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Effects of recycled aggregates from construction and demolition wastes on mechanical and permeability properties of paving stone, kerb and concrete pipes

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HIGHLIGHTS

- Aggregate recycling from construction and demolition wastes.
- Concrete masonry production with recycled aggregate addition.
- Optimum waste addition ratio was determined in concrete products.

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ABSTRACT

The main objective of this research is to investigate the utilization criteria of the recycled aggregates gained from construction and demolition wastes, in the production of various ready-mixed and precast concrete elements. Within this scope, construction and demolition waste materials were selectively separated to have homogeneous concrete wastes in the recycling plant. Then, fine and coarse aggregates were achieved from concrete wastes. Recycled concrete aggregates were than crushed to specific sizes; physical properties were determined and compared with those of normal aggregates. Finally, these recycled aggregates were investigated about their utility in the industrial production of various concrete products like ready-mixed concrete, concrete pipe, paving stone and kerbs. Also some studies were done to determine durability and permeability properties of these products. It can be concluded that the use of recycled aggregates in the production of various concrete elements is possible with proper separation and classification. Moreover, lower replacement rates should be applied to obtain sufficient conditions which are specified in related product standards.

1. Introduction

Solid wastes become one of the most important environmental problems nowadays. As a result of increasing construction activities, construction and demolition waste represent a substantial percentage of the overall solid waste.

After urban renewal programs or natural disasters like earthquakes, demolition of older buildings leads to environmental problems particularly in larger urban areas. In addition, scarcity of raw material sources resulting from increased aggregate usage, have motivated stakeholders in construction industry about utilization of recycled aggregates [1]. Older buildings with expiring service life and the buildings which cannot meet new structural requirements and expectations are being demolished during the recent years in Turkey.

Construction wastes mainly occur as a result of this demolition activities and natural disasters like earthquakes. In a study, the composition of construction and demolition wastes was given (in Fig. 1) [2].

The European Union construction industry generates 531 million tonnes construction and demolition wastes per year which represents nearly one quarter of the existing waste materials in the world (Table 1) [3].

In the European Union's 27 member countries, approximately 46% of the construction and demolition waste is recycled.

After the examination of recycled aggregate standards, some classification studies were performed based on the test results of these aggregates, waste source and waste content. Table 2 shows

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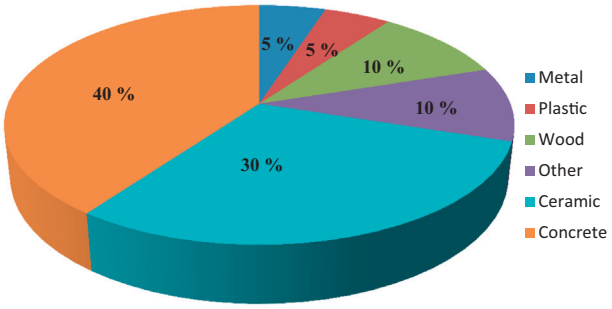

Fig. 1. Composition of construction demolitions [2].

Table 1
EU construction and demolition waste quantity and recycling rates [3].

Country	CDW*	Recycling %	Country	CDW*	Recycling %
Denmark	5.27	94	Malta	0.8	0
Estonia	1.51	92	Holland	23.9	98
Finland	5.21	26	Poland	38.19	28
France	85.65	45	Portuguese	11.42	5
Germany	72.40	86	Romania	21.71	0
Greece	11.04	5	Slovakia	5.38	0
Hungary	10.12	16	Slovenia	2.00	53
Ireland	2.54	80	Spain	31.34	14
Italy	46.31	0	Sweden	10.23	0
Latvia	2.32	46	England	99.10	75
Lithuania	3.45	60	EU-27	531.38	46
Luxemburg	0.67	46	*Million tonnes		

the allowed utilization rates of recycled aggregate in concrete production in different countries [4].

The most effective way to eliminate the waste problem in construction is reuse, recycling and reduces the construction materials in construction activities. The most usual way to recycle concrete rubble is indicated as bound (normal aggregate replacement in new concrete) and unbound (road base, trench, etc.). According to researches, acceptable recycled aggregate replacement is specified as 30% into new concrete products [5]. Silva et al. stated that recycled aggregates usually belong to normal weight in terms of density and almost always exhibit higher water absorption values than normal aggregates. They concluded that selective demolition should be promoted and enforced after their statistical analysis of data available in the literature [6].

