Improvement of Local Gypsum Plaster Setting Time by the Combined Usage of (TGP) and (PVA) Additives.

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Abstract  An investigational study had been done in this research to improve the setting time of Local Gypsum Plaster by using two additives, namely: Tree Glue Powder (TGP) and Polyvinyl Acetate (PVA). For this objective four sample mixtures had been made, the first sample is the reference sample (mixture without additives), the second and the third mixtures are made by adding one of the two additives; Tree Glue Powder (TGP) and Polyvinyl Acetate (PVA) respectively, while the fourth mixture is prepared by the addition of both additives (TGP and PVA) together. Because of the importance of “the Compressive Strength” property in gypsum works, it was taken into consideration together with the “Setting Time” property in the assessment of results in this study. It was found that, when adding (TGP) alone with a content of (1.0 %), the setting time of the mixture was extremely increased by (333.8 %) as compared with that of the reference mixture, while the compressive strength is reduced by (18.8 %). And when the other additive (PVA) with a content of (4%) was added to the (TGP) mixture (altogether), an almost similar increase in the setting time has occurred (equals 306 %), with an attendant slight improvement in the compressive strength (equals 2.2 %).

1. Introductions.
In the latest years gypsum products had been remarkably utilized as in doors’ finishing. Homes, mainly in Europe and the USA, are either constructed from or lineup with gypsum based productions preferred by architectural engineers for their supreme characteristics, like attainable abundance of inexpensive raw materials, volumetric constancy, vocal and thermal insulation, fire resistance, quite low poisonousness and the comparatively low energy and heat needed in its production [1]. Gypsum is also utilized in numerous implementations further than the building domain: for example in molds manufacturing for ceramic productions [2], in medical [3], and dental equipment or implantations [4], furthermore, it is the main constitutive in cements to postpone its’ setting time [5]. Large number of gypsum plasters’ implementations are mainly based on its’ particular characteristics ([6], [7]). Numerous investigators tried to enhance plaster characteristics and expand its’ domain of implementations by adding other materials to it ([7], [8], [9]). One of these additives is "Silica gel" (a vastly porous form of silica), it’s a byproduct of sodium silicate manufacture with gorgeous heat and...
fire resistance, chemical constancy, together with a high specific surface area, and large water sensitiveness. Besides that, its’ irregular shape decreases unit weight in addition to thermal conductivity and enhances the large heat resistance of plaster compounds with insignificant loss of compressive strengths ([2],[10]). Yielding strengths, elastic modules, and internal bonds of plaster-boards had been noticed to be enlarged with the addition of Nano SiO2 [11]. Silica fume, in fact, is an excellent pozzolanic material with a large reaction rate, though it is scarcely utilized with gypsum [12]. The (water/gypsum) ratio has a considerable effect on the major physical properties of the hardened gypsum, like its volumetric unit weight, total open porosity, and other correlating properties such as its’ moisture, mechanical, thermal and acoustic insulation characteristics. Theoretic (water/gypsum) ratio substantial for the rehydration of calcium sulphate hemi-hydrate CaSO4½H2O into calcium sulphate de-hydrate CaSO42H2O is (0.187). Supplemental water, in a so-called over stoichiometric quantity, is substantial for the operation of hardening of the gypsum’s paste. The characteristics of the hardened gypsums produced from gypsum pastes by castings, pressings, or vibrating, depends upon their value of (water/gypsum) ratio [13].

2. Research Objective.
The objective of this study is to get the highest possible improvement in the setting time property of “local gypsum” plaster without decrease (if possible) in its compressive strength property. Two additives namely ; Tree Glue Powder (TGP) and Polyvinyl Acetate (PVA) were used individually and altogether for this objective.

3. Experimental Work.

3.1. Materials.

3.1.1. “Local Gypsum” Plaster.
Constituents which are outcome from the calcination of gypsum (CaSO4.2H2O) and possessing the chemical composition of hemi-hydrate (CaSO4.1/2H2O) are called "Gypsum Product". Even though they’re similar in composition and x-ray deviation peak, they’re varied in their physic-mechanical characteristics. They are consisting of 3-major kinds : Gypsum, Plaster of Paris, and Dental stones, each kind has many forms [14]. The second type (when locally manufactured) is of our concern in this study. Local Gypsum Plaster utilized as a major constituent material in this study is calcium sulfate hemihydrate gypsum (CaSO4.1/2H2O) , brought from local market in Baghdad / Iraq.

3.1.2. Tree Glue Powder (TGP).
The glue that is extracted from an arbor called “Arrack” (naturally grown in Persia) is utilized mainly by carpenters for woody work after it is subjected to grinding process, but here it was utilized (perhaps unprecedentedly) as an additive to “local gypsum” plaster mixtures.

