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The Possibility of Enhancing Some Mechanical Properties of Ferro-Cement Mortar by Waste Plastic Fibers

Prof. Dr. Abdulkader Ismail Abdulwahab Al-Hadithi* , Zayd Abdul-Jabbar Al-Obaidi

Dams & Water Resources Engineering Dept. College of Engineering, University of Anbar, Ramadi, Al-Anbar, Iraq.

A R T I C L E I N F O

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****Corresponding Author:***
Email:
al_hadithi2000@yahoo.com

A B S T R A C T

Developing countries like Iraq suffers from high quantities of solid waste such as beverage plastic bottles. This type of waste forms one of the serious enviror pollution resources. The main aim of this research is to study the effect of adding Plastic Fibers (WPF) on the mechanical properties of ferrocement mortar. Waste resulting from cutting plastic beverage Polyethylene Terephthalate (PET) bot electrical shredder machine, which is used to cut paper, was added with different ratios of fibers to cement mortar, and these percentages were (0.5%, 1.0%, Reference mix was made for comparative reason. The following tests were n investigate ferro-cement mortars mechanical properties as followed: comp strength, flexural strength and density Results showed that, the compressive s decreased slightly with the increase in WPF content. The lowest value of comp strength in (14, 28 and 56) days was (37.1 MPa) for (Vf=1.5%) at (14) days te Decrease ranged was between (1.1-12.2) percent with respect the reference mix. F strength increased with increased of the waste plastic fibers volume. The highest v flexural strength in (14, 28 and 56) days was (8.22 MPa) for (Vf=1.5%) for (56) da The increase in the flexural strength in (14, 28 and 56) days ranged between 16.67) % with respect to reference mix.

INTRODUCTION

Ferrocement is generally defined as a kind of composite material consisting of cement mortar and layers of reinforcing mesh or small diameter bars closely spaced (Ramli et al , 2012). The composite of this construction material has been widely and successfully used for the construction of different structures which include silos, tanks, folded roofing, shells and bearing walls (Al Rifaie et al, 2000 ; Narayanaswamy et al ,1981). This composite material used in building with cement, sand, water and wire mesh material.
It is fireproof, earthquake safe and does not rust, rot or blow down in storms. It has a broad range of applications which include components in a building, repair of existing building.

FIBER REINFORCED CONCRETE

Unreinforced concrete has a low tensile strength and a low strain capacity at fracture. These shortcomings are traditionally overcome by adding reinforcing bars or prestressing steel. Reinforcing steel is continuous and is specifically located in the structure to optimize performance. Fibers are discontinuous and generally distributed randomly throughout the concrete matrix. It is now well established that the addition of short, discontinuous fibers plays an important role in the improvement of the mechanical properties of concrete. It increases elastic modulus, decreases brittleness; controls crack initiation, and its subsequent growth and propagation. Debonding and pull out of the fibers require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the material to cyclic and dynamic loads(Sharma et al, 2009). Fiber-reinforced polymers (FRP) are being increasingly used in civil engineering applications such as concrete confinement, shear reinforcement, and flexural reinforcement in the form of wraps around beams and columns. FRPs have been successfully used in other areas such as the aerospace industry, but their use for civil engineering purposes is relatively new (BÖer et al , 2013). Ductility improvement is an important goal in concrete science and must be taken into account by researchers. Fiber reinforcement allows for crack bridging mixtures, taking advantage of a mechanism that restrains crack opening and enhances the energy absorption of the concrete composites (Francesco et al, 2008). There were many attempts to develop the properties of ferrocement by adding different types of fibers one of them that which was done by Gaylan (2008).

Waste Plastic

The world's plastic consumption has increased incredibly in recent decades (Wu et al, 2013). Plastic solid waste (PSW) presents challenges and opportunities to societies regardless of their sustainability awareness and technological advances(Al-Salem & Lettieri, 2009). The field of concrete technology is advancing at a faster rate. Many inventions in the field of concrete technology have expanded the horizon of the construction industry. These new inventions facilitate to produce the requisite concrete of required nature and property. Many wastes, which are producing environmental pollution, are also finding an effective place in the preparation of concrete. Thus, by using these wastes, which are causing environmental pollution one, can, produce concrete that is having the desirable properties. One such waste, which is causing the environmental pollution, is the plastic. The plastic is a non-biodegradable/ non-perishable material. The plastics will neither decay nor degenerate either in water or in soil. In turn it pollutes the water and soil. The plastic if burnt releases many toxic gases, which are very dangerous for the health. Such plastic can be used in concrete in the form of fibers to impart some additional desirable qualities to the concrete (Prahallada & Prakash ,2010). Many research tried to use waste plastic as aggregates or fibers added to concrete (Al-Hadithi, 2008; Panyakapo & Panyakapo,2008; Ismail & Al-Hashimi, 2008; Foti, 2011 ; Foti, 2013) .

