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Effect of polyethylene on properties of normal and heavy weight concrete

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Abstract— the aim of this work is study the behavior of different types of concrete (normal and heavyweight mixes with different percentage of polyethylene particles as partial replacement of aggregate by 5, 10 and 15% of aggregate. Density, water absorption, slump compressive strength and indirect tensile strength had been studied and presented. The linear attenuation coefficient (μ) for studied samples using Co^{60} radioactive source of 40 Bq/so was determined. The effect of high temperature of 150°C for one hour for test specimen was also investigated. The results showed that the slump, density, compressive, splitting strength and coefficient of attenuation of normal and heavy weight concrete containing different percentage of polyethylene particles were decreased compared to conventional concrete.

Index Terms— polyethylene; Heavy weight concrete; Normal weight concrete; Mechanical properties polyethylene; Indirect tensile strength

1 Introduction

CONCRETE is a wide spread material for radiation shielding. Heavy weight concrete is defined as concrete with unit weight ranging from about 2900 and 6000 kg/m3 while unit weight of conventional concrete (i.e. Normal-weight concrete) varied between 2200 and 2450 kg/m³. (Goguen, et al 2010) measured radiation transmission of heavy weight concretes including normal and barite aggregates for different γ-ray energies and calculated linear attenuation coefficients. These results were found about 0.138–0.157 cm−1 for barite concrete and about 0.102–0.107 cm−1 at 1.25 and 1.33 MeV, respectively.

Bashter et, al. (1996a, 1996b) studied heavy weight concretes including hematite- serpentine, ilmenite-limonite as control absorber in nuclear reactors γ-rays and neutron particles shielding. Bashter (1997) studied heavy weight concretes including hematite-serpentite,ilmenite-limonite,basalt-magnetite,ilmenite,basalt,steel and magnetite for only photon radiation shielding and calculated linear and mass attenuation coefficients from10keVto 1 GeV [6]. The volume of polymeric wastes like tire rubber and polyethylene terephthalate bottles (PET) is increasing at a fast rate. An estimated 1000 million tires reach the end of their useful lives every year and 5000 million more are expected to be discarded in a regular basis by the year 2030. Up to now a small part is recycled and millions of tires are just stockpiled, landfilled or buried.

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For PET bottles annual consumption represent more than 300,000 million units. The majority is just landfilled (Sidique, et al., 2007). They also concluded that, Tire rubber and PET wastes represent a serious environmental issue that needs to be addressed with urgency by the scientific community. Investigations carried out so far reveal that tire waste concrete is specially recommended for concrete structures located in areas of severe earthquake risk and also for applications submitted to severe dynamic actions like railway sleepers.

2 Review Stage

This material can also be used for non-load-bearing purposes such as noise reduction barriers. Investigations about rubber waste concrete show that concrete performance is very dependent on the waste aggregates. Further investigations are needed to clarify for instance which are the characteristics that maximize concrete performance. As to PET based concrete the investigations show that this material is very dependent on the treatment of these wastes.

At present PET fibers are already used to replace steel fibers and some authors even report the use of PET concrete mixtures for repairing concrete should clarify which treatments can maximize concrete performance being responsible for the lowest environmental impact. Further investigations should also be carried on about the use of other polymeric wastes in concrete.

Ali Sadrmomtazi et. Al, [Ismail and et al 2007)] mentioned that, the combined effects of waste Polyethylene Terephthalate (PET) particles and pozzolanic materials on the rheological, mechanical and durability properties of self- compacting concrete (SCC) are evaluated. The replacement ratios of fine aggregates with the same weight of waste PET aggregates are 5, 10 and 15 weight percent (wt. %).

Moreover, the replacement ratio of cement with the same weight of silica fume and fly ash is 10 and 30 wt. %, respectively. The workability of SCC containing waste PET particles was determined using slump flow, V-funnel and L-box tests. Mechanical (compressive, tensile and flexural strengths and

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modulus of elasticity), rheological (L- Box, slump flow and V-funnel) and durability (water absorption and electrical resistance) properties are assessed. The results show that waste PET particles can be reused as aggregates in SCCs. Use of waste PET in SCC decreases compressive, tensile and flexural strengths. However, pozzolanic materials (fly ash and silica fume) compensate the loss of strength caused by adding PET. The use of waste PET has several advantages. Waste PET has no effect on electrical resistance and decreases the brittleness of concrete. Moreover, waste PET reduces environmental problems, protects natural resources and decreases the dead load of buildings due to its low unit weight.

