Gypsum as a Construction Material- A Review of Recent Developments

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Abstract

Gypsum, due to its unique property and pleasing appearance has made it the material of choice in the construction industry. Gypsum products hold a pre-dominant position in the construction space due to their excellent insulation property both thermal and acoustic and effective fire protection. When used precisely with the innovative materials gypsum can develop the ability against moisture penetration and stability towards impact. Several research works have been done on the mechanical property and durability of gypsum under various circumstances. 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: Gypsum panel, plasterboard, fibre-reinforced composites, mechanical properties, thermal studies, PCM

I. INTRODUCTION

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 ubiquitious 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. This paper presents a survey of the existing literatures highlights of various attempt made by the researchers to improvise the mechanical properties and durability of gypsum products.

A. Gypsum properties and Forms:

Gypsum is a naturally occurring mineral with the chemical formula $CaSo_42H_2O$, known as Calcium sulphate dihydrate. The three hydration levels: Anhydrate with the chemical formula $CaSo_4$, dihydrate with the chemical formula $CaSo_42H_2O$ (Gypsum), hemihydrate with the chemical formula $CaSo_41/2H_2O$ (plaster). Gypsum produced from hemihydrates essentially occurs in two forms α-hemihydrates and β-hemihydrates. Their reactivity with water and the strength of the hydration products of these two forms of hemihydrate are different. Infrared and diffraction studies showed no difference in their structure. The brittleness of the hydration product of α-hemihydrates mitigates its use as a construction material and hence β-hemihydrates are widely used. The low density and high porosity of β-hemihydrates contributes to the fire-proofness, acoustic performance regulating the humidity of walls. Since Plaster of Paris is mainly composed of β-hemihydrates it has gained great industrial importance and has prompted several researchers to undergo studies on the hemihydrate of calcium sulphate.

B. By Product Gypsum:

Apart from the naturally occurring calcium sulphate dihydrate ($CaSo_42H_2O$) also known as Gypsum there are also other by-product gypsum obtained from the solid wastes of several chemical industries. The two most common types of industrial by-product gypsum are Phospogypsum, Fluorogypsum.

1) Phospogypsum:

Phospogypsum is the most important gypsum based by-product from the fertilizer industry which is produced about several million tons every year. The main composition of Phospogypsum is Gypsum ($CaSO_4.2H_2O$) and hence is used widely in the construction industry.

2) Fluorogypsum:

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

Constituents	*%*
CaF_2	1.32
SiO_2 + insoluble in HCl	1.65
$Al_2O_3 + Fe_2O_3$	0.65
CaO	42.2
MgO	0.05
SO_3	55.1
Loss on Ignition	0.31
pH	2.8

C. Hydration of Gypsum:

The hydration of calcium sulphate hemihydrate (Gypsum) starts immediately after it is mixed with water. The hydration process is a complex one mainly involving three stages:

1) At first stage the dissolution of hemihydrates in water takes place after which the dihydrate is hydro precipitated from the solution. The precipitation of the dihydrate is quick due to its lower solubility.

$$CaSo_4\,0.5H_2O + 1.5\,H_2O \rightarrow CaSo_4 2H_2O$$

2) The nucleation and growth of dihydrate crystals takes place in the next stage forming an interlocking mass of the crystal.
3) The complete depletion of hemihydrate leading to the formation of dihydrate is the final stage.

Though the dihydrate formation is endothermic, the total process is exothermic which is accompanied by the evolution of large amount of heat. The crystallisation of gypsum takes place during hydration.

D. Mechanism of Hydration:

The hydration mechanism needs a thorough understanding since the properties of Gypsum are mainly influenced by the process of hydration and properties of hemihydrates. Several theories have been put forth since ancient times to explain the mechanism of hydration. The two most widely accepted theories since ancient days are Lavoisier theory, Lechatellier's theory.

A theoretical and experimental study on the gypsum hydration was performed by Q.L.Yu et al., in which the changes occurring in the microstructure of the gypsum crystals were explained. This study also explained the speed of hydration changes at every stage due to the consumption of hemihydrate and formation of dihydrate.