Polyethylene Terephthalate (PET)

PET exists as an amorphous (transparent) and as a semi-crystalline (opaque and white) thermoplastic material. In general, it has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, stiffness, ductility and hardness while the amorphous type has better ductility but less stiffness and hardness. PET has good barrier properties against both oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. Other applications include food trays for oven use, roasting bags, audio/video tapes as well as mechanical components and synthetic fibers UNEP (2009).

MATERIALS AND METHODS

The experimental program was planned to investigate the effect of using waste plastic fibers WPF on the mechanical properties and density of Ferro-cement mortar.

Materials:

Cement:

The cement used through this work was Ordinary Portland Cement type I and it conforms to the Iraqi specification No. 5 (1999).

Fine Aggregate:

The fine aggregate used is natural sand brought from Ramadi region. It was clean, free of organic impurities and deleterious substances and relatively free of clay. The grading of sand is conformed to the requirements of the B.S 882(1992) specification.

Mixing Water:

Ordinary drinking water was used for mixing and curing for all specimens.

Fibers:

Rectangular shape of waste plastic fiber with dimension (20 × 4 mm) and thickness of (0.3) mm was used to this research. Density of WPF was equal to 1400 kg/m3.The waste fibers made by shredded beverage bottles made of (PET) into a regular shapes and dimensions using shredder machine .Fibers were added to the mixes as a ratio by volume of mixture of 0.5%

,1.0% and 1.5% respectively. Fig.1 shows the WPF which is used in this research while TABLE (5) shows the some of the physical properties of WPF.

TABLE 1. CHEMICAL ANALYSIS OF CEMENT

No.	Oxides composition	Content %
1.	Limestone ($CaCo_3$)	72.4% - 75.6%
2.	Clay (SiO_2)	21.0% - 24.6%
3.	Bauxite (Al_2O_3)	3.11.7% - 2.0%
4.	Iron (Fe_2O_3)	1.1% - 1.4%

TABLE 2. PHYSICAL TEST OF CEMENT

No.	Test Type	Result	Specification Limits
1.	**Initial Setting**	135 min.	More Than 45 min.
2.	**Final Setting**	195 min.	Less Than 600 min.
3.	**Compressive Strength (3) Days**	25.23 N/mm^2	More Than 15 N/mm^2
4.	**Compressive Strength (7) Days**	27.26 N/mm^2	More Than 23 N/mm^2

TABLE 3. SIEVE ANALYSIS OF SAND

Sieve Size (mm)	Accumulated Percentage Passing%	Limits of (B.S.882/1992) Zone (M)
4.75	100	89-100
2.36	73.5	65-100
1.18	59.6	54-100
0.6	43.8	25-80
0.3	14.2	5-80
0.15	3.1	0-15

TABLE 4. RESULT OF WATER TEST

Test Type	Result(mg/l)	Limits Of Specification(mg/l)
SO_3 -2 ions	480	1000
CO_3 -2 ions	66	1000
Cl_2 -2 ions	336	500

TABLE 5. SOME OF THE PHYSICAL PROPERTIES OF (PET) PLASTICS

Type	Poly(ethylene terephthalate) (PET)
Density (g/cm^3)	1.41
Tensile (Young's Modulus) MPa	1700
Water absorbtion %	0.5
Melting temperature T_m	538
Ultimate strain ε %	180
Flexural modulus (rigidity) E MPa (3-point Flexure)	2,000
Yield strain ε % (Tensile)	4
Breaking strength σB MPa (Tensile)	50

Fig. 1- a: Waste Plastic Fibers

Fig. 1- b: Samples of Waste Plastic Fibers

Preparation of Mortar Specimens:

Four mixes were used in this research. All proportions were (1:2) cement: sand. The first mix was reference mix, whereas WPF was added with different volume ratios of fibers to cement mortar, and these percentages were (0.5%, 1.0%, 1.5%). Table (6) shows the details of the cement mortar mixes.

