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Effect of Recycle Waste Fine Aggregate Replacement on Strength and Corrosion of Steel Bars Exposed to Various Environmental Conditions of Polypropylene Fiber Concrete

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Abstract:

Concrete plays an important role as a construction material in most of infrastructure projects because of its low cost and ease of manufacture. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. This study investigated effect of using recycle waste material as a sand replacement on fresh and hardened fiber concrete properties. Three types of recycle material were used marble waste, red brick waste and ceramic waste. The corresponding three classes of sand replacement were 15%, 28% and 20% respectively. Proportions of mixes determined using ACI 318-2019 recommendations. Cubes have a dimension of 100×100×100 mm were chosen to study compressive strength of concrete. Cylinders have a dimension of 70×100 mm were chosen to study corrosion of steel bars. All the specimens of the experimental work were casted and tested at concrete research and Material Properties Laboratory, "Faculty of Engineering, Fayoum University". The tested samples were curing in pure water and sea water (environmental conditions). The concrete cubes and cylinder were tested at the curing ages of 28, 60,90,180 and 270 days. Slump and compacting factor tests were carried out to check the effect of sand replacement with marble waste, red brick waste and ceramic waste on consistency and workability of concrete. From results, it was observed that the slump and compacting factor decreased with using marble waste, red brick waste and ceramic waste sand replacement. Partial replacement of Sand by marble waste, red brick waste and ceramic waste increase compressive strength of Polypropylene fiber concrete. Compressive strength of polypropylene fiber concrete at 270 days for samples immersed in pure water, increased by 12.2%, 10.8% and 9.5% of that without sand replacement for 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement, respectively. While for polypropylene fiber concrete samples immersed in sea water, compressive strength at 270 days increased by 5.0%, 3.75% and 2.5% of that without sand replacement for 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement, respectively. Corrosion rate of steel bars of polypropylene fiber concrete samples at all studied ages is smaller than that of standard mix (without fiber). Also, corrosion rate of polypropylene fiber concrete samples with sand replacement (marble waste, red brick waste and ceramic waste) is smaller than that of polypropylene fiber concrete without sand replacement (100% sand). Reduction in corrosion rate of polypropylene fiber concrete samples immersed in sea water at 270 days with 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement is 32.4%, 22.3% and 40% of that without sand replacement, respectively.

***Key Word**: Fiber Concrete; Marble waste; Red brick waste; Ceramic waste; Slump; Compacting factor; Compressive strength; Corrosion rate; Polypropylene fibers (PF).*

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I. Introduction

The demand of natural sand is quite high in developing countries since the available sand is not able to meet the demand of construction sector. Natural sand takes millions of years to form and it is not replenishable. In such a situation use waste material can be an economic alternative to the river sand. The demand for natural sand in the construction industry has consecutively increased resulting in the reduction of sources and an increase in price. Thus, an increased need to identify a suitable substitute that is eco-friendly and inexpensive has emerged which boosted the usage of, marble waste, red brick waste and ceramic waste as fine aggregate in concrete.

Countries all over the world suffer from solid waste headache, Solid Waste generation in Egypt has increased to reach the level of 20.5 million tons per year 2010, (SWEEPNET, 2010) [1]. It is projected to reach 35 million tons per year in 2025 (United Nations, 2011) [2].

Marble has been commonly used as a building material since the ancient times. The industry's disposal of the marble powder material, consisting of very fine powder, today constitutes one of the environmental problems around the world (Corinaldesi et al., 2010) [3]. Marble blocks are cut into smaller blocks in order to give them the desired smooth shape. During the cutting process about 25% the original marble mass is lost in the form of dust. In Turkey marble dust is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the marble dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment Abbreviation: WMD, Waste marble dust; UPV, ultrasonic pulse velocity. (Karasahin and Terzi, 2007) [4]. In addition to marble powder, silica fume, fly ash, pumice powder and ground granulated blast furnace slag are widely used in the construction sector as a mineral admixture instead of cement (Demirel and Yazicioglu, 2008, 2007) [5, 6]. Marble dust can be used either to produce new products or as an admixture so that the natural sources are used more efficiently and the environment is saved from dumpsites of marble waste (Hameed and Sekar, 2009) [7]. Many studies have been conducted in literature on the performance of the concrete containing waste marble dust or waste marble aggregate, such as its addition into self-compacting concrete as an admixture or sand (Corinaldesi et al., 2010; Alyamac and Ince, 2009; Guneyisi et al., 2009; Unal and Uygunoglu, 2003) [8-11], as well as its utilization in the mixture of asphaltic concrete (Karasahin and Terzi, 2007; Akbulut and Gurer, 2007; Binici et al., 2007, 2008) [12-15] and its utilization as an additive in cement production (Aruntas et al., 2010) [16].

Corrosion of steel bars in concrete is a major and an important cause in the deterioration of concrete structures. In the past years several researches have been conducted on the corrosion of reinforcing steel bars in concrete structures. Some of the main factors studied were: Causes interfered with the corrosion process, the development of methods to control reinforcing steel bars corrosion and the assessment of durability models enabling estimates on the service life of reinforced concrete structures affected by corrosion. Many factors that influence the reinforcing steel bars corrosion process, among which the influence of chloride ions and concrete carbonation, the mix design and curing Conditions of concrete, the chemical composition of the pore solution and the properties of the concrete cover are some of the most important. In addition, there are several local variables, as the mineralogy of raw materials, the influence of local exposure conditions and traditional construction practices, which may influence the reinforcing steel bars corrosion process. All these factors should be taken into account when attempting to assess the extent of reinforcing steel bars corrosion on a reinforced concrete structure [17-22]. Roberge [23], mentioned that Chloride attack is a major concern in reinforced concrete. The chloride may originate from the constituents of the concrete mix itself or from the diffusion of chloride ions from the surrounding environment. Broomfield, [24], investigated that the chlorine in pore solution causes the adjacent metal to go into dissolution at a local site. Sagüés et al [25], indicated that with time progresses, chloride from the seawater diffuses through the concrete cover and builds up near the steel-concrete interface. Ai Hongmei, Bai Junying [26], indicated that the Corrosion of steel in concrete is an electrochemical process; the two most common conditions inducing rebar corrosion and breakdown of passive film in reinforced concrete are carbonation and chloride erosion. Elsener, B., [27], Corrosion of steel in concrete occurs either due to the formation of microcells, or macro cells. Ann and Song [28], Investigated the two main phenomena such as carbonation and chloride attack may lead to a breakdown in the surface layer of ferrous hydroxide that covers the steel in the alkaline concrete environment. Bob [29], investigated that the mechanism of ingress of aggressive agents depends on the exposure conditions of the concrete, but all three processes can occur simultaneously. All of the transport mechanisms rely heavily on the quality of the concrete microstructure, which is a function of its total porosity, the size and distribution of pores and capillary tubes of the cement stone and the aggregates that make up the concrete, and the degree to which the coarser pores are interconnected.

