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Improvement of Gypsum Properties Using S.F.Additive

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Abstract: ***In this research an attempt has been made to study the effect of adding S.F. additive (by weight) to improve gypsum properties (compressive strength, bulk density, and porosity). The research plan consists of using nine mixes of gypsum which had been divided in to three groups according to S.F. content (by weight) 0.0%, 0.6% and 1.2%. Each group was divided in to three sub-groups according to (water/gypsum) ratios (0.3, 0.35 and 0.4). It was found that, the addition of S.F. to the gypsum mixes, increases the compressive strength and bulk density, but deceases the porosity. It was also found that, the compressive strength and bulk density were decreased with the increase of (water/gypsum) ratios, whereas, the porosity increases.***

Keywords: gypsum=local juss, silica fume, compressive strength, bulk density, porosity

1. Introduction

In the recent years gypsum products have been exceedingly used as in-door finishing. Houses, especially in the U.S.A. and Europe, are either built from or lined with gypsum-based products favored by architects because of their superior properties, such as obtainable availability of in-expensive raw materials, volumetric stability, acoustic and thermal insulation, fire resistance, quite low toxicity and the comparatively low energy and temperatures needed in its manufacture [1].Gypsum is also used in several applications beyond the construction field : e.g. in making molds for ceramic products [2], in medical [3], and dental accessories or implants [4], furthermore, it is the major constituent in Portland cement in order to delay its setting time [5]. The numerous applications of gypsum plaster are primarily based on its specified properties [6], [7].

Many researchers have attempted to develop plaster characteristics and extend its range of applications through the addition of other materials [7], [8], [9]. One of these additives is "Silica gel" (a highly porous form of silica), it is a by-product of the sodium silicate industry with fabulous heat and fire resistance, chemical-stability, along with a large specific surface area, and high water sensitivity. In addition, its erratic nature reduces density as well as thermal conductivity and promotes the high temperature durability of plaster composites with trivial loss of compressive strength [2], [10].The yield strength, elastic modulus, and interior bond of plasterboards have been observed to increase whennano-SiO_2 is added[11]. Silica fume, in turn, is a very good pozzolanic material with a high reaction rate, although it is rarely used with gypsum [12]. Many authors have reported that the addition of ultra-fine sand (U.F.S.) or micro-silica improves the mechanical properties of Portland cement pastes [13, 14].

The water-gypsum ratio has an influence on the basic physical characteristics of the hardened gypsum, such as its volumetric density, total open porosity, and other related characteristics such as its moisture, mechanical, thermal and acoustic insulation properties. The theoretical water-gypsum ratio necessary for the hydration of calcium sulphate hemi-hydrate $CaSO_4 \cdot ½H_2O$ into calcium sulphate dehydrate $CaSO_4 \cdot 2H_2O$ is (0.187). Additional water, in a so-called over-stoicheiometric quantity, is necessary for the process of hardening of the gypsum paste. The properties of the hardened gypsum made from a gypsum paste by casting, pressing, or vibrating, depend on the value of the water-gypsum ratio [15].

2. Experimental Work

2.1 Materials

2.1.1 Gypsum

2.1.1.1 Gypsum products

Materials that are resulted from the calcinations of gypsum ($CaSO_4.2H_2O$) and having the chemical composition of hemihydrate ($CaSO_4.1/2H_2O$) are called "Gypsum Products". Although they are identical in composition and x-ray diffraction peaks, they are different in their physio-mechanical properties. They consist of three main types: local juss, plaster, and dental stones, each type has several varieties[16]. The first type has our concern in this research.

2.1.1.2 Localjuss

The word "juss" is derived from the Assyrian word "jasso". Local juss in iraq is a material produced from calcined gypsum by the "Koor method" Gypsum rock pieces are placed on openings in the koor dome and the heat source is at the base of the dome. Heating continues for 24 hours. The final product the juss is a mechanical mixture of anhydrite, bassanite and unburnt gypsum.