3.1.3. Polyvinyl Acetate (PVA).
Vinyl acetate (CH2−CH−O2CCH3 = C4H6O2) is prepared from ethylene by reaction with oxygen and acetic acid over a palladium catalyst. Under the action of free radical initiators, vinyl acetate monomers (single unit molecules) can be linked into long, branched polymers (large, multiple unit molecules), in which the structure of the vinyl acetate repeating units is:

$$\text{CH}_2\text{CH}$$

$$\text{O}_2\text{CCH}_3$$

The monomer can be polymerized while dispersed in water to form a milky-white emulsion. This fluid can be processed directly into latex paints, in which the PVA forms a strong, flexible, adherent film. It can also be made into a common household adhesive known as white glue or Elmer’s glue.
Polynvinyl acetate (PVA), usually pointed out as woods gluten, off-white gluten, carpenters gluten, schools gluten, Elmer gluten in the USA, or P.V.A. gluten, is an aliphatic rubberiest synthetical polymer having the chemical composition : \((\text{C}_4\text{H}_6\text{O}_2)\), it is also utilized here (may be for the first time) in the current study as an additive to “local gypsum” mixtures.

3.1.4. Mixing water.
Distilled water is utilized for mixing-up all “local gypsum” mixtures in the current work.

3.2. Gypsum Mixtures.
Four mixtures of Local Gypsum Plaster had been used in this study according to the content (by weight) of TGP and PVA : 0 %, 1 % (for TGP) and 0%, 4% (for PVA). The (water / gypsum) ratio used for all these mixtures is fixed at (0.5). The constituent materials (Local Gypsum Plaster, TGP, PVA and water) of all mixtures were weighted quantities. The mixtures details are illustrated in Table (1).

Table 1. Details of mixtures.

| Mixture No. | TGP content by weight (%) | PVA content by weight (%) | (W/G) ratios | Ingredients Per (100g) of Local Gypsum Plaster |
|-------------|---------------------------|---------------------------|--------------|---------------------------------------------|
| Mix1        | 0.0                       | 0.0                       | 0.5          | (100g) Gypsum + (0.0g) TGP + (0.0g) PVA + (50g) water |
| Mix2        | 1.0                       | 0.0                       | 0.5          | (100g) Gypsum + (1.0g) TGP + (0.0g) PVA + (50g) water |
| Mix3        | 0.0                       | 4.0                       | 0.5          | (100g) Gypsum + (0.0g) TGP + (4.0g) PVA + (50g) water |
| Mix4        | 1.0                       | 4.0                       | 0.5          | (100g) Gypsum + (1.0g) TGP + (4.0g) PVA + (50g) water |

3.3. Procedure of Mixing
In the beginning (TGP) powder was dry mixed with the “local gypsum” plaster powder, afterwards the required magnitude of water was poured onto the mixture, and then re-mixed by hand for (approximately half minute), and poured into the mold. The mold has been vibrated for about 10 seconds. After about 30 minutes, the cubic \((50\times50\times50)\)mm. samples were taken off from the mold. Then, the samples were exposing to sun at approximately 38 °C heat. For mixtures with (PVA) additive, the selected quantity of (PVA) is mixed well with the required quantity of water, and then they are added to the “local gypsum” plaster.

3.4. Testing Program.

3.4.1. Setting Time.
The most common shortcoming of gypsum plaster mixtures, particularly in the process of preparing their pastes is that their setting times are relatively small (i.e. when compared with concrete or cement pastes), this shortcoming does not give enough time for the workers to do their work comfortably, this actuates us to study the influence of the assigned additives (TGP and PVA) individually and together on the setting time values of “local gypsum” plaster for the objective of extending them as much as possible. The device that is commonly used to measure setting time property is the so-called (Vicat apparatus), which consist of a graduated plate attached to a (300 gm.) weighted rod ended with a (5cm. length) & (1mm. diameter) needle and a cylindrical pan having \((7 \times 4)\)cm. dimension. The device is illustrated in Fig.(1-a), and the related test was executed according to {ASTM : C472-99}[15].

3.4.2. Compressive Strength.
Test is carried out for the (50 mm.) cubic specimens used in this research at age of seven days to determine their compressive strength. The testing machine used in this study is illustrated at fig.(1-b) and the related test was executed according to {ASTM : C472-99}[15].

