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EFFECT OF CHANGE IN MIX PROPORTIONS ON SOME PROPERTIES OF CONCRETE CONTAINING ATTAPULGITE MINERAL ADMIXTURE

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This project investigated the effect of high reactivity Iraqi High-Reactivity Attapulgite (HRA) on some properties of concrete (e.g., compressive strength, splitting tensile strength and flexural strength) when mixing proportions were changed. Three mixes of concrete were made (1: 1.69: 2.13), (1: 1.13:1.68) and (1: 0.89: 1.96), with (water/cement) ratios (0.48, 0.41 and 0.32), for 35, 45 and 60 N/mm^2 target compressive strength respectively. The percentage increase in the compressive strength at 28 days were 48.29%, 49.64% and 42%, respectively, compared with compressive strength for the same mix at 7 days. In addition, the increase in splitting tensile strength at 28 days was 45.27%, 31% and 30%, and in flexural strength at 28 days was 30%, 52.47% and 26.18%, for the above mixes respectively, compared with strength for the same mix at 7 days.

Keywords: Compressive strength, Splitting tensile strength, Flexural strength.

1 INTRODUCTION

Admixtures are a material other than water, aggregate, and cement, that are used as an ingredient of concrete or mortar, added to the mixture immediately before or during mixing. Mineral admixtures are used in powder form, their fineness at least at the value of cement used together (Kazem 2005). There are two kinds of admixtures: Chemical admixtures and mineral admixtures (Wan 2012). Mineral-admixture are finely-divided siliceous materials added to concrete in relatively large amounts, generally in the range of 20%–70% by mass of the total cementitious material (Mineral admixture 2010). Pozzolana additions to concrete offer a convenient and practical means of achieving improvements in many of the engineering properties of concrete, such as compressive strength, splitting tensile strength, and flexural strength. The use of highly-active pozzolanic materials may produce a concrete with a high performance and special features in both fresh and hardened concrete states.

1.1 The Mechanism of Pozzolanic Reactions in Concrete

Neville and Brooks (2010) showed that the pozzolanic admixture presence in concrete will cause strengthening in the transition zone between the cement paste and aggregate, which contains more voids than cement paste (for a higher porosity). The pozzolanic admixture works as the filler of these voids, because it has a high fineness and produces additional gel through its reaction with $Ca(OH)_2$. This is the important agent in strengthening the transition zone between cement paste and aggregate. Pozzolanic materials react with $Ca(OH)_2$, which is generated by the hydration of main compounds of cement (C_3S and C_2S). Eq. (1) and Eq. (2) show the reactions:

$$2C_3S + 6H \longrightarrow C_3S_2H_3 + 3Ca(OH)_2 \tag{1}$$

$$2C_2S + 4H \longrightarrow C_3S_2H_3 + Ca(OH)_2 \tag{2}$$

Mehta and Paulo (2006) showed that the C-S-H forming reaction, where the comparison between Portland cement with pozzolana is useful for the purpose of understanding the reasons for the difference in their behavior, as in Eq. (3) and Eq. (4):

For Portland cement:

$$C_3S + H \xrightarrow{\text{fast}} \text{C-S-H} + \text{CH} \tag{3}$$

For cement and pozzolana:

$$\text{Pozzolan} + \text{CH} + \text{H} \xrightarrow{\text{slow}} \text{C-S-H} \tag{4}$$

The reaction between pozzolan and calcium hydroxide is called the pozzolanic reaction. The technical advantage of using pozzolan in cement is, first, the reaction is slow, therefore the rates of heat liberation and strength development will be accordingly slow. Second, the reaction involves lime (i.e., the consumption of lime), which has an important bearing on the durability of the hydrated paste in acidic environments. Third, pore-size distribution studies of hydrated Portland cement and Portland cement containing pozzolan have shown that the reaction products are very efficient in filling up the capillary spaces, thus improving the strength and impermeability of the system. Also, Aitcin (2004) showed that the chemical reactions of finely-divided pozzolans with CH under moist conditions are called the pozzolanic reaction. The reaction of Portland cement and pozzolan progresses like an acid-base reaction of lime and alkalies with oxides (SiO_2, Al_2O_3, and Fe_2O_3) of the pozzolan.