Gypsum (Local juss) used as a main matrix in this project was calcium sulfate hemihydrate gypsum ($CaSO_4.½H_2O$), which was obtained from local market in Baghdad.

2.1.2. Silica Fume (S.F.)

Silica fume is highly reactive pozzolanic substance and is a byproduct from the production of silicon or ferro- silicon metal. It is a very fine powder and composed from the flue gases from electric arc furnaces. The silica fume that is used in this research is a product from Sica Manufacturer in Egypt and has the product name "Sika Fume-HR"

2.1.3. Mixing water

Ordinary potable water was used for mixing to all gypsum mixes in this study.

2.2 Gypsum Mixes

Nine mixes of gypsum have been studied in this research, these mixes were divided in to three groups according to S.F. content (by weight) 0.0%, 0.6%, and 1.2%. Each group was divided into three sub-groups according to (water/gypsum) ratio (0.3, 0.35 and 0.4) as shown in Fig. (1) and table (1).

Table 1: Description of mixes

Mix No.	Designation of mixes	S.F content % by weight	(W/G) ratio	Ingredients Per (100g) Gypsum	
Mix 1	Mix 0S-3W	0.0	0.30	(100g) Gypsum +(0.0g) S.F +(30g) water	GROUP (1)
Mix 2	Mix 0S-3.5W	0.0	0.35	(100g) Gypsum +(0.0g) S.F +(35g) water	
Mix 3	Mix 0S-4W	0.0	0.40	(100g) Gypsum +(0.0g) S.F +(40g) water	
Mix 4	Mix 6S-3W	0.6	0.30	(100g) Gypsum +(0.6g) S.F +(30g) water	GROUP (2)
Mix 5	Mix 6S-3.5W	0.6	0.35	(100g) Gypsum +(0.6g) S.F +(35g) water	
Mix 6	Mix 6S-4W	0.6	0.40	(100g) Gypsum +(0.6g) S.F +(40g) water	
Mix 7	Mix 12S-3W	1.2	0.30	(100g) Gypsum +(1.2g) S.F +(30g) water	GROUP (3)
Mix 8	Mix 12S-3.5W	1.2	0.35	(100g) Gypsum +(1.2g) S.F +(35g) water	
Mix 9	Mix 12S-4W	1.2	0.40	(100g) Gypsum +(1.2g) S.F +(40g) water	

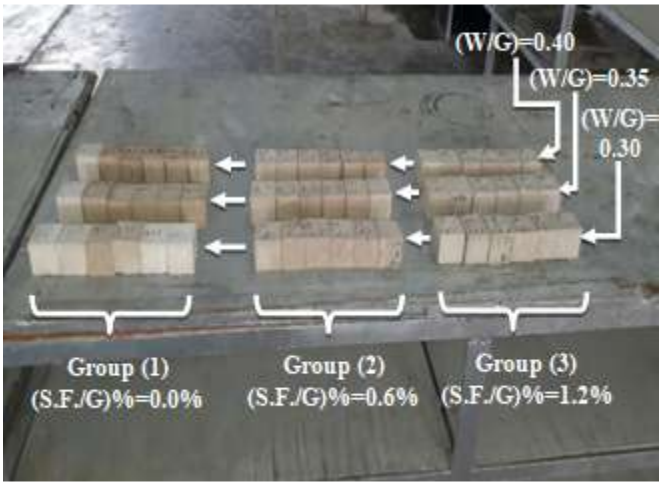

Figure 1: Groups of Tested Specimens

2.3 Mixing Procedure

All mixes were made by weighted quantities (gypsum, S.F. and water). In the beginning S. F. was added to the gypsum and be dry- mixed, then the specified quantity of the water was added to the mix, and re-mix handly for (approximately 30 seconds), then poured in to the mold. The mold has been vibrated benefiting from the vibration of a(small generator) for about 10 second. After 30 minutes, the cubic (5×5×5cm) specimens were taken off from the mold. Then, the specimens were exposed to the direct sun light for about two days at approximately 38 C° heat.