TABLE (6) . DETAILS OF THE CEMENT MORTAR MIXES.

Symbol	Cement Content for 1m3 (kg)	Proportion Cement: Sand (by weight)	Fiber : Mix Ratio % (by volume)	W / C Ratio %
R	655	1 : 2	0	0.45
FR0.5	651.725	1 : 2	0.5%	0.45
FR1	648.450	1 : 2	1.0%	0.45
FR1.5	645.175	1 : 2	1.5%	0.45

Mix Preparation:

Initially, the required materials for the concrete mix were weighed according to the mix proportions. A mechanical mixer of the capacity (0.1) m^3 operated by electrical power was used, the half of fine aggregate and cement were mixed before adding of water. All fibers strew during dry mixing, then the listing quantity of cement and sand were added to matrix. The mixing continued until the dry mix became homogenous, and finally water were added and mixing continues until uniform mix is obtained.

Casting, Compaction and Curing:

The molds were lightly coated with mineral oil before use according to ASTM C192-88(1988). For cubes, cylinders and prisms casting was carried out in different layers each layer is of 50mm. Each layer was compacted by using a vibrating table for (15-30) second until no air bubbles emerged from the surface of the mortar, and the mortar is leveled off smooth to the top of the molds.

Compressive Strength:

Compressive strength was determined using of (100×100×100)mm cubes according to B.S. 1881 , Part 116(1983).

Flexural Strength:

According to ASTM (192-88)(1988). Concrete prisms of (100×100×500) mm were prepared and two point load test was carried out according to ASTM (C-78-84)(1994).

Density

This test is carried out according to ASTM C642-97(2003). Dry density measured at 28 days on three cubes of (100×100×100) mm for every mix .

(Note: All tests were done in room temperatures and the value of this temperature varied between (15-28)C^o)

RESULTS AND DISCUSSION

Compressive strength:

The relationship between compressive strength at different ages and volume of fiber is shown in Fig.2. From this figure it can be seen that, the compressive strength of all specimens' increases with time, that can be attributed to the fact of progress in cement hydration with time (Mehta, 2006), but the percentage of increasing in compressive strength differs between the reference mix and the fiber reinforced mortar. The lowest magnitude of compressive strength at (14) days curing is (37.1MPa) for specimens with V_f equal to (1.5%) and the lowest magnitude of compressive strength at (28) days curing is (40.2 MPa) for specimens with V_f ratio equal to (1.5%), while at (56) days curing, the respective lowest magnitude is (43.5 MPa) for specimens with (1.5%) V_f ratio. Fig.3. shows the effects of adding WPF on the compressive strength with age for various for specimens with various V_f ratio .That decrease in compressive strength might be due to the forming of segregate on mix and this action led to form stiff bond about these bulks. Therefore, the existing of waste plastic fibers allows the absorption of water inside the porous. Also, exciting of waste plastic fiber reducing the density of cubes, and that led to decrease the compressive strength of composite (Al-Hadithi , 2013). Using of waste plastic fiber increased the porous inside the mortar structure and that caused reducing the compressive strength.

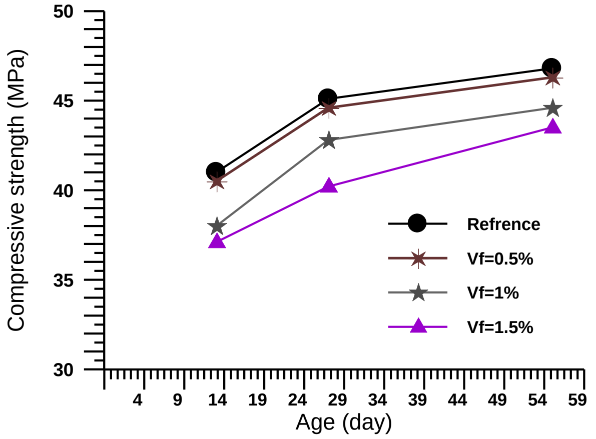

Fig. 2. The relationship between compressive strength and volume of fiber during different ages of curing.

