Fabrication green concrete by Recycled wastepaper

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Abstract. The presented study provides the results related to examining using the wastepaper as additional materials with regard to the concrete mixes which will be utilized for construction purposes, thus it should be indicated that the resulting has suitable mechanical strength. Furthermore, the wastepaper fibers have been applied in 3 percentages which are 0.6%, 0.8% as well as 1% volume fraction, also curing ages 7, 14 as well as 28 days. With regard to such studies, normal concrete, density, spitting strength, compressive strength, flexure tensile strength as well as the water absorption paper fiber concrete have been determined. The results indicated that adding wastepaper will cause reduction in density by (0.24%), while increasing the compressive strength, the splitting strength, the flexural tensile strength as well as water absorption by (22.56%), (17.63%) and (4.819%) and (44.19%) respectively, at (28) days of curing age in the case of adding (0.8%) of wastepaper via volume. Paper fiber concrete is considered to be eco-friendly and inexpensive concrete.

Keywords: Waste papers; Compressive strength; Splitting strength; Flexural strength

1. Introduction

The concrete is made with materials waste which are eco-friendly so called as Green concrete. The addition of wastepaper could be utilized as light-weight aggregate in concrete for improving its the thermal insulation properties in addition to the toughness characteristics that are related to concrete materials [1]. They verified that with the addition of insignificant fraction (typically 0.5-2% by volume) regarding the short fiber to concrete mix throughout mixing. Results indicated that fiber bridge cracks in matrix could offer some resistance to the crack propagation as well as the crack opening prior to being pulled out or stressed to rupture. Furthermore, indicated improving the concrete’s tensile properties [2], also indicated the use of wastepaper as addition material with regard to the concrete mixes which is applied for the building projects. There are 4 concrete mixes consisting of wastepaper (0%, 0.5%, 0.7% in addition to 1%) by volume regarding concrete as addition material with regard to the concrete mixes. The results indicated that adding wastepaper is going to increase compressive strength in addition to the flexural strength related to concrete by (34.21%) and (42.4%) at curing age of (90) in the case when wastepaper of (1%) has been added by volume [3]. They have examined that using as concrete’s addition material will be significant to housing projects. There are 4 concrete mixes consisting of wastepaper (0%, 5%, 10%, 15% in addition to 20%) by cement’s weight as addition material regarding the concrete mixtures. They indicated that wastepaper’s addition decreased the concrete’s mechanical strength, as well as indicating that the paper’s content will be increasing the ratio of water to cement for mix will also be increased [4]. Actually, the approach related to the green concrete was considered to be lengthy to not just the waste materials, yet also to the nano-engineered materials which might be enhancing the mechanical properties of concrete, therefore [5], its life-cycle. Concrete has been majorly recognized for consisting of 4 ingredients: additives, aggregates, cement, as well as water. Carbon track regarding the production of cement in the world, such emissions are the result of: (a) fossil fuel’s burning
throughout the process of manufacturing, that is needed for heating raw materials to 1400 Celsius in rotating kiln [6,7] disposal regarding such paper wastes cause extreme costs regarding landfills in addition to manpower [8,9–15].

2. Experimental work

a. Cement

The ordinary Portland cement of type (1) produced in Iraq with commercial name (mass) that made by (Bazian Company/ Iraq) was utilized in this work. The chemical analysis in addition to the physical properties related to the cement used as can be seen in tables 1 and 2. The results of the test indicated that the cement in accordance with Iraqi Specification No. (5)/ 1984 [16].

Table 1. The chemical composition as well as the major compounds of OPC

| Oxide composition | Abbreviation | % by weight | Limit of IQS No.5/1984 |
|-------------------|--------------|-------------|------------------------|
| Lime              | CaO          | 64.6        | -                      |
| Silica            | SiO₂         | 20.63       | -                      |
| Alumina           | Al₂O₃        | 5.4         | -                      |
| Iron oxide        | Fe₂O₃        | 3.65        | -                      |
| Magnesia          | MgO          | 0.7         | ≤ 5%                   |
| Sulphate          | SO₃          | 2.4         | ≤ 2.8%                 |
| Loss of Ignition  | L.O.I.       | 2.55        | ≤ 4%                   |
| Lime saturation factor | L.S.F. | 1 | 0.66-1.02 |
| Insoluble residue | I.R.         | 0.9         | ≤ 1.5                  |

Main compound (Bouge eq.) | By weight of cement
Tricalcium silicate | C₃S | 54.02 | -
Diocalcium silicate | C₂S | 18.41 | -
Tricalcium aluminate | C₃A | 8.36 | -
Tetracalcium alumino ferrite | C₄AF | 11.36 | -