In a study, five mixes with water-to-cementing material (w/cm) ratio of 0.40 were produced with various recycled aggregate contents and tested against two control mixes. The recycled aggregate contents in the mixes were 10%, 20%, and 30% by coarse aggregate volume replacement, as well as 10% and 20% fine and coarse (granular) aggregate volume replacement. The coarse recycled aggregate mixes performed better than the granular recycled aggregate mixes in terms of flexural and splitting tensile strengths, linear drying shrinkage, water absorptivity and rapid chloride-ion permeability, where the test results were significantly affected by the ultrafine present in the granular recycled aggregate [7].

In the study conducted by Tu et al., the recycled aggregates achieved from C&D wastes were used in production of high performance concrete (HPC). From the results, it was seen that the designed HPC with recycled aggregate had a slump as more than 180 mm and slump-flow as larger than 550 mm. These initial values were found feasible for HPC slump requirements, however highly slump reduction occurred after 1 h because of the recycled aggregates high absorption capacity [8].

López-Gayarre et al. showed that water absorption increases up to 34% with the replacement of natural aggregates by recycled ones up to 50% and the percentage of replacement does not affect the compressive strength of concrete, being affected only by the quality of the recycled aggregates employed [9]. However, Lovato et al. concluded that the water absorption of concretes was more negatively affected by the fine aggregate replacement then the coarse aggregate replacement [10].

The aim of this study is to determine the utilization criteria of the recycled aggregates from construction and demolition (C&D) wastes in the production of various concrete components. Within this scope, construction and demolition waste materials, were selectively separated and fractured to specific sizes in the facilities of ISTAC Istanbul Environmental Management Industry and Trading Corporation and were investigated for their utility in the industrial production of various concrete products like ready-mixed concrete, concrete pipe, paving stone and some other prefabricated products. The physical properties of the obtained aggregates were determined and compared to normal aggregates. Also some studies were done to determine durability and permeability properties of these products.

2. Experimental procedure

Some aggregate tests were conducted in order to determine the properties of recycled aggregates and to compare with normal aggregates. In this scope, 49 experimental samples were prepared for 10 different aggregate tests, 42 experimental samples were prepared for 6 different fresh and hardened concrete tests and 36 experimental samples were prepared to be used in 11 different industrial products. Mechanical and durability properties of concrete mixes which were produced by substitution of normal aggregates with recycled aggregates were determined. At the final stage of the study, industrial scale productions were carried out with these concrete mixtures containing recycled aggregates and properties of the industrial products were determined.

2.1. Materials

2.1.1. Cement

The cement used is CEM I 42.5R type, while its specific weight is 3.14 g/cm^3 and the Blaine specific surface is 345 m^2/kg. Its composition is shown in Table 3.

Table 2
Allowed recycled aggregate utilization in some countries [4].

Countries	Applications	Recycled aggregate in volume (%)	Recycled fine aggregate utilization	Concrete grade	Other materials in weight (%)
Belgium	In nonaggressive environmental effects	0–100	In the states when it is provided of normal aggregate's standards	Max C30/37 depending on the aggregate	<1 non-mineral mixes
Denmark	In nonaggressive environmental effects	0–100 for >4 mm part	Permitted	Max 21 MPa depending aggregate	–
Germany	Except in strong chemical effect and reinforced concrete	Only 0–42 for broken concrete	Max 7% for <2 mm part	Max C35/45	<0.2 wood and plastic material
Japan	In moisture free components	Only 0–42 for broken concrete	Permitted	Max C30/37 depending aggregate	Max 10 kg/m^3 gypsum and max 2 kg/m^3 asphalt
Holland	In nonaggressive environmental effects	Only 0–20 for broken concrete	Permitted up to 20%	According to all concrete building standards	Max 1% bitumen and max 0.15 organic matter
USA	In concrete and reinforced concrete components	Only 0–100 for broken concrete	Permitted	According to ACI 318-95	–