Experimental Study for Ability to Use Plaster of Pairs Instead of Normal Concrete

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Abstract

This research investigated the possibility of using plaster of Paris instead of cement in some internal structural parts and non-exposed to moisture by casting (nine) samples divided in three group. First group was normal concrete, second was plaster of pairs concrete group and finally plaster of Paris with aggregate concrete. All of them have the same dimension (1000×150×200) mm and the same reinforcement ratio. Group one was cured with water while the rest were isolated in a place far away from the moisture. All sample designed to be failed in flexural. The process of testing was divided in two methods; for properties of material used as explain above and for samples tested under two-point load at several curing time (7,28 and 90) days. Each period consists of three samples one from each group. The result showed that the third group (plaster of Paris with aggregate concrete) approximately closer to normal concrete in applying a load by the ratio of (98%) in 7 days, (87%) in 28 days and (94%) in 90 days. While the second group (plaster of pairs concrete) was acceptable when compared with normal concrete because of missing aggregate.

Keywords normal concrete, plaster of pairs, aggregate, reinforcement ratio, curing, and moisture.

1. Introduction

Mesopotamia is the oldest in using plaster rocks and its product. Throughout the ages, with evidence of characterization of the successive civilizations, as research and studies conducted in archaeological sites are shown the best selection of materials and the most appropriate to the environment. Through the physical residues of archaeological and heritage materials since the start of rural settlements and the emergence of buildings with distinctive architectural features and distinct. Plaster is an important material as it is used as a whitish material in construction, joining the bricks, also used in (mortar, arches, domes, bonding materials, whiteness, decoration and light blocks). Plaster properties can be improved by adding some materials like tar, fiber plants, cement etc.

Plaster has been used since ancient times for many purposes, in recent decades, production has doubled globally by building factories, improving their productivity, and developing new and more sophisticated products [1]. The most important of these products can be presented as follows:

- Reinforced plaster panels as internal partitions (reducing dead loads of construction parts in multi-story buildings and consequent lower cost of foundations) and plaster panels for secondary ceilings [1].
- Fireproof plaster plates to prevent the rapid transition of heat to other parts of origin with same times safely and without damage, the plaster works naturally as a fire-resistant spraying system because the plaster contains about 21% of the water united within the crystalline structure, so delays heat transfer [2].
- Sound-proof plastered panels with plant materials with cellulose fibers such as wood saw reeds, glass fibers or mineral wool with porous or decorative facets and the resulting face with high sound absorption [3].
- Plaster blocks of different types (normal, lightweight, armed with agricultural waste, improved with Nora and additives to improve products using glue and others) [4].
- Concrete plaster (in different sizes) mixed with sand, sand and Nora, rubble (brick breaker), rubble (waste and debris of buildings) [5].
- Load and Non-load bearing walls (precast, casting site) [5].
- Exterior walls (tiling, plates, scattering) [5].

1.1 The research aim

The objective of this study is to investigate the flexural behavior (in terms of first crack load (Pcr), ultimate flexural strength (Pu), ultimate deflection (Au) and load-deflection behavior) of simply supported singly reinforced beam having dimensions of (1000×150×200) mm under symmetrical two points loads, and the other main objective of this study is the focus on the influence of concrete constituents on the materials properties of all type concrete are used in this study.

Most of the previous researchers were partially replace Portland cement in construction products while the purpose of this research is to study the possibility of using plaster instead of concrete in some internal structural parts and non-exposed to moisture.

2. Methodology

All sample design to be the Failure as a flexural failure and the design load is (80kN) according to (ACI-318-14) [6], as shown in (Fig. 1)
The Properties of Material that Used

Table 1: Chemical Composition of cement

| Oxide       | Component | Abbreviation | Content by weight (%) | Limit of Iraqi Specification No.1598 |
|-------------|-----------|--------------|-----------------------|--------------------------------------|
| Lime        | CaO       |              | 63.11                 |                                      |
| Silica      | SiO₂      |              | 20.37                 |                                      |
| Alumina     | Al₂O₃     |              | 3.15                  |                                      |
| Iron oxide  | Fe₂O₃     |              | 4.86                  |                                      |
| Magnesia    | MgO       |              | 1.68                  | 5.0 % (max)                          |
| Sulfate     | SO₃       |              | 5.17                  | 2.0 % (max)                          |
| Loss on ignition | L.O.I |          | 1.72                  | 4.0 % (max)                          |
| Soundness   | L.E.      |              | 0.69                  | 1.5 % (max)                          |
| Lime equiv. | L.E.      |              | 0.45                  | (0.6-1.0) %                          |

Table 2: Physical Properties of cement

| Properties               | Test Results | I.O.S 1598 |
|--------------------------|--------------|------------|
| Specific surface area (Blaine Method), cm²/g | 4026         | 2900       |
| Mortar Compressive strength (MPa) at | | |
| 3 days                  | 24           | 15         |
| 7 days                  | 32           | 22         |
| Setting Time(min)        |              | 3.10       | 0.45 |
| Soundness: water (%)     |              | 0.22       | 0.0 max |

