Utilization of Pulverized Local Wastes for Production Sustainable Reactive Powder Concrete

Mushtaq Sadiq Radhi¹, Zainab M. R. Abdul Rasoul¹ and Laith Mohammed Ridha Mahmmod¹
¹Department of Civil Engineering, College of Engineering, University of Kerbala, 56001, Karbala, Iraq.
E-mail: mushtaq.sadiq@uokerbala.edu.iq (Mushtaq Sadiq Radhi)

Abstract. The aim of current experimental research is to examine the performance of the Reactive Powder Concrete modified by Pulverized Local Wastes materials. In this research, Reactive Powder Concrete was adapted by using local wastes (finely crushed ceramic tiles wastes) with Portland cement, silica fume, water, and chemical admixture through partially replacement of fine sand for sustainable practice in construction. This study exploited normal curing process at ambient temperatures as an alternative of higher temperatures steam curing for sustainability of construction works. To assess the behavior of the modified Sustainable Reactive Powder Concrete mixes, splitting and compressive strengths of Reactive Powder Concrete were inspected experimentally, and then associated with traditional Reactive Powder Concrete mix (the control mix). Furthermore, the hardened density of the modified Sustainable Reactive Powder Concrete was checked. The inquiry results directed that substituting the fine sand partially by Pulverized Local Wastes (finely crushed ceramic tiles wastes) is an adequate method for construction applications. Consequently, the compressive strength and spilling strength of modified Sustainable Reactive Powder were maintained by using 10% of finely crushed ceramic tiles wastes. Results illustrate that Reactive Powder Concrete have an insignificant strength loss with 10% sand replacement for compressive strength and splitting strength. The reduction percent in the compressive strength and splitting strength at 28 days are 12.37% and 8.55%, respectively, linked with related control mix.

1. Introduction
The utilization of wastes ceramic in construction materials is of prospective research value to develop the building industry sustainability. The theoretical achievement of utilization these waste materials can be itemized in three categories depending on particle size, shape and morphology as follows; Firstly, waste ceramic powder to fine aggregate which used as completely or partially replacement from natural sand in concrete or mortar fabrication. Secondly, waste ceramic utilize as recycled coarse aggregate by complete or partial replacing for normal coarse aggregate. Thirdly, it is used as cementitious replacement material with pozzolanic influence for mortar and concrete[1][2][3]. Reactive Powder concrete is a cement based binder material with high compressive strengths and it be different from Ultra High Performance Concrete in higher content of cement and much smaller maximum grain sizes of aggregate, which usually finer than 600 µm. The main design principles of the Reactive Powder concrete depend on improving the mixture homogeneity through omitting of the coarse aggregate [4].

Numerous of earlier investigations have studied the usage of ceramic waste in concrete as a replacement of natural aggregates (fine or/and coarse) or cement. Wioletta et al. [5] found that, afterward incorporating of powdered ceramic waste as incompletely replacement from the fine
aggregate at percent ranged from 10% to 20% in concrete mortar, the compressive strength and the flexural strength somewhat increased when compared with corresponding conventional concrete. Halicka et al. [6] accomplished an investigation on the concrete incorporation ceramic waste. The authors substituted the normal aggregates with smashed waste ceramic aggregates prepared from ceramic waste. They observed that the resistance of abrasion, settled by measurements of height changes in the sample, was improved in case of the concrete containing ceramic waste. The similar tendency was perceived for resistance to elevated temperature, compressive strength, and splitting tensile strength. Sui et al [7] tested calcium carbonate concrete demolition as pozzolanic replacement materials in ecoefficient reactive powder concretes, as fractional replacement of silica fume with calcium carbonate waste concrete powder (15%, 30%, and 45%) and implemented hardened concrete properties tests, alike Compressive strength and flexural strength. They found that the flexural strength and compressive strength of reactive powder concrete with calcium carbonate waste concrete powder, as an alternative of silica fume had no noticeable difference with conforming values of reference specimens. Kushartomo et al. [8] executed an investigation on the influence of the powdered discarded glass on the behaviour of the reactive powder concrete. The crushed quartz was interchanged by powdered glass waste with divisions 10%, 20%, and 30%. The results displayed that the usage of powdered glass waste was satisfactory to interchange crushed quartz in reactive powder concrete. Asteray et al. [9][10][11] were implemented researches to study the reactive powder concrete behaviour that adjusted by finely waste powder raw materials (waste glass, waste ceramic and fly ash). The results demonstrated that complete substituting of the silica fume by finely powdered waste glass and fly ash combination with 15% replacement of powdered waste ceramic from fine sand is an encouraging line for civil engineering construction applications owing to the upgrading of the mechanical properties of adapted reactive powder concrete. Zhu et al.[12] tested the accomplishing of powder prepared from recycled waste materials (solids of cement and clay bricks) to increase ecologically friendly and cost saving of the reactive powder concrete by replacing silica fume with fractions ranged between 20% and 100%. The outcomes revealed that as the percentage of silica fume diminished in reactive powder concrete, the mechanical properties (compressive and flexural strengths) were declined on account of recycled powdered waste increased.

