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A Review in Sustainable Plastic Waste in Concrete

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ABSTRACT

Recently times, industrial development has increased, including plastic industries, and since plastic has a very long analytical life, it will cause environmental pollution. Therefore studies have resorted to reusing recycled plastic waste (sustainable plastic) to produce environmentally friendly concrete (green concrete). In this research, some studies were reviewed and then summarized into several things, including the percentage of plastic replacement from the aggregate and the effect of this percentage on the fresh properties of concrete, such as the workability and the effect of plastic waste on the hardening properties of concrete such as dry density, compressive, tensile and flexural strength.

Keywords: plastic waste, green concrete, fresh and hardening properties.

مراجعة عن نفايات البلاستك المستدام في الخرسانة

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الخلاصة

في الآونة الأخيرة ازداد التطور الصناعي من ضمنها الصناعات البلاستيكية وبما أن البلاستيك له عمر تحليلي طويل جدًا ، فسوف يتسبب في التلوث البيئي لذلك لجأت الدراسات إلى إعادة استخدام النفايات البلاستيكية المعاد تدويرها (البلاستيك المستدام) في إنتاج خرسانة صديقة للبيئة (الخرسانة الخضراء). في هذا البحث تمت مراجعة بعض الدراسات ثم تلخيصها في عدة أمور منها نسبة استبدال البلاستيك من الركام وما تأثير هذه النسبة على الخواص الطرية للخرسانة مثل قابلية التشغيل للخليط ، وكذلك تأثير النسب على الخصائص الصلبة للخرسانة مثل الكثافة الجافة ، ومقاومة الانضغاط و الشد والانثناء.

الكلمات الرئيسية: النفايات البلاستيكية , الخرسانة الخضراء, الخواص الطرية والصلبة.

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1. INTRODUCTION

Plastic waste disposal is one of the environmental problems that increase with the increase in industrial development. On the other hand, the construction industry faces a problem due to insufficient and unavailability of building materials **(Vishnu, G., et al., 2017).** The low recycling rate of plastic waste contributes significantly to environmental pollution, so it is important to use plastic waste in various applications, such as using it in concrete as aggregate **(Alqahtani, et al., 2017).** Production of lightweight structural concrete with a maximum of 1850 kg/m^3 by using polyethylene Terephthalate waste (PET) as a coarse aggregate where the produced plastic is heated, cooled, and crushed to different gradients **(Zebua,2017).** Globally, the use of plastic had increased astronomically since the twenties of the last century, when plastic was developed for the first time for industrial use. Some statistics showed that in the year 2013 a two hundred ninety-nine million tons of plastic were produced worldwide. Plastic waste is often buried, and this process causes potential environmental risks. Thus, some research has focused on using plastic waste in concrete for various purposes **(Babafemi, et al., 2018).** The partial solution to environmental problems is the exploitation of plastic waste. The use of plastic waste in building materials and concrete reduces environmental pollution and also helps to reduce concrete costs. There are non-direct benefits such as reducing the cost of landfill waste and saving energy. There are various studies on the use of polyethylene terephthalate (**PET**) bottles on the mechanical properties of concrete. It has been found that plastic can reduce the weight of conventional concrete by (2-6)% and a decrease in the compressive strength by 33% for normal concrete **(Mohammed, 2018)**. The process of recycling waste plastic is expensive, and plastic does not decompose easily, but it takes a long time to decompose, which leads to major environmental pollution problems. Therefore, the landfill process for plastic waste should be avoided. Studies began in the nineties of the last century on the use of polyethylene as coarse aggregate or fine aggregate in concrete, the effect of different types and sizes on the properties of concrete were studied **(Abdel Moti, H. M., and Mustafa, M. A,2019).**