Numerous factors influence the microstructure inc1uding the quantity and type of cement, the water cement ratio (w/c), the grading and the maximum size of aggregate, the use of admixtures, and the compaction and the curing process. Fazio [30], indicated that Chloride ions may be present in concrete during manufacturing, or they may penetrate into the concrete from some source. Specific sources of chloride ions include accelerating admixtures that contain calcium chloride, salt-contaminated aggregates, seawater, salt spray, and most importantly, deliberately applied deicing salts. The researcher Jones [31], studied experimentally that after hardening, the pore solution in a hydrated Portland cement matrix remains alkaline with a pH value of around 13. In this environment, steel is protected by a thin but dense layer of protective oxides. This layer is known as "passive layer" which is formed spontaneously.

In these conditions, the passive layer is produced on the surface of reinforcing steel acting as a barrier for the anodic reaction. L. Xuean and W. Jun [32, 33] When chloride ions coexist in concrete with other anions (OH^-), chloride ions are Easier to be absorbed than OH^-, resulting in a much lower OH^- concentration near passive film than that in micro pores. This local reduction of pH value may initiate localized breakdown of the film. Lydon (1995) [34], Investigated the effect of w/c ratio on the intrinsic permeability of two types of concrete. It was found that the permeability increased with w/c ratio, with specimens whose ratio was 0.5 exhibiting a higher intrinsic permeability than those with a w/c ratio of 0.4. In another study by Ahmad et al. (2005) [35], indicated that the w/c ratio has a significant influence on permeability of concrete. It was shown that the permeability increased considerably with an increase in w/c ratio. They also reported, in accordance that the permeability increased more rapidly when the w/c ratio approached 0.6.

Yingshu [36], investigated the quality of the concrete cover is involved in the physical protection of steel from environment, because concrete transport properties control the ingress kinetics of aggressive agents. During this phase, no corrosion occurs and it usually takes many years for aggressive agents to reach steel surface and de passivate steel. Bentur, Berke and Diamond, [37], explained the oxide film that forms on the steel. Normally, the film is either ferrous or ferric in nature. Ferric oxide tends to be more stable and eventually any ferrous oxide is converted to the more stable ferric oxide. When chloride ions penetrate to the steel surface, the ions react with the ferrous atoms forming a soluble complex which dissolves in the pore solution removing a component of the protective oxide film. This occurs at locations on the steel where the ferrous oxide has not yet been converted to ferric Oxide. Since this is only in specific locations, there is a localized loss of passivity and chloride penetration often results in extensive and dangerous pitting corrosion

II. Research Significance

The main goal of this study is to investigate experimentally effect of using recycle waste material as a sand replacement on fresh and hardened polypropylene fiber concrete properties. Three types of recycle wastes were used marble waste, red brick waste and ceramic waste (all pass through sieve 4.75 mm). Mix design according to ACI 318 -2019 [38] recommendations, introduced to achieve the compressive strength and corrosion of steel bars in two different environment exposure conditions (pure water and sea water). In order to achieve this objective, a total of 150 cubes (100 ×100 ×100) mm and 150 cylinders (70 ×100) mm were casted and tested.

III. Experimental Work

3.1 Material Properties

Materials used in concrete mixtures were ordinary Portland cement grade 42.5, specific gravity of cement used was 3.15, fine aggregate, coarse aggregate (basalt), recycle waste (Marble waste, Red brick waste and Ceramic waste) and pure water. Fine and coarse aggregate were tested according to Egyptian standard specifications [39] and ASTM. List of tests presented following:

1. Sieve analysis of sand and coarse aggregate as shown in **Fig. 1** and **Fig. 2**.
2. Sieve analysis of recycle material (marble waste, red brick waste and ceramic waste) is shown in **Table 1** and **Fig.1**.
3. Maximum aggregate size of coarse aggregate and fineness modulus of sand as shown in **Table 2**.
4. Specific gravity of coarse and fine aggregate as shown in **Table 2**.
5. Unit weight of coarse and fine aggregate as shown in **Table 2**.
6. Properties of recycle material (Marble waste, Red brick waste and Ceramic waste) as shown in **Table 3**.
7. Properties of Polypropylene fibers (PF) from Sika company in **Table 4**.
8. The reinforcing steel bars were used Φ12 as longitudinal steel reinforcements. The yield strength of main reinforcement was 360 MPa.

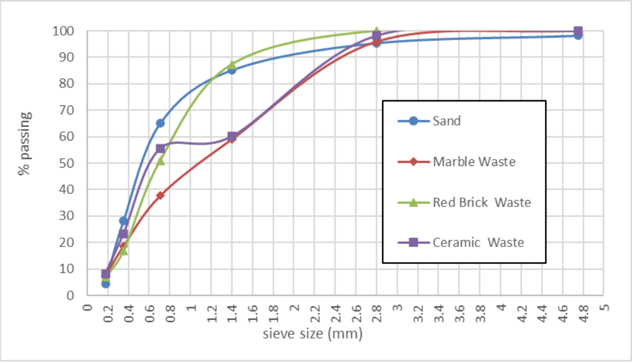

Fig. 1: Sieve Analysis of Sand and Recycle Wastes.

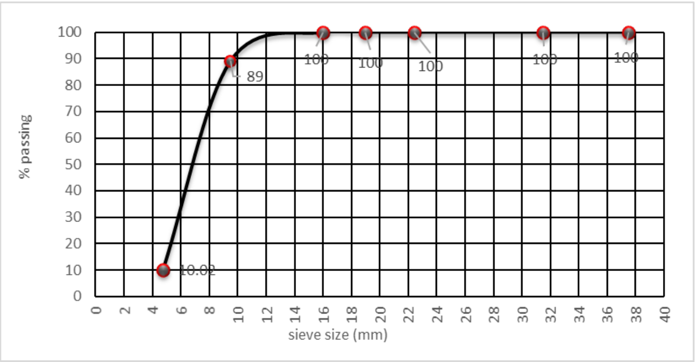

Fig. 2: Sieve Analysis of Coarse Aggregate.

Table 1: Sieve Analysis of Recycle Wastes.

Sieve Size(mm)	4.75	2.80	1.40	0.71	0.355	0.18	Pan
% Passing Marble waste	100	95.80	58.90	37.70	18.70	7.30	0.00
% Passing Red brick waste	100	100	87.3	51.0	16.8	6.9	0.00
% Passing ceramic waste	100	98.2	60.1	55.60	23.43	8.31	0.00

Table 2: Properties of Used Aggregates

Type of Test	**Value**
Maximum Aggregate Size [mm]	16
Fineness Modulus of Sand	2.24
Specific Gravity of Coarse Aggregate	2.73
Specific Gravity of Fine Aggregate	2.50
Unit Weight of Coarse Aggregate [t/m^3]	1.58
Unit Weight of Fine Aggregate [t/m^3]	1.77

Table 3: Properties of Recycle Waste.

Property	**Marble waste**	**Red brick waste**	**Ceramic waste**
Bulk Density (kg/m^3)	1118	1075	1584
Specific Gravity	2.68	2.7	2.63
Color	White	Red	White

Table 4: Properties of Polypropylene Fibers (PF) from Sika Company.

Density	0.91 gm nominal
Length	18 mm
Diameter	0.02mm
Tensile Strength [N/mm^2]	300 – 400
Elongation	> 80%
Absorption	Nil
Specific Surface Area	250 sq meter per KG
Melt Point	160 ºC
Ignition Point	365 ºC
Thermal Conductivity	Low
Electrical Conductivity	Low
Acid Resistance	High
Alkali Resistance	100%

3.2 Mix Design

Table 5a and Table 5b show contents of 1 m^3 concrete for control mix. Mixtures are designed using the American code (ACI 318-2019) [38] recommendations.

