Sustainable management of medical waste plastic by incorporating in lightweight concrete mixes

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Abstract- The accelerating growth of populations and industrialization has increased the amount of waste generation. Among wastes, medical waste is becoming a serious issue as they induce potential health problems and they are hazardous to the environment. A little attempt in this research paper is to use the required size of medical waste plastic crushed medical devices in concrete with partial substitution of fine aggregates and it has the ability to dispose of large quantities of catastrophe waste in a beneficial way. In this study, 265 experiments and 340 tests were implemented. More than 174 kg of shredded medical waste plastic (MWP) was used to partially substitute of fine aggregate at 0%, 2%, 4%, 6%, 8% and 10%. The tests of concrete mixes included slump, fresh and hard densities, flexural strength, compressive strength, water absorption, and leaching test. The tests were obtained in a different curing ages of 7, 14, and 28 days for the concrete mixes. It is found that when waste plastic increased from zero to 10% of the sand in the mix, the slump, compressive, and flexural strength of concrete decreased by the ratios of 67.94%, 15.78%, and increase by 29.34 % respectively at 28 days age.

Keywords- waste management, medical waste, aggregate, Recycle, Polyethylene terephthalate (PET)

1. INTRODUCTION

One of the major causes of environmental contamination and a serious challenge that we have to solve is the growing generation of waste plastic. Hospitals are among the most important waste plastic generators as a type of medical waste. The waste produced in hospitals typically ranges from 1.4 to 2.2 kg of waste per day, 55 % of which involves plastics. The non-biodegradable nature of plastic renders it a threat to the environment [1, 2]. The modern world used plastic every day until now due to its manufacturing low cost, lightweight and reasonable ease to form. However, waste plastic becomes a concern worldwide. The transfer of waste plastic to new products that benefits people would minimize the amount of plastic waste that is not used. In order to minimize the concrete's own weight, the replacement of aggregate by waste plastic in concrete industry, not only save the environment, but also benefit the construction sector. This initiative can be seen as an update perspective in research activities to contribute the environmental issues and concrete technology [3]. Many attempts have recently been made to use waste plastic efficiently in various industries to minimize the harmful influences of waste plastic disposed of or burned. Concrete is one of the most common building materials used worldwide, and due to the population growth and urbanization, its applications is expected to increase further in the future. Increased demand for concrete would lead to an increase in the supply of all concrete materials, including aggregates that make up between 60-70% of the volume of concrete [4]. The processing of waste plastic as cement-based materials, such as concrete mixes, emerges as a safer choice for the disposal of waste plastic due to its economic and environmental benefits by partial or complete substitute of the aggregate in the concrete mix. Furthermore, for lightweight concrete with low strength application, any modification method with waste plastic could be an ideal option [5]. Gesoglu et al. [6] investigated the mechanical and fracture properties of plastic waste (PW) powder self-compacting concretes (SCCs) in different quantities used as a cement substitute material. Partial for at 5 %, 10%, 15 %, 20% and 25% by weight, the quantity of cement was substituted by PW powder. Mechanical characteristics of SCCs were checked at 28 days for compressive and splitting tensile strengths, flexural strength as well as elasticity modulus. The results showed that the mechanical properties of SCCs modified by PVC powder decreased while the concretes became less brittle. Hameed and Ahmed [7] stated that the use of polyethylene terephthalate (PET) at 1% results in a 58% improvement in compressive strength Compared to the batch for reference. Results of flexural strength showed that the use of PET increased the flexural strength values by 23.11 %, and 25.59% compared to the reference batch at 1 %, and 3 %. The 1% PET ratio also gave the optimum value of splitting tensile strength with a 130 % increase ratio. As the density values increased, the density values clearly decreased. A percentage of PET content, a decreasing density ratio of close to 14%, particularly 10% of PET. Mohammed et al. [8] demonstrated that to produce concrete with acceptable properties, there is a potential to substitute coarse or fine aggregate with 30% or less of poly vinyl chloride (PVC) aggregate. There is a slight loss of slump (workability), water absorption, and various mechanical strengths in this plastic material. No more than 8% loss of compressive and splitting tensile strengths has been observed. Muniraj et al. [9] used waste plastic as a cement, fine aggregate and coarse aggregate with replacement ratio 10%. The results proved that the compressive strength, split tensile strength, and flexural strength decreased with the increase of plastic waste replacement percentage at the age of 14 days. Hama [10] investigated the performance of concrete prepared with different types of plastic as partial substitution of sand. The findings indicated that fine plastic aggregates decrease the compressive strength and elasticity modulus of concrete and that the specimens were more deformed than control specimens before failure under stress and impact loads. In addition, with an increase in plastic content, the bonding strength between concrete and steel reinforcement decreased, particularly one with a larger particle size. The study aimed to experimentally investigate the validity of recycling medical waste plastic to partially replace the fine aggregate in lightweight concrete mixes as a sustainable approach for medical waste management. The study involved the examination of fundamental mechanical properties of concrete mixes.