Similiar study conducted by W.A.Cunningham et al., showed that the hydration process occurring in Plaster of Paris is essentially a solution recrystallisation process in which the dissolution of hemihydrate takes place by the subsequent crystallisation of needle like gypsum which varied somewhat in their sizes but were of same type crystals.

The hydration of calcium sulphate hemihydrate was also investigated by A.J.Leury et al., in which the diffraction studies characterised the difference between α and β forms of hemihydrates. It was revealed that the structural differences in crystal size of the two hemihydrates occurred due to their production mode. The time taken by the two hemihydrates to complete the hydration reaction was same but the α form showed a comparatively lesser induction period and the rate of dihydrate precipitation was lesser.

E. Water demand:

When mixed with water the calcium sulphate based gypsum plaster begins to solidify or harden whose property depends on the amount of water added or water/gypsum ratio. The stoichiometric requirement of water for complete hydration process is 18.6g per 100 grams of the calcium hemihydrate powder. But the plaster is usually mixed with higher amount of water to obtain the higher degree of consistency to make it easily workable and mouldable, If the water added to gypsum exceeds very much than the stoichiometric requirement creates pores internally which gives reduced mechanical strength of plaster.

The investigation on the microstructure and mechanical properties produced β-hemihydrate gypsum was done by Q.L.Yu et.al. The study was aimed at the workability of the gypsum and influence of water on the flow ability. The shape factor and the deformation coefficient for the investigated β-hemihydrate were derived in this study.

F. Setting of Gypsum Plaster:

The hydration process occurring in the paste causes the setting of the plaster and thereby develops its strength. The setting not only involves the physical changes but is also a physico-mechanical phenomenon. The gypsum has a relatively large internal surface after hardening is not a compact mass, but is a porous solid material consisting of large interlocking crystals which is in shape of plate and needles. The engineering and physical properties especially the rigidity of the gypsum are mostly affected by the microstructure of the gypsum pastes after it is hardened. The Le chatellier's law clearly explains the mechanism of setting of gypsum plaster. The rate of setting of the gypsum plaster is mainly dependant on the following: fineness and purity of the gypsum and the mixing velocity of the gypsum plaster.

Several standards have been established to demarcate the limits of setting times of gypsum plaster which establishes a standard time of at least 20mins for a initial setting when the gypsum is to be manually applied and 50 minutes as the initial setting time when it is to be mechanically sprayed.

The periodical changes occurring in the rheology of the gypsum during the setting phenomenon has a critical role to play in the application of gypsum based materials. For the immediate application of the gypsum materials a high water-gypsum ratio is usually employed thereby creating a material with initial consistency prolonging the setting time of gypsum mitigating the high material consumption. A certain period is required after the mixing procedure to raise the consistency up to a desired level for easier productivity. A standard setting time if essential because if the gypsum sets too fast then a considerable amount of gypsum will be set due to the property of gypsum or due to the variability in the environment which consequently reduces the available working time.

II. EXPANSION OF GYPSUM

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. The magnitude of expansion mainly depends on the fineness of gypsum powder, the effect of water-gypsum ratio, the addition of retarders or accelerators, the added sand/lime paste.

A. *Effect of Fineness of Gypsum Powder:*

The fine gypsum powder exhibits a greater expansion than a coarse material at a constant water-gypsum ratio.

B. *Effect of Water-gypsum ratio:*

Usually expansion reduces with increase in the water-gypsum ratio since the increase in the water-gypsum ratio creates more distance between the particles which will provide more space for the growth of crystals.

C. *Effect of Addition of Sand:*

Gypsum undergoes reduced expansion due to the addition of sand. It has been well established that adding sand reduces about the expansion to about one-half of the original expansion without sand. Coarse sand proves to be more effective than fine sand in expansion control.