Table 2. Physical properties of OPC

| Physical properties | Result | Limit of IQS. No.5 |
|---------------------|--------|--------------------|
| Specific surface (m²/kg) | 330 | > 230 |
| Setting time (Vicat’s method) | | |
| - Initial setting (hrs:min) | 2:45 | ≥ 45 min |
| - Final setting (hrs:min) | 5:00 | ≤ 10 hrs |
| Compressive Strength of Mortar | | |
| - 3 Days | 30.02 | ≥ 15 |
| - 7 Days | 35.31 | ≥ 23 |
| Autoclave (Soundness) | 0.01% | ≤ 0.8 |

b. Fine aggregate

The natural sand regarding zone (2) has been applied as fine aggregate, also it has been obtained from (Al-Ukhaider) region. The tests have been conducted for determining sulfate content, fineness modulus, as well as grading complied to the requirement of Iraqi specification No. 45/1984 [6]. It has been tested for determining sieve analysis as can be seen in table 3 in addition to the chemical and physical properties have been provided in table 4.
Table 3. Fine aggregate’s gradation

| Sieve size (mm) | Percentage passing % | Limit of IQS No.45\1984 |
|-----------------|----------------------|--------------------------|
| 10              | 100                  | 100                      |
| 4.47            | 96                   | 90-100                   |
| 2.36            | 78                   | 75-90                    |
| 1.18            | 61                   | 55-90                    |
| 0.6             | 40                   | 35-55                    |
| 0.3             | 16                   | 8-30                     |
| 0.15            | 5                    | 0-10                     |

Table 4. Physical and chemical properties regarding fine aggregate

| Properties                  | Test Results | Limits of IQS No.45\1984 |
|-----------------------------|--------------|---------------------------|
| Specific gravity (SSD)      | 2.5          |                           |
| Fineness modulus            | 3.01         |                           |
| Sulphate content%           | 0.137%       | ≤ 0.5%                    |
| Absorption%                 | 1.6          |                           |
| Clays and Fine material%    | 2.6%         | ≤ 5%                      |

c. Coarse aggregate
Crushed gravels having maximum size of (19mm) has been applied in the presented study as coarse aggregate. It has been conducted at Al-Nabaai to the north of Baghdad. The gradation related to the utilized coarse aggregate in addition to its chemical and physical tests have been indicated in tables 5 and 6. The test results indicated that coarse aggregate has been achieved on the basis of Iraqi standard specification No.45/ 1984 [17].

Table 5. Physical grading related to coarse aggregate.

| Sieve size (mm) | Accumulated percentage passing % | Limits of IQS.No.45\1984 (%) |
|-----------------|----------------------------------|--------------------------------|
| 37.5            | 100                              | 100                            |
| 20              | 92                               | 90-100                         |
| 12.5            | 75                               | 40-80                          |
| 9.5             | 40                               | 30-60                          |
| 4.75            | 2                                | 0-10                           |

Table 6. Properties of coarse aggregate

| Properties                  | Tests Results | Limit of IQS No.45\1984 |
|-----------------------------|---------------|--------------------------|
| Specific gravity            | 2.6           | -                        |
| Sulphate content%           | 0.023%        | < 0.1%                   |
| Water absorption%           | 0.8%          | -                        |

d. Water
The water has been utilized in this study for all the concrete mixes as well as curing regarding specimens from water –supply network system (spigot water).
e. Waste paper
The properties of wastepaper were depending on paper, s microstructure. In this work was used of wastepaper (printing paper) as the main material. For the purpose of studying the possibility of applying wastepaper fiber as additive in the concrete mixes. Printing wastepaper utilized in the presented research has been obtained from offices, libraries, as well as schools. Wastepaper’s physical properties are indicated in table 7. The papers have been cut into small shreds of dimensions (8 x 2 x 0.1)mm through paper shredder. Such small dimensions have been preventing the paper from clumping in the case when the wastepaper has been mixed with the water, the paper will evenly distribute in the papercrete mix. The paper has been soaked in room temperature water for a period of twenty-four hours for the purpose of preventing water from absorbing mixing water in the case when adding concrete mixing. After that, paper fiber has been picked out of soaking water and dried for ten minutes to be in saturated surface dry manner. Chemical analysis by Energy Dispersive X-Ray spectroscopy (EDX X Flash 6110 –Model ) regarding printing wastepaper (fiber) indicated in table 8. Figure 1 shows preparing wastepaper’s fiber.

| Properties physical          | Results |
|------------------------------|---------|
| Specific gravity             | 0.98    |
| Absorption%                  | 90      |
| Density (gm/cm³)             | 800     |

**Table 7. Physical properties of wastepaper**

**Table 8. Chemical analysis (Oxide composition) by (EDX) of fiber wastepaper (printing paper)**

| Oxide composition | Percentage content % |
|-------------------|----------------------|
| CaO               | 87.4                 |
| Al₂O₃             | 5.15                 |
| SiO₂              | 5.50                 |
| MgO               | 1.26                 |