1.2 Attapulgite Clay (Palygorskite)

Attapulgite, a naturally occurring mineral, is a crystalline hydrated magnesium alumina-silicate with a three-dimensional chain structure that gives it unique colloidal properties. Fully hydrated Attapulgite grades thicken liquids without swelling. Highly thermally-activated grades combine high surface area with porosity to optimize sorpitivity (Attapulgite 2007). Figure 1 shows Attapulgite clay on the ground surface in Al-Najaf Province.

Attapulgite is the principal mineral of Attapulgus clay, which is surface-mined by an open-pit method with stripping by scrapers, draglines, or bulldozers, and extraction by shovels, backhoes, small draglines, or front-end loaders. The clay is then loaded onto trucks and transported to the processing plant. It is then dried, milled, and sieved to obtain a desired range of particle sizes (Patterson 1992). Occasionally, special processes are used to enhance certain properties, such as adding 1% to 2% MgO to improve the viscosity, drying with high heat to remove the Zeolitic water from the channels in the structure (and increase the sorbent properties), and pulverizing to ultrafine particles for improving suspension properties and increasing the surface area (Murray and Zhou 2006).

Figure 1. Attapulgite clay on the ground surface in Al-Najaf Province in Iraq.

In addition, some Attapulgite are acid-activated, treated with sulfuric or hydrochloric acid to enhance its bleaching activation, for use in clarifying edible and non-edible oils. Murray (2007) noted that sulfuric acid is preferred because it is less expensive and is not as harsh as hydrochloric acid. This acid treatment can be a dry or wet process. The dry process involves crushing, drying, pulverization, acid treatment, and packaging. The wet process involves plunging (mixing clay with water), heating (around the boiling point), adding acid (sulfuric or hydrochloric), dewatering, drying, and then formed into a powder or granules. The difference between natural and acid-activated bleaching clay is that natural bleaching clay in aqueous suspension is slightly acid or neutral, whereas that of acid-activated bleaching clay is highly acidic (Palygorskite 2010).

2 EXPERIMENTAL WORK

2.1 Materials

(1) Cement: The chemical composition and physical properties of the cement use throughout this work conformed to the Iraqi specifications No. 5/1984 (IQS No.5 1984).

(2) Fine aggregate: It is conformed to the B.S. 882:1992 (B.S. 1992).

(3) Coarse aggregate: Crushed gravel of 19 mm maximum size from Al-Nebai district (in Iraq) was used which conformed to the B.S. 882:1992 (B.S. 1992).

(4) Water: Tap water used in the concrete mixture did not contain salts, is used for drinking, and conformed to Iraqi specifications. It was in regular use for all the mixes and for the curing of samples.

(5) High-Reactivity Attapulgite (HRA): The raw material for the production of active Attapulgite was Attapulgite clays. Attapulgite from Tar Al-Najaf (Injana) region in Al-Najaf Province was used to produce HRA. The raw material of Attapulgite contains rocks ground in a manner of storming, transforming it to highly-refined

powder for the purpose of making the most of their effectiveness. Table 1 shows the main properties of HRA:

Table 1. The main properties of Attapulgite.

After grinding		After burning at 750˚C			
Oxides	**Oxide content (%)**	**Oxides**	**Oxide content (%)**	**Property**	**Description**
SiO_2	51.8	SiO_2	60.48	Specific gravity	2.34
Al_2O_3	8.99	Al_2O_3	13.95	Fineness (m^2/ kg)	2109
Fe_2O_3	4.88	Fe_2O_3	6.07	Color	Bluish green
TiO_2	0.58	TiO_2	0.74		
CaO	7.11	CaO	8.46		
MgO	5.52	MgO	5.92		
SO_3	0.68	SO_3	1.2		
Na_2O	1.01	Na_2O	0.45		
K_2O	1.8	K_2O	2.47		
L.O.I	18.65	L.O.I	0.1		

The Attapulgite samples were burned at a temperature of 750˚C in the sample stills for thirty minutes. The optimum replacement percentage of Attapulgite was 6% by weight of cement (Al-Amide 2012).

2.2 Concrete Mix Design

Three concrete mixes were designed according to American specifications (ACI 211 2002) with slump 150 ± 5 mm. Table 2 shows the mix proportions for each mixture:

Table 2. Mix proportions for each mixture.