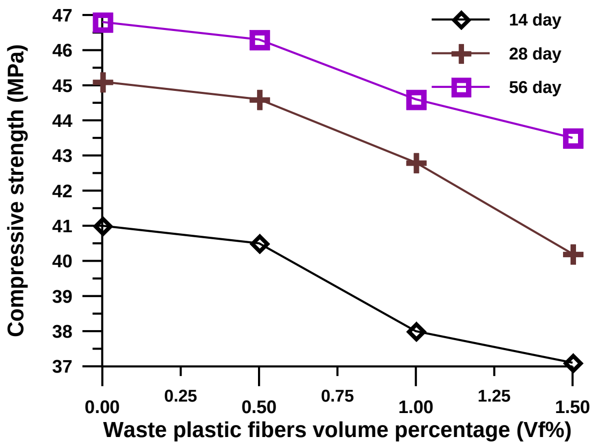

Fig.3. The effect of different volume of fibers on the compressive strength during different ages of curing.

Flexural Strength Test:

This strength was determined at ages of (14), (28) and (56) days for moist cured cement mortar prisms of (100×100×500) mm dimensions. The effect of curing ages on the flexural strength on various types of cement mortar was presented in Fig. 4.. The results indicated that flexural strength increased with the development of curing ages, also the flexural strength increased with the increase in the fibers volume of all ages for different types of mortar mixes.

At (14) days curing age the highest magnitude of flexural strength is (6.73MPa) for specimens with (1.5%) V_f ratio, at (28) days curing the highest magnitude of flexural strength is (7.90MPa) for specimens with (1.5%) V_f ratio while at (56) days curing, the highest respective magnitude is (8.22MPa) for specimens with (1.5%) V_f ratio. Fig. 5. illustrate clearly that the increase in the WPF content leads to development in flexural strength value at all testing ages. This increase in the flexural strength increase is can be attributed to the fact that the waste plastic fibers arrests cracks progression. Also, the addition of waste plastic fibers contributed to strengthen the interior tensile stresses (Al-Hadithi, 2008). In contrast, the increase in the flexural strength of specimens reinforced with waste plastic fibers is attributed to the fiber bridging effect, which prevented cracks from being opened widely.

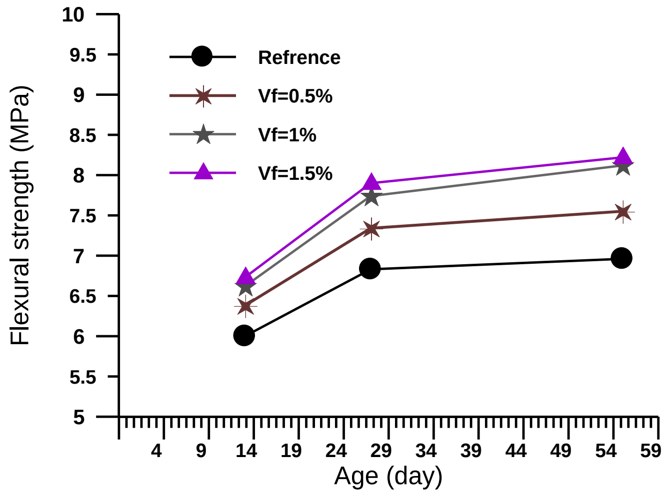

Fig. 4. The relationship between flexural strength and volume of fiber during different ages of curing.

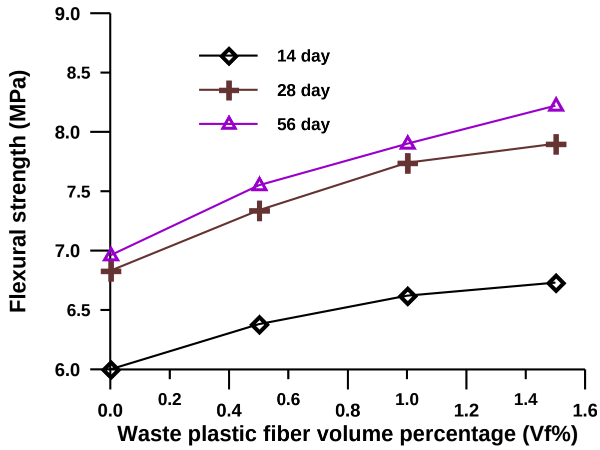

Fig.5. The effect of different volume of fibers on the flexural strength during different ages of curing.

