



Analysis of chemical and physical properties of water resistant gypsum in cement concrete

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Abstract

This paper gives an outline of the process of hydration, dehydration and setting of gypsum of the various admixtures on gypsum. This paper is also concerned with the effect of different types of fibres on gypsum products. Moreover, this paper tries to glean out the previous experimental and analytical studies on gypsum that will serve as a tool for future research works. Efforts have been made to summarize all the information available on the topics related to gypsum and suggestions for future work are also presented.

Keywords: analysis, chemical and physical properties, water, gypsum

1. Introduction

Concrete is a major component of most of our infrastructural facilities today in the 21st century because of its versatility in use. Concrete is used more than any other man-made material in the world.

Concrete is used in making pavements, small bungalows, high-rise buildings, classroom blocks, office buildings, dams, bridges, warehouses, motorways/ roads, bridges, parking structures, fences and poles. In nutshell, concrete is applied in parts of foundations to buildings and used to make floor slabs, columns, beams, lintels, roof, staircases, walls, arches, etc. Concrete is an artificial stone-like material used for various constructional purposes and manufactured by mixing cement and various aggregates, such as sand, pebbles, gravel, stone, shale, etc with water and sometimes admixture and allowing the mixture to harden by hydration. Better still, concrete could be a composite material, which is made up of filler and a binder (Falade, 2009; Gupta and Gupta, 2004 and Nawy, *et al.*, 2008) [1-3].

Gypsum is the set retarder for Ordinary portland cement (OPC). Without gypsum, ground clinker exhibits flash setting in a few minutes, due to the rapid hydration of calcium aluminates to form calcium aluminate hydrate (CAH). The hydration of C₃A releases profuse exothermic heat making the matrix stiff, minimising the chances for remixing. The CAH, thus formed, does not contribute for strength of the matrix and, moreover, hampers the hydration of calcium silicate. The sequence of reactions, in the absence of gypsum, totally vetoes the commercial use of cement. The following chemical reaction, in the absence of gypsum, is explanatory in this regard.

Many in the cement and concrete industry know the role of gypsum as set retarder or set regulator. But the complementary role of gypsum, as accelerator to render high early strengths, is generally unnoticed. This knowledge gap lead to a misunderstanding that the addition of more gypsum means additional retardation in setting, which is not true. The

formation of ettringite at threshold levels accelerates the hardening process and thus hastens strength gain at early ages. Gypsum is considered to be one of the oldest construction material whose usage dates back to several thousand years ago. The growing negative environmental impacts of cement industry and high cost associated with the manufacture and transport of Portland cements have made gypsum an effective alternative to the hazardous cementitious products. The abundant availability and ubiquitous nature of gypsum both as a natural mineral and as a by-product from several chemical industries have made the gypsum products gain momentum during the last decades. Though gypsum has proved to be the best and cost effective construction material due to its excellent physical property, it has a number of limitations such as high permeable to water, porous nature, low compressive strength, low flexural and tensile strength. The gypsum products compared to conventional products thus making it suitable for indoor applications. Investigations have been done by various researchers to improve the performance of gypsum to extend its usage to the exterior by the usage of appropriate additives to modify the hydrophilic nature of gypsum thus making it a durable material to exhibit longer service.

2. Methodology

Initially the volume of gypsum plaster contracts during the casting process. When the setting is rapid the contraction is negligible, whereas the linear contraction occurs in the retarded hemihydrates. When the setting commences that is when only a part of gypsum is hydrated the contraction stops and expansion sets in. The force associated with the growth of gypsum crystals attributes the expansion allowing for the sufficient ordering of the gypsum crystals. The crystals are free to grow until the mass attains rigidity. After the gypsum has attained rigidity then they restrain the motion of the free ends preventing expansion.

An admixture is usually defined as a material other than the

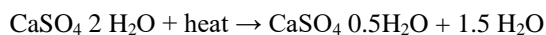
conventional components used in concrete that can be used as an ingredient either during batching or mixing to modify the property of freshly mixed, setting or hardened property of the cementitious mixture. The attainment of the required standards of performance of the gypsum based composite materials is possible only when the dosages admixtures are precise and exact. The various commonly used admixtures in gypsum composite are water soluble polymer which increases consistency, adhesion and water retention, retarders that controls setting time, air entrainers which mechanically stabilizes the air voids to give a smooth finishing appearance and super plasticizer to control the workability even at a low water-gypsum ratio.