3 Experimental Programme

3.1 Materials

Ordinary Portland cement (CEM - 42.5 N) was used. The sand used was local siliceous natural sand with a specific gravity of 2.54 and a fineness modulus of 2.60, the coarse aggregate was both natural coarse aggregate dolomite with a nominal maximum size of 20 mm, specific gravity of 2.63 and barite (manufactured by EDFFO Company – Edffo city – Aswan – Egypt) with a nominal maximum size of 10-12 mm and specific gravity of 2.61, polyethylene materials were added as partial replacement of 5, 10 and 15% by weight of aggregate. A summary of (CEM - 42.5 N) chemical composition of cement and aggregates were presented in Table 1 and Table 2.

TABLE 1
Chemical composition of Cement

Oxides Cont.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2	P_2O_5	L.O.I.
	21	6.1	3	61.5	3.8	0.4	0.3	2.5	1.68	1.27	1.6

TABLE 2
Chemical composition of Cement

Oxides Cont.	$BaSO_4$	Fe_2O_3	CaO	MgO	Al_2O_3	Si	LOI	Total heavy	Water	PH	Moisture
Baritee	95%	0.03	0.01	0.04	0.04	0.04	0.5	0.00%	0.10%	7-9.5%	0.10%

Experimental program was presented as two phase:
Phase I: It's amid to study the behavior of normal and heavy weight concrete containing different percentage of polyethylene. Seven concrete mixes for normal and heavy weight concrete, four concrete mixes for normal weight concrete containing different percentage of polyethylene. Three concrete mixes for heavy weight concrete containing different percentage of polyethylene.
Phase II: Amid to study the effect of γ rays on normal and heavy weight concrete containing 5%, 10% and 15 % polyethylene as a partial replacement of aggregates. Also phase II study the effect of 150°C on different mixtures.

3.2 Concrete mixes

Seven concrete mixes for normal and heavy weight concrete, four concrete mixes for normal weight concrete containing different % of polyethylene. M1 0% Polyethylene, M2 5% Polyethylene, M3 10% Polyethylene, M4 15% Polyethylene. Three concrete mixes for heavy weight concrete containing different % of polyethylene. M5 0% Polyethylene, M6 5% Polyethylene, M6 10% Polyethylene, M7 15% Polyethylene. Quantities required to produce one cubic meter of concrete are given in table 3. Where, in partial cement replacement stage, the absolute volume of each mix was 1 m³ assuming 2% entrapped air.

TABLE 3
Concrete mix proportions

Mix Code	Cement	Water	Sand	Dolomite	Polyethylene	Poly.
	kg/m^3	L/m3	kg/m^3	kg/m^3	kg/m^3	%
NC-Standard	445	200	665	1025	0	0
NC-M_1	27	13	42	65	0	0
NC-M_2	27	13	42	65	5.35	5
NC-M_3	25.6	12.35	39.8	61.75	10.1	10
NC-M_4	24.3	11.7	37.8	58.5	14.5	15
Mix Code	Cement	Water	Fine barite	Coarse Barite	Polyethylene	Poly %
HC-Standard	445	200	910	1400	0	0
HC-M_5	27	13	48.5	75	0	0
HC-M_6	25.6	12.35	46	71.25	5.85	5
HC-M_7	24.3	11.7	43.65	67.5	11.11	10

4 Results & Discussion

4.1 Fresh concrete

For fresh properties of concrete, the slump test was carried out according to the ESS 1658/2006 specification. The results of slump test and density were shown in Table 4 and Table 5

TABLE 4
Slump test of normal and heavy weight concrete

Mix Code	Slump test						
	Normal concrete				Heavy weight		
	M1	M2	M3	M4	M5	M6	M7
Slump (cm)	7	6.2	5.1	4.8	6.5	6	5.4

From fig.1, it's shown that the percentage of slump of M2, M3 and M4 slump were decreased by 6.13 %, & 12.3 % and 20 % comparing with M1. The slump of (heavyweight concrete) M6 and M7 were decreased by 7.69 % and 15% comparing with M5... This reduction can be attributed to the fact that some particles are angular and others have non-uniform shapes resulting in less fluidity.