Insertion the powder of waste ceramic in reactive powder concrete as a replacement from normal fine sand, require less fineness of waste powder particle size and consume more quantity of the waste materials, when compared with replacement from silica fume. Therefore, the target of the present investigation is to realize whether a reactive powder concrete mix design incorporating finely crushed ceramic tiles wastes as partially substitution of natural fine sand is capable to attain a sufficient performance of the modified Sustainable Reactive Powder Concrete for structural applications. Six different replacement proportions, 0%, 10%, 20%, 30%, 40%, and 50% were considered in modified Sustainable Reactive Powder Concrete production. Then, the hardened mechanical properties such as splitting and compressive strengths at early ages were measured. Likewise, the hardened density of modified Sustainable Reactive Powder Concrete was checked.

2. Experimental Procedure

2.1. Materials

The modified Sustainable Reactive Powder Concrete considered here was produced by the following component.

2.1.1 Cementitious materials

In this research work, the cement used was ASTM type agreeing to ASTM C150 [13]. Type V (i.e. sulfate resisting Portland cement) that available of local markets commercially known as Al-jesser cement produced by Lafarge company. Silica fume was used as mineral admixture, it has specific surface area of (15 m²/g), bulk density of (700 km/m³) and specific gravity of 2.3. The chemical compositions of used binder materials (cement and silica fume) are presented in Table 1.
Table 1. Compound composition of binder materials.

| Materials    | Chemical Composition |
|--------------|----------------------|
| Cement       | SiO$_2$ 20, Fe$_2$O$_3$ 5.1, Al$_2$O$_3$ 4.0, CaO 59, MgO 2.1, SO$_3$ 1.9 |
| Silica Fume  | SiO$_2$ 94.6, Fe$_2$O$_3$ 0.15, Al$_2$O$_3$ 0.58, CaO 0.34, MgO - |

2.1.2 Fine Aggregate
Fine sand with grain size passing through sieve size (600 µm) and retained on sieve size of (150 µm) was used in this research, the fine sand with this size is a necessary component in making reactive powder concrete.

2.1.3 Superplasticizer
High performance super plasticizing admixture based on polycarboxylic polymer with high efficiency in reducing mixing water and keeping low water to binder ratio is used to the mixtures. The dosage of used superplasticizer was (2%) as recommended by manufacturer.

2.1.4 Pulverized Waste Material
Ceramic tile waste is inorganic material, it was used as sustainable material with a specific replacement volumetric percentage by fine aggregate. The first step in preparing this material was collecting the crushed and useless ceramic from local demolished or under maintenance houses and construction buildings, the collected material was smashed into small fractions ranged from 100 to 200 mm size by a manual hammer. Then, the small fractions were fed into a laboratory grinder to get the final material. The production from the crusher was cleansed with tap water to remove the crusher dust that may affect the workability of fresh concrete hence the properties of hardened concrete. The final step is sieving the crushed ceramic waste to get a similar grading of fine aggregate. Figure 1 clarify these steps.