Table 5a: Mix Proportions for Control Mixture.

Mix Details	**Cement (kg/m^3)**	**Sand (kg/m^3)**	**Basalt (kg/m^3)**	**Water (kg/m^3)**	**PF (kg/m^3)**	**Proportions**
Standard (Plain Concrete)	411.11	733.85	1005.87	185	0	1:1.79:2.45 W/C = 0.45
Standard + PF	411.11	733.46	1005.36	185	0.90	

Table 5b: Mix Proportions.

Mix Details	**Cement (kg/m^3)**	**Sand (kg/m^3)**	**Basalt (kg/m^3)**	**Water (kg/m^3)**	**Replacement (kg/m^3)**	**PF (kg/m^3)**
15% Marble Waste + PF	411.11	620.70	1001.08	185	109.54	0.90
28% Red brick Waste + PF	411.11	524.46	994.2	185	203.96	0.90
20% Ceramic Waste + PF	411.11	582.74	996.2	185	145.68	0.90

3.3 Test specimens

The experimental program of this study involved testing of 150 cubes (100 ×100 ×100 mm) as shown in **Fig.** 3, 150 cylinders (70 ×100 mm) as shown in **Fig. 4**.

Fig. 3: Cubes (100 ×100 ×100 mm) During Casting

Fig. 4: Cylinders (70 ×100 mm) During Casting

3.4 Test setup

All Cubes (100 mm×100 mm×100 mm) and Cylinders (70 mm×100 mm) were divided into two groups (A and B) according to the environment exposure condition (pure water or sea water). Group A is kept in pure water during the period of Studying, while group B is kept in sea water during the period of studying. Both of the two groups were tested to achieve compressive strength and corrosion of steel bars at 28 days, 60 days, 90 days, 180, and 270 days as shown in **Figs. 4** and **5**.

Fig. 4: Cube (10 × 10 ×10 cm) during Compressive Strength test

Fig. 5: Cylinder (7 × 10 cm) During Measuring Corrosion

3.5 TESTS

3.5.1 Fresh Concrete Tests

3.5.1.1 Slump Test

For measure the consistency of each fresh mix and compare between conventional mixes and others include recycle waste, slump test has performed. Tools for slump test essentially consist of a metallic mold on the form of a cone having internal dimensions of 20 cm diameter bottom, 10 cm diameter top and 30 cm in height. The mold is placed on a smooth, horizontal and non-absorbent surface. The fresh test sample of concrete is taken from the pan mixer immediately after mixing and is placed into the cone mold at three layers. Each layer is compacted 25 times by a standard tamping rod. Slump is measured immediately by determining the vertical distance between the height of the mold and that of highest point of the specimen being tested as shown in **Fig. 6**.

Fig. 6: Slump Test.

3.5.1.2 Compaction Factor Test

Value of workability is estimated by the compaction factor apparatus as shown in **Fig. 7**. The compaction factor can be determined by filling the upper cone with fresh concrete and allow concrete sample to fall in the lower cone by opening the upper cone's door. At last, the sample is allowed to fall again in the cylinder and is weighted with the sample (partially compacted). After that, the cylinder is filled with fully compacted sample and is weighted (fully). Finally, compacted factor is determined (partially weighted / fully weighted).

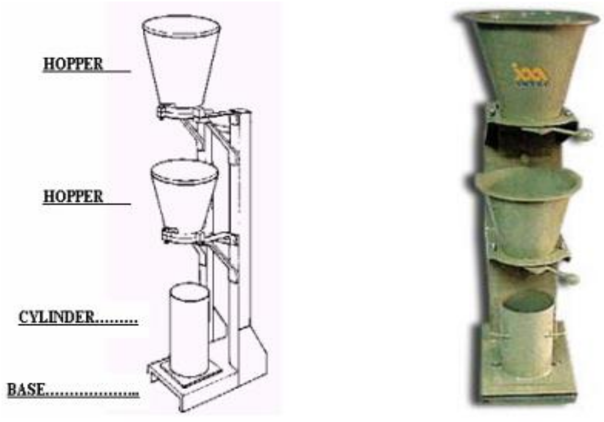

Fig. 7: Compacting Factor Apparatus.

3.5.2 Hardened Concrete Tests

Tests of hardened concrete play an important role in controlling and confirming its quality. Tests help to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability.

3.5.2.1 Compression Strength Test

For compressive strength test, prepared 30 cubes specimens for each mix, of dimensions 100 × 100 × 100 mm were caste. After 24 hours specimens were demolded and were transferred to curing tank in pure water (15 cubes for each mix) and sea water (15 cubes for each mix) where they were allowed to cure for 28, 60, 90 days, 180, and 270 days. These specimens were tested in compression testing machine (shown in **Fig. 4**). In each category, for each mix 3 cubes, their average value is reported by using following form:
Compressive strength = Load / Area (kg/cm^2)

3.5.2.2 Corrosion Rate

Cylindrical specimens (70 mm in diameter and 100 mm in length) with rebar in its middle (12 mm in diameter and 100 mm in length) were to assess the corrosion rate. Cylinders were cast with the mix, and the rebar was placed vertically, in the middle, and parallel to the long side of the mold. The mix was filled in layers by ensuring it was distributed evenly, and the mold was compacted in the vibrating table. Samples were de-mold after 24 h and cured in the specified water (either in fresh water or sea-water) for 28, 60, 90 days, 180, and 270 days.

IV. Experimental Results and Discussion

4.1 Fresh Concrete Properties

4.1.1 Slump Test Results

Results of slump test for sand replacement with marble waste, red brick waste and ceramic waste mixes is shown in **Fig. 8**. The results indicated that, slump value is reduced with sand replacement with different wastes.

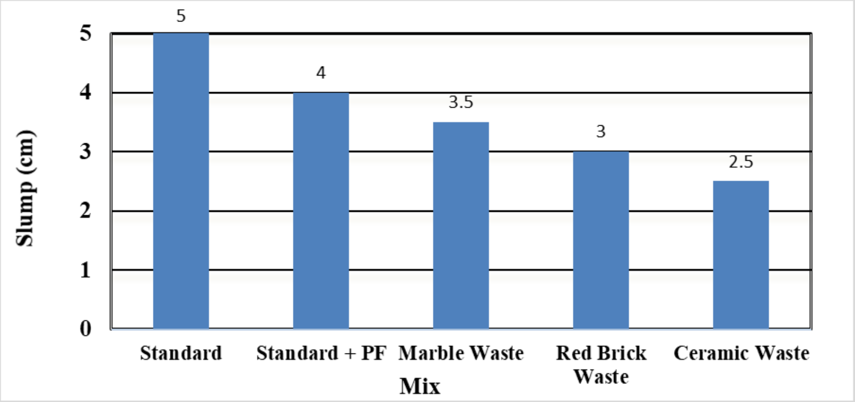

Fig. 8: Slump Test for Recycle Sand Replacement.

4.1.2 Compaction Factor Test Results

Compacting factor for sand replacement with marble waste, red brick and ceramic waste is shown in **Fig. 9**. Also, test results shown that, compacting factor value is reduced with sand replacement with different wastes.

