. It has been determined that the addition of palm leaf decreases the depth of water treatment depending on time, the porosity of the samples with high level of palm leaf addition increases and the compression and bending strength decreases.

Keywords: Concrete, Organic waste, Palm leaf

Öz: Palmiye yaprakları toplum tarafından yaygın olarak kullanılmayan, sadece üst üste yığılan ve çevreye karışan kokulara neden olan bitkisel atıklardır. Bu atık malzemeyi inşaat sektörüne yönlendirmek, atık bertaraf sorunlarının üstesinden gelinmesine ve sürdürülebilirliğin desteklenmesine yardımcı olur. Binalardan beklenen en önemli özellikler, depolanacak ürünler veya içinde yaşayacak canlılar için en uygun çevre koşullarının oluşturulması ve uzun süre güvenle kullanılabilmesidir. Binaların yapımında mümkün olan en ucuz, güvenli ve optimum çevre koşullarını oluşturabilecek malzemeler kullanılmalıdır. Seçilecek malzemeler yeterli mukavemet ve dayanıklılığa, yüksek ısı ve ses yalıtımına ve hafifliğe sahip olmalıdır. Tek katlı binalar aşırı yüke maruz kalmadığından malzeme seçiminde ısı yalıtımının yüksek ve hafif olması önemlidir. Betonun dünyada yapı malzemesi olarak yaygınlaşmasından bu yana betonu daha hafif, daha ucuz ve daha iyi yalıtkan hale getirme çabaları önem kazanmıştır. Uygulaması kolay olan hafif beton, son yıllarda önemli bir yapı malzemesi olmuştur. Hafif betonun yapı malzemesi olarak kullanılması ile malzeme açısından ekonomi, depreme dayanıklılık, ısı ve ses yalıtımı için ikinci bir yalıtım malzemesinin ortadan kalkması gibi faydalar sağlanabilir. Bu çalışmada; Portland çimentosu (CEM I), palmiye yaprağı, CEN standartlarında kum ve su harcı üretimi kullanılarak deneysel çalışma; numune üretimi, kürleme, bazı fiziksel ve mekanik deneyler dört aşamada gerçekleştirilmiştir. Bitkisel bir atık olan palmiye yaprağının CEN standartlarında 0, 5, 10, 20, 30 ve %40 oranında ve %10 oranında çimento ile değiştirilerek beton üretiminde agrega olarak kullanılabilirliği araştırılmıştır. Çalışma sonuçları hem öğütülmüş palmiye yaprağı hem de palmiye yaprağı agrega ilavesinin betonun hemen hemen tüm özelliklerini önemli ölçüde değiştirdiğini göstermektedir. Bu değişimler fiziksel özellikler açısından farklı düzeylerdedir. Çalışma sonucunda, köpük miktarı arttıkça yayılma çapının arttığı, palmiye yaprağı ilavesinin ise yayılma çapını azalttığı tespit edilmiştir. Palmiye yaprağı ilavesinin zamana bağlı olarak su arıtma derinliğini azalttığı, yüksek oranda palmiye yaprağı ilave edilen numunelerin porozitesinin arttığı, basınç ve eğilme dayanımının azaldığı tespit edilmiştir.

Anahtar Kelimeler: Beton, Organik atık, Palmiye yaprağı

1. Introduction

In the current century, the urban-to-rural migration significantly increased especially because of the Industrial Revolution [1] and it even became one of the two important irreversible problems [2] together with the global climate change [3, 4]. Such that, the rate of urban population, which was only 9% in 1900s, worldwide increased to 47% in 2000 and estimated to increase to 90% by the year 2030 [5, 6].

Concentration of the population in urban areas also brought various problems with it [7]. One of the most important problems is, undoubtedly, the air pollution [8, 9]. In urban areas, pollution reached severe levels because of the traffic density and human activities [10], the level of pollution in air [11], water [12], and soil [13-16] increased significantly, and it became a global problem causing to the death of more than 7 million individuals annually [17].

The demand for urban areas increases the need for new residential areas [18-20] and construction of new housings [21-23]. This need also increases the demand for concrete, which is an important raw material especially in the building industry and constitutes an important share of construction costs [24-26]. Thus, the studies addressing the use of environmental wastes as an alternative to concrete in order to decrease the costs of concrete and to eliminate the environmental wastes gain more importance and many studies were carried out on this subject in recent years [27-29].

The plants grown for landscaping purposes constitute a significant portion in the wastes, which are an important factor in environmental pollution [30]. Although plants fulfill many ecologic, economic, and social functions in urban areas, the organs drying or falling as a result of the natural development process constitute an important source of pollution [31-34]. The most frequently used method in the elimination of plant wastes is the collection and combustion but this method results in a high level of carbon emission. Global climate change, which is one of the most important problems at the global scale, arises mainly from the carbon emission [35]. For this reason, different methods are needed for the elimination of organic wastes. In the present study, the usability of palm leaves, one of the most important organic wastes, as an additive to concrete is examined.