![Figure 1. Steps of preparing tiles waste](image)

2.2. Mixtures Proportions
Control mixture and other five mixtures are adopted in the experimental program of this research. Ceramic tile waste was used to partially replace fine aggregate with volumetric proportion of (10%, 20%, 30%, 40% and 50%). The mix proportions for control mixture is based on mix reported in previous local literatures [14] [15][16], the compositions of all mixtures are listed in Table (2), the quantities of used ceramic tile waste are clearly illustrated in this table. Constant superplasticizer
dosage and water to binder ratio of (0.175) were used in all mixtures as fine aggregate and ceramic tile waste were used with saturated surface dry condition.

Table 2. Mixtures Proportions (kg/m$^3$)

| Mixture designation | Cement | Silica Fume | Fine aggregate | Ceramic Tile Waste | superplasticizer | Water |
|---------------------|--------|-------------|----------------|--------------------|------------------|-------|
| Mix-00              | 880    | 220         | 970            | -                  | 2%               | 154   |
| Mix-10              | 880    | 220         | 874            | 75                 | 2%               | 154   |
| Mix-20              | 880    | 220         | 748            | 160                | 2%               | 154   |
| Mix-30              | 880    | 220         | 682            | 226                | 2%               | 154   |
| Mix-40              | 880    | 220         | 586            | 302                | 2%               | 154   |
| Mix-50              | 880    | 220         | 490            | 377                | 2%               | 154   |

2.3 Specimens Preparation

The dry cementitious materials (cement and silica fume) were blended with fine aggregate and ceramic tile waste (in mixtures used in) for 1 minute. Then the pre-mixed superplasticizer with water were put into the mixture of powders and aggregate and were mixed for another 6 minutes, the homogeneous fresh mixture was poured in non-absorptive steel moulds and compacted with vibrating table. The specimens were packed with nylon sheets for 24 hours, then demoulded and watery cured in $(24\pm 4^\circ C)$ until the age of test.

2.4 Testing Methods

In order to investigate the influence of powdered ceramic tile waste content on mechanical properties of reactive powder concrete, compressive strength, splitting tensile strength and density were conducted. Specimens for compressive and density tests are (50 mm) cubes, the compressive strength test was implemented agreeing to ASTM C 109 [17], furthermore density test according ASTM C 642 [18], cylinder specimens (100 × 200 mm) are used for splitting tensile strength according to ASTM C 496 [19]. Three samples at each test age were adopted for all mixes; the average of this results is served as the final value of compressive, splitting tensile strength and density.

3. Rustles and discussion

3.1 Compressive strength

The compressive strength, as one of the most essential properties of hardened concrete, is the representative material value for the ordering of concrete in national and international codes. To examine the outcome of changed waste ceramic aggregate contents on compressive strength of in modified Sustainable Reactive Powder Concrete, six mixes were tested at ages of (3, 7, and 28) days to determine strength development as a function of age, three cubes (50 mm) are used within this test. Figure 2 displays the results of compressive strength tests for each type of mix used in this study. It can be observed from the results of Figure 2 that adding ceramic waste to Reactive Powder Concrete provides a marked negative effect on the measured compressive strength. Increasing waste ceramic aggregate from 0% , 10% , 20%, 30%, 40%, and 50% in an acquired decrease in compressive strength, the reduction percent at 3 days for 10% , 20%, 30%, 40%, and 50% are (10.52%, 13%, 15.07%, 15.59%, and 16.1%), likewise at 7 days, (8.91%, 12.03%, 15.12%, 15.56%, and 16.69%) . Lastly, at 28 days (12.37%, 26.98%, 31.91%, 32.75%, and 33.33%) associated with related control mix. The decrease in compressive strength in ages 3, 7 and 28 days may be because of the weakness and brittleness of ceramic waste particles, which generate a weakness points inside concrete leading to
this decreasing in compressive strength. Also adding waste materials decreased the strength due to lack of moisture. There is little results indicated on reactive powder concrete contains waste ceramic, but Siddesha [20] and Sivaprakash et. al. [21] studied the effect of waste ceramic in normal concrete, and they observed similar trend.