(a) (b) (c) (d)
f. Proportion of the mix

The mix proportion has been developed for getting about 25MPa compressive strength regarding the control concrete. Lastly, mix proportion through weight has been [1 :1.60 : 2.37] cement: fine aggregate :coarse aggregate, water cement ratio regarding 0.48 has been used. Different proportions related to waste paper have been examined through batching each one of the mixes with 0%, 0.6%,0.8% as well as 1% through volume as can be seen in table 9. The properties regarding the freshly mixed concrete have been determined, also the test specimens were increase of waste paper, also 3 cube specimens wear test regarding the concrete for the compressive strength, also 3 cylindrical samples have been test for splitting strength and 2 prisme with regard to the flexural strength at (7, 14, 28) days regarding the curing period. Overall 96 specimens have been made for experimentations in the presented study.

g. Testing

The compressive strength has been achieved in this study depending on (B.S.1881: Part 116) [7], whereas flexural tensile strength and the splitting tensile strength based on (ASTM C-78) [8] and (ASTM C-496) [9]. In which, water absorption, density according to (ASTM C 642) [10], and (B.S 1881:part 114:1989) [11] respectively.

3. Results and Discussion

a. Density

The density results for samples of conventional concrete and concrete mixes containing (paper fiber) wastepaper as addition by volume related to concrete tested at different ages 7, 14 and 28 days of (100x100x100) mm for paper fiber concrete, which contain (0%, 0.6%, 0.8% and 1%) of paper fiber by volume of concrete. The dry densities results of paper fiber concrete range between (2391-2473) kg/m³, (2410-2473) kg/m³ and (2432- 2512) kg/m³ for the different studies mixes at 7, 14 and 28 days respectively. As it can be seen from the fig (2), density increase from 2498 kg/m³ to 2512 kg/m³ on 0.6% addition of wastepaper at 28 days relative to than conventional mix, The increment in density due to modification of the microstructure of concrete and decreasing the capillary pores which leading to raise the density while it is decreased from 2498 kg/m³ to 2492 kg/m³ and it is decreased from 2498 kg/m³ to 2432 kg/m³ on 0.8% and 1% addition of wastepaper by volume of concrete at 28 days receptivity, the reduction in the air dry density due to lower density of paper fiber which caused to decrease the density of concrete mixes. This result shows agreement with [18-19]
Figure 2. Results of dry density test at different ratios of wastepaper fiber contents

b. Compressive strength

Such property results regarding the samples of the conventional concrete as well as the concrete mixes containing (paper fiber) wastepaper as addition by volume regarding concrete tested at different ages of 7, 14 and 28 days of (100x100x100) mm, that consist of (0%, 0.6%, 0.8% as well as the 1%) regarding paper fiber by volume of concrete. Test results increased the compressive strength related to the concrete took place following curing age of (28) days. Figure (7) indicates compressive strength results with regard to the concrete specimens consisting of various volume fractions related to the paper fiber at age (7, 14 in addition to 28) days. The test results indicated that increasing volume fraction related to the waste paper up to (1%) by volume concrete result in increasing the compressive strength up to (22.56%) in mix (P-0.8) at 28 days in comparison to control mix. With regard to the mix (P-0.6), that consists of wastepaper of (0.6%), compressive strength elevated by (12.70%) at (28) days of curing age in comparison to the control mix with wastepaper of (0%). With regard to mix (P-1), that consists of wastepaper (1%), compressive strength elevated by (12.13%) at (28) days of curing age in comparison to the control mix with wastepaper of (0%). Absorption as well as the void content regarding paper pulp have been typically high, therefore the paper might accommodate high water amount in concrete mix. With regard to such concrete type, hydration concrete, result in shortage regarding the water in cement paste. With regard to this stage. Water content in the paper might be promoting water supply internally to concrete with regard to the continuous hydration. Such hydration products filling pores or micro-crack as well as improving concrete properties.

Figure 3. Compressive strength results of paper fibers mixes

c. Splitting tensile strength

The splitting tensile strength results with regard to samples with dimensions (200x100) mm cured in water and tested at ages (7, 14, 28). It can be showed from figure (4), that the splitting strength of convention strength was enhanced by addition of 0.6%, 0.8% and 1% by volume of concrete of fibers wastepaper. Also, splitting strength elevated with the increase in the curing age from 7 to 28 day, and the maximum splitting strength was 17.63% for 0.8% by volume of concrete for fibers wastepaper at 28 days curing. The increment in splitting tensile strength because of fibers of wastepaper fill in the concrete voids with a significant bonding ability to the blend, hence, the voids are reduced, also there has been an increase in concrete’s splitting strength, resulting in enhancement in the strength. This result shows agreement with pervious work [20-21]
d. Flexural tensile strength