4. Results & Discussions.

4.1. Setting Time:

4.1.1. Influence of (TGP) on Setting Time of Local Gypsum Plaster with Various (PVA) Contents.

Table and Figure (2) presents the effective of (TGP) on the setting time of the “local gypsum” plaster with two (PVA) contents (0% and 4%). They reveal that with the addition of (TGP) alone the setting time is considerably increased by (333.8 %) [as compared with the reference mixture]. This behavior might be attributed to the emulsifying nature of (TGP + water) solution coating some of gypsum particles with a thin film of it and hence isolating them from their contribution in the hydration process, and this outcome is lined with that stated by Hatim et al.[16]. The percentage of this increasing was enlarged to (424.8 %) with presence of (PVA) (together with TGP) [when the mixture of PVA alone is considered as an assumed reference mixture].

Table 2. Influence of (TGP) on Setting Time of Local Gypsum Plaster with Various (PVA) Contents.

| Mixture No. | (PVA) content by weight (%) | (TGP) content by weight (%) | (W/G) ratios | Setting Times (min) | Percentages of increasing (%) |
|-------------|------------------------------|-----------------------------|--------------|---------------------|-------------------------------|
| Mix1        | 0.0                          | 0.0                         | 0.5          | 12.50               | ----                          |
| Mix2        | 0.0                          | 1.0                         | 0.5          | 54.22               | 333.8                         |
| Mix3        | 4.0                          | 0.0                         | 0.5          | 9.67                | ----                          |
| Mix4        | 4.0                          | 1.0                         | 0.5          | 50.75               | 424.8                         |
4.1.2. Influence of (PVA) on Setting Time of Local Gypsum Plaster with Various (TGP) Contents.

Table and Figure (3) presents the effective of (PVA) on setting time of the Local Gypsum Plaster with two (TGP) contents (0% and 1.0%). They illustrate that when adding (PVA) alone the setting times are decreased by (22.6 %) [as compared with the reference mixture], this behavior may be attributed to the adhesive nature of (PVA + water) solution which helps to expedite hardening process. The percentage of this decrease is reduced to (6.4 %) with the presence of (TGP) (together with PVA) [when the mixture of TGP alone is considered as an assumed reference mixture].

**Table 3.** Effect of (PVA) on Setting Time of Local Gypsum Plaster with Various (TGP) Contents.

| Mixture No. | (TGP) content by weight (%) | (PVA) content by weight (%) | (W/G) ratios | Setting Times (min) | Percentages of decreasing (%) |
|-------------|-----------------------------|-----------------------------|--------------|---------------------|-----------------------------|
| Mix1        | 0.0                         | 0.0                         | 0.5          | 12.5                | ----                        |
| Mix3        | 0.0                         | 4.0                         | 0.5          | 9.67                | 22.6                        |
| Mix2        | 1.0                         | 0.0                         | 0.5          | 54.22               | ----                        |
| Mix4        | 1.0                         | 4.0                         | 0.5          | 50.75               | 6.4                         |
Figure 3. Effect of (PVA) on Setting Time of Local Gypsum Plaster with Various (TGP) Contents.

4.2. Compressive Strength:

4.2.1. Influence of (TGP) on Compressive Strength of Local Gypsum Plaster with Various (PVA) Contents.
Table and Figure (4) presents the influence of (TGP) on the compressive strength of the Local Gypsum Plaster with two (PVA) contents (0% and 4%). They reveal that with the addition of (TGP) alone the compressive strengths is decreased by (18.8 %) [as compared with the references mixture]. This behavior might be attributed to the emulsifying nature of (TGP + water) solution coating some of gypsum particles with a thin film of it and hence isolating them from their contribution in the hydration process, and this outcome is lined with that stated by Hatim et.al.[16]. The percentage of this decrease in reduced to (13.4 %) with the presence of (PVA) (together with TGP). The reduction in the percentage of decrease may be attributed to the adhesive nature of the (PVA + water) solution which plays a positive role in minimizing the bad effect of TGP in reducing the compressive strengths of “local gypsum” plaster mixtures.

Table 4. Influence of (TGP) on Compressive Strength of Local Gypsum Plaster with Various (PVA) Contents.

| Mixture No. | (PVA) content by weight (%) | (TGP) content by weight (%) | (W/G) ratios | Compressive Strengths (MPa) | Percentages of decreasing (%) |
|-------------|-----------------------------|-----------------------------|--------------|----------------------------|------------------------------|
| Mix1        | 0.0                         | 0.0                         | 0.5          | 15.78                      | ----                         |
| Mix2        | 0.0                         | 1.0                         | 0.5          | 12.82                      | 18.8                         |
| Mix3        | 4.0                         | 0.0                         | 0.5          | 18.62                      | ----                         |
| Mix4        | 4.0                         | 1.0                         | 0.5          | 16.12                      | 13.4                         |
4.2.2. Influence of (PVA) on Compressive Strength of Local Gypsum Plaster with Various (TGP) Contents.

