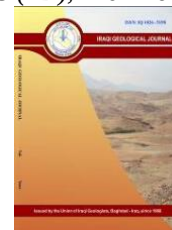




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The Effect of Adding Concrete Wastes to Iraqi Ordinary Portland Cement

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Abstract

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The research relied on taking five samples: The first sample is the Iraqi Ordinary Portland Cement. Physical tests were carried out for the purpose of comparison with other samples, as the rank of the Ordinary Portland Cement sample under study was 52.5R, according to the Iraqi specification No. 5, 2019. The second sample is concrete waste that was crushed then added water to it in known proportions according to the Iraqi specification and making a paste for concrete wastes only, but it failed to compressive strength and soundness. Three other samples of concrete waste 25%, 30%, and 35% with Ordinary Portland Cement as the addition of concrete wastes, were a partial substitute for the Ordinary Portland Cement. The results of the physical tests including fineness, setting time soundness, and compressive strength that were conducted on the third and fourth samples 25% and 30% were good results within the Iraqi specification No. 5, 2019. The result of physical tests at 35% of concrete wastes failed to test compressive strength. The results of mixing the concrete wastes with the Ordinary Portland Cement under consideration, showed that they can be mixed in various ratios and obtain different results. The more the concrete wastes mixed with the cement, the less the quality of the mixed cement was reaching the highest ratio that led to the failure of the mixture with the concrete wastes in terms of the physical properties. Basically, the mixture ratio of concrete wastes with the cement depends on the quality of the cement and its class in accordance with the compressive strength, and concrete waste quality.

Keywords: Ordinary Portland Cement; Concrete wastes; Physical tests; Compressive strength

1. Introduction

The concrete is composed of gravel, sand, and cement to which water is added with a specified and determined ratio. The concrete is subjected to damage and corrosion with time (Jedidi and Benjeddou, 2018) and the debris of concrete accumulates in the valleys and changes the path of the rainwater discharged at the entrances of the cities. This debris accumulates annually in huge quantities as is of high resistance to the atmospheric factors, they don't decompose or disintegrate and therefore, the problem of pollution has become increasingly high all over the world (Karlsson, 1998).

This research aim: Getting rid of the concrete wastes by means of grinding them and mixing them with cement, which leads to the protection of the environment from the pollution resulting from the random dumping of concrete wastes and thus reducing the consumption of the raw materials used in producing the cement in order to get a high-quality cement with less cost, which meets the Iraqi

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specification No. 5, 2019. The collected sample of waste concrete are from the center of Mosul city and the cement is from Mosul market (Fig.1). Researches and studies on recycling concrete wastes are few and they don't exceed reusing the cement concrete as debris used in construction. AlQattan et al. (2011) indicated that cement wastes can be used as concrete debris after breaking them into small pieces as an alternative for gravel and sand and this yielded better results in the tests of compression resistance and soundness compared to using gravel and sand, the concrete is characterized with high absorptive capability, high density, and good flexibility. They pointed out that it is possible to use concrete waste in road construction and pave the roads and sidewalks. Rosman et al. (2014) studied the potential of making concrete molds from concrete wastes and using them as debris or mixing 5%percentage of cement to reduce the heat emitted from the concrete. Additionally, Khalid et al. (2019) studied the process of adding industrial cement wastes (silica foam) and Fly ash to the Ordinary Portland Cement (OPC) to produce an environment-friendly cement, get rid of the industrial pollutants, and reduce the economic cost of cement produced as he compared the physical properties of the two products and obtained good results.

2. Materials and Methods

- **Cement:** The OPC class 52.5R, (this type gives commprasive strength of more than 52.5 N/mm² after 28 days) which meets the Iraqi specification No. 5, 2019 was produced in Iraq, the physical properties Table 1.
- **Concrete wastes:** The concrete wastes of the buildings demolished were used after conducting the processes of crushing and grinding at the laboratory. A paste was made of these wastes and then the physical tests were performed as shown in Table 1.
- **Sand:** The standard laboratory sand with silica of not less than 98% and good granule gradation and meeting the Iraqi specification 5, 2019.
- **Water:** Sterilized water was used in making the cement and mortar cement.