D. *Effect of Accelerators/Retarders:*

The addition of retarders and accelerators causes a change in the specific size of crystal formed and also found to be effective in minimizing expansion. The formation of shorter and thicker gypsum crystals which fills more easily the growing space are aided by the use of retarders. The accelerators aid the formation of shorter and smaller crystals.

E. *Effect of Admixtures in Gypsum Plaster:*

To establish the gypsum as a popular and perfect finishing material it should also satisfy the contemporary requirements such as delayed setting time, workability, high strength towards compression, flexure and tensile, water impermeability, excellent insulation to thermal and acoustic, perfect bonding strength and resistance towards sag.

From the studies done on the optimisation of gypsum based composite material by M.Arikan and K.Sobolev showed that the consistency of gypsum reduced with increase in the dosage of water soluble polymer. These admixtures such as retarders, air entraining agents, super plasticizers also increased the setting time of gypsum slightly.

The effect of citric acid on the gypsum plasters was investigated by Marcos Lanzon et al., in which the results showed that the addition of citric acid even at low dosages effectively delayed the setting time of Gypsum whereas higher dosages had no effect on the setting time.

Aakanksha Pundir evaluated the properties of super plasticizer blended gypsum plaster and concluded that the consistency was reduced due to the addition of gypsum plaster. The reason for this reduced consistency was the better dispersion of the gypsum particles in water due to the addition of super plasticizer.

Similar studies to modify the physical property of Gypsum by the addition of clay mineral were performed by M.Murat and A.Attari et al. The strength of gypsum which contained more than 10% weight of clay minerals showed lower strength than pure gypsum plaster. To obtain these desirable properties the application of several numbers of chemical admixtures and mineral additives in gypsum were found necessary.

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.

III. Dehydration

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 ($CaSo_4 2H_2O$) to hemihydrate ($CaSo_4 0.5H_2O$) takes place.

$$CaSO_4\ 2\ H_2O + heat \rightarrow CaSO_4\ 0.5H_2O + 1.5\ H_2O$$

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

$$CaSO_4\ 0.5H_2O + heat \rightarrow CaSO_4 + 0.5\ H_2O$$

A. *Fibre reinforced Gypsum plaster:*

Gypsum products like the other inorganic cements lags in tensile strength eith strong compressive strength. To overcome the brittle failure of the matrix phase at a low water/gypsum ratio, the organic and inorganic fibres may be incorporated into the gypsum matrix thereby assuming durable gypsum composite with a light weight nature.

The two essential methods of reinforcing the gypsum matrix with the fibrous material includes,

1) The first method in which concentration of fibres is done on the tensile zone to compensate the external tensile stresses acting whereas the matrix phase can compensate the compression forces
2) The second method is the formation of homogeneous mixture in which the fibres are uniformly dispersed in the matrix phase. The easier incorporation and ability to flow without segregation of fibres into the gypsum matrix is possible due to the rheology of gypsum. Depending on the type of fibres added the strength of the fibrous gypsum composite material either increases or decreases.

Another most important factor which defines the efficiency of fibre reinforced gypsum plaster is its fibre/gypsum ratio which is commonly known as reinforcement/modular ratio.

B. *Glass Fibre Reinforced Gypsum plaster:*

Glass fibres have several advantages such as high modulus of elasticity, remarkable fire resistant property and hence they are used in gypsum plaster as reinforcement to improvise the performance of Gypsum.

Table – 2
Physical properties of E-type glass fibre

Diameter of the fibre filament, µm	*8-10*
Number of filaments in a strand	*204*
Tensile strength of glass fibre, MPa	*1750*
Young's modulus of glass fibre, MPa	*6890-7600*

Gypsum holds a pH value of 7 and hence non-alkaline in nature. This property makes the gypsum compatible with the glass fibres without causing any deterioration to both the physical and chemical composition of glass fibres.

Majumdar studied the bond between the glass fibre and gypsum plaster and reported that the bonding mainly depends on the magnitude of water/plaster ratio.