Density Test :

The relationship between the density at different ages and the various ratios of waste plastic fiber and various (V_f) ratios is shown in fig. 6.. It can be noticed that adding the WPF reduces the density. The values of the density ranged from (2225) to (2400) kg/m3. The reason of this decrease in the density is the low density of waste plastic fiber (which it is represent one of the WPF mortar components).

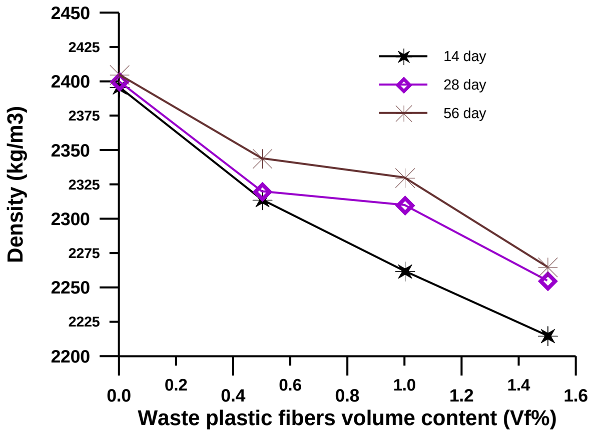

Fig .6. The effect of different volume of fibers on the density during different ages of curing.

CONCLUSION

Based on the extensive research works, the following conclusions can be drawn:-

The increase of (V_f) ratio from 0.5% to 1.5% had resulted in:-

1- For Compressive and Flexural Tests:

(a) A decrease in the 14 days compressive strength from 41.0 N/mm^2 for reference mix to 40.5 N/mm^2 (V_f= 0.5%), to 38.0 N/mm^2(V_f = 1.0%) and to 37.1 N/mm^2 (V_f = 1.5%).

(b) A decrease in the 28 days compressive strength from 45.1 N/mm2 for reference mix to 44.6 N/mm^2 (V_f = 0.5%), to 42.8 N/mm^2 (V_f = 1.0%) and to 40.2 N/mm^2 (V_f = 1.5%).

(c) A decrease in the 56 days compressive strength from 46.8 N/mm^2 for reference mix to 46.3 N/mm^2 (V_f = 0.5%), to 44.6 N/mm^2 (V_f = 1.0%) and to 43.5 N/mm^2 (V_f = 1.5%).

(e) An increase in the 14 days flexural strength from 6.00 N/mm^2 for reference mix to 6.38 N/mm^2 (V_f = 0.5%), to 6.62 N/mm^2 (V_f = 1.0%) and to 6.13 N/mm^2 (V_f = 1.5%).

(f) An increase in the 28 day flexural strength from 6.83 N/mm^2 for reference mix to 7.34 N/mm^2 (V_f = 0.5%), to 7.74 N/mm^2 (V_f = 1.0%) and to 7.00 N/mm^2 (Vf = 1.5%).

(g) An increase in the 56 day flexural strength from 6.96 N/mm2 for reference mix to 7.55 N/mm^2 (V_f = 0.5%), to 8.12 N/mm$_2$ (V_f = 1.0%) and to 7.22 N/mm^2 (V_f = 1.5%).

2. Dry density of mortar cubes was (2400) kg/m^3 at 28 days. Adding waste plastic fibers cause a decrease in the density and the lowest density was (2255) kg/m^3 for (V_f = 1.5%).