2.4 Testing Program

In this research, the 50 mm cubic specimens were tested at age of about one month or over to evaluate: the compressive strength [tests according to ASTM C473][17], porosity [using the liquid kerosene (or air) method], and the bulk density [where the volume were calculated by using the displaced mercury method] for all gypsum mixes.

3. Results & Discussion

3.1. Compressive strength

3.1.1 Effect of S.F content on compressive strength of gypsum with variable (W/G) ratio

Fig (2) and table (2) show the results of the compressive strength of the gypsum specimens with respect to S.F. content. These results reveal clearly that the compressive strength increases with the increasing of S.F. content for all (water/gypsum) ratios (0.3, 0.35, and 0.4), the reason for this increase might be related to the chemical effect of S.F. on the (water –gypsum) reaction which strengthens the interior bound between gypsum crystals. The effect of adding S.F. by weight (from 0.6% to 1.2%) to the mixes, is clearly obvious for (water/gypsum) ratios (0.3 and 0.35) rather than (0.4) ratio.

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Table 2: Effect of S.F. content on gypsum compressive strength with variable (W/G) ratios

Mix No.	S.F. content % by weight	Compressive strength MPa	Percentage of increase	(W/G) ratio
Mix 1	0.0	7.41	-------	0.3
Mix 4	0.6	8.15	9.9	
Mix 7	1.2	15.07	103.3	
Mix 2	0.0	4.13	-------.	0.35
Mix 5	0.6	5.60	35.5	
Mix8	1.2	10.10	144.5	
Mix 3	0.0	3.20	-------	0.4
Mix 6	0.6	4.93	54.0	
Mix 9	1.2	7.72	141.2	

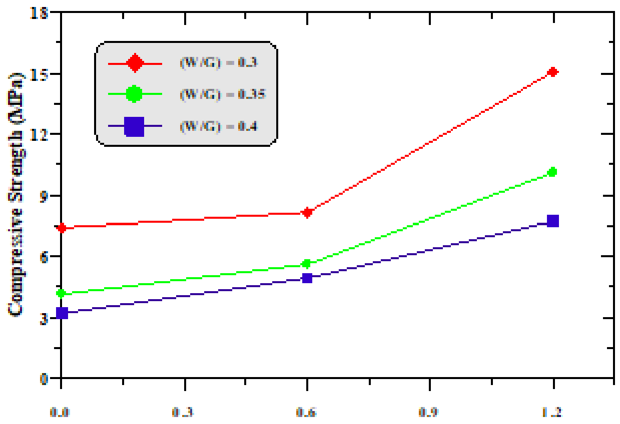

Figure 2: Effect of S.F. content on gypsum compressive strength with variable (W/G) ratios.

3.1.2 Effect of (W/G) ratio on compressive strength of gypsum with variable S.F. content

Fig (3) and table (3) show the effect of (W/G) ratio on the compressive strength of gypsum with variable S.F. content. These results illustrate that the compressive strength of the specimens decreases with increasing (W/G) ratios for all S.F. contents (by weight)0.0%, 0.6%, and1.2%.The reason of this result may be attributed to the fact that when (W/G) increases, the excessive water will stimulate the gliding of particles and then decrease the cohesion between them which lead to the decrease in compressive strength [15], another interpretation behind this result is that when the water increase, the amount of water excessive to the reaction water will produce voids after its evaporation and hence weakens the gypsum internal structure and as a result leads to a decrease in the material strength [18], [19].

Table 2 illustrated that the percentage of increases of compressive strength when decreasing (W/G) ratio, (in almost) diminished with adding S.F. The reason of this phenomenon may be attributed to the chemical effect of adding S.F., that increase the interior bond between gypsum crystals and hence lowering the effect of (W/G) ratio.

