Some Properties of Concrete Containing Waste Brick As Partial Replacement Of Coarse Aggregate And Addition Of Nano Brick Powder

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Abstract. The accumulation of construction and demolition waste is one of the major problems in modern construction. Hence, this research investigates the use of waste brick in concrete. Seven different concrete mixes were investigated in this study: a control concrete mix, three mixes with volumetric replacement (10, 20, and 30)% of natural aggregate with brick aggregate, and two mixes with the addition of nano brick powder at a percentage level of 5–10% by weight of cementitious materials. And the last one was mixed with 10% nano brick and 10% coarse brick aggregate. The experimental results for the additive of nano brick powder showed an enhancement in mechanical properties (compressive, flexural, and tensile strength) compared to the control mix for all ages, while the mixes with 10% coarse brick replacement also showed a slight improvement in the mechanical properties up to 5.33%, 2.79%, and 2.38% for compressive, splitting tensile, and flexural strength, respectively, at 28 days. The nano particles modified the mechanical properties of the CBA concrete when mixed with 10% nano brick and 10% coarse brick aggregate, up to 11.54%, 8.56%, and 3.3% for compressive, flexural, and tensile strength, respectively, at 150 days.

1. Introduction
Concrete is made up of a variety of elements, including coarse aggregate, fine aggregate, cement, and water, which are mixed in different proportions to obtain a specified strength. The yearly concrete production is estimated to be 11 billion metric tons. With increasing environmental pressure to decrease solid waste and recycle as much as possible, the concrete industry has adopted a number of methods to achieve this goal, including the substitution of various waste materials for fine aggregate and coarse aggregate. Construction and demolition waste are produced in massive quantities all over the world. These wastes are primarily increasing year after year [1,2]. The current focus of the sustainable construction environment is on the construction material resources used in the production of concrete. Exploration of alternative ingredient materials such as cement and aggregates made from industrial by-product waste is an innovative solution for future construction environmental sustainability. One of the most important materials used in the production of concrete is aggregate. The use of aggregate in the manufacturing of concrete is significant since aggregate accounts for
roughly 70% to 75% of the volume of concrete [3]. Recycled aggregate made from construction and demolition waste can be used in a variety of civil engineering projects, contributing significantly to the country's economic and environmental sustainability [4]. To deal with the dumping of demolition waste and the exploitation of NAs, more attention is being paid to recycled aggregate concrete [5]. Supplementary cementitious materials (SCMs) are finely ground solid materials used to substitute some of the cement in a concrete mix. Chemical reactions between these components and hydrating cement result in a modified paste microstructure. SCMs may improve concrete workability, mechanical properties, and durability, in addition to having a positive environmental impact. SCMs can have pozzolanic, latent hydraulic, or a combination of these properties [6]. The term pozzolan refers to a silicate material that, when finely divided and exposed to water, reacts chemically with calcium hydroxide to produce cementitious compounds [7]. Because of its pozzolanic properties of clay brick powder (CBP), it is a suitable candidate to substitute cement in concrete production [8,9,10]. Clay brick manufacturing requires exposure to high temperatures, ranging from 600 to 1000 C, which causes the structure of its silicates to change, resulting in an amorphous compound that reacts with lime at room temperature [11].

The use of pozzolanic nano-particles in the concrete matrix is one of the most recent innovations in concrete design. The growth of the strength-bearing crystals in cement paste can be increased or controlled by using pozzolanic nanoparticles [12]. That nanoparticles have a large surface area in relation to their size and that the small size of nano materials gives them additional properties compared to ordinary materials, and this is the reason for attracting attention to their use in the production of new materials with new and advanced properties. That nano materials can be described as materials that have one dimension at least (1-100 nm) [13]. Many studies have been carried out on the use of waste clay brick materials in the concrete industry.