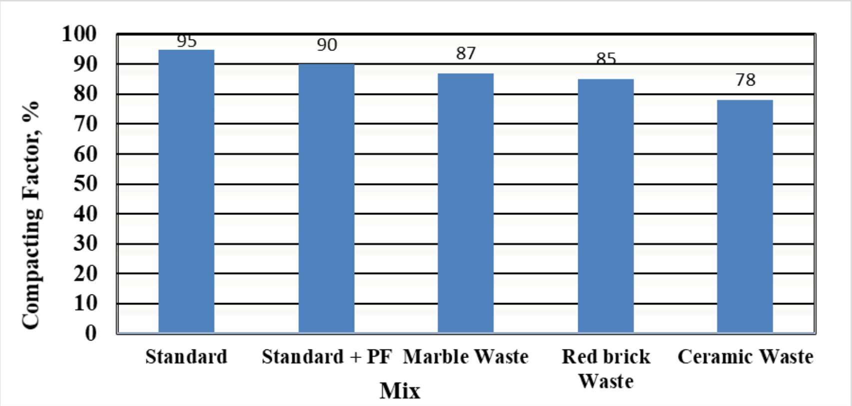

Fig. 9: Compaction Factor for Recycle Sand Replacement.

4.2 Hardened Concrete Properties

4.2.1 Compressive Strength Test Results

4.2.1.1 Marble Waste Sand Replacement of Polypropylene fibers (PF) Concrete

Table 6 and **Fig. 10** show compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, and marble waste sand replacement of samples **immersed in pure water**. The results demonstrated that: -

- Compressive strength is increased with increase of concrete ages.
- Compressive strength for Polypropylene fibers (PF) samples without sand replacement (100 % sand) are larger than that of standard samples (without PF).
- Largest increase in compressive strength occurs for mixes with PF and 15% marble waste replacement.

Table 6: Average Compressive Strength at 28, 60, 90, 180 and 270 Days for Sand Replacement with Recycle Material of Samples Immersed in Pure Water.

Mix Details	Compressive Strength (Kg/cm^2)				
	28 days	**60 days**	**90 days**	**180 days**	**270 days**
Standard (Without PF)	320	330	340	355	360
Standard + PF	330	340	345	360	370
15% Marble waste + PF	335	350	375	405	415
28% Red brick waste + PF	333	345	350	380	410
20% ceramic waste + PF	340	358	387	396	405

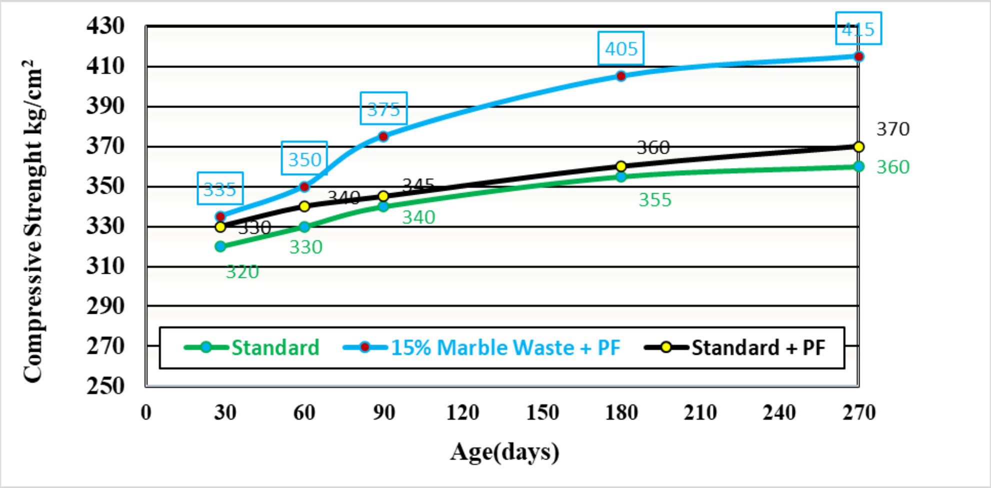

Fig. 10: Compressive Strength Variation for Marble Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Pure Water** at Different Ages.

Table 7 and **Fig. 11** show compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, and marble waste sand replacement of samples **immersed in sea water**. The results demonstrated that: -

- Compressive strength is increased with increase of concrete ages.
- Compressive strength for Polypropylene fibers (PF) samples without sand replacement are larger than that of standard samples (without PF).
- Largest increase in compressive strength occurs for mixes with PF and 15% marble waste replacement.

Table 7: Average Compressive Strength at 28, 60, 90, 180 and 270 Days for Sand Replacement with Recycle Material of Samples **Immersed in Sea Water**

Mix Details	**Compressive Strength (Kg/cm^2)**				
	28 days	**60 days**	**90 days**	**180 days**	**270 days**
Standard (Without PF)	330	346	360	379	390
Standard + PF	345	362	380	390	400
15% Marble waste + PF	380	396	405	410	420
28% Red brick waste + PF	375	383	396	400	415
20% ceramic waste + PF	350	375	395	405	410

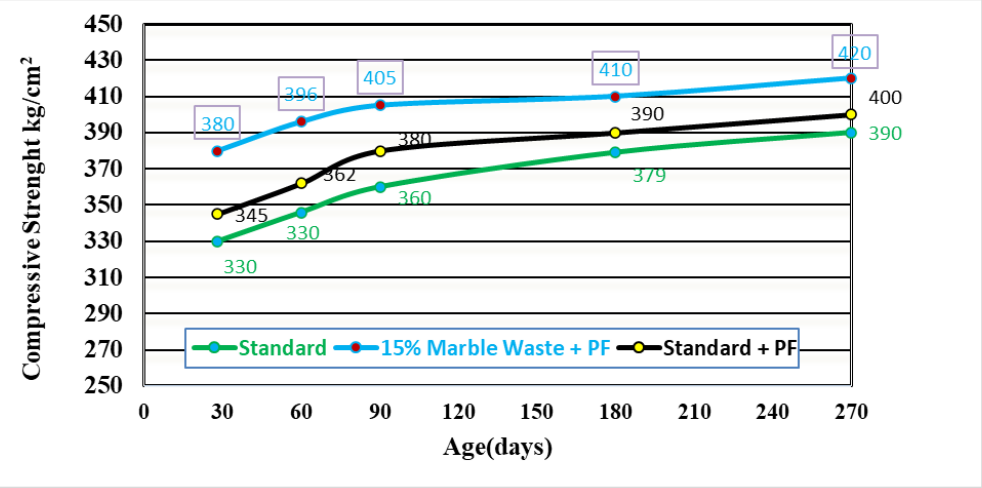

Fig. 11: Compressive Strength Variation for Marble Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in sea Water** at Different Ages.

4.2.1.2 Red Brick Waste Sand Replacement of Polypropylene fibers (PF) Concrete

Fig. 12 shows compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, red brick waste sand replacement of samples **immersed in pure water**. The results indicate same trends and observations of marble waste sand replacement.