Table 3: Effect of (W/G) ratio on compressive strength of gypsum with variable S.F content

Mix No.	(W/G) ratio	Compressive strength MPa	Percentage of increase	S.F. content % by weight
Mix 1	0.3	7.41	131.3	0.0
Mix 2	0.35	4.13	28.9	
Mix 3	0.4	3.20	-------	
Mix 4	0.3	8.15	65.3	0.6
Mix 5	0.35	5.60	13.5	
Mix 6	0.4	4.93	-------	
Mix 7	0.3	15.07	94.3	1.2
Mix 8	0.35	10.10	30.8	
Mix 9	0.4	7.72	-------	

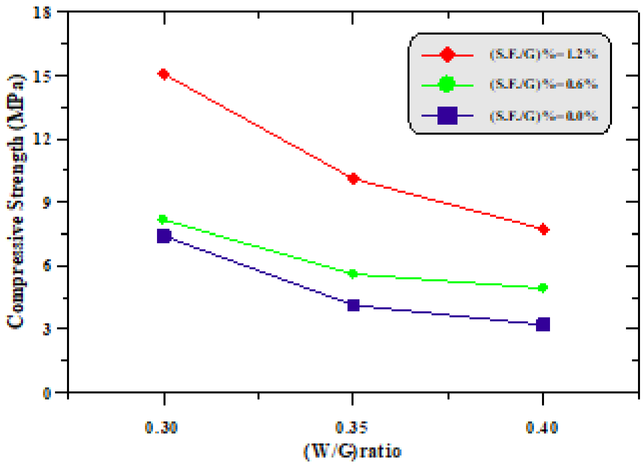

Figure 3: Effect of (W/G) ratio on compressive strength of gypsum with variable S.F content

3.2 Bulk density

3.2.1 Effect of S.F. content on bulk density of gypsum with variable (W/G) ratio

Fig (4) and table (4) displays the result of the bulk density of the gypsum specimens. These results reveal that the bulk density increases slightly with the increasing of S.F. content for all (water/gypsum) ratios (0.3, 0.35, and 0.4). The interpretation of this increase may be because the S.F. particles tend to fill the interstitial spaces between the gypsum grains causing the increase in the weight without increasing the volume, and as a result increasing the bulk density, in addition to the chemical effect of S.F. on eliminating the voids in the mix.

Table 4: Effect of S.F. content on bulk density of gypsum with variable (W/G) ratios

Mix No.	S.F. content % by weight	bulk density Kg/m3	Percentage of increase	(W/G) ratio
Mix 1	0	1463.4	------	0.3
Mix 4	0.6	1490.8	1.87	
Mix 7	1.2	1539	5.16	
Mix 2	0	1399.5	------	0.35
Mix 5	0.6	1409.6	0.72	
Mix8	1.2	1421.2	1.55	
Mix 3	0	1342.3	------	0.4
Mix 6	0.6	1379.9	2.8	
Mix 9	1.2	1388.8	3.46	

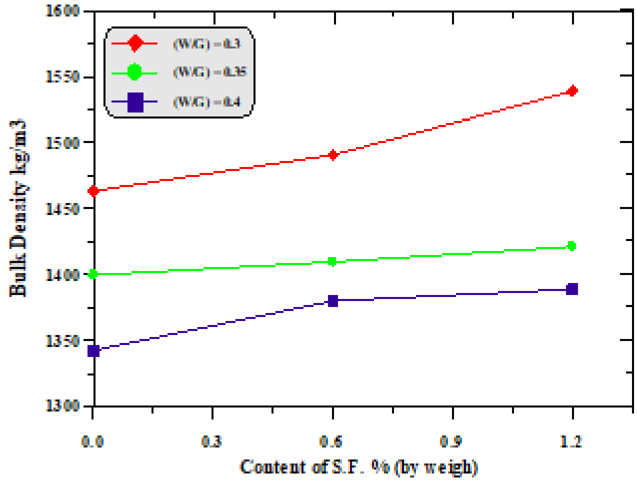

Figure 4: Effect of S.F. content on bulk density of gypsum with variable (W/G) ratios

3.2.2 Effect of (W/G) ratio bulk density of gypsum with variable S.F. content

Fig (5) and table (5) illustrates that the bulk density of the specimen's decreases with increasing (W/G) ratio for all S.F. contents (0.0%, 0.6%, and 1.2%). The reason of this decreasing maybe because of the generation of air bubbles trapped during the mixing process and the evaporation of the excessive water which is needed for workability purpose.