![Figure 2](image_url)  
**Figure 2.** The influence of insertion ceramic waste on the compressive strength.

3.2 Splitting tensile Strength

The tensile strength manages the behavior of the cracking and its influence on other properties like the stiffness and the durability of reactive powder concrete. The indirect splitting tensile strength test was performed agreeing to ASTM C496. 100 mm standard cylinders were adopted. The average of three cylinders was adopted at each testing age at (3, 7, 28 days). The splitting tensile strength for all the mixes were determined and the outcomes are plotted in Figure 3. It is clear from Figure 3, that the splitting tensile strength at early ages (3 and 7) days develop with higher rate than at later age (28 days). The results demonstrated that, increasing powdered waste ceramic aggregate from 0% to 50% attained reduction in splitting tensile strength, the reduction percent at 3 days for 10% , 20%, 30%, 40%, and 50% are (0.73%, 0.89%, 10.96%, 16.71%, and 44.23%). similarly at 7 days, (0.71 %, 2.45%, 8.82 %, 12.04%, and 16.76%) . Finally, at 28 days (8.55%, 10.67%, 11.68%, 21.65%, and 27.54%) associated with related control mix. This tendency comparable to compressive strength behavior as mentioned above, likewise reported by other researchers[20][21].
Figure 3. The results of the splitting tensile strength at different ages.

3.3 Hardened density
Cube samples with sizes (50 mm) were molded and then, applied for normal curing for 28 days. The average of three sample for each mix was adopted for the density test. Figure 4 shows the effect of the insertion different powdered ceramic waste fractions on the hardened density of reactive powder concrete afterward 28 days of curing. From this Figure, it can be distinguished that the density of reactive powder concrete marginally declines as increasing in the fraction of powdered waste ceramic, owing to the powdered waste ceramic is slightly lighter than fine normal sand. The proportions of reduction in Mix10,Mix20,Mix30, Mix40 ,and Mix50 compared to the control mix that without powdered waste ceramics are 0.55%, 0.63%,0.84%,0.97%, and 1.23% one-to-one. These outcomes are compatible with those stated by other researchers on the cement mortars [5].

Figure 4. The influence of the insertion the ceramics waste powder on the density.

4. Conclusions
For economic and environmental motives among the few, current experimental research were performed to assess the Reactive Powder Concrete mechanical properties that comprising Pulverized Local Wastes materials (finely crushed ceramic tiles wastes) for fractional replacement of fine sand . Consequently, the succeeding conclusions can be determined and they are applicable for the materials utilized and the range parameters in the present experimental study:
1- The mechanical properties of the modified Sustainable Reactive Powder Concrete were enhanced with the curing age, and the rate of development of the splitting tensile strength greater than of the development rate of the compressive strength.

2- Compressive strength of the modified Sustainable Reactive Powder Concrete decreased with increase in fine sand replacement with different replacing levels of finely crushed ceramic tiles wastes sand. The reduction of the compressive strength at 28 days age ranged about from 12% to 34%.

3- Splitting strength of the modified Sustainable Reactive Powder Concrete had similar trend of the compressive strength, also, the splitting tensile strength declined as the level of replacing of the powdered waste ceramics increased in the modified Sustainable Reactive Powder Concrete. The diminishing proportion of the splitting strength at 28 days age ranged about from 8% to 28%.

4- The hardened density of the modified Sustainable Reactive Powder Concrete likewise exhibited an insignificant reduction with increase the levels of finely crushed ceramic tiles wastes sand substituting.

5- For the sustainability applications issues, the reactive powder concrete can be manufactured by insertion finely crushed ceramic tiles wastes with percentage of replacement not more than 20% from the fine sand.

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