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# Potential Enrichment of Physical Properties of Gypsum Adding Palm Tree Ash and Saw Dust

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***Abstract***: Natural architecture uses locally produced materials to assure the strength of the construction elements. Palm tree is widely planted in the Gulf Countries and its annual abounded residues constitutes a greater environmental burden of being neglected and rarely used or recycled in efficient ways. The paper discusses the potential changes in the physical properties of pure gypsum cubes when utilizing additives such as the ash and saw dust of palm tree residues. The additives were added in various proportions by weight. Four groups of different laboratory tests were conducted on four different groups of cubic samples made of pure gypsum powder, admixture of gypsum and palm tree ash, and admixture of gypsum and palm tree saw dust. Results showed that both sawdust and ash of palm tree have significantly enhanced the physical properties of gypsum cubes tested in this paper, weight, porosity, and compressive strength..

***Keywords***: Building Materials; Gypsum; Palm Tree Ash and Saw Dust; Physical Properties, Compressive Strength

## 1. INTRODUCTION

Gypsum is an important building material that has many commonly known uses, such as gypsum boards and paints. Gypsum is at the forefront of basic materials used in building and construction [1]. It has many important characteristics such as: fire resistance, sound absorption, heat insulation, considerable bending strength, light weight, low cost, long life, fast solidification and ease of composition [2]. Current necessities for gypsum compounds for execution or mortaring comprise organized setting time, workability, sag resistance, compressive and flexural strength, ideal bond to bricks and concrete, waterproofing, and better thermal and acoustic. These advances were accomplished by the diligence of some chemical admixtures and mineral additives among them are superplasticizers, water-soluble polymers and the admixtures responsible for retarding and air-entraining [3]. In late years, considerable interests have been demonstrated in the investigation of date palm waste products as reinforcing and insulating materials to raise the mechanical properties building materials. Consequently, many literatures have been published on gypsum and the effects of some additives on its associated properties. This paper was conducted to investigate the properties of gypsum cubic blocks by adding the sawdust and ash separately to gypsum powder.

Sharma et al. [4] presented an effort to develop the low durability of clay blocks by reinforcing it with the rural natural waste materials of Grewia Optiva and Pinus Roxburghii. The results showed and increase by 72% to 68% in the durability of the blocks reinforced with fibers of Grewia Optiva and Pinus Roxburghii.

Sharma et al. [5] investigated improving the compressive strength of adobe using natural fibers of Grewia Optivia and Pinus Roxburghii. The reinforcement with these fibers resulted in an increase in the compressive strength by about 94–200% and 73–137% for Grewia Optivia and Pinus Roxburghii respectively.

Sharma et al. [6] investigated enhancing soil sustainability and stabilizing it with natural fibers of Pinus roxburghii and Grewia optiva. Results revealed an increase in the compressive strength by 131–145% when adding fiber P. roxburghii and 225–235% when adding fiber G. optiva for the cubical and cylindrical specimens respectively.

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Zak et al. [7] presented an experiment to enhance the compressive strength of earth bricks using different admixtures of earth, cement, gypsum, hemp and flax fibers. The results indicated that the impacts of adding fibers hemp and flax is very limited on the compressive strength. Cement and gypsum reduced the binding force of the clay and highly decreased strength.

Li et al. [8] stated that the addition of cotton stalk to gypsum had a substantial impact on its mechanical properties. Cotton stalk fiber was treated with emulsion to increase its combination with gypsum. The results illustrated that, although the composite of gypsum had lower strength, its insulation and fire resistance properties had improved.

On the other hand, Wu [9] studied the shear performance of gypsum panels when being longitudinally reinforced with glass fiber. The attained results showed that persistence of the longitudinal reinforcement had no significant issue on the shear strength, whereas it caused a small impression on their early stiffness, stiffness degradation, ductility ratio, and energy dissipation capacity.

Turgut and Algin [10] mixed limestone powder and wood sawdust. The properties of the obtained material such as weight, water absorption, compressive strength, flexural strength and ultrasonic velocity satisfied the appropriate international standards. Therefore, the product had potentials for uses for walls, ceiling panels, sound panels, wooden board substitute, and a cheap alternate to concrete blocks.