REFERENCES

1. Al Rifaie, W. N. and A-Ihmedawi, A. N. (2000). Structural Behavior of Ferrocement Shell Roofs, Journal of Ferrocement.
2. Al-Hadithi, Abdulkader Ismail. (2008). Some Properties of Concrete Using Waste Plastic Fiber with a Very Small Percentages. The First International Engineering Sciences Conference of Aleppo University (IESC"2008),Aleppo,Syria.
3. Al-Hadithi. Abdulkader Ismail ; Al-Ejbari Ahmed Tareq and Jamil, Ghassan S.,(2013). Behaviour of Waste Fiber Concrete Slabs Under Low Velocity Impact. Iraqi Journal of Civil Engineering. Volume (9), Issue No.(1), pp:135-148.
4. Al-Salem, S.M. ; Lettieri, P.; Baeyene, J. (2009).Recycling and recovery routs of plastic solid waste (PSW): A review. Waste Management Journal, No.29, pp:2625-2643.
5. ASTM 78-1994. Standard Test Method For Flexure Strength of Concrete {Using Simple Beam with Third-Point Loading}. Annual Book of ASTM Standard, American Society for Testing and Materials, Philadeghia, Pennsylvania. Vol.04-02, 1994.
6. ASTM C642-97,(2003). Standard Test Method for Density, Absorption and Void in Hardened Concrete . Annual Book of ASTM Standard, Vol. 04.02.
7. ASTM CI92-88 ,(1998). Standard Practice for Making and Curing Test Specimens in the Laboratory. Annual Book of ASTM Standard, Philadeghia, Vol. 04-02, pp.112-118.
8. B.S. 882, (1992). Aggregates From Natural Sources For Concrete. British Standards Institution.
9. BÖer, Paul; Holliday, Lisa ; Kang, Thomas H.-K.;(2013).Independent environmental effects on durability of fiber-reinforced polymer wraps in civil applications: A review. Construction and Building Materials Journal, No. 48, pp:360-370.
10. British Standard Institute BSI, (1983), B. S. 1881: Part 116, “Method for Determination of Compressive Strength of Concrete Cubes”.
11. Foti, Dora .(2011). Preliminary analysis of concrete reinforced with waste bottles PET fibers. Construction and Building Materials Journal, No.25, pp:1906-1915.
12. Foti, Dora,(2013). Use of recycled waste pet bottles fibers for the reinforcement of concrete. Composite Structures Journal , No.96, pp:396-404.

13. Francesco Bencardino, Lidia Rizzuti, Giuseppe Spadea and Ramnath N. Swamy, (2008) .Stress-Strain Behavior of Steel Fiber-Reinforced Concrete in Compression. Journal of materials in civil engineering ,ASCE , P. P255 .
14. Gaylan , A. Anwar.(2008).Behavior of fiber reinforced ferrocement slabs under static and cyclic loadings. Ph.D. Thesis, Building and Construction Eng. Dept., Univ. of Technology, Baghdad, Iraq.
15. Iraqi specifications - No(5).(1999). Portland Cement.
16. Ismail, Zainab Z.; Al-Hashmi, Enas A.(2008).Use of waste plastic in concrete mixture as aggregate replacement.Waste Management Journal, No.28, pp:2041-2047.
17. Mehta, P. Kumar ; Monteiro Paulo J. M.(2006). Concrete, microstructure, and materials", 3d edition, MicGraw-hill, p. 650.
18. Narayanaswamy V P, Surya Kumar G V, Sharama P C. (1981). Precast Ferrocement Trough Element for Low-Cost Roofing. Journal of Ferrocement ; Vol. 11, No.1.
19. Panyakapo, Phaiboon ; Panyakapo, Malika.(2008). Reuse of thermosetting plastic waste for lightweight concrete. Waste Management Journal, No.28, pp:1581-1588.
20. Prahallada M. C and Prakash K.B. (2010). Effect Of Replacement Of Cement By Micro-silica 600 On The Properties Of Waste Plastic Fibre Reinforced (WPFRC) Concrete An Experimental Investigation", International Journal of Civil and Structural Engineering, VOL. 2, NO. 1,p.p: 222-223.
21. Ramli ,Mahyuddin; Tabassi , Amin Akhavan.(2012). Mechanical behaviour of polymer-modified ferrocement under different exposure conditions: An experimental study", Composites Journal : Part B, Vol. , No. 43, pp:447-456.
22. Sharma A, Reddy GR, Varshney L, Bharath kumar H, Vaze KK, Ghosh AK, et al.(2009). Experimental Investigations on Mechanical and Radiation Shielding Properties of Hybrid Lead-Steel Fiber Reinforced Concrete. Nuclear Engineering and Design Journal, p.p:1180-1185.
23. UNEP, (2009). Converting Waste Plastics Into a Resource. United Nations Environmental Programme, Division of Technology, Industry and Economics, International Environmental Technology Centre Osaka/Shiga.
24. Wu, Guiqing ; Jia, Li; Xu, Zhenming .(2013). Triboelectrostatic separation for granular plastic waste recycling: A review. Waste Management Journal, No.33, pp:585-597.