C. *Mechanical and Durability Studies on GFRG:*

M.A.Ali and F.J.Grimer studied the effect of variation of gypsum/plaster ratio on the mechanical strength of plaster and reported that the glass fibre proved to be an efficient reinforcement due to the effective interaction between glass fibres and plaster. With reference to the impact strength it was observed to attain high impact value for a glass content of 10% in gypsum.

Table – 3
Comparison of structural strength of the fibre-reinforced board

	Asbestos cement sheet	*GFRG plaster board*
Matrix	*Ordinary Portland cement*	*Gypsum Plaster*
Asbestos content	*10 to 15 wt%*	*-*
Glass fibre content	*-*	*6 to 10 wt%*

Strengths		
Flexural lb/in^2(N/mm^2)	*4000 (28)*	*3500 to 5000 (24 to 35)*
Tensile lb/in^2(N/mm^2)	*2000 (14)*	*1800 to 2500 (12 to 18)*
Impact lb/in^2(Nmm/mm^2)	*10 to 15 (1.75 to 2.50)*	*250 to 300 (44 to 53)*

The water resistant gypsum based composite was developed by Manjit singh and Mridul Garg in which the results showed that the length and quantity of fibres has an effect on the strength and concluded that a length of 50mm was found to be optimum.

Table – 4
Physical properties of water-resistant gypsum binder

Fineness, cm^2/g	*3100*
Setting time, min	
Initial	*70*
Final	*145*
Bulk density, g/cm^3	*1.2*
Compressive strength, MPa (28 days)	*35.0*
Soundness, mm	*1.60*
Water absorption, %	*6.0*
pH	*11.5*

The study on various types of external plaster by subjecting them to weathering process and artificial ageing was done by Jerzy Bochen. This study mainly focussed on the pore structure whereas the mechanical and physical properties were also investigated and compared.

The porosity of the glass fibre reinforced gypsum plaster was studied by M.A.Ali and B.Singh which revealed that the porosity increased with increase in fibre content and also the length of the fibre had an effect on porosity.

The modification of the conventional glass fibre reinforced gypsum was done by J.Bijin and C.Vander Plas by the addition of specially selected thermosetting plaster. Several investigations on the study formed composite material showed that the mechanical property was excellent under tension.

The durability of glass fibre reinforced gypsum composites was studied by Manjit Singh and Mridul Garg. The weight loss and strength of the composite subjected to alternate wetting and drying cycles was reported.

The study on glass fibre reinforced gypsum modified by the polymers was done by Byen and Vander Plas in which the plaster was exposed to accelerated ageing condition and 400 cycles of alternate wetting and drying. The results showed that the disintegration of glass fibre reinforced gypsum were observed greater than the polymer modified gypsum due to this exposure.

D. Gypsum Reinforced by Natural Fibres:

The harmful effects of non-degradable and non-renewable nature of synthetic and mineral fibres have encouraged several researchers to replace them with the eco-friendly natural fibres. The advantages of natural fibres include their recyclable nature, impact on healthy living, low cost, low density and low thermal conductivity. Despite the several advantages, a limited works have been done on the use of natural fibres as reinforcements to gypsum plaster since they exhibit weak interaction with gypsum matrix.

Fabio Iucolano et al., studied the different chemical treatment methods on the abaca fibres and its effect on gypsum based composite. The water treated abaca fibres showed better performance rather than the EDTA treated fibres due to their aggressiveness on the surface of the fibres.

Rute Eires et al., developed a new eco-friendly gypsum material who showed that incorporation of cork into the gypsum reduced their mechanical performance.

The wood fibre as plaster reinforcement changed the brittle type of failure to that of pseudo ductile failure in the study done by R.S.P.Coutts.

When cotton stalk fibre/gypsum composites were tested by Guozhong Li et al., the formation of a flexible interfacial layer between gypsum and fibres in the composites which contained fibres pre-treated with styrene acrylic acid emulsion.

Studies done by F.Hernandes also proved that both gypsum and cork are compatible to each other but this new composite had a decreased mechanical property.