Alireza investigated the influence of nano SiO2 particles on RHA blended concrete water absorption. It was discovered that in the presence of nano SiO2 particles up to 2%, RHA can substitute cement up to 20%, improving the physical and mechanical properties of concrete,[14]. Mukharjee and Barai investigated the compressive strength and characteristics of the Interfacial Transition Zone (ITZ) of concrete using recycled aggregates and nano-silica. The addition of nano-silica to concrete improved its compressive strength and enhanced its microstructure. This research investigated the effect of waste material used as coarse aggregate and nano material on the fresh and hardened properties of concrete[15]. Ge et al. studied the behaviour of concrete with CBP cement replacements of 10% to 30% by CBPs of various particle sizes, and it was discovered that as the amount of CBP and its particle size increase, the compressive strength decreases[16]. Kulovana et al. studied concrete with a water/cement ratio of 0.4 and up to 60% CBP as a cement replacement. Their findings show that replacing 20% of the cement in concrete does not affect the mechanical or physical properties of the concrete, and that using this material improves thermal conductivity by up to 50% [17]. Schackow et al. investigated the durability of mortars using fired CBP. The results for compressive strength are encouraging, showing an increase in the strength of up to 40% with the use of CBP [18]. They attributed these results to a decrease in the pore structure of the mortars caused by CBP, which they attributed to the filler effect of the fine CBP particles. Also, because of the filling effect of the fine CBP particles, amorphous compounds (silica, alumina, and calcium hydroxide) produce silicate/aluminate hydrates that are comparable to those produced in cement hydrations, which contribute to the increased strength. According to controls [19, 20], CBA can be used to manufacture concrete with a 28-day compressive strength of 20 to 30 MPa with a replacement rate of less than 50%. When the CBA substitution ratio exceeds 50%, however, a considerable reduction in compressive strength occurs.

2. Materials

2.1. Cement

Sulfate-resistant Portland cement Type V (Al-Mass, 42.5R), conforming to IQS No.5/ 2019 [21] was used in all concrete mixes. Tables 1 and Table 2 represent the chemical and physical properties of cement respectively.
Table(1): Chemical composition and main compound of Cement

| Oxide composition | Abbreviation | Percent by weight | Limit of IQS No.5/2019 |
|-------------------|--------------|-------------------|------------------------|
| Lime              | CaO          | 63.28             |                        |
| Silica            | SiO₂         | 21.92             |                        |
| Alumina           | Al₂O₃        | 4.5               |                        |
| Iron oxide        | Fe₂O₃        | 5.37              |                        |
| Sulfate           | SO₃          | 2.4               | ≤ 2.5% If C₃A ≤ 3.5    |
| Magnesia oxide    | MgO          | 2.17              | ≤ 5%                   |
| Loss on Ignition  | L.O.I        | 1.97              | ≤ 4%                   |
| Insoluble residue | I.R          | 1.07              | ≤ 1.5                  |
| Tri calcium silicate | C₃S       | 46.2              |                        |
| Di calcium Silicate | C₂S       | 28.07             |                        |
| Tri calcium aluminate | C₄A      | 2.85              | ≤ 3.5%                 |
| Tetra calcium aluminoferrite | C₄AF | 16.32             |                        |

Table(2): Physical properties of Cement

| Physical properties | Limit of cement | Limit of IQS No.5/2019 |
|---------------------|-----------------|------------------------|
| Specific Surface Area (Blaine Method), (cm²/gm) | 4795 | > 3000 |
| Setting Time : | | |
| -Initial Setting, (hrs: min) | 2:10 | ≥ 00:45 |
| -Final Setting, (hrs: min) | 3:25 | ≤ 10:00 |
| Compressive Strength of Mortar MPa: | | |
| 2days | 27 | ≥ 20 MPa |
| 28-days | 44.5 | ≤ 42.5 MPa |

2.2. Fine Aggregate

Natural sand zone (3) conforming to Iraqi specification IQS No.45/1984 [22] was used as fine aggregate in this study. The physical and chemical tests of fine aggregate and its grading shown in Tables 3 and 4.

Table(3): Physical & Chemical properties of Sand

| Properties               | Specification       | Value    | Limit of of IQS No.45/1984 |
|--------------------------|---------------------|----------|-----------------------------|
| Rodded Dry Density (Kg/m³) | ASTM C29/C29M     | 1694     | .....                        |
| Specific Gravity         | ASTM C128-07a      | 2.5      | .....                        |
| Absorption %             | ASTM C128-07a      | 0.8      | .....                        |
| Sulfate SO₃ %            | Guidelines No.3/500, 2018 | 0.044 | ≤ 0.5%                     |
| Fineness Modulus FM      | ASTM C136-06       | 2.4      | .....                        |

Table(4): Grading of Sand

| Sieve Size (mm) | Cumulative Passing % | Cumulative Passing% Limit of IQS No.45/1984 Zone [3] |
|----------------|----------------------|-----------------------------------------------------|
| 10             | 100                  | 100                                                  |
| 4.75           | 100                  | 90-100                                              |
| 2.36           | 96.2                 | 85-100                                              |
| 1.18           | 81                   | 75-100                                              |
| 0.6            | 61                   | 60-79                                               |
| 0.3            | 19                   | 12-40                                               |
2.3. **Coarse Aggregate**