An effect to modify the physical properties of Gypsum plaster by the addition of clay minerals was performed by Mural *et al.*, in which the high chemical reactivity of the raw materials was obtained by the thermal activation of clay. The properties of clay also improved the water resistance of Gypsum binder and also decreased the migration of water into the micro pores of the hardened material.

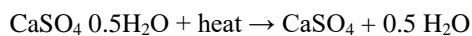
3. Results and Discussion

Gypsum also known as Calcium sulphate dehydrate is structurally combined with two water molecules contains about 20.9% of water by weight. This water can be easily removed by elevating the temperatures of gypsum. Gypsum loses its water content by two steps of endothermic decomposition:

The initial dehydration is the process in which the conversion of dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to hemihydrate ($\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$) takes place.



At a temperature of about 80°C the dehydration starts at a slower pace which becomes rapid at around 120°C . The entire dehydration process is completed approximately at 160°C . The formation of a soluble anhydrate is at either 300°C or at 650°C which is commonly called dead burned gypsum. The conversion of hemihydrate to anhydrous gypsum is the second dehydration reaction which is chemically represented as



The cardinal waste material produced from the hydrofluoric and industry is the Fluorogypsum produced in millions per annum causing a problem both from the point of disposal and environmental nuisance. This fluorogypsum can be used as a binder in composites due to their chemical composition.

Table 1: Chemical composition of Fluorogypsum

S. No.	Constituents	Percentage
1.	CaF_2	1.32
2.	SiO_2 + insoluble in HCl	1.65
3.	Al_2O_3 + Fe_2O_3	0.65
4.	CaO	42.2
5.	MgO	0.05
6.	SO_3	55.1
7.	Loss on Ignition	0.31
8.	pH	2.8

The production of water resistant gypsum binder involves the blending of Portland cements with ground granulated blast furnace slag with an additive such as organic retarded in the β -hemihydrates or Phosphogypsum which is followed by the grinding in a ball grinder.

Table 2: Physical properties of water resistant gypsum

Properties	Blended Gypsum Binder	Plain Gypsum Plaster
Fineness, $\text{cm}^2 \text{g}^{-1}$	3100	3000
Setting time, min		
Initial	70	25
Final	145	-
Bulk density, G cm^{-3}		
1-day	1.54	1.10
3-day	1.68	-
7-day	1.85	-
28-day	1.95	-
Compressive		
strength,	10.10	13.30
1-day	23.10	-
3-day	28.60	-
7-day	35.00	-
28-day		
Soundness, mm	1.60	1.10
Water absorption, %	6.00	33.00
pH	11.5	6.9

The additive can be a water repellent solution or hydraulic binders and in some cases the calcium sulpho-aluminate clinker to improve the water resistance.

The study of the pore structure of the blended water resistant gypsum binder by the use of mercury porosimeter was done by Singh *et al.* (1994) [4], who showed that the total pore volume decrease as the hydration period of blended gypsum increased. Moreover, the β -hemihydrate plaster exhibited a greater pore volume and porosity than the blended gypsum binder.

The study on the leaching behaviour of the mixture containing Plaster of Paris and calcium sulphoaluminate clinker was done by Kuryatnyk *et al.* (2010) [5], which presented that the extraction of the sulphate by the plaster reduced due to the presence of the clinker.

At the same time increase in the leaching behaviour was obtained with increase in the amount of sulphoaluminate clinker.

To improve the water resistant property of gypsum products a new composite binder was made from the industrial by-product fluorogypsum, granulated blast furnace slag and Portland cements by Garg *et al.* (2014) [6] and Sophia and Sakhieswaran (2016) [7]. The composite binder showed enhanced properties with low water absorption characteristics and due to the improved early age strength of the binder this can be incorporated for precast elements.

4. Conclusion

This paper presents the research done on the gypsum based composites with a special focus on the chemical composition and physical properties of the composites. The hydration of gypsum is influenced strongly by the water content and the

accelerating/retarding agents are formed effective in the rate of hydration on setting. The rate of hydration for both of α and β form of hemihydrate were same. The by-product gypsum also known as chemical gypsum such as Phosphogypsum and Fluorogypsum proves to be an asset for the manufacture of gypsum boards. The new gypsum based construction material with improved thermal storage capacity and fire protection is possible by the combination of phase changing materials with the conventional gypsum. Thus these phase changing materials with gypsum can be used to reduce the energy consumption in the building maintaining the thermal comfort.

5. References

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