2. MATERIALS AND METHODS

2.1 Materials

The local Iraqi markets supported all the materials used in this research. In all concrete mixes, ordinary Portland cement (Type 1), commercially referred to as (Taslooja), was used. Tables 1 and 2 present the chemical analysis and physical properties of cement. Crushed gravel of (20) mm maximum size obtained from Tikrit city was a coarse aggregate. Tables 3 and 4, respectively, demonstrate the physical properties and sieve analysis of the coarse aggregate. The fine aggregate was river sand obtained with a maximum aggregate size of 5 mm from Tikrit City. The physical characteristics and sieve analysis are given in Tables 5 and 6, respectively. Medical waste plastic (MWP) was collected from the local hospitals, health centers, and medical clinics. The plastic waste represented by used syringes, fluid and blood bags and giving devices. After collection, the waste plastic was sterilized, and then the plastic waste was shredder by a mechanical machine to obtain the desired size. Maximum particle size was 5 mm with density of WPL 320 kg/m^3. Table 7 presents the physical and mechanical characteristics of MWP, and its gradation presented in Table 8. Fig.1 presents samples of the medical waste plastic (MWP).

2.2 Mixture proportioning

In this experimental analysis, two kinds of concrete mixes were prepared. The first mix was plain concrete (as a reference mix), consisting of 715 kg / m^3 of fine aggregate, 1020 kg / m^3 of coarse aggregate, 380 kg / m^3 of cement and 174.8 kg / m^3 of water, with a W / C ratio of 0.46. The second form of mixing was the concrete with waste plastic by 2%, 4%, 6%, 8 % and 10% weight percent as partial replacement of fine aggregate. According to ASTM C192 [11], the two types of concrete were cured for 7, 14, and 28 days,

2.3 Specimens and test of specimens

For the compressive strength test, fifty-four concrete cubes of size (150×150×150) mm were molded. One hundred and twenty-six concrete cubes of size (100×100×100) mm were prepared for fresh and hard densities and water absorption tests. Twenty-four prisms of size (70×70×380) mm were prepared for the test of flexural strength. Six cylinders of size (50×100) mm were prepared for the leaching test.

For the test of specimens, slump test was fulfilled according to ASTM C143-05 [12]. Casting, compacting and curing was conducted according to B.S.188:1952 [13]. Fresh density was carried out immediately after molding and compacting the specimens. according to B.S:188:1952 [13]. Dry density was measured according to B.S.1881:1952 [13]. Three cubes were represented the mean of the dry density. Water absorption test was carried out according to ASTM C 642 – 97 [14]. The cubes of size (100x100x100) were dried in an oven for 72 h at a temperature range of 100-110°C. The compressive strength test was conducted according to B.S:1881:1952 [13]. Cubes of size (150×150×150) mm were used for this test. The specimens were tested in the compression machine after being taken out from the curing water in their wet condition.

Flexural strength test was conformed to ASTM: C293-07 [15]. This test consisted of applying center point load on the specimen until failure occur. Four prisms represented the mean of the flexural strength. According to EPA SW-846 [16], this process was carried out. Test specimens were hung and immersed in containers filled with 2 liters of distilled water leaching fluid. The cylinders were divided into two groups, with one group being the reference group and the second group having a 10% sand substitute for plastic.