Natural crushed gravel with nominal maximum size 14mm used as a coarse aggregate. Table 5 and Table 6 shows its properties which conforms to Iraqi specification No. 45/1984[22].

| Properties                      | Specification          | Value   | Limit of IQS No.45/1984 |
|---------------------------------|------------------------|---------|--------------------------|
| Dry density (Kg/m³)             | ASTM C29/C29M          | 1600    | ----                     |
| Specific Gravity                | ASTM C127-1            | 2.64    | ----                     |
| Absorption %                    | ASTM C127-1            | 0.7     | ----                     |
| Sulfate SO₃ %                   | Guidelines No.3/500, 2018 | 0.047  | ≤ 0.1%                  |
| Aggregate Impact Value %        | BS 812:Part3:1975      | 2.405   | ≤ 45                    |
| Aggregate Crushing Value %      | BS 812:Part3:1975      | 17.77   | -----                   |
| Abrasion test by using Los-Angeles machine, % | ASTM C131-06          | 17.4    | ≤ 35                    |

| Sieve Size (mm) | Cumulative Passing % | Cumulative Passing % Limit of IQS No.45/1984 |
|-----------------|----------------------|---------------------------------------------|
| 20              | 100                  | 100                                         |
| 14              | 94.02                | 90-100                                      |
| 10              | 52.66                | 50-85                                       |
| 4.75            | 0.36                 | 0-10                                        |

2.4. **Crushed Brick Aggregate**

Steps For Preparing crushed brick aggregate are summarized in plate1, and the physical and chemical tests of crushed brick aggregate and its grading shown in Tables 7 and 8.

| Properties                          | Specification          | Value   | Limit of IQS No.45/1984 |
|-------------------------------------|------------------------|---------|--------------------------|
| Dry roded density (Kg/m³)           | ASTM C29/C29M          | 927     | ----                     |
| Specific Gravity                    | ASTM C127-1            | 2.154   | ----                     |
| Absorption %                        | ASTM C127-1            | 19.67   | ----                     |
| Aggregate Impact Value %            | BS 812:Part3:1975      | 38.24   | ≤ 45                    |
| Aggregate Crushing Value %          | BS 812:Part3:1975      | 41.22   | -----                   |
| Abrasion test by using Los-Angeles machine, % | ASTM C131-06          | 24.2    | ≤ 35                    |

| Sieve Size (mm) | Cumulative Passing % | Cumulative Passing % Limit of IQS No.45/1984 |
|-----------------|----------------------|---------------------------------------------|
| 20              | 100                  | 100                                         |
| 14              | 99.92                | 90-100                                      |
| 10              | 62.28                | 50-85                                       |
| 4.75            | 3.64                 | 0-10                                        |

2.5. **Nano waste brick**
Steps For Preparing Nano Brick Powder are summarized in plate1. Figure (1) showing the resulting of particle size analyses test of nano brick powder NBP, and table (9) show the chemical compost of NBP.

Plate (3.2): Steps for Prepare Coarse Brick Aggregate And Nano Brick Powder
Figure 1: Particle size analyses test of nano brick powder NBP

Table (9): Chemical composition of Nano Waste Brick

| Oxide composition | Abbreviation | Percent by weight | ASTM C618 limitations, Type N [23] |
|-------------------|--------------|-------------------|-----------------------------------|
| Lime              | CaO          | 20.20             |                                   |
| Silica            | SiO₂         | 54.82             |                                   |
| Alumina           | Al₂O₃        | 11.36             | SiO₂ + Al₂O₃ + Fe₂O₃ = 71.54 > 70 |
| Iron oxide        | Fe₂O₃        | 5.36              |                                   |
| Sulfate           | SO₃          | 0.83              | ≤ 4%                              |
| Magnesia oxide    | MgO          | 3.02              |                                   |
| Loss on Ignition  | L.O.I        | 1.25              | ≤ 10%                             |

2.6. Silica Fume
Silica fume (SF), has been utilized as an artificial pozzolanic admixture that has been shown to significantly improve mechanical properties. It used as 5% replacement level from the weight of cement for all mixes. As seen in Table (10) and Table(11), it meets the chemical and physical requirements of ASTM C1240[24]. (The SRPC and 5% SF were used for our other work on external sulfate attack).