2. HAZARDOUS PLASTIC WASTE

The growth of plastic waste is one of the fastest growing operations every year, with more than 500 billion plastic bags used (approximately one million bags every minute). Every year hundreds of thousands of whales, sea turtles, and marine mammals die because of eating plastic bags thrown into the sea. The process of disposing of plastic waste causes environmental pollution on land and sea, where the period of decomposition of plastic bags reaches 1000 years **(Raghatate A. tul, M., 2012).** Plastic is produced in very large quantities all over the world every year. The incorrect process of disposing of plastic waste leads to significant environmental and health problems **(Lokeshwari, M., et al., 2019).** As time passes, and the development taking place now, the production and use of plastic increases dramatically. Still, when disposing of plastic waste, it causes environmental problems due to its lack of decomposition. This means that it does not decompose naturally in the soil, causing environmental problems, so coarse plastic aggregates are used as an alternative to natural aggregates to reduce their consumption. Researchers have been trying for 50 years to discover alternative materials to use as an alternative to aggregates and cement (**Tayyab, S., et al., 2018).**

3. UTILIZATION OF PLASTIC WASTE AS AGGREGATE IN CONCRETE

Using electronic plastic (E-plastic) from computer in concrete as coarse aggregate with the maximum size of 12.5 mm and flaky shape. Coarse aggregate was replaced with percentages (10, 20, 30, 40, and 50) % of electronic plastic by volume **(Kumar, K. S.,** and **Baskar, K. 2015).**

Plastic waste bottles are crushed and cut into small pieces and used as coarse aggregates with volumetric replacement ratios (5, 10, and 20) % from the volume of natural coarse aggregate. The specific gravity of plastic aggregate was 1.4, and the size range was between (4.75 to 9.5) mm **(Hossain, et al., 2016).** The plastic waste of polypropylene (**PP**) and polyethylene terephthalate (**PET**) was used as a replacement with ratios of (10, 20, 30, 40, and 50) % of the natural aggregate. The 10% replacement rate is satisfactory, but the concrete density decreases at 20% and more **(Patil, P. S., et al., 2014).**

4. ADVANTAGES OF ADDING PLASTIC WASTE TO CONCRETE

The thermal analysis of concrete containing 20% plastic as a substitution ratio of coarse aggregate and water to cement ratios (0.4,0.45, and 0.5) found that the thermal conductivity of concrete containing plastic waste is less than normal concrete. For this reason, concrete containing plastic is considered more thermal insulation than normal concrete **(Ahmed, M. M.,** and **Raju, S. S. 2013).** Concrete containing plastic aggregates are used to decrease the weight of the concrete unit, thus reduces the dead weight of the building **(Hossain, et al., 2016).** Using plastic waste to production solid paving blocks, where the compressive strength of concrete containing plastic equal to normal concrete led to decrease the construction cost and decrease the cost of plastic waste disposal techniques such as landfill and burning that cause environmental pollution **(Panimayam, S. A., et al., 2017).** The thermal conductivity of concrete containing plastic waste in proportions of (15, 25, and 45) % decreases by (14.6, 22.2, and 26.5) %, respectively. This decrease is due to the lower thermal conductivity of the plastic compared to natural aggregates, which leads to an increase in the thermal insulation of concrete **(Khalil, W.I.,** and **Mahdi, H. M., 2020)**

5. PROPERTIES OF CONCRETE CONTAINING SUSTAINABLE PLASTIC WASTE

5.1 Fresh Properties of Concrete Containing Plastic Waste Aggregate

5.1.1 Workability

Through previous research, the workability of concrete when using superplasticizer increases with the increase of the proportions of replacing plastic with natural aggregate. As shown in **Table 1.** The slump values for the percentages of plastic addition with the use of the superplasticizer **(Pirzada, R. A., et al., 2018)**

Table 1. Slump values **(Pirzada, R. A., et al., 2018).**

Replacement plastic %	Values of the slump (mm)
0	48
5	56
10	63
15	70
20	78

Through slump test results, it was found that concrete containing plastic replacement ratios (A = 0, B = 15, C = 25, D = 45) % the slump value increases with the increase in plastic ratios of coarse aggregate. As shown in **Table 2.** The workability of concrete containing plastic is more than normal concrete due to the nature of the plastic aggregate, which does not have the ability to absorb mixing water compared to the natural aggregate **(Khalil, W. I.,** and **Mahdi, H. M. 2020).**