Such property results for samples with dimensions (400 x 100 x 100) mm cured in water and tested at ages (7, 14, 28) days. It might be showed from the figure (4-18), that flexural strength regarding convention strength was increment by addition of 0.6%, 0.8% by volume of concrete of fibers wastepaper. The recorded flexural tensile strength results range from (4.511-4.726) MPa, (4.27-4.915) MPa and (4.087-4.15) MPa for paper fiber in concrete at 7, 14 and 28 days. The raise in strength between ages is due to the increase hydration products with time which leads to decreasing porosity and voids. The addition of (0.6%) of paper fiber wastepaper caused increment in flexural strength of concrete reaching (1.828%, 3.414%, 0.789%) respectively at (7,14 and 28) days of curing as relative to the control blend. Also, the addition of (0.8%) of paper fiber waste by volume of concrete caused increment in flexural tensile strength reaching (6.54%, 7.516% and 4.819%) respectively at (7,14 and 28) days of curing as relative to the control blend. This increment is attributed to the fibers fill in concrete voids with a significant bonding ability to the blend, hence, the voids are decreased and flexural strength of concrete is raised. This results show agreement with pervious work [22]. While the addition of (1%) of paper fiber wastepaper by volume of concrete caused a considerable decrease in flexural tensile strength of concrete reaching (7.742%, 8.913% and 11.494%) days of curing as relative to the control blend. The reduction in flexural tensile strength due to the fact that raising the content of cellulose paper (low strength paper) yields a lot of voids in the specimen. From the test results it is concluded that (P-1) mix with the percentage of wastepaper addition showed decreasing in the flexural strength compared with other mixes. This reduction is attributed to the higher capillary porosity of cement matrix is caused by the porosity of the paper, as well as, the low strength paper which contributes in decreasing in bond between the aggregate and cement paste. This results shows agreement with pervious work [22-23]

Figure 4. Results of splitting tensile strength
Such test is of high importance with regard to the concrete’s durability, which depends upon the total amount of water absorption of concrete. Water absorption is a process that water gets into the pores and voids of concrete. The water absorption results for samples with dimensions (100 x100 x 100) mm cured in water and tested at ages (7, 14, 28) days. Figure (6) illustrate the average results regarding water absorption for all paper fibers concrete mixes. It contains 0%, 0.6%, 0.8% and 1% of paper fiber by volume of concrete. Results demonstrate that all paper fibers samples exhibit significant raise in water absorption with increasing curing ages. The results indicated that the concrete sample with (0.6%) of paper fibers exhibited decreased in absorption value by about (5.484%) at 28 days when compared with their corresponding normal concrete. The water absorption decreased when the density of the blend is increased. While the results indicated that the concrete specimens with (0.8% and 1%) of paper fibers exhibited increase in absorption values by about (44.19% and 80.591%) respectively at 28 days, when compared with their corresponding normal concrete. The water absorption increased with increasing waste paper fibers paper. High amounts regarding water absorption has been because of the existence regarding cellulose materials which is simply absorbing water as well as retaining it for long time. This result shows agreement with pervious work (R.Selvaraj and L.R.Singh at el [22-23]).
Figure 6. Water absorption Results of paper fiber concrete mixes

4. Conclusions
The dry density of paper fibers wastepaper concrete mixes was increased with age of curing. The waste paper fibers do not affect the density significantly at lower percent ratio of paper fibers addition less than 0.6% by volume. Then density of paper fibers concrete decreases with higher wastepaper fibers content (0.8% and 1%) by volume. The dry density result for (P-0.6) blend is close to result of conventional mix.the concrete mixtures containing wastepaper, compressive strength increased with increasing regarding wastepaper’s content up to (1%) by volume related to the concrete. The best fiber content has been (0.8%) by concrete volume. Such addition level result in massive elevation in the compressive strength. Such elevation has been (22.56%) at (28) days regarding age in comparison to control concrete. Generally, each group related to the concrete mixes consisting of wastepaper, splitting tensile strength elevated with the elevation in the content with regard to wastepaper up to (1%) by volume of concrete. The best fiber content is (0.8%) by concrete volume. This increase reached to (17.66%) at (28) days of age in comparison to the control concrete. The flexural tensile strength fibers concrete mixes with (0.6% and 0.8%) of paper fiber exhibit increase in flexural tensile strength values by about (0.789% and 4.819%) respectively at 28 days, as relative to ordinary blend. While the (1%) blend of wastepaper fibers reduction in flexural tensile strength by about (11.498%). The wastepaper fibers concrete mixes with (0.8% and 1%) of paper fiber exhibit increase in absorption values by about (44.19% and 80.591%) respectively at 28 days, as relative to ordinary blend. While the (0.6%) blend of wastepaper fibers reduction in water absorption by about (5.483%).

The reuse of wastes is important from different materials It help to save and sustain the natural resources.

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