Table (10): Chemical analysis of Silica Fume

| Oxide composition | Oxide content % | ASTM C1240 limitations |
|-------------------|-----------------|-------------------------|
| SiO₂              | 92.83           | ≥ 85                    |
| L.O.I             | 1.59            | ≤ 6                     |
| Moisture content  | 0.33            | ≤ 3                     |

Table (11): Physical properties of Silica Fume used

| Physical properties | Silica Fume | Limit of specification ASTM C1240 |
|---------------------|-------------|-----------------------------------|
| Percent retained on 45μm(No.325) sieve, max, % | 8           | ≤ 10                                |
| Pozzolanic strength Activity Index (at 7 days) | 127.6       | ≥ 105                               |
| Specific Surface m²/g | 15          | ≥ 15                                |

2.7. Mixing Water
Tap water was used in this research for both mixing and curing of the concrete mixes. And it's conforming the Iraq specification no. 1703/1992 [25].

### 2.8. High Range Water Reducing Admixture (Super-Plasticizer)

High Performance concrete Super-Plasticizer (Flocrete PC200) was used to reduce water/cement ratio and increase the concrete durability. It was adding at a dosage range 0.5-2.5 liter per 100 Kg of the cementitious materials. It used to keep workability within acceptable limits. And it complies with ASTM C 494[26] type A & type G depending on dosage use.

### 3. Concrete mix design

A control mix was made with sulfate resistant Portland cement (without waste brick) and proportioned according to ACI 211.1-91[27]. For this mix, the specified minimum compressive strength at 28 days was 31 (38.75 for cube) MPa. The cement content was 400 kg/m$^3$ with 5% silica fume replacement from weight of cement, the w/c ratio was 0.45, many trial mixes were used to ensure that the desired properties and amount of HRWRA were achieved. In order to achieve the scope of this investigation, seven concrete mixes were investigated; control concrete mix, three mixes with volumetric replacing (10, 20, 30)% of natural coarse aggregate with brick aggregate, and two mixes with addition of nano brick powder in percentage level (5, 10)% by weight of cementitious materials, and the last mix using 10% nano brick and 10% coarse brick aggregate. As shown in Table (13), details of mix design. Furthermore, the constant parameters for all mixes were (cement 400kg/m$^3$, 5% silica fume replacement by weight of cement, sand 780kg/m$^3$, and a W/C ratio of 0.45).

Table (12) details of mix design

| Mix No. | Concrete mix | Coarse aggregate kg/m$^3$ | Brick aggregate kg/m$^3$ | Nano brick Kg/m$^3$ | HRWR admixture * |
|---------|--------------|---------------------------|--------------------------|--------------------|-----------------|
| 1       | RFC          | 970                       | 0                        | 0                  | 0.5             |
| 2       | BA10         | 873                       | 56.2                     | 0                  | 0.6             |
| 3       | BA20         | 775.7                     | 112.4                    | 0                  | 0.65            |
| 4       | BA30         | 679                       | 168.5                    | 0                  | 0.7             |
| 5       | NB5          | 970                       | 0                        | 20                 | 0.6             |
| 6       | NB10         | 970                       | 0                        | 40                 | 0.7             |
| 7       | N10A10       | 873                       | 56.2                     | 40                 | 1               |

* L/100 Kg of cementitious materials

### 4. Tests Performed

For both fresh and hardened concrete, the following tests were performed and all of them were accomplished in the building research directorate:

#### 4.1. Slump Test

The slump test is the common test to estimate the workability of concrete to evaluate the W/C ratio required and optimum dosage of (HRWRA) for concrete mix. This test was carried out according to ASTM C143[28].

#### 4.2. Fresh Density

The test was carried out in accordance with ASTM C138[29] The mold was weighed empty, then filled with concrete and weighed again. The wet density for all concrete mixes was determined by taking the average weight of three specimens.

#### 4.3. Dry density

The dry density of concrete was determined according to BS 1881-114[30] using cube specimen (100*100*100) mm.
4.4. Compressive Strength Test
The compressive strength test was done according to BS 1881:part 116-1989[31] using cube specimens with dimensions (100×100×100)mm. The cubes tested by using (TONI PACT3000) model of 3000KN capacity compression machine with a digital indicator. Test was performed on specimens at age 7, 28, 90, 120 and 150 days.

4.5. Splitting Tensile Strength Test
Splitting tensile strength test was done according to ASTM C 496-17[32]. Cylinder specimens with dimensions 100×200 was used in this test. The average of three cylinders has been registered. This test is performed at age of 7, 28, 90, 120 and 150 days.

4.6. Flexural Strength Test
It was conducted by using 75×75×300 mm prism specimens, the prisms supported simply with clear span of 225mm under canter points loading according to ASTM C293-08[33]. And the age of testing was 7, 28, 90, 120 and 150 days.

5. Results and discussion
5.1. Slump Test
The results of slump values for all concrete mixes are showed in Figure 2. Results indicate that the using of coarse brick aggregate as partial replacement of natural coarse aggregate (10, 20 and 30)% by volume cause an increase in the dosage of Super-Plasticizer (S.P) required as compared with control mixes.