Table 2. Slump values of concrete containing plastic **(Khalil, W. I., and Mahdi, H. M. 2020).**

Replacement plastic %	Values of the slump (mm)
0	95
15	96.5
25	98
45	100

5.2 Hardening properties of concrete containing plastic waste aggregate

5.2.1 Dry density

During studying the density of concrete at 28 days that containing plastic with replacement ratios (25, 50, 75, and 100) %, it was found that the density value ranges from 1433Kg/m^3 to 2483Kg/m^3, as shown in **Table 3.** The reason for the decrease in the density of concrete with the increase in the replacement ratios is due to the plastic density equal to 370 Kg/m^3, which is considered low compared to the natural aggregate **(Osei, D. Y., 2014).**

Table 3. The density of concrete with percentage replacement of plastic **(Osei, D. Y. 2014).**

Percentage Replacement plastic %	Dry density (kg/m^3)			
	7 days	14 days	21 days	28 days
0	2425	2433	2446	2483
25	2146	2158	2211	2307
50	1916	1947	1947	1972
75	1604	1609	1628	1653
100	1402	1408	1428	1433

The density of concrete contained plastic less than the density of reference concrete. The dry density decreases with the increase of polypropylene (PP) as coarse aggregate. The highest decrease in density reached 1961kg/m^3 at the replacement rate of 30% and w/c = 0.48. The reason that the lower polypropylene density compared to the usual coarse aggregate **(Sayem, A. S. M., et al., 2015).**

5.2.2 Strength of concrete containing plastic

The compressive strength of concrete containing plastic decreases with increasing the plastic replacement ratios (10 and 20) %, respectively, compared to control concrete, as shown in **Fig.1**.**(Ahmed, M. M.,** and **Raju, S. S., 2013).**

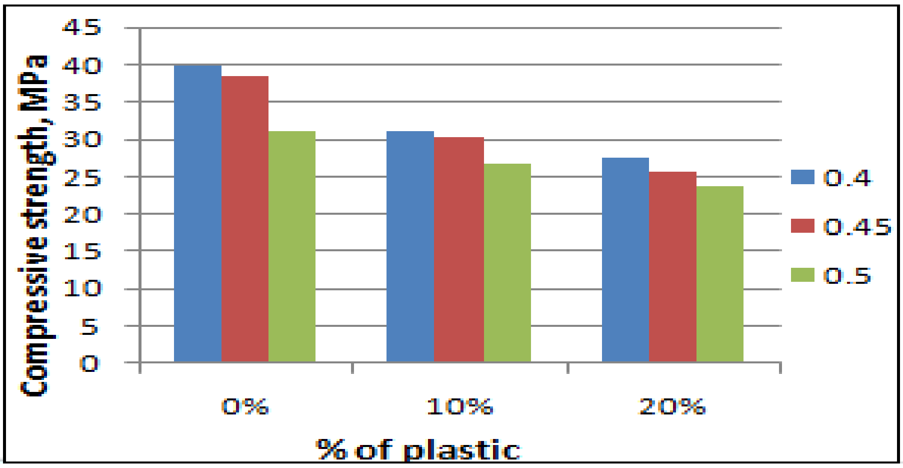

Figure 1. Percentages of plastic replacement and compressive strength for different w/c ratios).