Table 5: Effect of (W/G) ratio on bulk density of gypsum with variable S.F. content

Mix No.	(W/G) ratio	bulk density Kg/m^3	Percentage of increase	S.F. content % by weight
Mix 1	0.3	1463.4	9.02	0.0
Mix 2	0.35	1399.5	4.26	
Mix 3	0.4	1342.3	-------	
Mix 4	0.3	1490.8	10.9	0.6
Mix 5	0.35	1409.6	2.15	
Mix 6	0.4	1379.9	-------	
Mix 7	0.3	1539.0	10.81	1.2
Mix 8	0.35	1421.2	2.33	
Mix 9	0.4	1388.8	-------	

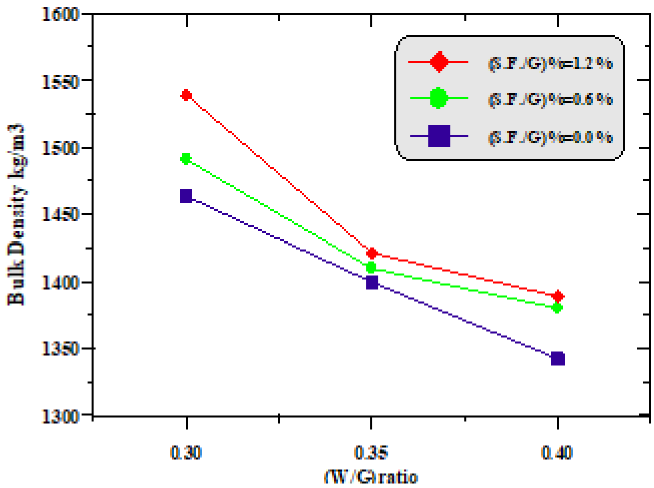

Figure 5: Effect of (W/G) ratio on bulk density of gypsum with variable S.F. content

3.3 Porosity

3. 3.1 Effect of S.F content on porosity of gypsum with variable (W/G) ratio

Fig (6) and table (6) display the result of the porosity of the gypsum specimens. These results reveal clearly that the porosity decreases with the increasing of S.F. content for all (water/gypsum) ratios (0.3, 0.35 and 0.4). The reason of this decreasing may be because the particles of S.F. tend to fill the interstitial spaces between the gypsum grains causing a decrease in the voids inside the gypsum mass which lead to a decrease in porosity. In addition to the chemical effect of S.F. (on the gypsum) in reducing these voids

Table 6: Effect of (W/G) ratio on porosity of gypsum with variable S.F. content

Mix No.	S.F. content % by weight	Porosity %	Percentage of decrease	(W/G) ratio
Mix 1	0.0	36.49	------	0.3
Mix 4	0.6	30.78	15.64	
Mix 7	1.2	28.17	22.80	
Mix 2	0.0	44.19	------	0.35
Mix 5	0.6	38.95	11.85	
Mix8	1.2	31.82	27.99	
Mix 3	0.0	46.43	------	0.4
Mix 6	0.6	43.48	6.34	
Mix 9	1.2	35.88	22.72	