3. RESULTS AND DISCUSSION

3.1 Slump test (Workability)

The effect of partial replacement of WPL on the slump test is presented in Fig .2. The results show the tendency of plastic waste slump to decrease below the reference mix by 6.6, 5.7, 4.5, 3.4, and 2.5 for MWP1, MWP2, MWP3, MWP4, and MWP5, respectively. The decreasing ratios of slump below the reference mix of those mixes were 15.38, 26.92, 42.31, 56.41, and 67.94, respectively. This decrease can be attributed to the fact that some particles are angular and others have less fluidity due to non-uniform shapes. The results are in a good agreement with the findings reported by [17] as well as by [18].

3.2 Tests of fresh density and dry densities

The fresh density test results for MWP-concrete mixes are shown in Fig.3. The fresh density tends to decrease with increasing the substitution ratio. For mixes of 2 %, 4 %, 6 %, 8% and 10 %, of waste plastic replacement ratio, the decrease in the density values of the MWP- concrete mixes were 2.98%, 3.38 %, 4.3%, 5.21% and 5.94%, respectively. The density reduction could be due to the MWP density which is less than the sand by 80.7%, resulting in a decrease of plastic density fresh density. The dry density tests are shown in Fig.4 for the MWP- concrete mixes. At each curing age, the dry densities of the MWP-concrete mixes decreased as the ratio of waste plastic increased. At 28 days of age, the lowest dry density was 2310 kg / m^3. This observation was in a good agreement with the findings previously outlined by [19].

3.3 Water absorption

The weight percentage of absorbed water in concrete mixes are shown in Fig.5. The results showed that the ability to absorb water increased with an increase in the MWP ratio. This increase in the absorption of water may be attributed to the higher percentage of plastic waste added to the mix, thus increasing the total voids distributed in the samples [20].

3.4 Compressive strength tests

Results of compressive strength for concrete mixes at 7, 14 and 28 days are shown in Fig.6. The findings indicate a tendency for compressive strength waste plastic concrete mixes to decrease with the increase in the waste plastic ratio for each curing age below the plain concrete mix. The lowest compressive strength was in the order of MWP5, MWP4, MWP3, MWP2 and MWP1 below the plain concrete mix. However, the minimum compressive strength value (38.34MPa) was higher than the minimum value (17.4MPa) of lightweight concrete for structural application for 10% aggregate replacement at 28 days of curing age. [21] Reported that when waste plastic is used as fine aggregate, the compressive strength decreases with the increasing the PET.

3.5 Flexural strength test

The flexural strength test results for the MWP-concrete mixes are presented in Fig.7. These results demonstrated that the flexural strength of MWP-concrete mixtures at each curing age were decreased with increasing the MWP ratio in these mixtures. This pattern, as well as the hydrophobic nature of the plastic content that can restrict cement hydration, may be due to the decrease in adhesive strength between the surface of waste plastic particles and the cement paste. [22] Observed a similar trend using recycled waste plastic (polyethylene) as fine aggregate.

3.6 Leaching test

The results of leaching experiments showed that the target elements in the leachant were absent. The leaching test results showed that none of these components were detected in the leachant. The findings of the leaching test suggested that the use of MWP is non-hazardous for concrete mixes and could fulfill the requirements of products for clean construction.

4. CONCLUSION

The aim of this study was to investigate and evaluate the recycling of medical waste plastic recycling in order to partially replace the fine aggregate in concrete mixes. The findings showed an environmentally friendly, sustainable approach for a proper management of this hazardous medical waste. Test results of the MWP-concrete mixes revealed that with increasing the waste material, the slump of the MWP-concrete mixes decreased. In spite of the decline of the slump values of these mixes, these mixes were easy to work. As the MWP ratio in the concrete mix increased, the fresh and dry density values decreased. Compressive strength waste plastic concrete mixes to decrease with the increasing the MWP ratio. The lowest compressive strength value for 10% aggregate replacement at 28 days of curing age was 38.34MPa which is higher than the minimum acceptable value (17.4MPa) of lightweight concrete for structural application. The flexural strength of MWP- concrete mixes at each curing age is likely to decrease with the increase of the waste plastic ratio.