The reason for this is that brick aggregate roughness and it's particle shape. For concrete maxes containing NBP showed a reduction in slump results which require more addition of SP in order to keep the acceptable range of the slump (75-100)mm at same w/cm ratio (0.45). the addition of NBP to control mix with high fineness needs to be justified with SP and that is compatible with [34].

Finally, the concrete mix containing 10% replacement of coarse brick aggregate and 10% addition of NBP need the highest quantity of (SP) up to (50%) compared with control mix.

5.2. Fresh and Dry Density
Figure 3 shows the results of fresh and dry concrete densities with varied percentages of coarse brick aggregate and nano brick powder substitution. As can be observed, as the amount of coarse brick aggregate increases, the fresh and dry densities decrease. Fresh density was slightly lower at around (0.80%, 1.93%, and 2.81%) at 10%, 20%, and 30% of CBA content. While for dry density, the replacement levels of 10%, 20%, and 30% CBA caused reductions in the dry density of around 1.73, 3.31, and 4.61% respectively, compared to the control mix. The coarse brick aggregate has a lower dry rodded density and specific gravity than natural coarse aggregate, which accounts for the reduction.

Increasing the NBP concentration as a partial addition of cement causes a noticeable increase in the concrete's densities. At 5% and 10% NBP content, the fresh density increase was 1.37% and 3.47%, respectively. Because NBP has high fineness, the packing effect of it as a filler into interstitial spaces...
within the skeleton of the hardened microstructure of cement mortar is high, which results in increased density. While the percentage increase in dry bulk density at 28 days for NB5 and NB10 concrete mixes compared to the control concrete mix was (1.74% and 4.46%), respectively. This is due to the pozzolanic reaction's effect, which leads the concrete matrix and transition zone to densify, as well as the pore-size and grain-size refinement processes. In addition to the packing effect of NBP as a filler.

5.3. Compressive Strength Test

Figure 4 and table 13 shows the results of compressive strength with varied percentages of course brick aggregate and nano brick powder.

When compared to RFC, at 7 days the maximum increase in compressive strength was found in concrete with 10% RCA, with a percentage increase of 5.33%. For 28 and 90 days the compressive strength remains the highest at replacement level 10% up to (5.65% and 4.76%) respectively. The compressive strength of concrete containing 20% CBA was found to be slightly higher than the target strength of 38.75 MPa at 28 days, but lower than that of RFC, it decreased around (10.19%) compared with RFC mix at 28 days. While the compressive strength of concrete containing 30% CBA was found decreased at all ages up to 26.73% at 150 days.

Both the 5% and 10% addition levels of nano-brick powder mixed with NBP resulted an increase in the compressive strength at all ages. At 150 days, the mix with a 10% BP replacement exhibited the highest growth of up to 26.15%. The increase in compressive strength of concrete mixes containing 5% and 10% nano brick powder is due to the amorphous state of NBP (small particle size) and extremely large surface area, in which the NBP reacts more quickly with free lime in the hydration reaction, producing more secondary C-S-H gel and efficiently filling the capillary pores in the matrix [35].
Figure 4: Percentages of increasing and decreasing of Compressive Strength (%) comparing to control mix

5.4. Splitting Tensile Strength Test

Figure 5 and table 13 shows the results of splitting tensile strength with varied percentages of coarse brick aggregate and nano brick powder. When compared to RFC, the splitting tensile strength of concrete at 7 days was found to be increased in all replacement levels around (2.63, 1.86, and 1.08)% for (10, 20, and 30)% respectively, when NCA was replaced with CBA. At 28, 90, 120, and 150 days, the splitting tensile strength increased for replacement level 10% up to (2.79, 1.40, 0.82, and 0.50)%. While it decreased for other replacement levels at ages 28, 90, 120, and 150 days, it was around (5.23, 6.64, 7.11, and 7.52)% for 20% CBA, and (8.44, 12.55, 14.06, and 14.72)% for 30% CBA.

Figure 5 also shows the tensile strength results of mixes with different NBP ratios. The tensile strength of NBP concrete appears to grow as the NBP ratio increases. When utilizing 5% and 10% NBP, the rise in the tensile strength is up to 11.29% and 22.51% respectively at 150 days. NBP works in two ways to improve the tensile strength of hardened cement concrete. The first mechanism involves the packing of NBP as a filler into interstitial spaces within the skeleton of a hardened microstructure of concrete, enhancing its density and strength. The pozzolanic effect is a second mechanism. The enhancement of bond strength and solid volume is achieved when aluminosilicate elements in NBP react with the lime elements of calcium oxide and hydroxide in cement [36].