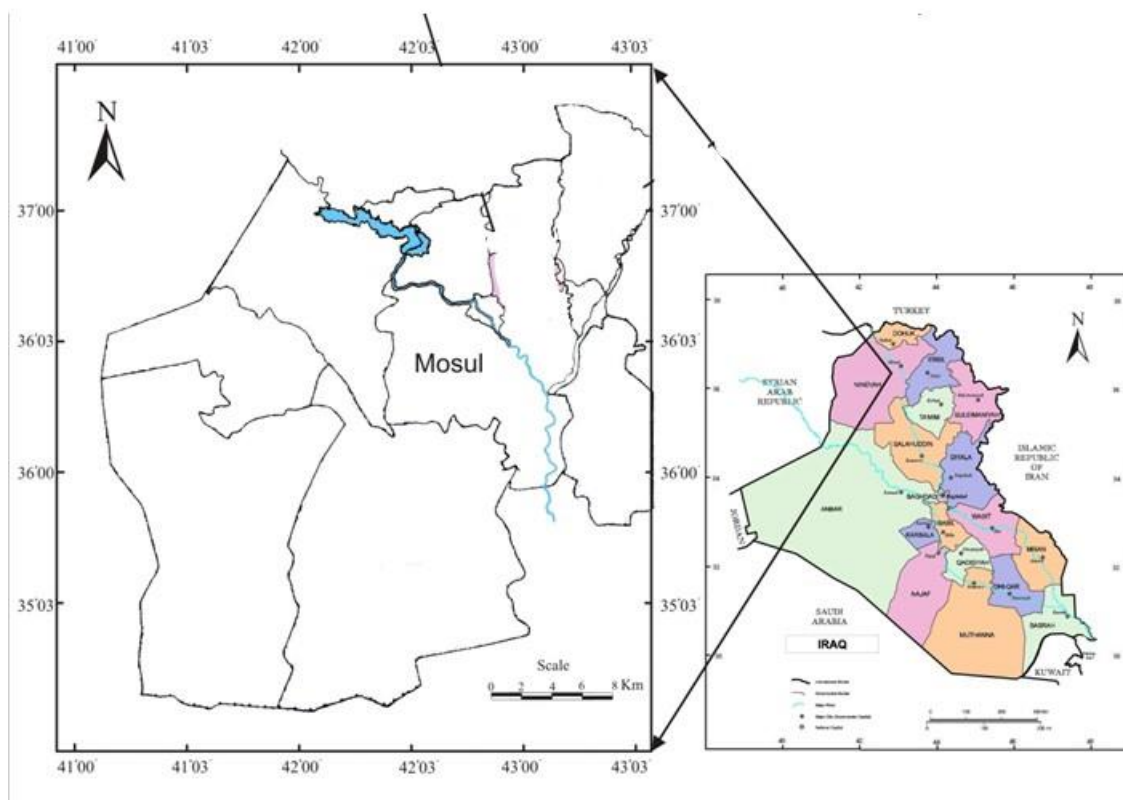


Fig.1. Location map of the study area

3.1. Concrete Mixture

Five mixtures were marked as follows

- The concrete mix consists of 25% cement, and 75% of standard sand according to the Iraqi specification 5, 2019 (Table 1).
- The ground concrete wastes are only used as OPC mixed with standard sand (Table 1).
- Three mixtures of grinded concrete wastes with percentages of 25%, 30%, and 35% of the weight of the OPC, mixed with 75%, 70%, and 65% of the OPC and standard sand (Table 2).

3.2. Laboratory Work

Physical tests were performed on the concrete wastes after selecting a random sample from the areas where old houses were demolished. The sample was crushed into smaller pieces using a laboratory crusher and then they were ground to a good degree of fineness using a laboratory grinder after that the physical tests were performed (Table 1). The paste showed a medium solidification (Fig. 2b) and this indicates that there is a cohesiveness strength between the granules of the crushed concrete. The physical tests were conducted on the sample of them cement alone and then the process of adding the concrete wastes with percentages of 25%, 30%, and 35% (Table 2) of the cement weight to the OPC sample and conducting the physical tests according to the Iraqi specification No. 5, 2019 for each percentage and then making comparisons for all the samples. These tests are:

- The test of fineness: This test was performed for the cement fineness and the fineness of the concrete waste and for mixtures of concrete wastes mixture and cement before conducting the addition process at each addition percentage. The fineness tests were performed using the method and the device Blain. This method depends on calculating the specific surface area of the cement by measuring the time required for the depletion of one volume of the air through a specific layer of the cement with a certain permeability. The speed of the air passing through the cement layer depends on the sizes of the cement particles of the Iraqi specification No. 5, 2019.
- Determining the consistency of the paste: Vicat device was used to determine the standard consistency of the paste and to determine the quantity of water added to the paste for all the samples (the sample of OPC, the sample of the ground concrete wastes and the sample of the mixture of the cement wastes with different percentages, as the main standard consistency of the mixture paste for each percentage was determined alone) and according to the Iraqi specification No. 5, 2019.
- Soundness test: It is the measurement of the increase in the mold length of the cement paste after it is hardened and then it is exposed to a temperature and a pressure of 21 kg/cm^2 for three hours on the condition that the increase in the average increase in the mold length shouldn't exceed 0.8% the Iraqi specification No. 5, 2019. The test of soundness was determined by making molds for all the samples in question (Fig. 2a) and the dimensions of the mold are $285 \times 25 \times 25 \text{ mm}$ with a variation of $\pm 0.7 \text{ mm}$ concerning the height and width using the Autoclave.
- Test of initial and final setting time: It is the time required for the cement paste to be hardened. The initial and final setting time was determined by making a paste for all the samples and then they were put in a cylinder mold (Fig. 2b) using the Vicat device and the initial and final setting time was calculated according to the Iraqi specification No. 5, 2019.