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Tables

Table 1 Chemical composition of cement

Compounds	Abbreviation	Weight (%)
Lime	CaO	61.65
Silica	SiO_2	21.25
Alumina	Al_2O_2	04.4
Iron oxide	Fe_2O_3	3.30
Sulfite	SO_3	2.10
Magnesia	MgO	1.89
Loss of ignition	L.O.I	1.58
Lime saturation factor	L.S.F	0.89
Insoluble residue	I.R	0.49
Tricalcium silicate	C_3S	48.13
Dicalcium silicate	C_2S	26.43
Tricalcium aluminate	C_3A	6.30
Tetra calcium aluminoferrite	C_4AF	8.96

Table 2 Physical properties of cement

Compounds	**Abbreviation**	**Limits of cement**	**Limit of I.Q.S No. 5/1984**
Finesse (m^2 /Kg)	—	300	≥ 230
Initial setting time (min)	I.S.T	131	≥ 45 min
Final setting time (h)	F.S.T	240	≤ 10h
Soundness (%)	–		≤ 0.8
3 days age compressive strength (Mpa)	C_s	24	≥ 15
7 days age compressive strength (Mpa)	C_s	35	≥23

Table 3 Physical properties of gravel

Properties	**Results**	**Limit of I.Q.S No. 45/1984**
Specific gravity	2.52	-
Bulk density (Kg/m^3)	1500	-
Absorption (%)	0.50	-
Sulfate content (as SO3) (%)	0.014	0.5 (Max.)

Table 4 Sieve analysis of gravel

Properties	**Passing %**	**Limit of I.Q.S No. 45/1984 Zone (2)**
20	100	95-100
14	70.5	-
10	46.1	30-60
5	1.9	0-10
pan	-	-

Table 5 Physical properties of sand

Properties	**Value**	**Limit of I.Q.S No. 45/1984**
Specific gravity	2.56	-
Bulk density (Kg/m^3)	1660	-
Absorption (%)	1.2	-
Sulfate content (as SO3) (%)	0.13	0.5 (Max.)

Table 6 Sieve analysis of sand

Properties	Passing %	Limit of I.Q.S No. 45/1984 Zone (2)
10	100	100
4.75	91.5	90-100
2.36	80	75-100
1.18	56.5	55-90
0.6	42.1	35-59
0.3	10.9	8-30
0.15	3.6	0-10

Table 7 Physical properties of plastic

Properties	Value
Type	PPE (PE, LDPE)
Bulk density (Kg/m^3)	320
Size	≥ 5mm
Shape	Aboard distribution dimension Fabriform with varying length and width
Color	Different color

Table 8 Sieve analysis of plastic

Properties	Passing %	Limit of I.Q.S No. 45/1984 Zone (2)
10	100	100
4.75	95	90-100
2.36	82	75-100
1.18	33	55-90
0.6	16	35-59
0.3	9	8-30
0.15	4	0-10