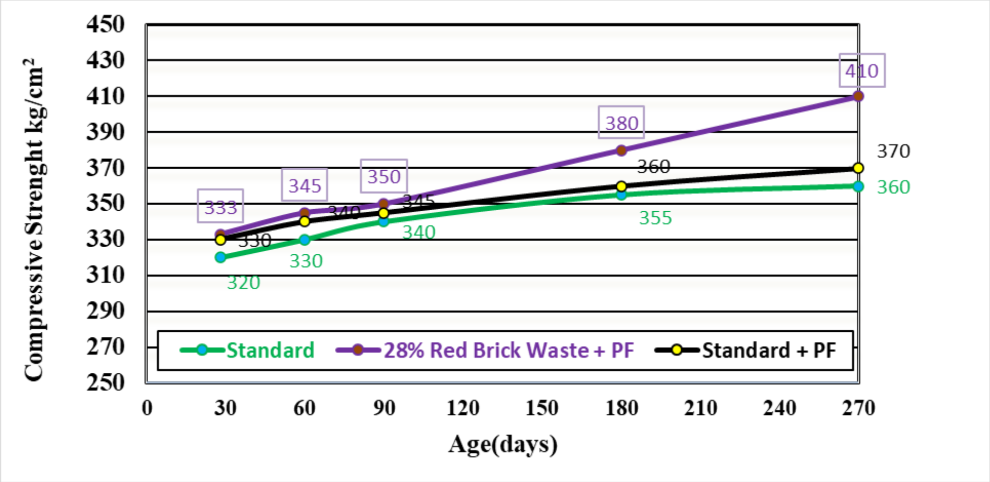

Fig. 12: Compressive Strength Variation for Red Brick Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Pure Water** at Different Ages.

Fig. 13 shows compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, red brick waste sand replacement of samples **immersed in sea water**. The results indicate same trends and observations of marble waste sand replacement.

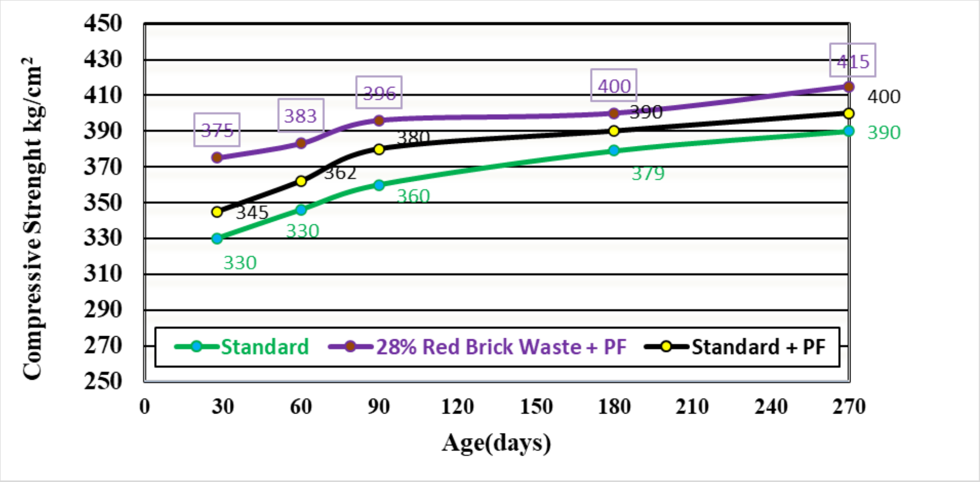

Fig. 13: Compressive Strength Variation for Red Brick Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Sea Water** at Different Ages.

4.2.1.3 Ceramic Waste Sand Replacement of Polypropylene fibers (PF) Concrete

Fig. 14 shows compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, ceramic waste sand replacement of samples **immersed in pure water**. The results indicate same trends and observations of marble waste and red brick waste sand replacement.

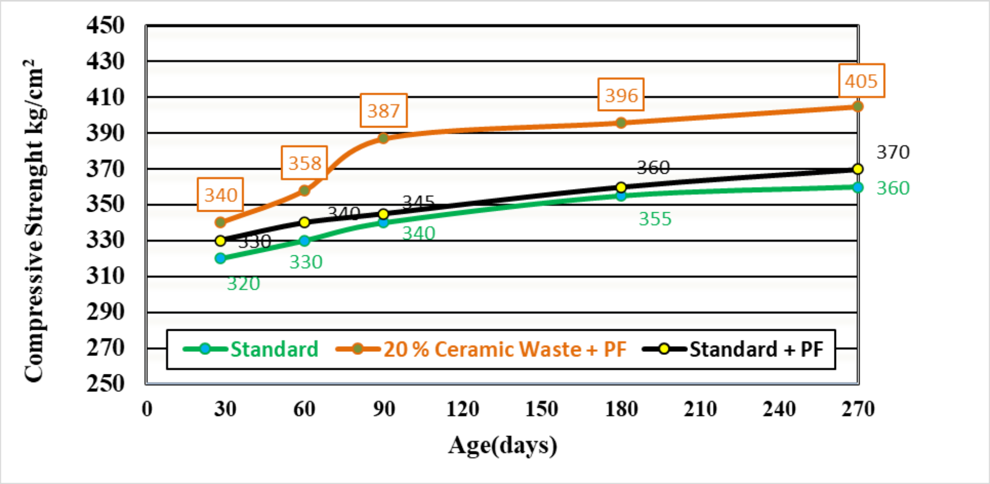

Fig. 14: Compressive Strength Variation for Ceramic Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Pure Water** at Different Ages.

Fig. 15 shows compressive Strength Variation at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, ceramic waste sand replacement of samples **immersed in sea water**. The results indicate same trends and observations of marble waste and red brick waste sand replacement.

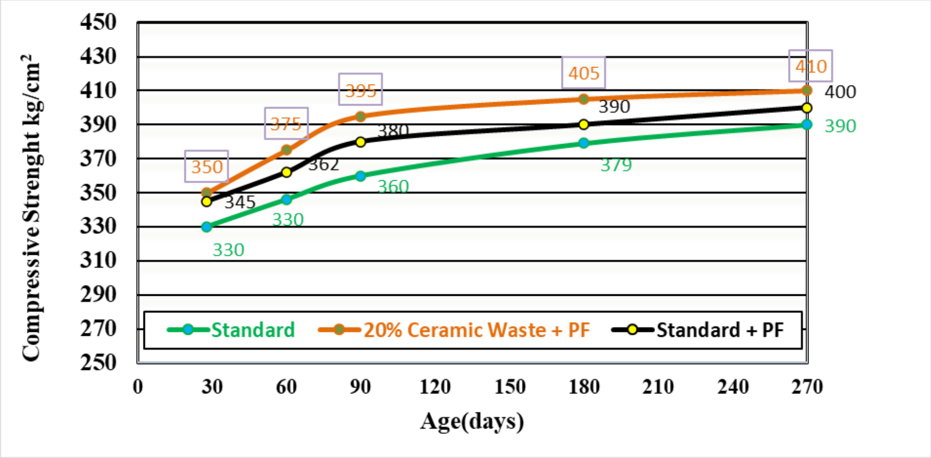

Fig. 15: Compressive Strength Variation for Ceramic Waste Replacement, Standard and Standard with PF for Samples **Immersed in Sea Water** at Different Ages.