Table 3: Chemical Composition of Plaster of Paris

| Component               | Test Results | The limit of blended No. 26 % |
|-------------------------|--------------|------------------------------|
| Fines water             | 0.13         |                              |
| Calcium oxide           | 2.71         | 9 (max)                      |
| LOI                     | 0.49         | 9 (max)                      |
| SiO₂                    | 0.45         |                              |
| Al₂O₃                   | 0.51         |                              |
| Fe₂O₃                   | Nil          |                              |
| SO₃                     | 56.96        | 4% (max)                     |
| CaO                     | 39.21        | 3.5 from 5.0               |
| MgO                     | 91.21        | 0.5% (max)                  |
| Total                   | 95.99        |                              |

The mix proportion for (Normal Concrete) is designed according to ACI recommended practice ACI 211.1-91[7]. The target compressive strength is (25MPa). Groups one consists of (N.C.) and material proportions which are 1:1.33:2.89 water/cement = 0.44 (this ratio has been taken after several experimental mixtures) by weight, as shown in the (Table 9) below

Table 4: Physical Properties of Plaster of Paris

| Properties               | Test Results | I.O.S 1598 |
|--------------------------|--------------|------------|
| Specific surface area (Blaine Method), cm²/g | 6%           | 1.15-4%    |
| Setting Time (hr)        | 20           | 20         |
| Compressive strength (MPa) | 115          | 45 (max)   |

Table 5: Grading of Fine Aggregate

| Sieve size (mm) | % Passing by weight | Limits of the I.O.S No.1598 |
|-----------------|---------------------|----------------------------|
| 10              | 100                 | 100                        |
| 4.75            | 90.25               | 90-100                     |
| 2.36            | 78.5                | 75-100                     |
| 1.18            | 61.1                | 55-90                      |
| 0.60            | 45.31               | 35-55                      |
| 0.30            | 14.64               | 6-30                       |
| 0.15            | 0.02                | 0-3                        |

Table 6: Physical Properties of Fine Aggregate

| Specific gravity | 2.33 | - |
| Sulfate content  | 1.50%| <=0.50% |
| Absorption       | 2.23 | - |

Table 7: Grading of Coarse Aggregate

| Sieve size (mm) | % Passing by weight | Limits of the I.O.S No.45/1994 |
|-----------------|---------------------|-------------------------------|
| 20              | 100                 | 100                           |
| 14              | 100                 | 90-100                        |
| 10              | 74.3                | 50-85                         |
| 5               | 3.5                 | 0.10                          |

Table 8: Physical Properties of Coarse Aggregate

| Specific gravity | 2.80 | - |
| Sulfate content  | 0.0%  | 0.7 % (max) |
| Absorption       | 0.72% | - |

Table 9: Mix Proportions for Normal Concrete Strength

| Groups | Cement (kg/m³) | Sand (kg/m³) | Gravel (kg/m³) | Water (Liters/m³) |
|--------|----------------|-------------|----------------|-------------------|
| One    | 415            | 552         | 1200           | 183               |

Then two group mixtures are used in Plaster of Paris concrete. The first mix is Plaster of Paris only with (water/powder = 0.45) by weight, this mix used for the first group. The second is Plaster of Paris with Coarse Aggregate (0.5) and (water/powder = 0.45) by weight, designed according to (ASTM C 317/C 317M – 00 and C 956 – 04) recommended the practice, used for group two, as shown in the (Table 10) below, all this mixture where be obtained from several laboratory mixture:

Table 10: Plaster of Paris Concrete Proportion Mixture

| Groups | Plaster of Paris (kg/0.09 m³) | Gravel (kg/0.09 m³) | Water (L/0.09 m³) |
|--------|-----------------------------|---------------------|--------------------|
| Two    | 180                         | 0                   | 85                 |
Nine structural specimens (reduced-scale) beam (sometimes called replica models) are prepared for experimental work purposes. These specimens are divided into three groups, each group consists of three beams of dimensions (1000 x 150 x 200) mm as shown in (Table.11) with all details:

**Table 11: Complete Details of Specimens**

| Type of Material | Group no. | Beam Name | Aggregate ratio% | curing times (Days) |
|------------------|-----------|-----------|-------------------|--------------------|
| Ordinary Concrete | Group One | BC1       | 2.89              | 7                  |
|                  |           | BC2       | 2.89              | 28                 |
|                  |           | BC3       | 2.89              | 90                 |
| Plaster of Paris | Group Two | BP1       | 0.0               | 7                  |
|                  |           | BP2       | 0.0               | 28                 |
|                  |           | BP3       | 0.0               | 90                 |
| Plaster of Paris concrete | Group  Three | BP1. A    | 0.5               | 7                  |
|                  |           | BP2. A    | 0.5               | 28                 |
|                  |           | BP3. A    | 0.5               | 90                 |

* These quantities are ratio from cement and Plaster of Paris.