Figures

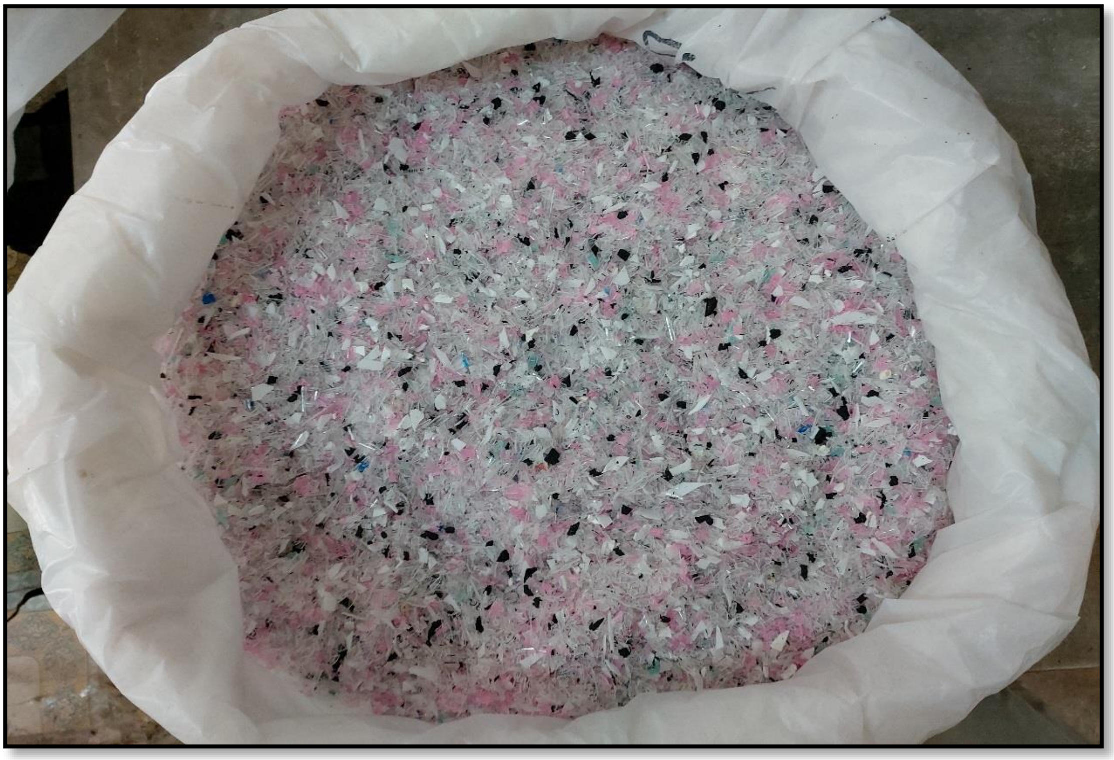

Fig. 1 Sample of crushed waste plastic

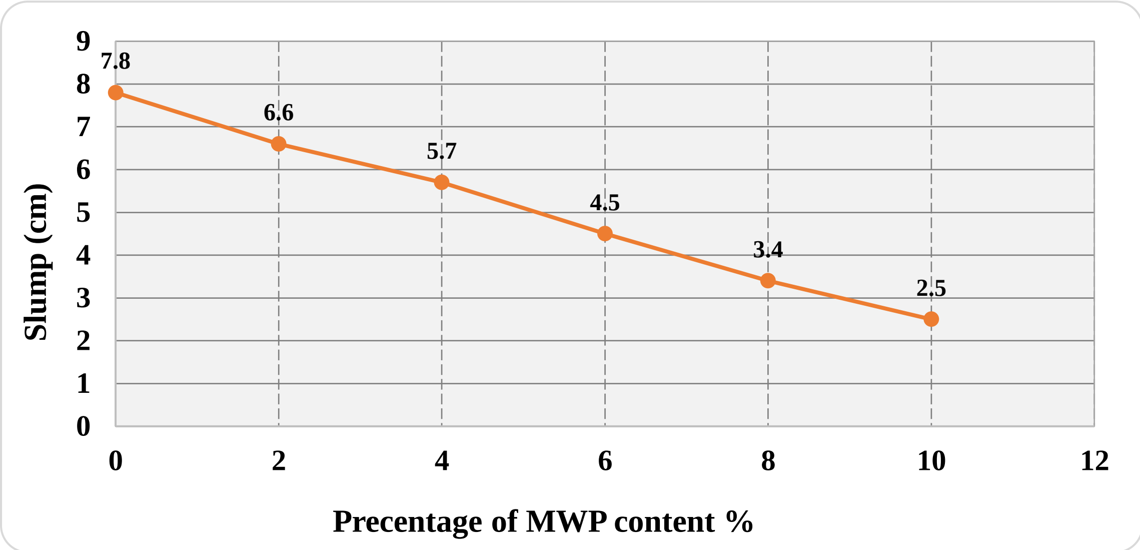