4.2.2 Corrosion Rate

4.2.2.1 Marble Waste Sand Replacement of Polypropylene fibers (PF) Concrete

From **Table 8** and **Fig. 16** show corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, marble waste sand replacement of samples immersed in pure water. It is clear that from the given results, the corrosion rate values increased with the increase of concrete age. Also, the corrosion rate at all ages is decreased with PF samples than that of standard mixes (without PF) and the smallest corrosion rate values occurs for polypropylene fibers concrete samples with marble waste sand replacement.

Table 8: Corrosion Rate Values at 28, 60, 90, 180 And 270 Days for Sand Replacement with Recycle Material, Samples **Immersed in Pure Water**

Mix Details	**Corrosion Rate (μm/ yr.)**				
	28 days	**60 days**	**90 days**	**180 days**	**270 days**
Standard (Without PF)	273.9	308	315.9	350.8	380.9
Standard + PF	190.7	235.7	304.2	327.5	360.1
15% Marble waste + PF	153.7	192.5	250.1	307.6	350.4
28% Red brick waste + PF	103.7	106.4	132.1	140.4	180.2
20% ceramic waste +PF	120.1	190.4	215.2	300.3	330.6

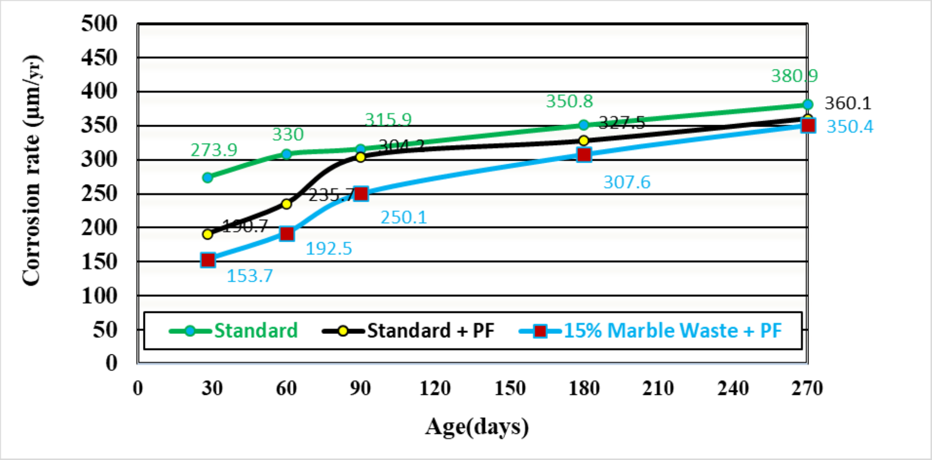

Fig. 16: Corrosion Rate Variation for Marble Waste Sand Replacement, Standard and Standard with PF all Samples **Immersed in Pure Water** at Different Ages.

Table 9 and Fig. 17 show corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, marble waste sand replacement of samples **immersed in sea water**. The results indicated that, the corrosion rate for all samples at all ages is larger than that immersed in pure water. Also, corrosion rate is increased with the increase of concrete age.

Table 9: Corrosion Rate Values at 28, 60, 90, 180 And 270 Days for Sand Replacement with Recycle Material, Samples **Immersed in Sea Water**

Mix Details	**Corrosion Rate (µm/ yr.)**				
	28 days	**60 days**	**90 days**	**180 days**	**270 days**
Standard (Without PF)	524.7	656.7	838.7	871.9	960.7
Standard + PF	362.3	449.7	476.0	556.8	668.4
15% Marble Waste + PF	262.5	272.9	301.9	350.8	451.8
28% Red Brick Waste + PF	264.4	397.2	458.7	486.5	519.6
20% Ceramic Waste + PF	255.3	265.1	289.6	298.9	400.8

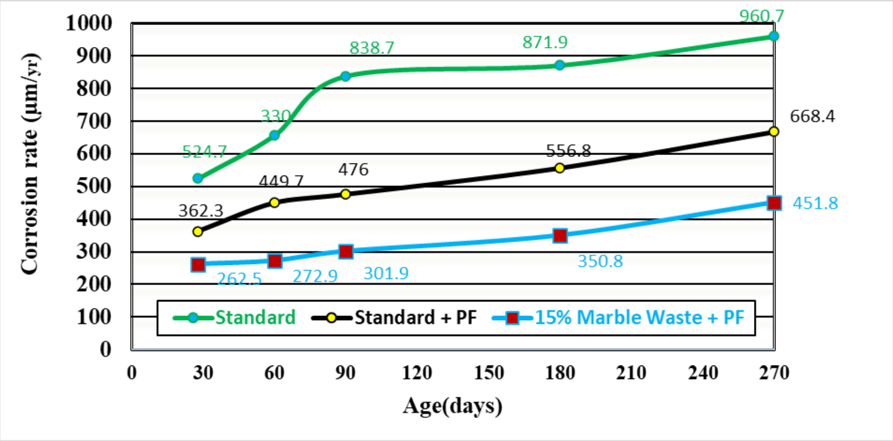

Fig. 17: Corrosion Rate Variation for Marble Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Sea Water** at Different Ages.

4.2.2.2 Red Brick Waste Sand Replacement of Polypropylene fibers (PF) Concrete

Fig. 18 shows corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, red brick waste sand replacement of samples **immersed in pure water**. The results indicate that, same trends and observations of marble waste sand replacement samples.

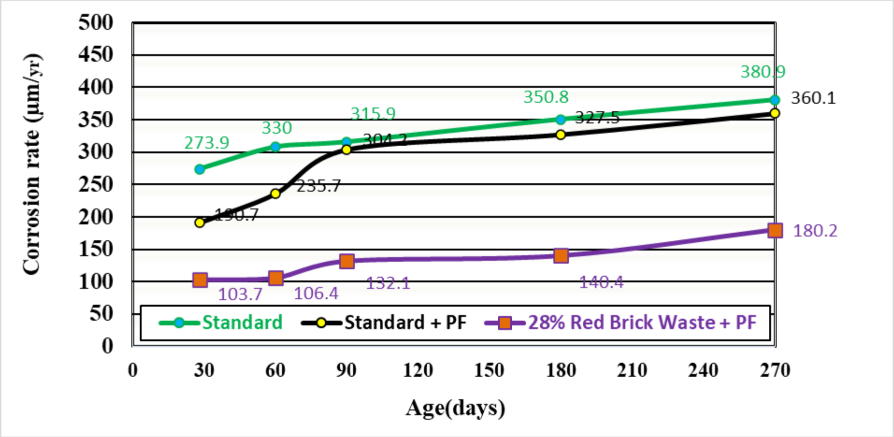

Fig. 18: Corrosion Rate Variation for Red Brick Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Pure Water** at Different Ages.

Fig. 19 shows corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, red brick waste sand replacement of samples **immersed in sea water**. The results indicate that, same trends and observations of marble waste sand replacement samples.