Liangyuan and Zongli [11] debated the features inducing the performance of Gypsum-based composite material such as water/cement ratio, and retarder quantities. It was concluded that the strength and coefficient of softness increased compared to Gypsum. Portland cement quickened the thickening and improved the strength and softness coefficient of composite, but over dosage caused the fall of these coefficients.

Jia-yan et al. [12] studied the connection between Wood-Gypsum ratio and water Gypsum ratio and explored the effects of temperature on hydration process and the Gypsum morphology. It was concluded that both Water-Gypsum ratio and Wood-Gypsum ratio are crucial to improve the properties of the boards in 40°C and to shorten the hydration time and strengthen the boards.

Okunade [13] examined the impacts of adding sawdust and wood ash admixtures to clay mix to produce bricks. The results showed that the key influence of the sawdust admixture was reducing the dry density of the brick. Furthermore, the wood ash admixture attained denser products with higher compressive strength.

Brencis et al. [14] produced an energy saving material made of foam Gypsum and fibrous hemp in which sound absorption coefficient increased. It was also found that short fibers' reinforcement increased the density of foam gypsum, while long fibers decreased it.

Zhou et al. [15] studied the properties of Gypsum-based composites produced by mixing the powder of Gypsum with latex and Polyvinyl Acetate (PVA). Release time, density and impact strength were investigated. It was proved that PVA contributed to delaying of time release and increased impact strength. On the other side, sawdust reduced the density.

Sari [16] compared between two mixtures of polyethylene glycol with gypsum and clay in regard to low temperature-thermal energy storage. It was proved that compatibility between components in regard to capillary and surface tension enabled the composite for passive thermal energy storage applications in buildings.

Dai and Fan [17] developed a complex from gypsum and sawdust with a water-based epoxy spray. It was proved that sawdust water increased the flexural and compressive strength of gypsum by 10% and 7% respectively. Furthermore, analysis with optical microscopy confirmed that decrease of water uptake enlarged the Gypsum covering ratio from 42% to 68%.

Dai and Fan [18] studied the mechanical properties of a Bio-composite of wood sawdust and Gypsum. It was concluded that the saw dust ratio of 20% gained better flexural and compressive strengths compared with the 30% ratio.

Algarny et al. [19] surveyed the feasibility of adding palm tree sawdust to Gypsum powder to produce blocks for indoor usage. It was resolved that the shrinkage value, weight, and porosity value were significantly reduced by increasing the ratio of sawdust to Gypsum powder, whereas compressive strength was increased at the same time.

## 2. MATERIALS AND METHODS

The materials used are pure gypsum powder palm tree saw dust, and the ashes resulting from the burnt saw dust of the local palm tree fronds in the Eastern Province of the Kingdom of Saudi Arabia. Different mixing ratios of ash or saw dust to gypsum were added to produce gypsum cubes of 5 x 5 x 5 cm, Table 1. Three different laboratory tests were conducted at the same time for every two groups of the samples: weight, porosity, and compression strength.

**Table 1. Mixing ratio of Gypsum, water, and ash or sawdust**

| *Gypsum (gm)* | *Ash / Sawdust* | | *Water (gm)* |
|---|---|---|---|
| | % | (gm) | |
| 3000 | 0 | 0 | 1950 (65% of Gypsum weight) |
| | 1 | 30 | |
| | 2 | 60 | |
| | 3 | 90 | |
| | 6 | 180 | |

Source: the authors

Materials described were mixed together in the dry state. Then, water was added and mixed until the mixture became homogeneous before conducting the tests. Mixing time was not to exceed one minute, so as not to get water evaporates. Each test is equipped with a number of 25 specimens, at a rate of 5 specimens for each mixing ratio. The result recorded in the test was the average value of the 5 specimens of each mixing ratio. The total number of the tested specimens were 150 specimens. Unlike a number of other specimens that were excluded for defects during the casting or the processing of the test raising the number of specimens actually were consumed to more than 200 specimens.