**Fig. 2a.****Fig. 2b.**

Fig. 2.a. Molds of the soundness of the studied samples paste; **b.** A mold of paste of the concrete wastes powder sample only with water

- Compressive strength test: A mortar from the samples was made and six molds were prepared for each sample that forms three rectangular shapes in one mold with dimensions of $40 \times 40 \times 160$ mm. the first three molds are submerged in the water for two days and then they are halved to be six halved prisms and after that, the compressive resistance is measured (Fig. 3). Six readings are taken and the average readings are determined. The same process is repeated for the other three molds after submerging them in the water for 28 days according to the Iraqi specification No. 5, 2019.

**Fig. 3.** Testing the compressive strength of the samples.**Table1.** The physical specifications of the samples of OPC and powder concrete wastes

Physical Test		Limits (according to I.Q.S NO. 5/2019)	Result of Sample (C.W)*	Result of Cement (O.P.C)*
Water ml			80	118
Setting Time	Initial Min	≥ 45 Min	210	150
	Final Hours	≤ 10 Hours	4:00	3:05
Fineness (Blain)M ² /Kg		≥ 250 for O.P.C	399.5	379.5
	2 Days N/mm ² *	≥ 30 for class 52.5R	Failed	36.52
Compressive strength				
	28 Days N/mm ²	≥ 52.5 for class 52.5	Failed	58.94
Soundness	Autoclave %	$\leq 0.8\%$	Failed	0.06

R*: Ripped solidness cement; OPC*: Ordinary Portland Cement; C.W*: Concrete Waste; N/mm²* = Mega Pascal (Mpa)

Table2. The physical specifications of the samples of concrete wastes mixture with OPC at a ratio (25,30,35) %

Physical Test		Limits (according to I.Q.S NO. 5/2019)	Result of Mixture 25%	Result of Mixture 30%	Result of Mixture 35%
Water ml			110	102	100
Setting Time	Initial Min	≥ 45 Min	155	145	160
	Final Hours	≤ 10 Hours	3:40	3:10	3:30
Fineness (Blain)M ² /Kg		≥ 250 for O.P.C	415.7	415.7	388.9
Compressive strength	2 Days N/mm ²	≥10 for classes 32.5 and 42.5N* ≥20 for classes 42.5R and 52.5N ≥30 for class 52.5R	21.30	20.86	16.44
	28 Days N/mm ²	≥32.5 for class 32.5 ≥42.5 for class 42.5 ≥52.5 for class 52.5	37.89	35.21	29.34
Soundness	Autoclave %	≤ 0.8%	0.22	0.1	0.09

N*: Normal solidness cement

4. Results and Discussion

- The quantity of water decreases with the increase of the number of concrete wastes added (Table 2) because the cement is more effective (Wang et al., 2018) than the concrete wastes, therefore the quantity of water added to the cement alone is bigger than the quantity added to the concrete wastes and then it decreases gradually as the quantity of water in the cement paste alone was 118 ml, while it was 80 ml in the paste of the concrete wastes (Table 1). For the additional percentage, 25% of concrete wastes with the cement the quantity of water was 110 ml, but for the additional percentage of 30% of concrete wastes the water quantity was 102 ml and the quantity of water was 100 ml for the additional percentage of 35% of concrete wastes (Table 2). Because the effectiveness of the cement decreased with the increase of the addition, therefore, the temperature of the reaction or hydration decreased (Borštnar et al., 2020).
- The initial and final setting time increased with the increase of the percentage of adding the concrete wastes to the cement. This is because the hardening time depends on the cement's fineness (Almabrok and Khashin, 2019). demonstrated that the hydration begins from the surfaces of the granules and then penetrates to the center of the granules (Shetty, 2009). Therefore, the finer the granules are the faster the reaction with water due to the small size of the granule as water doesn't need much time to reach the center and this also depends on the quantity of gypsum added to the cement (Snelson et al., 201; Awadh and Awad, 2020). The more the quantity of gypsum in cement, the more time is required for the setting time of the cement paste (Jebli et al., 2021). Also, the water content has a great impact on setting time (Ehikhuenmen et al., 2019; Awad and Awadh, 2020), and adding the water to the standard paste of cement is due to a standard measurement, which is called the "Normal Consistency". So, the water quantity added to the cement decreases with the increase of the concrete wastes added to obtain the standard paste of cement (ASTM C150) (Table 1). The initial setting time of the concrete wastes was 210 minutes and the final time was 4 hours, whereas the initial setting time for the cement alone was 150 minutes and the final time was about three hours. This difference is due to the high effectiveness of the cement in terms of reacting with the water, unlike the concrete wastes, which need a longer time to be set well due to the low effectiveness (Table 2). On the other hand, were in the middle of these two time periods and all the