Fig. 2 Profile of slump test for concrete mixes

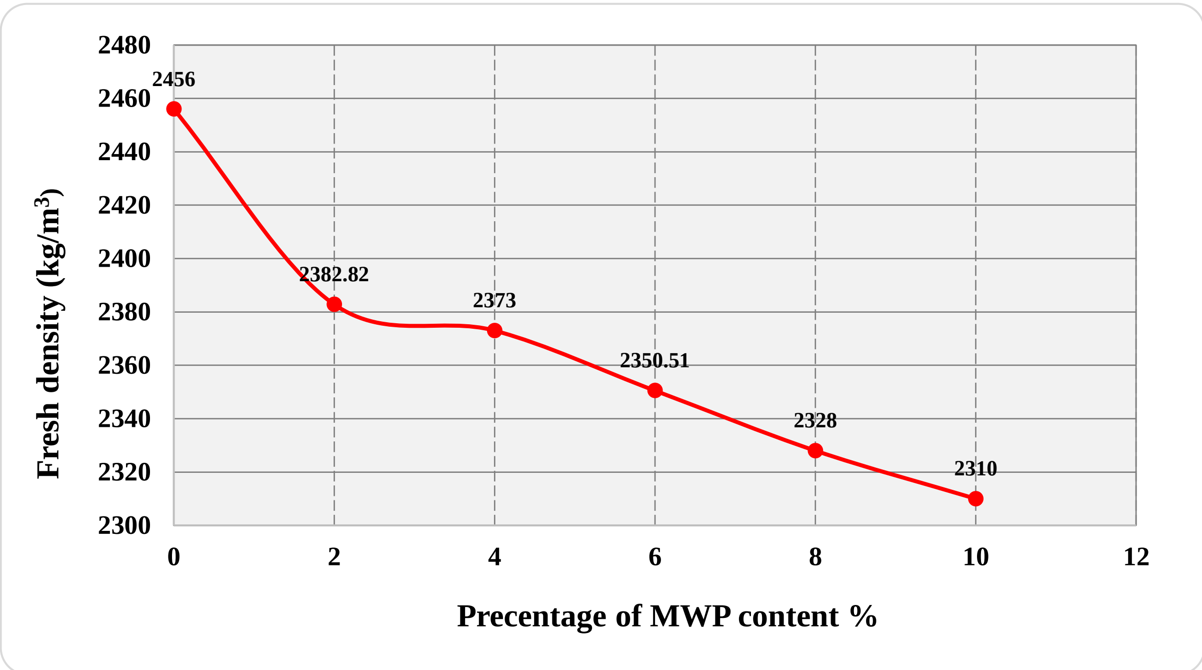

Fig. 3 Profile of fresh density for concrete mixes

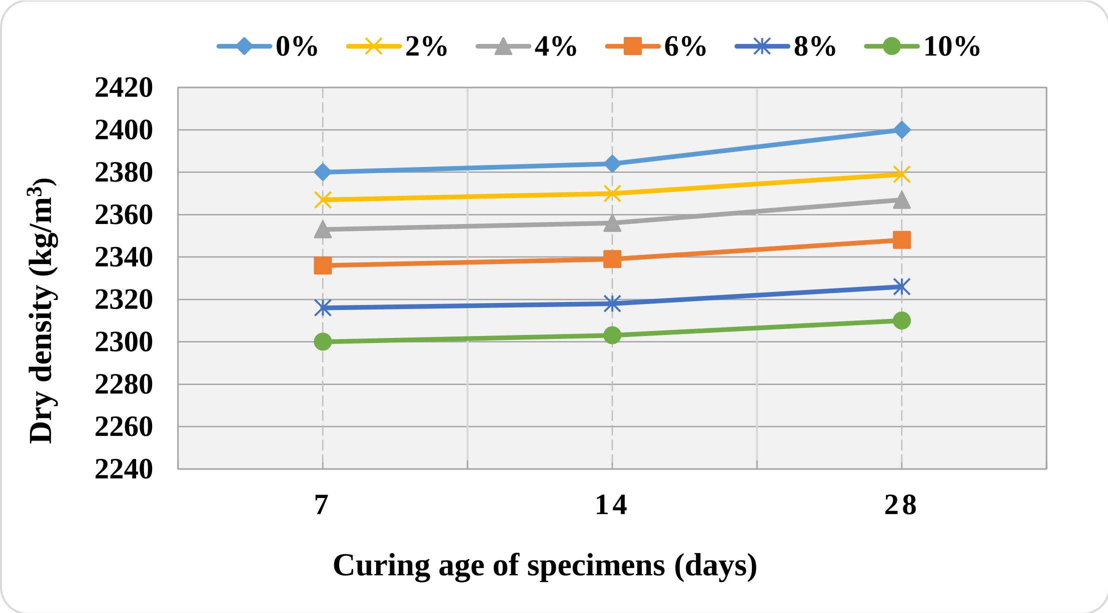