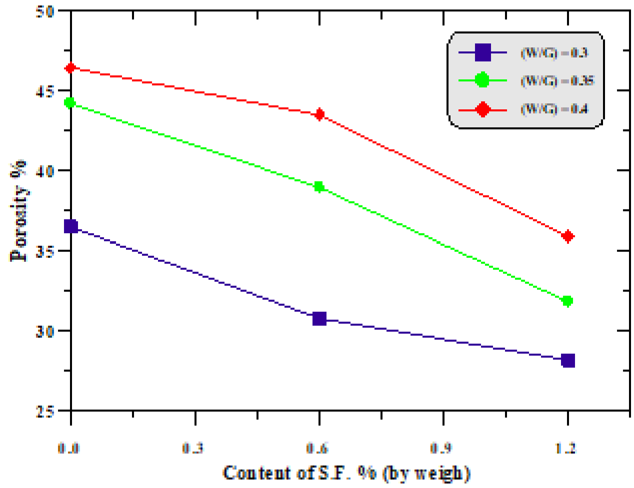

Figure 6: Effect of S.F content on porosity of gypsum with variable (W/G) ratio

3.3.2. Effect of (W/G) ratio on porosity of gypsum with variable S.F. content

Fig (7) and table (7) illustrates that the porosity of the specimens increases with increasing (W/G) ratio, for all S.F. contents (0.0%, 0.6%, and1.2%). The reason of this behavior (as mentioned before) may be because of the generation of air bubbles trapped during the mixing process and the evaporation of the excessive water needed for workability. Evaporation of the excessive water definitely increases the porosity of the hardened mass.

Table7: Effect of S.F content on porosity of gypsum with variable (W/G) ratio

Mix No.	(W/G) ratio	Porosity %	Percentage of decrease	S.F. content % by weight
Mix 1	0.3	36.49	21.40	0.0
Mix 2	0.35	44.19	4.82	
Mix 3	0.4	46.43	-------	
Mix 4	0.3	30.78	29.20	0.6
Mix 5	0.35	38.95	10.41	
Mix 6	0.4	43.48	-------	
Mix 7	0.3	28.17	21.48	1.2
Mix 8	0.35	31.82	11.31	
Mix 9	0.4	35.88	-------	

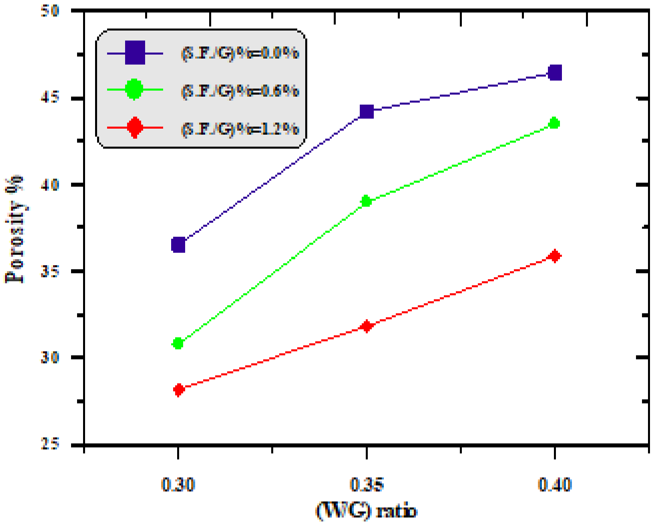

Figure 7: Effect of (W/G) ratio on porosity of gypsum with variable S.F. content

4. Conclusions

1) Addition of S.F. to the gypsum improves the compressive strength of gypsum. This improvement includes all (water/gypsum) ratios 0.3, 0.35, and 0.4. The percentage of increase in compressive strength when decreasing (W/G) ratio, is descended with the increasing amount of the S.F. added.
2) The bulk density of gypsum mass was slightly increased when adding S.F.to the gypsum mix.
3) The porosity of the gypsum mass decreased when S.F. was added to the gypsum mix.
4) When (water/gypsum) ratio was increasing, the compressive strength and the bulk density of the gypsum mass was decreased, whereas, the porosity was increased. This phenomenon includes all S.F. contents.

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