samples are within the range of the Iraqi specification No. (5) (2019). The initial setting time is not less than 45 minutes and the final setting time does not exceed ten hours.

- The results of physical tests (Table 1) (Table 2), that all the fineness results of the Blaine method are within the range of the Iraqi specification No. 5, 2019 concerning all the mixing percentages within the range ($\geq 250 \text{ m}^2/\text{Kg}$) for the OPC. The fineness is variable because it depends on the quality, percentages, and solidness of sand, gravel, and cement that exist in the concrete wastes, which are all variable factors because with time progression, there will be a decomposition process of the mineral phases that form the cement in the old concrete to its original elements (Neville, 2011). The fineness of the sample of concrete wastes powder was $399.5 \text{ m}^2/\text{kg}$ and the cement sample alone is $379.5 \text{ m}^2/\text{kg}$ (Table 1), for the sample of mixing the concrete with a percentage of 25% with the cement $415.7 \text{ m}^2/\text{kg}$, and for the sample of concrete waste mixture with a percentage of 30% with the cement and for the sample of a mixture of concrete waste with the cement with a percentage of 35% with the cement $388.9 \text{ m}^2/\text{kg}$ (Table 2).
- The results of the physical tests (Table 1)(Table 2) showed that the compressive strength of the cement sample alone is greater than the compressive strength of the cement to which concrete wastes are added as the compressive strength with an age of two days was 36.52 N/mm^2 and for the age of 28 days it was 58.94 N/mm^2 (Table 1). The compressive strength decreases gradually with the increase of the additional percentage of waste concrete because the activity of the cement decreased. The value of the compression strength of the mixture of cement with the concrete wastes percentage of 35% at the age of two days was 16.44 N/mm^2 . On the other hand, the compression strength at the age of 2 days was 29.34 N/mm^2 as a failure occurred at this percentage of addition to the sample of the concrete waste alone in terms of the compressive strength. The convergence in the values of the compressive strength in spite of increasing the quantity of the concrete wastes with percentages of 25% and 30% (Table 2) is due to the similarity in fineness. The change in fineness has an evident effect on the change in the compressive strength (Shahbazpanahi et al., 2021) because the more the fineness is the greater the compressive strength is and the impact on the two-day age is greater than on the 28 days age due to the increase in the reaction speed with the water in the early days as the fineness is directly related to the reaction speed (Yang et al., 2019).
- From the results of the physical tests (Table 1) (Table 2), it is clear that there was no change in the soundness of the paste of the cement mixed with the concrete wastes and that the extension rate remained unchanged and sometimes decreases with increasing the percentage of the concrete wastes added to the cement and this is due to the small percentage of the free lime and magnesium oxide (Li and Liu, 2005). The extension of the cement sample was 0.06% (Table 1), but it was 0.22% for the sample of the cement mixed with 25% of concrete wastes. However, the extension percentage decreased when increasing the additional percentage of concrete wastes to the cement at 30% and the value was 0.1% the extension percentage decreased by increasing the additional percentage of the concrete wastes to the cement at 35% with a value of 0.09% (Table 2). This guarantees the soundness of the concrete against the cracks and the exposure of the cement concrete to water depletion, decomposition, and melting, and eventually the weakness of the concrete resistance (Ylmén, 2013). The percentage of extension shouldn't be more than 0.8% according to the Iraqispecification No. 5, 2019.

5. Conclusions

The process of recycling the concrete wastes and adding them to the OPC accomplishes among purposes: decreasing the environmental pollution caused by the random dumping of the concrete wastes, decreasing the cost of cement production, and decreasing the amount of the raw material needed for the process of concrete production. So, the cement wastes can be used and added to the OPC with a

percentage of 30% of the cement weight and at the same time maintaining the Iraqi standard physical properties. We note in this research that the lower proportion of cement in the mixture of concrete wastes with OPC, the lower the proportion of added water.

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