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# AN INVESTIGATION OF THE POSSIBILITIES OF USING PHOSPHOGYPSUM AS A BUILDING MATERIAL[1]

**Fatma Nurhayat Değirmenci**

*Architecture Faculty, Department of Architecture, Balıkesir University, Balıkesir, Türkiye, nurhayat@balikesir.edu.tr, 0000-0001-7996-6139*

***Abstract***
*Phosphate rock is processed with sulfuric acid to obtain phosphoric acid. Phosphoric acid is used in fertilizer production. Approximately 4-5 tons of phosphogypsum is obtained as industrial waste for each ton of phosphoric acid in fertilizer production. It is estimated that 3 million tons of phosphogypsum is stored as waste in our country. A very small amount of phosphogypsum was used in soil improvement and road stabilization, while the rest was generally stored in open lands or dumped into rivers and seas. The supply of landfills for phosphogypsum, the amount of which increases every year as industrial waste, increases production costs. In order to bring phosphogypsum into the economy, studies are being carried out to investigate the possibilities of its use in the construction sector. Phosphogypsum has been used as a setting retarder in cement production, artificial aggregate production and road stabilization. In this study, examples of previous studies on the possibility of utilization of phosphogypsum from Bandırma Bagfas Fertilizer Plant waste in the construction sector are presented. The utilization of phosphogypsum together with other industrial wastes will provide economic contribution.*

***Keywords:*** *Phosphogypsum, Industrial Wastes, Building Materials.*

# FOSFOJİPSİN YAPI MALZEMESİ OLARAK KULLANIM OLANAKLARININ ARAŞTIRILMASI

***Özet***
*Fosfat kayasının sülfürik asitle işlenmesi sunucu fosforik asit elde edilmektedir. Fosforik asit gübre üretiminde kullanılmaktadır. Gübre üretiminde her bir ton fosforik asit için yaklaşık 4-5 ton fosfojips endüstriyel atık olarak elde edilmektedir. Ülkemizde 3 milyon ton fosfojipsin atık olarak depolandığı tahmin edilmektedir. Atık olarak fosfojipsin çok az miktarı toprak ıslahı ve yol stabilizasyonunda kullanılmış geri kalanı ise genellikle açık arazilerde depolanmış veya nehir ve denizlere dökülmüştür. Endüstriyel atık olarak miktarı her yıl artan fosfojips için atık depolarının temini üretim maliyetlerini arttırmaktadır. Fosfojipsin ekonomiye kazandırılabilmesi için inşaat sektöründe kullanım olanaklarını araştıran çalışmalar yapılmaktadır. Fosfojips, çimento üretiminde priz geciktirici ve bağlayıcı olarak ve yol stabilizasyonunda kullanılmıştır. Bu çalışmada, Bandırma Bağfaş Gübre Fabrikası atığı fosfojipsin inşaat sektöründe değerlendirilebilme imkânı ile ilgili daha önce yapılan çalışmalardan örnekler sunulmuştur. Fosfojipsin diğer endüstriyel atıklar ile birlikte değerlendirilmesi ekonomik katkı sağlayacaktır.*

***Anahtar Kelimeler:*** *Fosfojips, Endüstriyel Atık, Yapı Malzemeleri.*

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## 1. INTRODUCTION

The continuous increase in the world's population shows that nutritional needs will be an important problem in the future as it is today. Meeting the nutritional needs of the growing population brings with it the necessity of providing high yields from unit area in agricultural areas. For this reason, the use of fertilizers becomes important in order to increase productivity in agriculture. Chemical fertilizers, especially phosphorus fertilizers, are of great importance in modern agriculture. Phosphoric acid ($P_2O_5$), obtained by treating phosphate rocks with sulfuric acid ($H_2SO_4$), is used in the production of various types of chemical fertilizers (DAP: diammonium phosphate, MAP: monoammonium phosphate). For each unit ton of phosphoric acid produced in the fertilizer industry, approximately 4-6 tons of phosphogypsum is generated as industrial waste. Phosphogypsum production in the world is around 200-250 thousand tons per year. In 2014, phosphogypsum production was 225 thousand tons and this product is estimated to be 258 thousand tons in 2018 (Tayibi et al., 2009; International Atomic Energy Agency [IAEA, 2013]). In our country, there are phosphoric acid factories in Samsun, Bandırma, Mersin and Iskenderun and about 3 million tons of phosphogypsum is produced as waste annually. A very small portion of this waste is used in soil improvement and road stabilization, while the rest is generally stored in open land or dumped into rivers and seas (Değirmenci, 2008a). The capacity of the Bağfaş Phosphoric Acid Plant is 440 tons/day and the annual capacity of the plant is 150,000 tons (https://www.bagfas.com.tr/Asit.aspx). Considering that approximately 4-6 tons of phosphogypsum is obtained as waste for each unit ton of phosphoric acid, it is seen that the annual phosphogypsum production will be around 600-900 tons if the plant operates at full capacity. In Bandırma Bağfaş Fertilizer Factory, phosphogypsum, which is generated as waste in large quantities such as 3500 tons per day, causes significant storage problems as well as environmental pollution.