## 3. RESULTS AND DISCUSSION

### *3.1 Weight Test*

The specimens were casted in their molds and left for 24 hours. Then, they were taken out and weighed by a digital scale. The arithmetic average was calculated for each mixing ratio using the recorded weights of 5 different specimens. The results were as described in Fig. 1.

$$P, \% = [(W - D)/V] \times 100$$

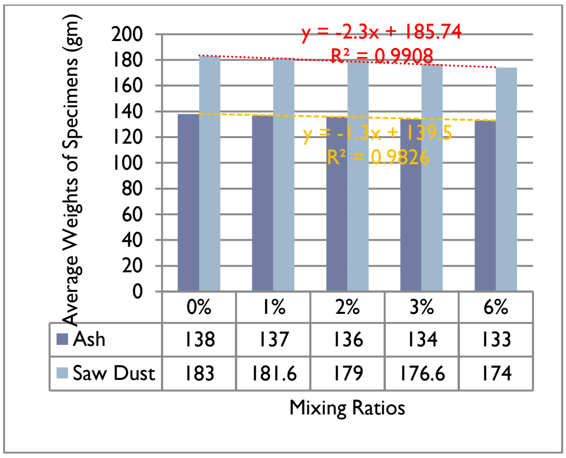


**Fig. 1. Relationship between weights of the specimens and mixing ratios (the authors)**

Analysis of the results in Fig. 1 gives a clear indication that adding whether ash or sawdust reduced the specimens' weights. Similar results has been reported by the researchers Algarny et al. [19], Li et al. [8], and Arikan and Sobolev [3].

Addition of saw dust reduced the weight of the specimen more effectively than adding ash, as shown in the values of $R^2$ for the trendlines of both results. It can be justified as the saw dust has less density and less weight for a specific volume compared to the ash. Taking into account the constant volume of the cubic specimen tested, adding more saw dust reduces more weight of the specimen than adding more ash. Results indicates that the maximum weight reductions were 3.62% and 4.9% of the control specimen for ash and saw dust respectively at 6% mixing ratio. So, saw dust-gypsum admixtures would have more benefits for the construction industry and reduce the internal loads and stresses on the structural and construction elements of the buildings, Fig. 2.

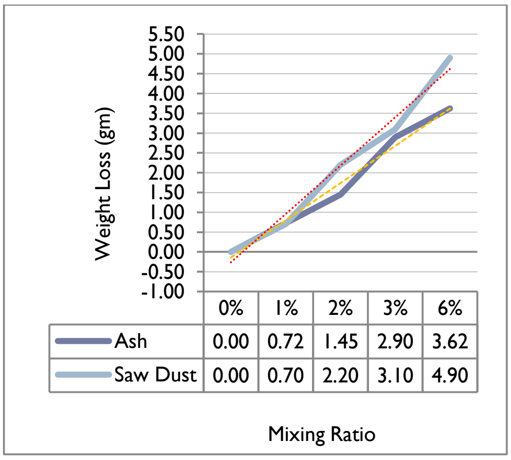


**Fig. 2. Weight loss of the specimens and mixing ratios (the authors)**

*3.2 Porosity Test*

In order to conduct the porosity test, the specimens were undergone the following steps:

1. The dry weights of the specimens were measured by a digital scale
2. The specimens were immersed in water for 24 hours
3. The wet weights of the specimens were measured by a digital scale
4. The following formula was applied to calculate the value of porosity in the specimen [20]:

*P: Porosity* *W: Saturated weight*
*D: Dry weight* *V: Specimen Dry Volume*

Fig. 3 shows that the addition of ash and sawdust significantly reduced the porosity value of the specimens. Lower porosity was recorded in higher mixing ratios. The result is consistent with the work reported by Algarny et al. [19], and Okunade [13]. The porosity values were reduced by 4.80 % and 3.77 % in the 6% admixtures of gypsum-ash and gypsum-sawdust respectively compared to the control specimens. Meaning that the sawdust has a limited impact on decreasing the porosity of gypsum cubes compared to the ash, this might be because sawdust has a lower density and bigger particle size compared to ash. Therefore, for a specific weight of ash or saw dust added to the gypsum powder, sawdust has relatively higher volume than ash leading to keeping more gaps between the particles of the gypsum powder compared to the case of adding ash which has a compacted higher density compacted form that introduces smaller quantities of gaps among the gypsum particles. So, gypsum-ash cubes are more convenient to applications that need less porosity compared to sawdust-gypsum cubes that suits the need for more porous materials.