Fig. 4 Profiles of dry density of concrete mixes

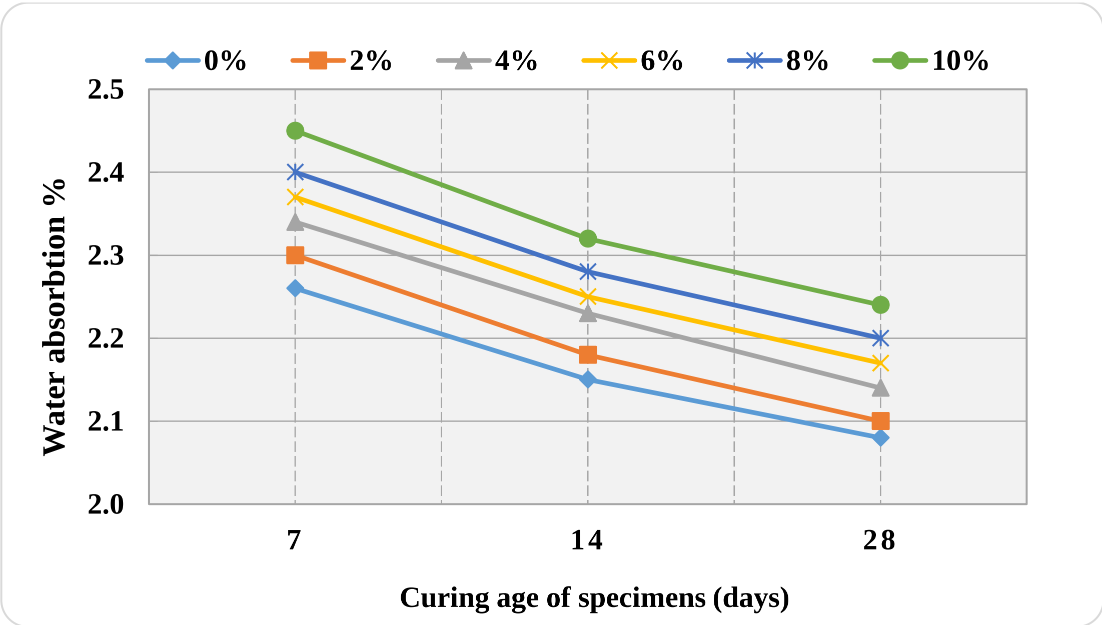

Fig. 5 Water absorption of MWP- concrete