Table and Figure (5) displays the influence of (PVA) on the Compressive strength of the Local Gypsum Plaster with two (TGP) contents (0% and 1.0%). They illustrate that with the addition of (PVA) alone the compressive strength is increased by (18 %) [as compared with the reference mixture], this behavior might be explained as follows: The micro-structure of the hardened gypsum plaster created by hydration of hemi-hydrated gypsum is usually porous, and the PVA polymer has the ability to fill in the voids inside the gypsum mass, and hence decreases the porosity, which lead to increase the compressive strength of the gypsum mass, this outcome is lined with that stated by Naji et.al.[17]. This percentage of increase is magnified to (25.7 %) with the presence of (TGP) (together with PVA) [when the mixture of TGP alone is considered as an assumed reference mixture].

**Table 5. Effect of (PVA) on Compressive Strength of Local Gypsum Plaster with Various (TGP) Contents.**

| Mixture No. | (TGP) content by weight (%) | (PVA) content by weight (%) | (W/G) ratios | Compressive Strength (MPa) | Percentages of increasing (%) |
|-------------|-----------------------------|-----------------------------|--------------|-----------------------------|------------------------------|
| Mix1        | 0.0                         | 0.0                         | 0.5          | 15.78                       | ----                         |
| Mix3        | 0.0                         | 4.0                         | 0.5          | 18.62                       | 18.0                         |
| Mix2        | 1.0                         | 0.0                         | 0.5          | 12.82                       | ----                         |
| Mix4        | 1.0                         | 4.0                         | 0.5          | 16.12                       | 25.7                         |
Figure 5. Effect of (PVA) on Compressive Strength of Local Gypsum Plaster with Various (TGP) Contents.

4.3. Privilege of the Combined Addition of (TGP) and (PVA):

4.3.1. On Setting Time.
Bar chart (1) displays the combined influence of (TGP) and (PVA) on the setting time of “local gypsum” plaster. It illustrates that when taking the case of (Mix1 : zero TGP and zero PVA) as a references case, then when we add TGP alone (Mix2), the setting time is highly enlarged by (333.8 %), whilst when we use PVA alone (Mix3), the setting time is decreased by (22.6 %), but when we use both TGP and PVA (Mix4), the setting time is considerably increased by (306 %), which means that the presence of (PVA) has a small effect in reducing the high amount of setting time induced by the individual use of (TGP) (i.e. alone). It is worthy to mention that the effect of using both additives (TGP) & (PVA) on setting time of “local gypsum” plaster is similar to the behavior of local gypsum (Juss) stated by Ref.[18].

Bar Chart 1. Combined Effect of (TGP) and (PVA) on Setting Time.
4.3.2. On Compressive Strength.
Bar chart (2) reveals the combined influence of (TGP) and (PVA) on the compressive strength of “local gypsum” plaster. It shows that when we take the case of (Mix1 : zero TGP and zero PVA) as a reference case, then when we add only TGP (Mix2), the compressive strength is decreased by (18.8 %), whereas when we use PVA alone (Mix3), the compressive strength is enlarged by (18.1 %), but when we use both TGP and PVA (Mix4), the compressive strength is enlarged by only (2.2 %), which means that a slight improvement in the compressive strength has resulted when using both (TGP) and (PVA).

5. Conclusions.
- When (TGP) is added alone to gypsum plaster, the setting time is considerably increased by 333.8 %, while the compressive strength is decreased by 18.8 % as compared with the reference mixture samples.
- When (PVA) is added alone to gypsum plaster, the setting time is decreased by 22.6 %, while the compressive strength is increased by 18.1 % as compared with the reference mixture samples.
- When using both TGP and PVA (Mix 4), the setting time is increased by (+306 %) as compared with the reference case (Mix 1 : zero TGP and zero PVA). When this percentage of decrease is compared with the (+333.8 %) [when T.G`: P. is added alone] and (22.6 %) [when PVA is added alone], it can be concluded that the presence of (PVA) (together with TGP) has a small effect in reducing the high amount of setting time induced by the individual use of (TGP) (i.e. alone).
- When using both TGP and PVA (Mix 4), the Compressive strength is enlarged by (+2.2 %) as compared with the reference case (Mix 1 : zero TGP and zero PVA). When this percentage of increase is compared with the(-18.8 %) [when TGP is added alone] and (+18.1 %) [when PVA is added alone], one can conclude that a small improvement in the compressive strength has resulted when using both (TGP) and (PVA).
- The final conclusion is that the combined usage of the two additives (TGP) and (PVA) have led to obtain a Local Gypsum Plaster mixture with an extended setting time and without any reduction in the compressive strength, on the contrary, its compressive strength have slightly increased.

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