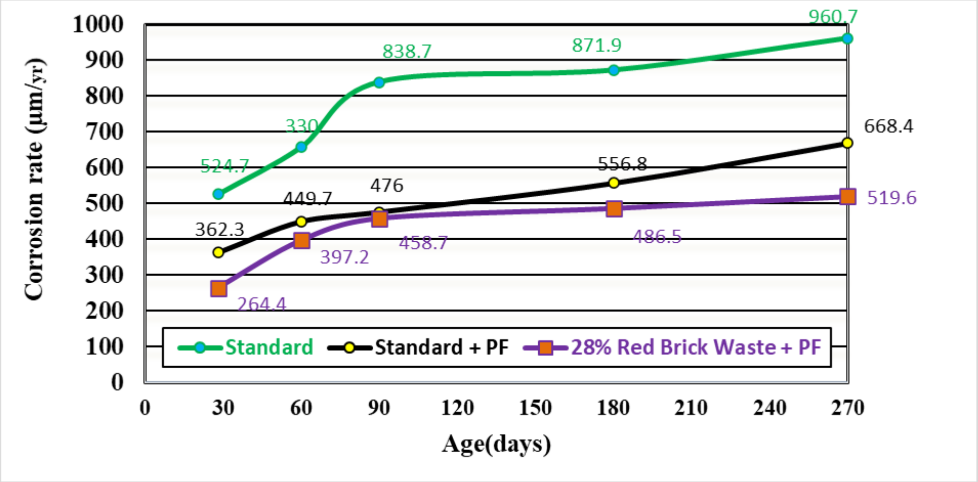

Fig. 19: Corrosion Rate Variation for Red Brick Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Sea Water** at Different Ages.

4.2.2.3 Ceramic Waste Sand Replacement of Polypropylene fibers (PF) Concrete

Fig. 20 shows corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, ceramic waste sand replacement of samples **immersed in pure water**. The results indicate that, same trends and observations of marble waste and red brick waste sand replacement samples.

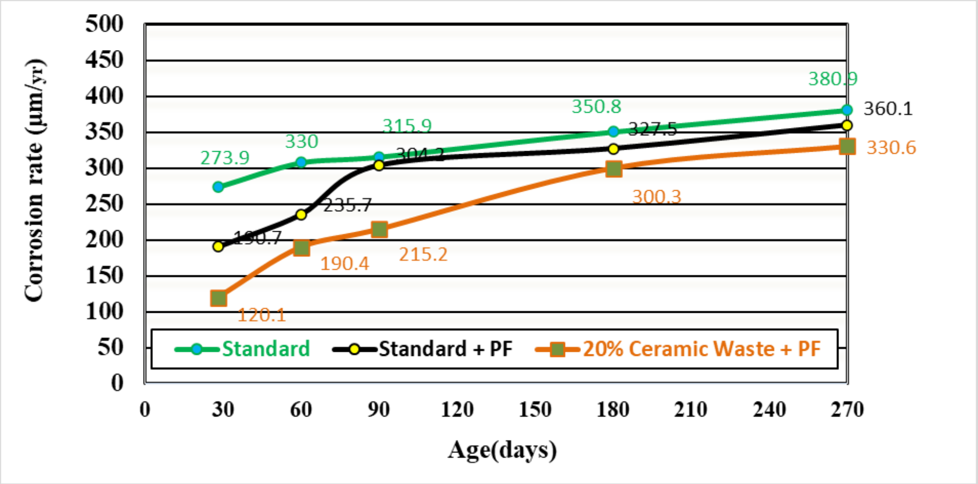

Fig. 20: Corrosion Rate Variation for Ceramic Waste Sand Replacement, Standard and Standard with PF for Samples **Immersed in Pure Water** at Different Ages.

Fig. 21 shows corrosion rate values at 28, 60, 90, 180 and 270 days for standard mixture, standard with PF, ceramic waste sand replacement of samples **immersed in sea water**. The results indicate that, same trends and observations of marble waste and red brick waste sand replacement samples.

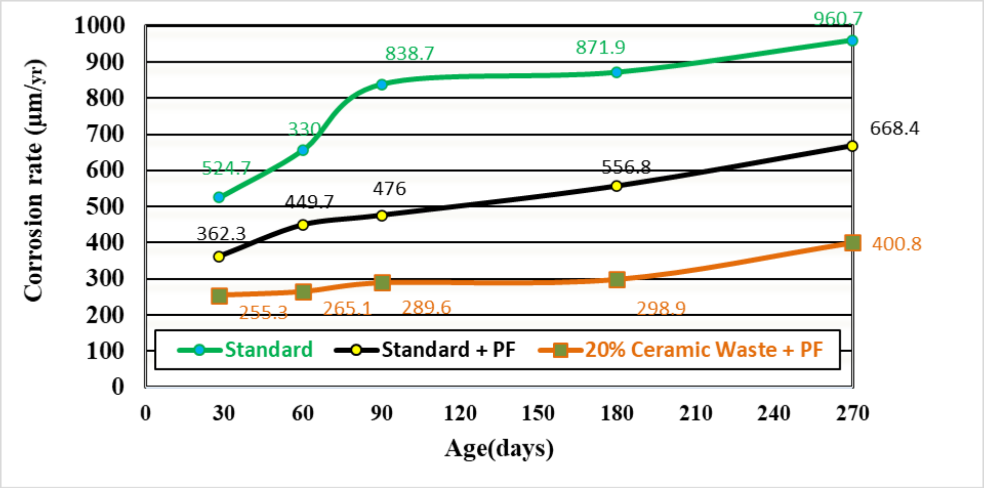

Fig. 21: Corrosion Rate Variation for Ceramic Waste Sand Replacement, Standard and Standard with PF all Samples **Immersed in Sea Water** at Different Ages.

V. Conclusions

From the current study, the following conclusions were drawn:

1- The waste material is introduced as a competent binder in enhancing fiber concrete properties.
2- The slump and Compaction factor values is decreased with using marble waste, red brick waste and ceramic waste as sand replacement.
3- The slump of test samples ranged between (2.5 cm to 5 cm).
4- The Compaction factor of test samples ranged from 95% to 78%.
5- Compressive strength of all samples that immersed in pure water and sea water is increased with the increase of time.
6- The rate of increase in compressive strength for samples immersed in pure water is larger than that immersed in sea water.
7- Compressive strength of polypropylene fiber concrete at 270 days for samples immersed in pure water, increased by 12.2%, 10.8% and 9.5% of that without sand replacement for 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement, respectively.
8- For polypropylene fiber concrete samples immersed in sea water, compressive strength at 270 days increased by 5.0%, 3.75% and 2.5% of that without sand replacement for 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement, respectively.
9- Compressive strength of Polypropylene fibers concrete samples at 270 days immersed in sea water is 1.2%, 1.22% and 1.23% of that immersed in pure water for 15% marble waste, 28% red brick waste and 20% ceramic waste, respectively.
10- Corrosion rate of steel bars of polypropylene fiber concrete samples at all studied ages is smaller than that of standard mix (without fiber).
11- Also, corrosion rate of polypropylene fiber concrete samples with sand replacement (marble waste, red brick waste and ceramic waste) is smaller than that of polypropylene fiber concrete without sand replacement (100% sand).
12- Reduction in corrosion rate of polypropylene fiber concrete samples immersed in pure water at 270 days with 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement is 2.7%, 49.96% and 8.2% of that without sand replacement, respectively.
13- Reduction in corrosion rate of polypropylene fiber concrete samples immersed in sea water at 270 days with 15% marble waste, 28% red brick waste and 20% ceramic waste sand replacement is 32.4%, 22.3% and 40% of that without sand replacement, respectively.