Figure 5: Percentages of increasing and decreasing of Spalling Tensile Strength (%) comparing to control mix
5.5. Flexural strength

Table 13 and Figure 6 show the results of flexural strength with varied percentages of coarse brick aggregate and nano brick powder.

Figure 6 show the flexural strengths of concrete mixtures using different quantities of CBA aggregate. When 10% of the natural coarse aggregate was substituted with CBA, the flexural strength showed a slight increasing up to 2.37% at 28 days. The angular form and surface roughness of crushed brick strengthen the connection between the CBA aggregates and the cement paste, resulting in a little increase. The flexural strength of concrete specimens decreased significantly as the replacement amount of CBA was increased to 20% and 30% at all ages. This might be due to the large proportion of waste brick aggregate in these mixtures, which has lower strength and hardness than natural coarse aggregate [37,38].

The mixes with 5% and 10% NBP showed an improvement of up to 6.22% and 17.01%, respectively, at age 150 days. This is due to the pozzolanic influence of NBP particles, which reacts with calcium hydroxide created during the first hydration process and transforms it to C-S-H, one of the main binder products for concrete, is responsible for the increased strength of specimens including NBP. NBP also acts as a nucleus and is well bonded to the C-S-H gel.

| Mixes | BA10 | BA20 | BA30 | NB5 | NB10 | N10A10 |
|-------|------|------|------|-----|------|--------|
| RFC   |      |      |      |     |      |        |
| 7     | 32.28| 34.00| 28.80| 25.50| 34.38| 38.70  |
| 28    | 43.20| 45.64| 38.80| 33.40| 46.60| 54.60  |
| 90    | 46.20| 48.40| 42.30| 36.00| 51.10| 59.50  |
| 120   | 49.70| 49.77| 43.70| 37.40| 54.30| 63.40  |
| 150   | 52.00| 51.00| 44.00| 37.50| 58.80| 65.60  |
| RFC   |      |      |      |     |      |        |
| 7     | 2.90 | 2.97 | 2.95 | 2.93 | 3.22 | 3.42   |
| 28    | 3.35 | 3.44 | 3.17 | 3.06 | 3.48 | 3.84   |
| 90    | 3.64 | 3.69 | 3.40 | 3.18 | 3.79 | 4.20   |
| 120   | 3.77 | 3.80 | 3.50 | 3.24 | 4.05 | 4.51   |
| 150   | 3.89 | 3.91 | 3.60 | 3.32 | 4.33 | 4.77   |

Figure 6: Percentages of increasing and decreasing of Flexural Strength(%) comparing to control mix

| Test          | Ages (Days) | RFC | BA10 | BA20 | BA30 | NB5 | NB10 | N10A10 |
|---------------|-------------|-----|------|------|------|-----|------|--------|
| Compressive   | 7           | 32.28| 34.00| 28.80| 25.50| 34.38| 38.70| 34.20  |
| Strength      | 28          | 43.20| 45.64| 38.80| 33.40| 46.60| 54.60| 47.30  |
|               | 90          | 46.20| 48.40| 42.30| 36.00| 51.10| 59.50| 52.30  |
|               | 120         | 49.70| 49.77| 43.70| 37.40| 54.30| 63.40| 56.00  |
|               | 150         | 52.00| 51.00| 44.00| 37.50| 58.80| 65.60| 58.00  |
| Splitting     | 7           | 2.90 | 2.97 | 2.95 | 2.93 | 3.22 | 3.42 | 3.22   |
| Tensile       | 28          | 3.35 | 3.44 | 3.17 | 3.06 | 3.48 | 3.84 | 3.50   |
| Strength      | 90          | 3.64 | 3.69 | 3.40 | 3.18 | 3.79 | 4.20 | 3.81   |
|               | 120         | 3.77 | 3.80 | 3.50 | 3.24 | 4.05 | 4.51 | 4.04   |
|               | 150         | 3.89 | 3.91 | 3.60 | 3.32 | 4.33 | 4.77 | 4.23   |
| Flexural      | 7           | 3.81 | 3.85 | 3.60 | 3.38 | 3.93 | 4.17 | 3.95   |
| Strength      | 28          | 4.40 | 4.51 | 4.17 | 3.87 | 4.57 | 4.95 | 4.61   |
|               | 90          | 4.66 | 4.68 | 4.37 | 4.05 | 4.90 | 5.28 | 4.88   |
|               | 120         | 4.77 | 4.80 | 4.43 | 4.13 | 5.05 | 5.45 | 4.95   |
|               | 150         | 4.83 | 4.87 | 4.48 | 4.17 | 5.13 | 5.65 | 4.99   |
6. Conclusions
The use of waste brick as a volumetric partial replacement for crushed brick aggregate up to 10% and as an addition by weight of cement with nano-brick powder up to 10% to produce good properties in concrete. For concrete mixes containing NBP or CBA, the results showed a reduction in slump values which required more addition of SP in order to keep the acceptable range of the slump (75-100) mm at the same w/cm ratio (0.45). And the fresh and dry density showed a decrease with increasing replacement of crushed coarse aggregate with CBA. But they increased when we used 5% and 10% additions of NBP.
For compressive strength, the optimum content of coarse brick aggregate was 10% with a maximum development of 5.6% compared to specimens with 0% CBA aggregate at 28 days. And it decreased as the replacement level increased, up to 26.73% at 30% of CBA at age 150 days. While it increased for all additional levels of NBP. While the flexural strength of recycled concrete was found to be slightly increased at 10% CBA, it was only around 2.37% compared with the control mix at 28 days. And it was decreasing with an increasing percentage of coarse brick aggregate. While it increased when used with 5% and 10% of NBP. From a tensile strength point of view, the optimum replacement of CCA with RCA was found to be at 10%. For either replacing, tensile strength showed an increase at 7 days only, and it decreased for later ages, up to 14.72% for 30% of CBA at 150 days. The nano particles modified the mechanical properties of the CBA concrete when mixed with 10% nano brick and 10% coarse brick aggregate, up to 11.54, 8.56, and 3.3% for compressive, tensile, and flexural strength, respectively, at 150 days.