When replacing plastic waste with proportions (15, 25, and 45) % of the volume of coarse aggregate, the researchers found that the compressive strength, tensile, and flexural strength decreases with an increase in the replacement ratio compared to the reference mixture, as shown in **Table 4**. The reason for the decrease in the strength to compressive, tension, and flexural was due to the weakness in the bonding strength between the cement paste and the plastic surface, which leads to failure in the interfacial transition zone and the low strength of plastic aggregate **(Khalil, W. I.,** and **Mahdi, H. M. 2020).**

Table 4. Percentage decrease of Compressive, Tensile, and Flexural strengths of plastic concrete **(Khalil, W. I., and Mahdi, H. M. 2020).**

Age and mix symbol	Percentage decrease of Compressive strength %		Percentage decrease of Tensile strength %		Percentage decrease of Flexural strength %	
Age (days)	7	28	7	28 days	7	28
B (15%)	18.18	29.14	38.23	18.1	22.58	15.29
C (25%)	24.80	33.80	58.82	51.38	40.32	22.35
D (45%)	40.79	49.51	78.43	70.83	64.51	31.76

The compressive strength of concrete containing plastic decreases with increasing the plastic replacement (20% decreases with 1% of the addition of plastic bag pieces). On the other hand increase in the tensile strength of concrete was observed by adding up to 0.8 % of plastic bag pieces in the concrete mix **(Atul, 2008).**

In **Table 5,** a summary of some previous studies, including replacement percentages, quantities of materials, water-cement ratios used, and their effect on the fresh and hardened properties of concrete, is given.

Table 5. The Summary of previous studies used plastic in concrete mix.

Refer.	Replacement ratio %	Fresh and hard Properties	Remark
(Abdel Moti, H. M., and Mustafa, M. A., 2019).	1.M1=0% reference mix 2.M2=5% polypropylene (PP) recycled plastic from sand 3.M3=10% polypropylene (PP) recycled plastic from sand	1-The slump values for substitutes percentages tend to increase by 9.09% and 18.18% for substitutes 5% (M2) and 10% (M3) (depending on sand volume) compared to the control mix, respectively. 2- For the fresh density, the 5% replacement showed an increase of 0.134% compared to the control mix, which is a very slight increase, and the uneven distribution may be the reason for this result. But the 10% decreased by 4.095% compared to the control mix. The variation between the sand and the plastic aggregate is the main contributor to this reduction. 3- The dry density for both (7 and 28) days of cured samples tends to be lower than the control mix. The difference in percentage between plastic pellets and sand density is 69.5%, which explains the lower weight of concrete mixes containing 5% and 10% PP pellets. 4- Compressive strength for seven days of the cured Sample decrease by 18.5%and 9.42% respectively when replaced 5% and 10% from the fine aggregate. The 5% might have encountered some unnoticeable problems while mixing the (PP) pellets in the concrete mix and The compressive strength decreased for (28) days by 15.08% and (12.72) % for (5)% and (10)%, respectively. 5- The splitting tensile strength reduced by 18.15% and 14.03% for the 5% (M2) and 10% (M3) respectively compared to the control mix (M1). For the 5% and 10% of	1-Using cement content 375 Kg/m^3 2-Using coarse aggregate content 1145 Kg/m^3 with a maximum size of 20 mm 3- Using fine aggregate content (700,665 and 630) Kg/m^3 for (M1,M2 and M3), respectively 4-water content 180 Kg/m^3 (w/c = 0.47)

		the control mix. This may be due to the weak bond between the cement paste and the polypropylene (PP) surface. 6- The flexural strength increased by 8.33% and 19.44% for the substitutes 5% and 10%, respectively, compared to the control mix since the polypropylene (PP) pellets have higher bending resistance than the sand.	5- Using polypropylene (PP) content (55and 70) Kg/m^3 For (M1and M2), respectively.
(Almeshal, I., et al., 2020)	PET waste plastic replacement of fine aggregate by (10, 20, 30, 40, and 50)%	1- The Slump values decrease by (12, 50, and 88)% for (10, 30, and 50)% of PET replacement, respectively. 2-Compressive strength decreased by (1.2, 4.2, 31, 60 and 90.6) % for (10, 20, 30, 40, and 50) % of PET replacement respectively. 3- Tensile and flexural strengths reduced by (10.5–85.5)% and (2.4-84.2)% , respectively for PET (10–50)% replacement	1-cement content $370kg/m^3$ 2- water cement ratio 0.54
(Arivalagan, S., 2020).	1-reference mix (S1) 2- S2, S3, and S4 replacement of coarse aggregate by (10, 20, and 30)%, respectively.	1- The slump values of concrete mixture was reduced when increasing e-waste plastic after 10% in concrete where S1= 90 mm ,S2 =110 mm ,S3= 100 mm and S4 = 93 mm 2- The compressive strength was increased (20) % e-waste replacement at (7,14 and 28) days, but the compressive strength reduction to (30)% replacement of e-plastic. The poor bond strength of Electronic plastic led to this reduction. The maximum compressive strength at 28 days reached to 37Mpa for 20% replacement 3-The maximum split tensile strength at 28 days was reached to 5.5 MPa for 20% replacement but decrease to 3.75 at 30% replacement. weaker bonding between PVC and cement particles lead to this reduction 4- The flexural strength increase for 20% replacement at 28 days but reduced for (30)% replacement weaker bonding	1-Cement content 390kg/m3 2- Fine aggregate content 675 kg/m^3 3-Coarse aggregate content (S1=1150,S2 =1050, S3=850, and S4 = 650) kg/m^3 4- e-plastic content (30, 55, and 85) kg/m^3 for S2, S3, and S4, respectively