A research to develop gypsum based composite as an alternative to timber was done by Manjit Singh and Mridul Gargh in which the natural fibres such as sisal, coconut coir, mestha and bhabar were used. The fibrous gypsum board of comparable high strength was produced by sisal and coconut coir fibres (at the ratio of 80:20 parts by weight).

The waste additives such as rice husk ash, slag were incorporated in gypsum by A.A.Khalil et al., and manufactured a light weight gypsum plaster suitable for non-load bearing units.

E. Synthetically Modified Gypsum Plaster:

The high cost associated with mineral fibres and the hydrophilic nature of natural fibres made the researchers to find out the other ways of preventing a catastrophic failure of the gypsum composites. The synthetic polymer reinforcements have been found effective due to their distinguished property. Gypsum plaster are also used in conjunction with an epoxy resin due to their superior performance, excellent adhesion, low shrinkage, high compressive flexural and tensile strength, with exceptional chemical resistance and ease of curing.

Studies done by S.Eve et al., showed that the polyamide fibres delayed the setting time of gypsum and also reduced the total swelling.

Similar study also showed that the incorporation of polyamide fibres increased modulus of elasticity, compressive and tensile strength with increase in the proportion of the fibres.

Vermiculite and polypropylene fibres were added to the gypsum composite by Osman Gencel et al. The vermiculite reduced the compressive strength and polypropylene fibres were found to enhance the strength.

Investigation on the physical and chemical properties of polymer plaster composites done by Adnan Colak showed that the setting time increased with the increase in percentage of latex in the gypsum composites.

The impregnation of Plaster of Paris with methyl methacrylate increased the compressive and tensile strength. The optimum quantity of epoxy resin required to maximize the strength was found to be 20ml.

In a similar study done by Adnan Colak on the characteristics of acrylic latex modified and partially impregnated gypsum composites showed a significant improvement in flexure behaviour. The fibres and microfibres of shredded tires were added to the gypsum plaster where a slight decrease in the mechanical strength was observed. The tensile strength of the polyethylene fibres decreased during the chlorosulfonation of the fibres and the modulus of elasticity increased.

The strain capacity of the gypsum plaster was studied by the addition of rubber particles obtained from recycled tyre. The addition caused greater water retention with comparison to non additivated gypsum plaster.

The exploration methods for preparing cements and plasters with superior performance done by Andreii A.Zolotarev et al., in which the plaster was modified by water soluble fullerons. Through this addition the impact resistance was nearly doubled.

The hybridisation effects of sisal and glass fibres on the strength of gypsum plasters were studied by D.A.John et al. These fibres increased the bulk density with a decrease in compressive strength.

F. Thermal Studies of Gypsum Plaster:

Gypsum plasterboards have an inherent property of passive fire protection due to its ability to mitigate the penetration of fire. This property is due to the chemical composition of Gypsum and hence it requires better understanding of the performance of gypsum boards at elevated temperatures including the physical and microstructural changes. The thermal properties are tedious to measure since the condensed water in the cooler parts of the gypsum apparently affects the experimental results.

Q.L.Yu et al., investigated the dehydration process and microstructure of gypsum boards produced from β-hemihydrates at elevated temperatures. The conductivity of the gypsum boards and void fraction with reference to the free moisture on the system was validated experimentally and also by derivation of a model.

The heat transfer model was calibrated to study the values of conductivity of gypsum plaster boards which were used as a lining to provide fire resistance.

The study of the experimental validation on the fire modelling of gypsum was performed by K.Ghazi Wakili et al. The experimental results of the density, thermal conductivity and heat capacity of the gypsum were expressed as a function of temperature and the thermal properties were measured after different heat treatments.

Olga Axenenko et al., performed the finite element modelling of the thermal process that occurred when the plaster board were exposed to fire. The concept of dehydration during the heating of the gypsum plaster boards were analysed and showed that the dehydrated part had no influence in the load carrying capacity of the gypsum plasterboard.