References

[1]. SWEEPNET. Country report on the Solid Waste Management in Egypt. Retrieved January 24,2012, from The regional solid waste exchange of information and expertise network in Mashreq and Maghreb countries: http://www.sweep.net.org/ckfinder/userfiles/net.org/ckfinder/userfiles/files/country-profiles/rapport-Egypte-en.pdf

[2]. United Nations Statistics Division World Statistics Pocketbook Country Profile: Egypt Retrieved March 04, 2012, from http://data.un.org/CountryProfile.aspx?crName=EGYPT

[3]. Corinaldesi V, Moriconi G, Naik TR (2010). Characterization of marble powder for its use in mortar and concrete. Const. Build. Mat., 24: 113-117.

[4]. Karasahin M, Terzi S (2007). Evaluation of marble dust in the mixture of asphaltic concrete. Const. Build. Mat., 21(3): 616-620.

[5]. Demirel B, Yazıcıolu S (2007). The effect of silica fume on the mechanical properties of carbon fiber reinforced lightweight concrete. Süleyman Demirel University J. Nat. App. Sciences. 11(1): 103-109.

[6]. Demirel B, Yazıcıolu S (2008). Thermoelectric behavior of carbon fiber reinforced lightweight concrete with mineral admixtures. New Carbon Mater., 23(1): 21-24.

[7]. Hameed MS, Sekar ASS (2009). Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate. ARPN J. Eng. Appl. Sci., 4(4): 83-89.

[8]. Corinaldesi V, Moriconi G, Naik TR (2010). Characterization of marble powder for its use in mortar and concrete. Const. Build. Mat., 24: 113-117.

[9]. Alyamac KE, Ince R (2009). A preliminary concrete mix design for SCC with marble powders. Const. Build. Mat., 23(3): 1201-1210. Aruntas HY, Gürü M, Dayı M, Tekin I (2010). Utilization of waste marble dust as an additive in cement production. Mater. Design., 31(8): 4039-4042.

[10]. Güneyisi E, Gesoglu M, Özbay E (2009). Effects of marble powder and slag on the properties of self compacting mortars. Mater. Struct., 42: 813-826.

[11]. Unal O, Uygunoglu T (2003). Investigation of mechanical properties of waste marble dusty concrete which under the effect of freeze and thaw. Turkey 4 th Marble Symposium; December, pp. 147-157.

[12]. Karasahin M, Terzi S (2007). Evaluation of marble dust in the mixture of asphaltic concrete. Const. Build. Mat., 21(3): 616-620.

[13]. Akbulut H, Gürer C (2007). Use of aggregates produced from marble quarry waste in asphalt pavements. Build. Environ., 42(5): 1921-1930.

[14]. Binici H, Kaplan H, Yilmaz S (2007). Influence of marble and limestone dusts as additives on some mechanical properties of concrete. Sci. Res. Essay, 2(9): 372-379.

[15]. Binici H, Shah T, Aksogan O (2008). Kaplan H. Durability of concrete made with granite and marble as recycle aggregates. J. Mater. Process. Tech., 208(1-3): 299-308.

[16]. Aruntas HY, Gürü M, Dayı M, Tekin I (2010). Utilization of waste marble dust as an additive in cement production. Mater. Design., 31(8): 4039-4042.

[17]. A. Bentur, Steel corrosion in concrete: fundamentals and civil engineering practice. , Taylor & Francis, 1998.

[18]. Frangopol, Dan M., Kai-Yung Lin, and Allen C. Estes., " "Reliability of reinforced concrete girders under corrosion attack."," Journal of Structural Engineering , vol.123, pp. 286-297., 1997.

[19]. Sidney Mindess, J.Francis Young, Concrete, Prentice-Hall, 1981

[20]. P. Schiesl, M. Raupach, in: C.L. Page, k.W.J. Treadaway, P.B. Bamforth (Eds.), Corrosion of Reinforcement in Concrete, Elsevier, London, l990.

[21]. (Yingshu, Y., Yongsheng Ji, Surendra P. Shah, 2007. Comparison of Two Accelerated Corrosion Techniques for Concrete Structures. ACI Structural Journal 104, 344– 347).

[22]. G. Glass, C. Page, N. Short, Corros. Sci. 32 (l99l) l283.

[23]. Roberge, P. R. 2000. Handbook of Corrosion Engineering. McGraw-Hill.

[24]. Broomfield, J. P. 2007. Corrosion of Steel in Concrete: Understanding, Investigation and Repair.Taylor & Francis, New York .USA.

[25]. A.N. Sánchez and A.A. Sagüés, “Probabilistic Corrosion Forecasting of Steel in Concrete with Potential Dependent Chloride Threshold,” pp. 408-413 in Proceedings of the 1st International Conference on Ageing of Materials & Structures, K. van Breugeland E.A.B. Koenders, Eds., Delft University of Technology, Delft, The Netherlands(2014c).

[26]. Ai Hongmei, Bai Junying, "Study on the Effect of Oxygen Ions on the Steel Corrosion in Concrete," in Communications and networks, International Conference, 2011.

[27]. Eisener, B. (2002). Macrocell corrosion of steel in concrete - implications for corrosion monitoring. Cement & Concrete Composites, V.24, No.l, pp. 65-72.

[28]. Ann, K. Y. and Song, H. W. 2007. Chloride threshold level for corrosion of steel in concrete.

[29]. Bob, C. (1996). Probabilistic Assessment of Reinforcement Corrosion in Existing Structures. In R.K Dhir (Ed.), Concrete in the Service of Mankind: Concrete Repair, Rehabilitation and Protection (pp. 17-28). London: E & FN Spon.

[30]. Fazio, R. (1999). The Assessment and Prediction of Reinforcing Steel Corrosion on the Dickson Bridge (Thesis). Mc Gill University, Montreal: Department of Civil Engineering.

[31]. Jones, D. A. (1996, Principles and prevention of corrosion, Upper Saddle River: Prentice Hall.)

[32]. L. Xuean, "Cause of Steel Corrosion in Concrete and Its Prevention," vol. 7, 2009.

[33]. W. Jun, "Reasons of steel corrosion and corrosion—resistance design in concrete, "vol. 8, 2008.

[34]. Lydon, F. D. 1995. Effect of coarse aggregate and water/cement ratio on intrinsic permeability of concrete subject to drying. Cement and Concrete Research, 25(8), pp. 1737-1746.

[35]. Ahmad, S., Azad, A. K. and Loughlin, K. F. 2005. A study of permeability and tortuosity of concrete. 30th Conference on Our World in Concrete and Structures: 23-24 August 2005, Singapore.

[36]. (Yingshu, Y., Yongsheng Ji, Surendra P. Shah, 2007. Comparison of Two Accelerated Corrosion Techniques for Concrete Structures. ACI Structural Journal 104, 344– 347).

[37]. Bentur, A., N.S. Berke, and S. Diamond (1997). Steel Corrosion in Concrete. London: E & FN Spon.

[38]. ACI COMMITTEE 318-19, Building Code Requirements for Structural Concrete and Commentary, 2019.

[39]. ECP-203,3rd ed. " Laboratory test guide for concrete materials, Appendix III, The Egyptian Code for Design and implementation of Concrete Structures, 2015.