		between **PVC** and cement particles lead to this reduction	5- w/c ratio 0.45
(Rai, B. et al., 2012).	Plastic pallets replacement of fine aggregate by (5,10, and 15)%	1-Fresh density decrease by 5%, 8.7%, and 10.75% for 5%, 10%, and 15%, respectively, 2- Dry density of concrete containing plastic decreases with increasing the plastic replacement ratios (5, 10, and 15) %, respectively, where the density of concrete reached 2225 kg / m^3 at a replacement 15%. 3- The Slump values decrease by (72, 50, 39, and 26) mm for (5, 10, and 15) % of plastic pallets replacement, respectively. 4- Values of Compressive strength are (43, 41, 39, and 36) MPa for (5, 10, and 15) %of plastic pallets replacement, respectively.	1-Cement content 423 kg/m3 2- Fine aggregate content 469 kg/m^3 3-Coarse aggregate content 1282 kg/m^3 4- w/c ratio 0.44
(Nur Liza, R et al., 2013).	High density polyethylene waste (HDPE) was used in the concrete mixture with proportions of 10, 20, and 30%	The compressive strength at the age of 28 days decreased by 6.28, 19, and 35.77 % for mixtures containing HDPE proportions of 10, 20, and 30 %, respectively. The reason for the decrease in the compressive strength when increasing the proportions of plastic replacement is due to the weak bonding strength between the cement paste and the plastic (HDPE)	
(Jaivignesh, B., and **Sofi, A. 2017)**	plastic waste replacement of fine aggregate by (10, 15, and 20)% and replacement of coarse aggregate by (15, 20, and 25)%	1-Compressive strength decreased by (9.5, 13.77and 17.4) % for (10PF and 15PC, 15PF and 20PC, 20PF and 25PC) % of plastic waste replacement respectively at 28. 2-Split Tensile Strength decreased by (19.8, 14.35and 24.25) % for (10PF and 15PC, 15PF and 20PC, 20PF and 25PC) % of plastic waste replacement respectively at 28. 3-Flexural Strength decreased by (17.77, 25.18and 33.82) % for (10PF and 15PC,	1-Cement content 395 kg/m^3 2- Fine aggregate content 706 kg/m^3 3-Coarse aggregate

	PF= plastic fine aggregate. PC= Plastic Coarse aggregate.	15PF and 20PC, 20PF and 25PC) % of plastic waste replacement respectively at 28.	content 1151 kg/m^3 4- w/c ratio 0.5

6. CONCLUSIONS

1. Using plastic waste in the concrete lead to reduce of landfill cost and reducing the environmental pollution.
2. Plastic concrete is more insulating than ordinary concrete.
3. The workability and fresh density decrease by increase the percentage of plastic replacement.
4. The dry density decreased by increase the percentage of plastic replacement.
5. Compressive, split, and flexural strength decreased by increase the percentage of plastic replacement.

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