The mold used in casting the samples of research made of ply-wood lubricated with special oil to resist moisture and joint with a screw to facilitate process removal of samples as shown in (Fig. 2).

![Fig. 2: The Mold used in research](image)

After extruding from the mold the groups, one was curing with water while the rest were isolated in a place far away from the moisture for interval time (7, 28 and 90) days as shown in (Fig. 3).

![Fig. 3: The samples in the stage of curing](image)

3. Result and Discussion

The properties of the material have been computed according to a standard that showed in the (Table.12), same mechanical properties of hardened concrete that examined its self-applied at Plaster of Pairs to be easy compare between them.

**Table 12: Standard Used in Test**

| Specimens   | Number of specimens | Test                  | Standards of test |
|-------------|---------------------|-----------------------|-------------------|
|            |                     | Cube Compression     | BS 5: 1881: part 116 |
|            |                     | Strength              |                   |
|            |                     | Cylindrical Compress  | ASTM C39/C39M     |
|            |                     | Strength              |                   |
|            |                     | Splitting Tensile     | ASTM C496         |
|            |                     | Strength              |                   |
|            |                     | Modulus of Rupture    | ASTM E8C7         |

The compressive strength result obtains in two standards (cube and cylinder) showed that cylinder samples give the best result because of uniformly distribution of stress cross-section area and amount of (F'c) are being certified in design. Plaster with two states (with and without aggregate) Give good results and asymptotic to the normal concrete, because of a manufacturing method that used to produce plaster of Paris depend on, the degree of smoothing, burning temperature with another controlled factor process. That was clearly shown in the (Table.13)

**Table 13: Material Test Result in (28 Days)**

| Material                  | Cube Strength (f_c) MPa | Cylinder Strength (f'_c) MPa | Splitting Tensile Strength f_s (MPa) | Modulus of Rupture f_r (MPa) |
|---------------------------|-------------------------|-----------------------------|------------------------------------|-------------------------------|
| Normal Concrete           | 30                      | 26.6                        | 2.6                                | 2.3                           |
| Plaster of Paris concrete | 23                      | 20.6                        | 1.6                                | 1.73                          |
| Plaster of Paris concrete with aggregate | 26           | 22                          | 2.1                                | 2.05                          |

* Both plasters of Paris and normal concrete have the same standard used in the test in (Table.12).

The samples start failure (first crack) at load (from 8 to 27.5) kN, the less amount is (BP1) while the greatest (BP3, BC1) in spite of the (BP3) was without aggregate. But samples with aggregate give the highest value and asymptotic to the normal concrete in ultimate load this can be seen in the (Table.14)

**Table 14: The Result of Two-Point Load Test**

| Group No. | Specimens | First Crack load (F.C.L) (kN) | Ultimate load (U.L) (kN) | F.C.L U.L (%) |
|-----------|-----------|-------------------------------|--------------------------|---------------|
| 1         | BC1       | 27.5                          | 52.5                     | 52.4          |
|           | BC2       | 22.5                          | 94.5                     | 23.8          |
|           | BC3       | 18.5                          | 102.5                    | 17.1          |
|           | BP1       | 8                             | 44                       | 18.18         |
Both plaster of Paris and normal concrete have the same dimension (1000×150×200) mm.

Entering the curing time effect in computed Load-Deflection curve can be observed that in (Fig. 4) as well as (Fig. 5) and (Fig. 6) all of them in increasing curing time the ultimate load increased with decreased in deflection but the (BP3.A, BC3) samples give the highest value of ultimate load:

Fig. 4: Load – Deflection Curve of Specimen (BC)

Fig. 5: Load – Deflection Curve of Specimen (BP)

Fig. 6: Load – Deflection Curve of Specimen (BP. A)
The hydraulic universal testing machine (MFL system) is used to test all beam specimens. The testing machine has three scale loads (0 to 600 kN, 0 to 1500 kN, 0 to 3000 kN). The machine is shown in “Fig. 8”. The high capacity, stiffness, and dimensions of the testing machine make it more adequate to test different types of specimens. All the models were tested in the construction laboratory of Al-Mustansiriyah University College of Engineering.

4. Conclusion

The result appeared that normal concrete was still the best but when used the alternatives suggested in this research (Plaster of Paris with aggregate) give construction sufficient result where the percentage of convergence in two-point load test equal to (98%) in seven days, (87%) in twenty-eight days and (94%) in ninety days , as well as The material test in compressive strength give percent ratio of (82.71%), in splitting test (80.76%) and in modulus of rupture (89%). While plaster of Pairs without aggregate give the lowest result in all test, that indicate adding aggregate make an improvement to the properties. with increasing curing time, the strength of samples to load increased with decreased in deflection.

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