Phosphogypsum contains some trace elements that pose a potential hazard to human health and the environment, including radioactive contaminants such as arsenic, chromium, copper, zinc, cadmium, radium and uranium. Due to the potential radionuclide threat to human health, phosphogypsum is only allowed for limited agricultural and research use. Otherwise, the current permitted disposal method for phosphogypsum is bulk storage on agricultural land. The high volumes of phosphogypsum waste have prompted the fertilizer industry to minimize the disposal problems of this waste and to investigate its beneficial uses in different fields. In this study, the possibilities of recycling phosphogypsum into the economy as a building material were investigated and examples of previous studies on the use of phosphogypsum from Bandırma Bağfaş Fertilizer Factory waste as a building material were given.

## 2. DEFINITION AND PROPERTIES OF PHOSPHOGYPSUM

Phosphoric acid can be produced by several different methods, such as the treatment of phosphate rocks with thermal, hydrochloric acid, nitric acid or sulfuric acid. Treatment of phosphate rocks with sulfuric acid is the most widely used method, known as the wet method. Although this method is economical as a wet method, it causes the production of 4-6 tons of by-products for each ton of phosphoric acid production. In wet production, phosphoric acid and the by-product of the reaction are separated by filtration. The by-product CaSO4.2H2O is called phosphogypsum. Bağfaş fertilizer factory also produces phosphoric acid by wet method.

### 2.1 Physical and Chemical Properties of Phosphogypsum

Phosphogypsum is mainly in the composition of CaSO4.2H2O and contains impurities such as P2O5 and F- and organics. The chemical analysis results showed that about 93% of phosphogypsum is gypsum and the remaining 7% is phosphate, fluorite and organic matter, which are called impurities. The chemical properties of phosphogypsum from Bandırma Bağfaş Fertilizer Plant waste are given in Table 1. The chemical composition of phosphogypsum depends on the production method and storage conditions. Phosphogypsum is a gray, moist, fine-grained powder with a maximum size between 0.5 and 1.0 mm and 50-75% of particles finer than 0.075 mm. The specific gravity of phosphogypsum is between 2.3 and 2.6 and the moisture content is usually between 8-30%. Bagfas Fertilizer Plant waste phosphogypsum has a specific gravity of 2.96, Blaine value (m2/kg) of 467, moisture content of 13%, maximum dry unit weight of 14.70 kN/ m3 and grain distribution between 0.5-1.0 mm.

**Table 1.** Chemical composition of phosphogypsum and natural gypsum.

| Constituent (%) | Phosphogypsum | Natural gypsum |
|---|---|---|
| $SiO_2$ | 3.44 | 0.61 |
| $Al_2O_3$ | 0.88 | 0.10 |
| $Fe_2O_3$ | 0.32 | 0.10 |
| CaO | 32.04 | 37.00 |
| MgO | - | - |
| $SO_3$ | 44.67 | 46.18 |
| $Na_2O_3$ | 0.13 | 0.30 |
| $K_2O$ | - | - |
| $P_2O_5$ | 0.50 | - |
| $F^-$ | 0.79 | - |
| KK | 21.06 | - |

### 2.2 Impurities and radioactivity in phosphogypsum

Although the chemical composition of phosphogypsum is the same as natural gypsum, its impurities limit its use instead of natural gypsum. It was reported that calcining at 140oC-150oC was effective to remove impurities settled in the crystal lattice (Yılmaz, 1987). The calcination conditions of phosphogypsum were investigated at different temperatures and durations. The influence of calcination conditions on the strength of mortar specimens produced with fly ash and lime using phosphogypsum calcined at these times and temperatures was investigated. In the first stage of the study, a certain amount (1000 grams) of phosphogypsum was subjected to calcination at a constant temperature of 150oC and for different durations; 1, 2, 3, 4 hours. In the second stage, a certain amount (1000 grams) of phosphogypsum was subjected to calcination at a constant calcination time (2 hours) and different temperatures; 100oC, 125oC, 150oC, 175oC, 200oC. In the third stage of the study, 500, 1000, 1500 and 2000 grams of phosphogypsum were calcined in different amounts at constant calcination time (2 hours) and constant temperature (150oC). In the fourth stage of the study, 500 grams of phosphogypsum was calcined at 150oC for 2 hours. In the last stage of the study, phosphogypsum was not subjected to any calcination process, it was used as waste as it came to the laboratory and 28-day compressive strengths of mortars obtained using 60% phosphogypsum, 30% fly ash and 10% slaked lime were determined. It was observed that the compressive strengths increased as the calcination time and temperature increased and it was concluded that phosphogypsum can be utilized in the construction sector together with other industrial wastes (Değirmenci, 2001).