7. Reference
[1]. Animesh, K., Tiwari, J., & Soni, K. (2017). Partial replacement of fine aggregate and coarse aggregate by waste glass powder and coconut shell. Int. Res. J. Eng. Technol, 4(10), 1872-1876.
[2]. Sharifi, Y., Houshiar, M., & Aghebati, B. (2013). Recycled glass replacement as fine aggregate in self-compacting concrete. Frontiers of Structural and Civil Engineering, 7(4), 419-428.
[3]. Ephraim, M. E., & Rowland-Lato, E. O. (2015). Compressive Strength of Concrete Made with Quarry Rock Dust and Washed 10mm Washed Gravel as Aggregates. American Journal of Engineering, Technology and Society, 2(2), 26-34.
[4]. Tunc, E.T., 2018a. The effects of cement dosage on the mechanical properties of concrete produced with waste marble aggregate. 13th Int. Cong. Adv. Civ. Eng. 12e14 (ACE 2018).
[5]. Jiang, Y., Ling, T.C., Mo, K.H., Shi, C., 2019. A critical review of waste glass powder-Multiple roles of utilization in cement-based materials and construction products. J. Environ. Manag. 242, 440e449.
[6]. Ibrahim, A. M. (2013). The effect of nano metakaolin material on some properties of concrete. Diyala journal of engineering sciences, 6(1), 50-61
[7]. Justice, J. M. (2005). Evaluation of metakaolins for use as supplementary cementitious materials (Doctoral dissertation, Georgia Institute of Technology).
[8]. Böke, H.; Akkurt, S.; Ipek, B.; U’ gurlu, E. Characteristics of brick used as aggregate in historic brick-lime mortars and plasters. Cem. Concr. Res. 2006, 36, 1115–1122.
[9]. Puertas, F.; Barba, A.; Gazulla, M.F.; Gómez, M.P.; Palacios, M.; Martinez-ramirez, S. Ceramic wastes as raw materials in portland cement clinker fabrication: Characterization and alkaline activation. Mater. Constr. 2006, 56, 73–84. [CrossRef]
[10]. Vieira, T.; Alves, A.; de Brito, J.; Correia, J.R.; Silva, R.V. Durability-related performance of concrete containing fine recycled aggregates from crushed bricks and sanitary ware. Mater. Des. 2016, 90, 767–776. [CrossRef]
[11]. Aliabdo, A.A.; Abd-Elmoaty, A.-E.M.; Hassan, H.H. Utilization of crushed clay brick in concrete industry. Alexandria Eng. J. 2014, 53, 151–168. [CrossRef]
[12]. Belkowitz, J. S. (2009). An investigation of nano silica in the cement hydration process (Doctoral dissertation, University of Denver).
[13]. (ASTM E2456) standard terminology relating to nanotechnology. West Conshohocken PA,2006.(977-9)
[14]. Givi, A. N., Rashid, S. A., Aziz, F. N. A., & Salleh, M. A. M. (2010). Experimental investigation of the size effects of SiO2 nano-particles on the mechanical properties of binary blended concrete. Composites Part B: Engineering, 41(8), 673-677.