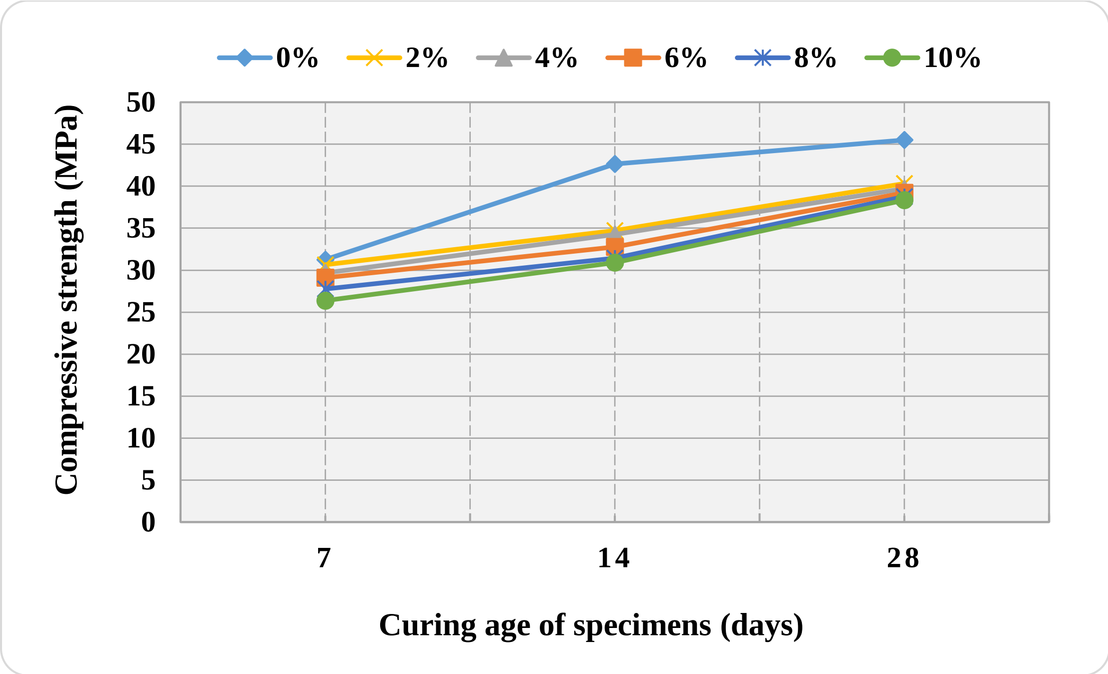

Fig.6 Compressive strength of MWP- concrete

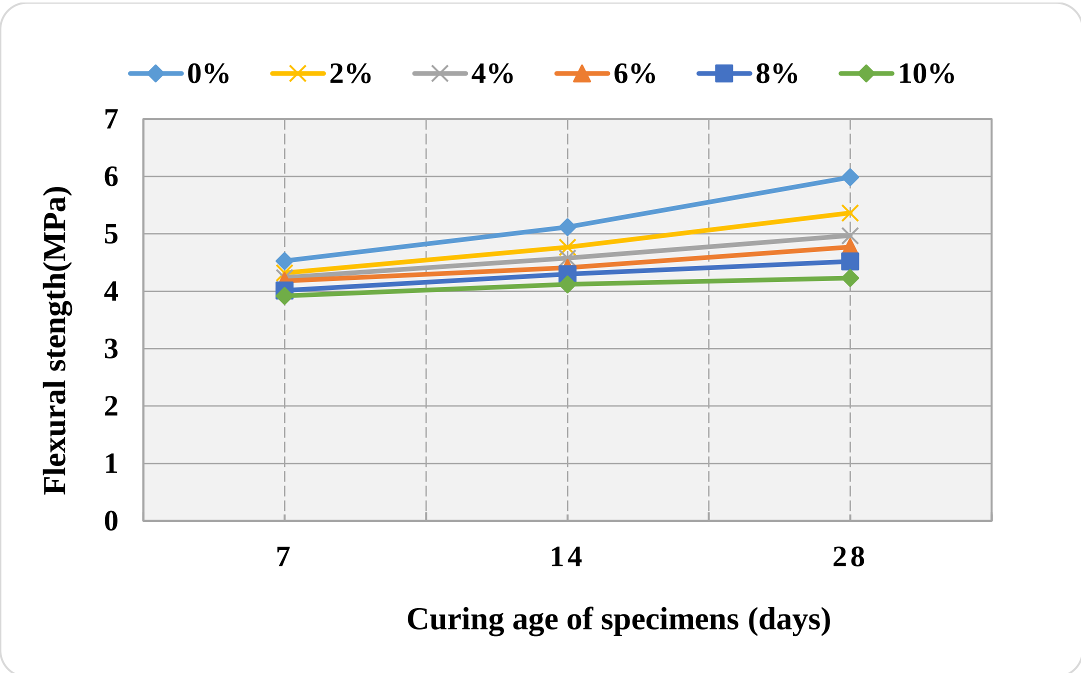

Fig.7 Flexural strength of MWP-concrete