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TABLE 5
Density of normal and heavy weight concrete

Mix Code	Density						
	Normal concrete				Heavy weight		
	M1	M2	M3	M4	M5	M6	M7
Density kg/m^3	2350	2250	2200	2100	2450	2410	2380

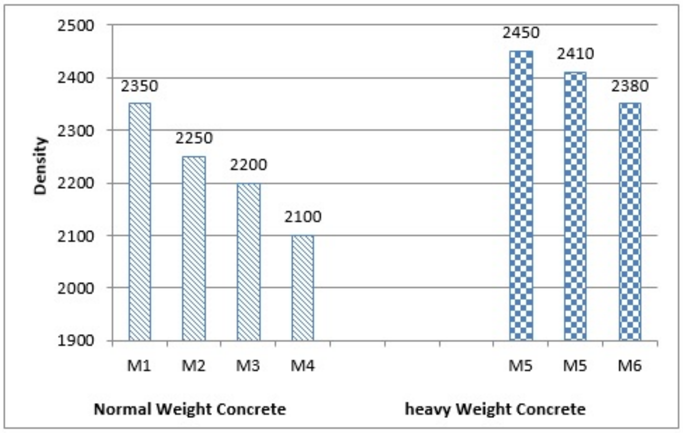

Fig. 1. Density of normal and heavy weight concrete

4.2 Hardened Concrete

The mechanical properties were measured using cubes of 150 x 150 x 150 mm for compression test at (7, 28) days and cylinder (150 x 300) mm for splitting tensile strength at age (28) days. Three specimens were used for each type of test as well as each type of concrete.

The results of compressive strength at 7, 28 days for normal and heavy weight concrete are shown in Table 4. Also, results of splitting tensile strength at 28 days are shown in Table 6

TABLE 6
Compressive and tensile strength of normal and heavy weight concrete

		Normal concrete				Heavy concrete		
Mix. ID		M_1	M_2	M_3	M_4	M_5	M_6	M_7
Comp. strength (kg/cm^2)	7 days	307.11	265.76	227.02	195.55	315.55	208.89	135.55
	28 days	383.82	296.99	233.33	201.13	388.05	236.08	154.18
Sp. tensile str. (kg/cm^2)	28 days	28.3	24	20.1	16.9	27	14.1	12.7

From fig.2, it's shown that the compressive strength of M2 M3 and M4 at 7 days were decreased by 13.4 %,25.3 % and 36.3 % compared to M1 and the compressive strength of M6 and M7 at 7 days were decreased by33.7 and 57 % compared to M5

From fig.3, it's shown that the compressive strength of M2 M3 and M4 at 7, 28 days were decreased by 22 %, 39 % and 47 % compared to M1 and the compressive strength of M6 and M7 at 7 days were decreased by 39 and 60 % compared to M5