G. PCM in Gypsum Plaster:

The phase changing materials can be defined as those materials that can be used to release or show effectively a large amount of heat that is usually accompanied during the process of solidification or melting. The stability in the temperature can also be constantly maintained during the process of heat transfer. The two methods by which the PCM can be integrated into the building structures are either adding the particles of PCM during the process production of materials or as a lamination to the prefabricated construction panels. Several investigations have been done on the performance of PCM in structures by the use of dynamic simulation of buildings.

The thermal characterisation of Gypsum boards in containing about 45% by weight of PCM reinforced with additives was studied by Alicia Oliver which showed greater thermal storage for the materials which contained up to 20%.

The composite gypsum materials were studied with the micro encapsulated PCM addition on the traditional gypsum materials in which showed that the density and thermal conductivity of the composite material were independent of the temperature.

The study of the thermal storage behaviour of gypsum boards by Chi-ming lai et al., with the incorporation of micro-encapsulated PCM showed that the melting latent heat and specific heat increased with increase in the percentage of micro-encapsulated in the gypsum boards.

H. Light weight Gypsum Plaster:

The manufacture of light weight gypsum plaster mainly incorporates the used of expanded perlite, vermialite and several other light weight aggregates in the gypsum thereby reducing the density of the resultant material.

The thermal property study on the light weight gypsum plaster made with polyurethane foams done by Geoff Thomasin which the foams from two different sources which were ground to different granulometric sizes.

C.Martias et al., presented the thermo-mechanical experiment on the gypsum composite material in which the experimental, numerical and analytical studies were done to postulate the effect of glass fibre, mica and vermiculite on the porosity, density and mechanical property of the gypsum.

The design strategies for the light weight gypsum composites was presented by Alena Vimmrova et al., in which the strategy of incorporating higher density matrix with a lower density aggregates and lower density foamed gypsum matrix with higher density aggregates was found successful. Moreover, the composites designed by the strategy of low density foamed gypsum matrix and higher density aggregates yielded high thermal insulation property with reduced compressive strength.

I. Water Resistant Gypsum boards:

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 Phospogypsum which is followed by the grinding in a ball grinder.

Table – 5
Physical properties of water resistant gypsum

Properties	*Blended Gypsum Binder*	*Plain Gypsum Plaster*
Fineness, $cm^2\ g^{-1}$	*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,		
1-day	*10.10*	*13.30*
3-day	*23.10*	*-*
7-day	*28.60*	*-*
28-day	*35.00*	*-*
Soundness, mm	*1.60*	*1.10*
Water absorption, %	*6.0*	*33.0*
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 Manjit Singh et al., 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 T.Kuryatnyk et.al., 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 silphoaluminate 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 Mridul Garg et al. 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.

IV. Conclusion

This paper presents the review on the research done on the gypsum based composites with a special focus on the physical properties, chemical composition, mechanical properties and efforts done to improve the tensile nature of gypsum by fibre bonding and durability of the composites. The following conclusions can be drawn from the previous experimental and analytical studies:

1) 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.
2) The fibres may be incorporated in gypsum to overcome brittle character of gypsum. The introduction of glass fibres in gypsum converts the brittle failure of gypsum matrix into a pseudo ductile behaviour. Several natural fibres are also found to increase the tensile behaviour of gypsum plaster. Synthetically modified gypsum binders are also found effective by the use of acrylic latex and polymer impregnation. The polyamide fibres also plays essential role in the dehydration process and setting of gypsum.
3) Light weight gypsum products can be produced by the polyurethane foams and several other strategies such as use of light weight aggregates. The thermal conductivity of the polyurethane foam based gypsum composite was also improved.
4) The fibrous gypsum boards produced from the natural, synthetic and mineral fibres are of comparable strength and better water resistance was observed for boards reinforced with glass fibres rather than organic fibres.

5) The by-product gypsum also known as chemical gypsum such as Phospogypsum and Fluorogypsum proves to be an asset for the manufacture of gypsum boards. The newly developed water resistant gypsum binder will be effective for use in gypsum reinforced composites and thus broadens the use of gypsum products to exterior applications.
6) 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.

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