2. Material and Method

In this study, several physical and mechanical properties of palm leaves, an important herbal waste, were examined and their usability as an aggregate in concrete production was investigated. Within the scope of this study, palm leaves, which are an organic waste, were ground and used as aggregate in production of PC 42.5 (Portland) cement, which was manufactured according to TS EN 196–1, together with CEN standard sand and mains water. Within the scope of this study, ground palm leaves were added into cement at different concentrations and several physical and mechanical properties of cement mortars were determined. For this purpose, first, the palm leaves to be added into cement were ground and sieved at the right size. The high void ratio and water absorption rate of resultant palm leaves caused the predetermined amount of water to be insufficient and insufficient setting and hydration in concrete. For this reason, the palm leaves to be used in concrete production were kept in water for half an hour until saturated. The calculation of the mixture of cement and palm leaf having the same particle size was made as the percentage of total aggregate volume. The percentages were set to be 0%, 10%, 20%, and 30% and named as K10PY0, K10PY10, K20PY0, K20PY10, K30PY0, and K30PY10, respectively, based on the foam density (PY: Palm Leaf). Within the scope of this study, 36 cement mortar samples were produced in total. The mixture ratios used in the experimental study are presented in Table 1 and the amounts of materials in Table 2.

Table 1. Mixture ratios

	Level 1	**Level 2**	**Level 3**
Foam rate (kg/m^3)	10	20	30
Milled Palm leaves (%)	0	10	

Table 2. Amounts of materials

Mixture	**K10PY0**	**K10PY10**	**K20PY0**	**K20PY10**	**K30PY0**	**K30PY10**
Cement	350	315	350	315	350	315
Milled Palm leaves (%)	0	35	0	35	0	35
Palm leaf aggregate	686,2	680,9	652,6	647,3	619	613,7
Water	245	245	245	245	245	245
Foam	10	10	20	20	30	30

The w/c ratio was set to be 0.70. Foam density is 140 g/l. Foam addition rates were 10, 20, and 30 kg/m^3. The flow diameters of foamed concretes were determined according to ASTM C 230 standard. Then, the mixtures were poured into molds with dimensions of 4*4*16 cm. Since the mixtures have the self-settling character, no vibration was performed. The foamed concretes, which were kept under laboratory conditions for 24 hours, were removed from the molds and the water cure was initiated. Foamed cements' compressive and bending strengths were determined using the samples with dimensions of 4*4*16 cm. Mechanical properties of samples were determined using the ASTM C348 and 349 standards. Compressive strength test was performed after the bending strength test. Compressive and bending strength tests of foamed concretes were performed on the 28th and 90th days.

Capillarity properties of the foamed concretes were determined using cube samples with dimensions of 5*5*5 cm according to ASTM C 1585. Water penetration depths of foamed concretes on the 24th hour were used. After 28 days of curing, foamed concretes were dried in drying oven for 3 days at 50°C and the capillarity test was initiated. Approx. 5mm-thick water sealant was applied to the sides of the foamed concretes and the water penetration depths were determined on the 24th hour. The results were evaluated according to the average values.

3. Result and Discussion

The test results (flow diameter and bending – compressive strength tests on the 28th and 90th days) of the samples are presented in Table 3.

Table 3. Sample test results

Mixture	K10PY0	K10PY10	K20PY0	K20PY10	K30PY0	K30PY10
Spread diameter (cm)	10	9,1	12,2	10,6	18,1	15,5
28. Day Flexural strength (MPa)	0,50	0,52	0,44	0,46	0,41	0,42
90. Day Flexural strength (MPa)	0,55	0,69	0,48	0,50	0,45	0,48
28. Day Compressive strength (MPa)	1,45	1,95	1,14	1,28	1,18	1,20
90. Day Compressive strength (MPa)	1,62	2,04	1,35	1,58	1,27	1,52

Given the results presented in Table 3, it can be seen that the sample with the highest flow diameter was K30 samples and that the flow diameter increased with increasing amount of foam. However, it was found that the flow diameters of all the samples added with ground palm leaf were lower when compared to the values found with the samples containing no palm leaf addition. The smallest flow diameter was found to be 9.10 cm in K10P10 and the longest one to be 18.10 cm in K30PY0.

Examining the bending strength results of the samples added with ground palm leaf and aggregate, it can be seen that the highest results were found to be in K10 samples (ranging between 0.50 and 0.69MPa) on both the 28th and 90th days and that there was no significant difference between K20 and K30 samples having the results ranging between 0.44 and 0.50MPa. Besides that, even though there was no remarkable difference, it can be seen that the bending strength results of PY10 samples were higher than those of PY0 samples. The compressive strength results of samples were very close to the bending strength results. In general, the highest compressive strength values were found to range between 1.45 and 2.04 MPa in K10 samples, whereas there was no significant difference between K20 and K30 samples ranging between 1.13 and 1.57 MPa and compressive strength values of PY10 samples were slightly higher than those of PY0 samples. The results obtained on the 28th and 90th days were found to be parallel. Examining the temporal change in the water penetration depths of mortars, it can be seen that the time-dependent water penetration depth decreased with increasing amount of foam addition. However, given the results, addition of ground palm leaf was more effective and the highest water penetration depth values in the shortest time were obtained from the samples K10PY0 and K20PY0.