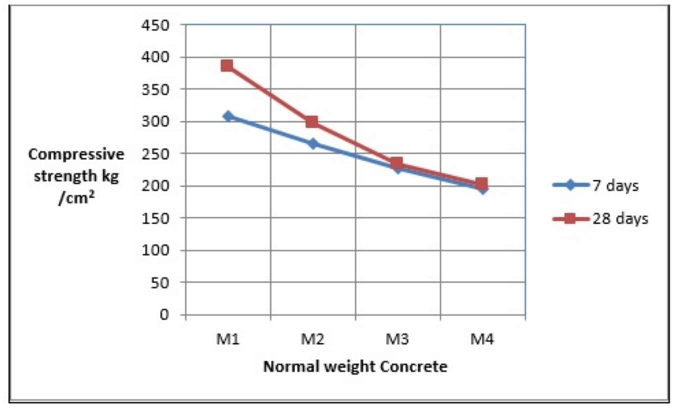

Fig. 2. Compressive strength of normal at 7 and 28 days

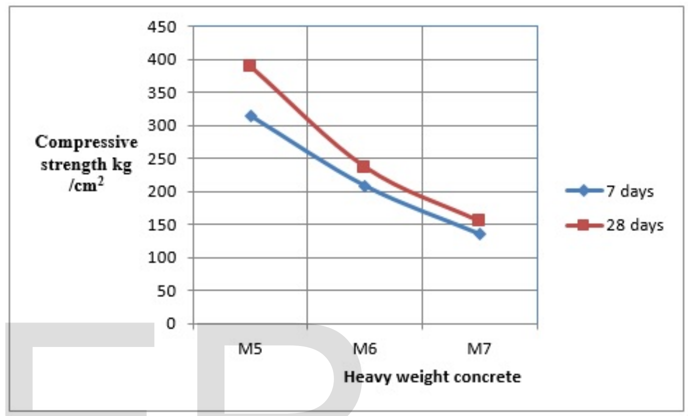

Fig. 3. Compressive strength of heavyweight concrete

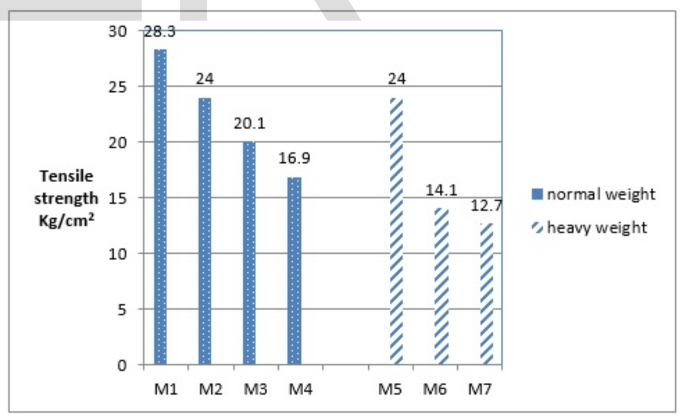

Fig. 4. Tensile strength of normal and heavy weight concrete 28 days

From fig 4, it's shown that splitting tensile strength of normal concrete M2 M3 and M4 at 28 days were decreased by 15.19 %,29 % and 40 % compared to M1 and the splitting tensile strength of heavy weight M6 and M7 at 28 days were decreased by 47.8 and 52.96 % compared to M5.

The compressive and tensile strength of the concrete containing polyethylene were decreased compared that the control concrete. This may be attributed to the decrease in adhesive strength between the surface of the polyethylene partials and cement past. In addition the polyethylene was hydrophobic materials which may restric the hydration of concrete mixture.

4.3 Radiation Shielding Test

The samples were cut out to 2,4,6,8,10 and 12 cm then exposed to gamma rays for 40 Bq/so. The results of attenuation coefficient µ were determined from equation 1 and the results were shown in table 5.

$$I = I_o \ e^{\mu x} \qquad (1)$$

I : Intensity of

I_o: Intensity of source incident on the shielding materials

µ: Attenuation coefficient for the shielding materials

x: Thickness of the shielding materials.

TABLE 7
Attenuation coefficient for normal and heavy weight concrete.

Mix ID	M1	M2	M3	M4	M5	M6	M7
µ	12	12	12	11	15	13	12

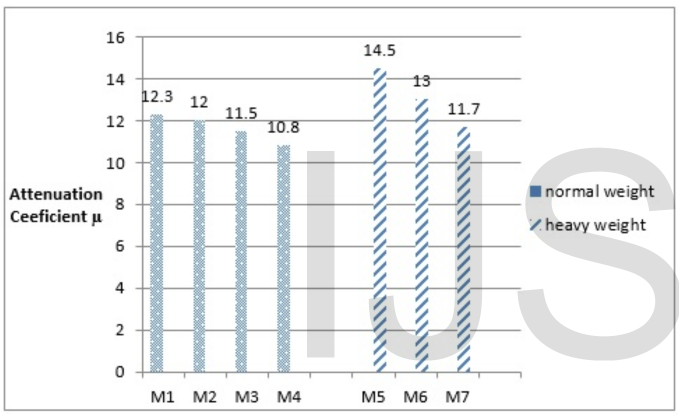

Fig. 5. Attenuation coefficient for normal and heavy weight concrete

From fig 5 it's shown that the attenuation coefficient µ for normal weight concrete with polyethylene M2, M3 and M4 were decreased by 2.4 %, 6.5 % and 12.19 % compared to M1. Also the attenuation coefficient µ for heavy weight concrete with polyethylene M6 and M7were decreased by 10.34 %, and 19.3 % compared to M5. This can be attributed that the density of concrete containing polyethylene were lower than the density of concrete without polyethylene.

6 Conclusion

In the present work, different percentage of polyethylene particles as partial replacement of aggregate by 5, 10 and 15% of aggregate were used in normal and heavy weight concrete to investigate the slump, density, compressive, tensile strength and attenuation coefficient of these concrete. We can concluded that:-

1. The slump of normal and heavyweight concrete containing polyethylene were decreased, it is attributed to the higher workability compared to the reference concrete
2. The use of polyethylene for both normal or heavy weight concrete reduce the density of all mixes, because the density of polyethylene was lower than that the sand by 63.77%
3. The compressive and tensile strength of the concrete containing polyethylene were decreased compared that the control concrete. This may be attributed to the decrease in adhesive strength between the surface of the polyethylene partials and cement past. In addition the polyethylene was hydrophobic materials which may restric the hydration of concrete mixture.
4. The attenuation coefficient µ for normal and heavy weight concrete with polyethylene particles were decreased comparing with the reference concrete, this can be attributed that the density of concrete containing polyethylene were lower than the density of concrete without polyethylene.

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