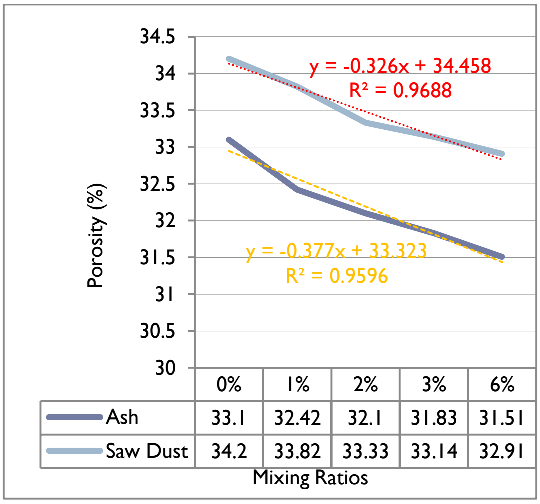


**Fig. 3. Porosity of the specimens and mixing ratios (the authors)**

*3.3 Compressive Strength Test*

For each admixture, five cubic specimens from each mixing ratio were prepared for a total of 50 specimens required for the test. The specimens were compressed in the compression strength instrument and the results were as shown in Fig. 4. The results show that both the sawdust and ash have significantly increased the compression strength of the specimens and improved their failure resistance, which is consistent with the work reported by Algarny et al.

[19], Arikan and Sobolev [3], and Okunade [13]. The resistance to fracture has increased by 125.83% and 62.9% for the specimens of 6% mixing ratio of sawdust and ash content respectively compared to the control specimen which is of pure gypsum. This result is tremendously important and can divert the use of gypsum in new building and construction applications due to its increased resistance to fracture in compression. Adding sawdust to the gypsum cubes will raise its compressive strength to almost double the value it will get if adding ash instead. The fibers content in the sawdust might be responsible for providing stronger bonds among the gypsum particles compared the case of adding ash which has already lost its fiber during the burning process.

The justification of the previous results can be explained as palm contains Wax, Phenol compounds and Pectin [21], which have chemical properties to enhance the physical properties of gypsum powder. Wax solidifies at normal temperature and melts in heat [22]. When adding water, the wax melts from the emitted heat and spreads within the gypsum particles, then the wax hardens increasing the cohesion of the admixture blocking the pores of gypsum, and reducing the porosity value of the cubes, while increasing its strength.

On the other hand, Pectin material gives the rigidity to the plant [21], and when added to gypsum it increases its hardness and compression strength.

In addition, Phenol is soluble in water [23], and it interacts with gypsum powder to produce salty water and stimulate the interaction between the granulated particles of gypsum and sawdust and ash of palm granules reducing porosity as well.

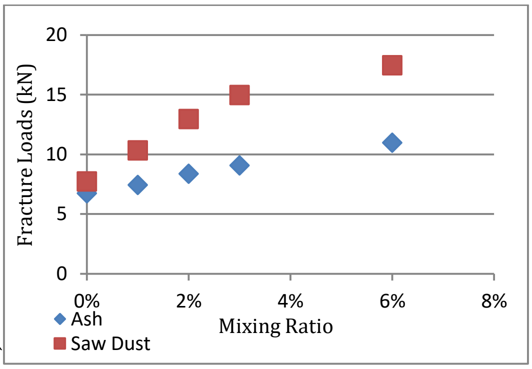


**Fig. 4. Fracture loads of the specimens and mixing ratios (the authors)**

## 6. CONCLUSION

Both sawdust and ash of palm tree have significantly enhanced the physical properties of gypsum cubes tested in this paper. Both induced weight loss but sawdust achieved more reduction. The weight of gypsum specimen is inversely proportional to the amount of sawdust or ash content; as lower weights were recorded with higher content of the additives in the specimen. In line with the previous result, porosity ratio in the specimen of gypsum cubes is inversely proportional to the amount of ash or sawdust. Both additives reduced the porosity of gypsum cubes, but ash has a broader reduction. On contrary, Compressive strength of the samples of gypsum cubes is directly proportional to the amount of ash or sawdust, where higher values of compressive strength were recorded in higher ratios of any of them in the specimen. The compressive strength the cubes gain when adding sawdust is almost double of that gained when adding the ash. The overall findings are encouraging to promote the use of leftover palm tree residues to enhance the physical properties of some building and finishing materials which leads to adding an economic value and securing more environmental protection against soil and air pollution.

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