4. Discussion and Conclusion

The results obtained in the present study showed that both ground palm leaf and palm aggregate additions significantly affected almost all the properties of concrete. These effects either decreased or increased the properties. For instance, it was found that the flow diameter increased with increasing amount of foam addition but addition of palm leaf decreased the flow diameter. It can be stated that the palm leaf addition decreased the time-dependent water penetration depth and that the porosity increased in the samples with higher palm leaf addition and their compressive and bending strength values decreased.

The increase in urbanization in recent years and the construction of multi-storey buildings in order to allow more individuals to live in the unit area significantly increased the use of concrete [21, 36, 37]. Concrete is one of the most widely used materials and one of the most important inputs in the construction industry and concretes having different characteristics are used in buildings having different structures. For instance, for the areas where the higher strength is demanded, the concretes with lower porosity and higher compressive strength are requested and, consequently, the concretes having lighter weight and higher isolation levels are preferred [38, 39, 40].

Besides these characteristics, another important factor is the cost of concrete. Cost and characteristics of concrete can significantly vary depending on the additives used [41-43]. Aiming to reduce the input costs in construction industry, several additives are used in order to decrease the cost of concrete that is the input, which affects the cost at most, among the additives [44-46]. The use of these additives causes an acceptable level of change in the cement characteristics and, sometimes, it may even give superior mechanical properties depending on the area of use of concrete [47, 48].

Some of the materials used as concrete additive cause severe environmental pollution. Thus, the use of these materials as concrete additive also allows for the recycling and elimination of the pollutants causing environmental pollution [49-51]. As known, environmental pollution is one of the most important problems of today [52]. Use of pollutant materials as concrete additive might significantly contribute to the reduction of environmental pollution [53, 54]. For this reason, the usability of various environmental wastes as concrete additive was investigated in many studies [55, 56].

In these studies carried out on this subject, the use of materials including waste glass and granulated glass [57], waste brick dust [58], waste ceramic [59], boron mineral wastes [60], waste tires [51, 61-63], hearth cinder [64], waste marble dust [65, 66], and fly ash [67, 68] as cement substitute was investigated.

However, the number of studies carried out on the use of organic wastes as cement substitute is relatively lower. Organic wastes are the wastes that have organic origins. All the organisms develop during their biological life processes and the development of organisms is shaped by their genetic structures [69-71] and environmental factors [72-74]. Although all the organs of plants grown in urban areas are mainly the carbon-based wastes, they also include trace amounts of various elements that are very harmful for human and environmental health. Some of these elements such as Pb, Ni, Cr, and Cd are called heavy metals [75] and almost all of them can be toxic, carcinogenic, or harmful to organisms. Thus, using these wastes as additive for concrete is very important for protecting the environment but the number of studies on this subject is very limited. In some of the studies carried out on this subject, the usability of oyster shell [76], olive wastes [77], forest wastes [78], fig wastes [79], rise husk ash [80, 81] and some of the other materials [82, 83] as concrete additive was examined. Environmental pollution has increased dramatically, especially in the last 30 years [84-86] and because of the rapid development of global economy, the type and level of chemical pollution have constantly increased, and this increase has reached a terrifying level for the ecosystems [87, 88]. In order to effectively control the pollution, using waste materials as concrete additive will help protect the environment and conserve natural resources.

5. Suggestions

It is known that using different materials as additive to concrete could significantly alter the characteristics of concrete. The concentrations, at which the additives could be used without pushing the characteristics of concrete outside the acceptable limits, constitute the main factor playing a determinant role in the usability of additives. The desired characteristics of concrete may change depending on the area of use. For instance, while the most important characteristic for the concretes to be used in load-bearing column is the strength, isolation becomes more prominent for the concretes constituting the borders of units. Different characteristics of concrete are altered by different additives. Thus, the additive that can be used for concretes desired to have a high strength would differ from the additives to be added into a concrete that is desired to have high insulation.

The benefits expected from using the additives as substitute (decreasing the cost, making use of the environmental wastes, improving the visual quality, etc.) would play a determinant role at which concentration the additives could be used as substitute. Hence, the studies examining to what extent the additives alter the characteristics of concrete, to what extent they affect the costs, what are the substitutes that can be used instead of each other, etc. would significantly contribute to the practice. The results achieved in the present study showed that ground palm leaf and raw palm leaf can be used as concrete additive. However, by making use of the results achieved, it should be examined if the changes these materials cause in the characteristics of concrete are within the acceptable limits depending on the purpose of use, the use of these materials.

Competing Interest / Conflict of Interest

The authors declare that they have no competing interests.

Author Contribution

We declare that all Authors equally contribute.

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