Target strength of concrete (N/mm^2)	Mix proportions	W/C ratio
35	1 : 1.69 : 2.13	0.48
45	1 : 1.13 : 1.68	0.41
60	1: 0.89 : 1.96	0.32

3 RESULTS AND DISCUSSION

3.1 Compressive strength

The results showed an increase in the compressive strength with age, due to the progress of hydration of cement compounds. The percentage increase in the compressive strength for 45 and 60 N/mm^2 target mixes compared with mix of 35 N/mm^2 target strength at age 7 days were 26.54% and 71.85% respectively. The percentage increase in the compressive strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 28 days, were 27.69% and 64.5% respectively. The percentage increase in the compressive strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 60 days, were 24.12% and 58.37% respectively. Generally, the rate of increase will depend on many factors, including temperature during molding, processing and cement type and quantity, as well as the shape and size of the form. The high temperatures accelerate the increase of strength in the early ages, and that the increase in cement content was also accelerates the speed of interaction and thus affecting the rate of speed of acceptance of strength (Figure 2).

3.2 Splitting Tensile Strength

The results showed increases in the splitting tensile strength with age, due to the progress of hydration of cement compounds. The percentage increase in the splitting tensile strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 7 days, were 25.93% and 50.62% respectively. The percentage increase in the splitting tensile strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 28 days, were 13.31% and 34.84% respectively. Generally, the rate of increase will depend on many factors, including temperature during molding, processing and cement type and quantity, as well as the shape and size of the form. The high temperatures accelerate the increase of strength in the early ages, and the increase in cement content also accelerated the speed of interaction, thus affecting the rate of speed of acceptance of strength (Figure 3).

3.3 Flexural Strength

The results showed increases in the flexural strength with age, due to the progress of hydration of cement compounds. The percentage increase in the flexural strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 7 days, were 16.57% and 78.63% respectively. The percentage increase in the flexural strength for 45 and 60 N/mm^2 target mixes, compared with mix of 35 N/mm^2 target strength at age 28 days, were 42.86% and 79.2% respectively. Generally, the rate of increase will depend on many factors, including temperature during molding, processing and cement type and quantity, and the shape and size of the form. The high temperatures accelerate the increase of strength in the early ages, and the increase in cement content also accelerated the speed of interaction, thus affecting the rate of speed of acceptance of strength (Figure 4).

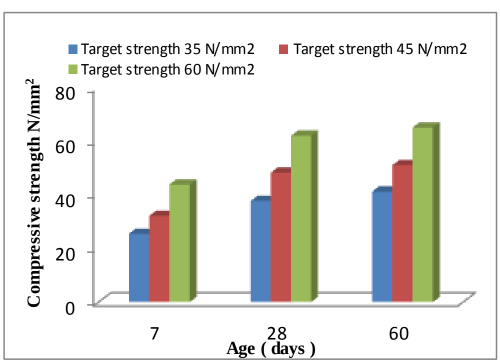

Figure 2. Compressive strength of mixes.

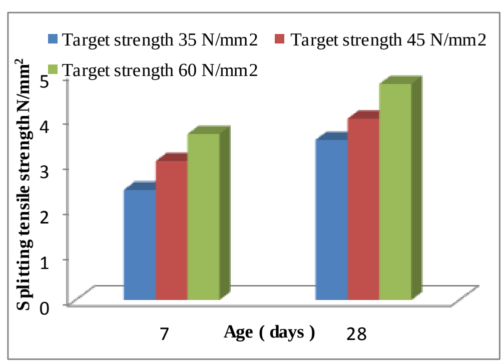

Figure 3. Splitting tensile strength of mixes.

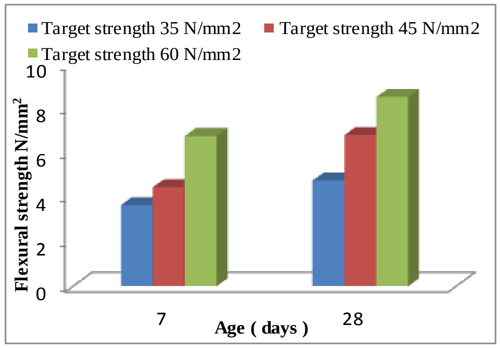

Figure 4. Flexural Strength of mixes.

4 CONCLUSION

The incorporation of 6% of High-Reactivity Attapulgite (HRA) as a partial replacement by weight of cement leads to increases in the percentages of compressive strength splitting tensile strength and flexural strength for all three mixes used in this study. Results also indicate that HRA is more effective on those properties (for all ages) when low cement content is used in the mix, i.e., 35N/mm^2 target strength mix compared with the other mixes used.

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