[15]. Mukharjee, B. B., & Barai, S. V. (2014). Influence of incorporation of nano-silica and recycled aggregates on compressive strength and microstructure of concrete. Construction and Building Materials, 71, 570-578.

[16]. Ge, Z.; Wang, Y.; Sun, R.; Wu, X.; Guan, Y. Influence of ground waste clay brick on properties of fresh and hardened concrete. Constr. Build. Mater. 2015, 98, 128–136.

[17]. Kulovaná, T.; Vejmelková, E.; Keppert, M.; Rovnaníková, P.; Keršner, Z.; Cerný, R. Mechanical, durability and hygrothermal properties of concrete produced using Portland cement-ceramic powder blends. Struct. Concr. 2016, 17, 105–115

[18]. Schackow, A.; Stringari, D.; Senff, L.; Correia, S.L.; Segadães, A.M. Influence of fired clay brick waste additions on the durability of mortars. Cem. Concr. Compos. 2015, 62, 82–89.

[19]. Q. Liu, X.N. Zhang, Experimental study on the mixture ratio and the compressive strength of concrete with Recycle crushed brick coarse Aggregate, Applied Mechanics and Materials, Trans Tech Publ, 2014, pp. 1362-1365.

[20]. T.U. Mohammed, A. Hasnat, M.A. Awal, S.Z. Bosunia, Recycling of brick aggregate as coarse aggregate, J. Mater. Civ. Eng. 27 (7) (2014) B4014005.

[21]. Iraqi Specification, No. 5, 2019, Portland Cement, Ministry of Planning, Central Organization for Standardization and Quality Control

[22]. Iraqi Specification, No.45/1984, “Aggregate from Natural Sources for Concrete and Construction”, Baghdad: The Central Organization for Standardization and Quality Control, 1984.

[23]. ASTM C 618-17a, “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”, American Society for Testing and Materials, 2017.

[24]. ASTM, C-1240-2003, “Standard Specification for Use of Silica Fume as a mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout”, vol. 04.01, pp. 1-2.4

[25]. Iraqi.Specification.No.1703/(1992),"used water in concert

[26]. ASTM C 494/C 494M-99a, “Standard Specification for Chemical Admixtures for Concrete”, American Society for Testing and Materials, 2001.

[27]. ACI 211.1. Reapproved 2009 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete. American Society for Testing and Materials.

[28]. ASTM C143/C143M-00, 2000, "Standard Test Method for Slump of Hydraulic - Cement Concrete".

[29]. ASTM C 138/C 138M-01a, “Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete”, American Society for Testing and Materials, pp.1-4, 2001.

[30]. BS 1881-114:1983 “ testing concrete - Part 114: Methods for determination of density of hardened concrete, British Standard,

[31]. BS 1881-116:1983, “Testing concrete- Part 116: Method for determination of compressive strength of concrete cubes” British Standard, 2003.

[32]. ASTM C496/C496M-17, “Standard Test Method for Splitting Tensile of Cylindrical Concrete Specimens”, American Society for Testing and Materials, 2017.

[33]. ASTM C293- 8, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading),

[34]. Gao, C., Huang, L., Yan, L., Jin, R., & Chen, H. (2020). Mechanical properties of recycled aggregate concrete modified by nano-particles. Construction and Building Materials, 241, 118030.

[35]. Hakamy, A., Shaikh, F. U. A., & Low, I. M. (2015). Characteristics of nanoclay and calcined nanoclay-cement nanocomposites. Composites Part B: Engineering, 78, 174-184.
[36]. Tawfik, T. A., Abd EL-Aziz, M. A., Abd El-Aleem, S., & Serag Faried, A. (2018). Influence of nanoparticles on mechanical and nondestructive properties of high-performance concrete. Journal of the Chinese Advanced Materials Society, 6(4), 409-433.

[37]. Khalil, W. I., Frayyeh, Q. J., & Ahmed, M. F. (2019, May). Evaluation of sustainable metakaolin-geopolymer concrete with crushed waste clay brick. In IOP Conference Series: Materials Science and Engineering (Vol. 518, No. 2, p. 022053). IOP Publishing.

[38]. Kesegić, I., Netinger, I., & Bjegović, D. (2008). Recycled clay brick as an aggregate for concrete: overview. Tehnički vjesnik, 15(3), 35-40.