Another factor limiting the utilization of phosphogypsum is the radionuclides it contains. The most active radionuclide observed in phosphogypsum is 226Ra. The U.S. Environmental Protection Agency (EPA) has set the activity limit for the use of phosphogypsum at 370 Bq.kg-1 (10 pCi g-1) (EPA, 1992). The European Atomic Commission (EURATOM, 1996) gives this limit as 500 Bq.kg-1 (13.5 pCi g-1). The average values of 226Ra activity concentrations were found as 250.8 Bq.kg-1 for Mersin Fertilizer Plant and 826.6 Bq.kg-1 for Bandırma Fertilizer Plant (Gezer, 2011:89). The average 226Ra concentration of phosphogypsum specimens analyzed at Çekmece Nuclear Research and Training Center (ÇNAEM) was 503 Bq.kg-1. The fact that phosphogypsum specimens contain 226Ra activity above the EPA limit value raises an environmental risk concern. The U.S. EPA (2005) refers to phosphogypsum as TENORM (Technologically Enhanced Naturally Occurring Radioactive Material) because it contains radium, uranium and their decay products. In Table 2, the activity concentrations of the radianuclides detected in the waste phosphogypsum of the Bağfaş Fertilizer Factory are given (Dartan, 2013: 144). These differences are due to both the natural structure of the location of the phosphate rock and the depth at which the specimen was taken and the spread of 226Ra in the phosphate rock.

**Table 2.** Activity Concentrations of Radionuclides Detected in Phosphogypsum (Bq/kg) (Dartan, 2013:144).

| Specimen | U-238 series | | | Th-232 series | | K-40 (1460 KeV) | Cs-137 (661 KeV) |
|---|---|---|---|---|---|---|---|
| | Ra-226 (186 KeV) | Pb 214 (351 KeV) | Bi-214 (609 KeV) | Th-208 (583 KeV) | Ac-228 (911 KeV | | |
| 1 | 514,5±30,0 | 502,5±11,2 | 491,0±11,2 | - | - | <ÖMD±153 | - |
| 2 | 515,5±47 | 468,2±11,2 | 485,2±11,4 | - | - | <ÖMD±151 | - |
| 3 | 491,1±28,5 | 485,0±11,2 | 474,3±11,2 | - | - | <ÖMD±152 | - |
| 4 | 525,1±28,7 | 549,6±7,2 | 500±7,5 | - | - | <ÖMD±100 | - |
| 5 | 470±31 | 473±37 | 467±25 | 4±2 | 8±2 | - | - |

## 3. USE OF PHOSPHOGYPSUM IN THE CONSTRUCTION

In the construction sector, phosphogypsum is used as a setting retarder and clinker raw material in cement production, as a secondary binder with cement and lime, in the production of block elements, mortar, brick and adobe, as filler in bituminous mixtures in road construction, and in soil and road stabilization.

### 3.1. Utilization of Phosphogypsum in Cement Production

In order to control the setting time of the cement, between 3% and 6% gypsum is added to the clinker. The excess amount of gypsum has a role in accelerating the setting time as well as the small amount of gypsum. For this reason, a certain amount of gypsum must be added in cement production and the amount of gypsum used as a setting retarder in the cement industry is increasing day by day. This has led the construction industry to search for a cost-effective alternative to gypsum. In previous studies, phosphogypsum was used as a setting retarder instead of natural gypsum in the cement industry. Phosphogypsum obtained from Bagfas was added to Portland cement at 1%, 3%, 5%, 7%, 10% and 12.5% and its effects on mechanical properties were investigated. The compressive strengths of Portland cements containing phosphogypsum and natural gypsum were compared. It was concluded that phosphogypsum can be used instead of natural gypsum in Portland cement production. The highest 28-day compressive strength was observed in the specimens containing 3% by weight phosphogypsum (Altun and Sert, 2004).

In another study, the usability of phosphogypsum with waste marble dust and silica fume in cement production was investigated. PC 42.5 cement was produced by grinding natural gypsum and clinker together and control cement was produced by grinding clinker and phosphogypsum together. All of the blended cements were obtained by grinding 5% by weight phosphogypsum with different proportions of clinker, marble dust and silica fume. It was reported that phosphogypsum increased the setting times of the cement compared to natural gypsum. The effect of phosphogypsum on the volume expansion and density of the cement was the same as that of natural gypsum, the unit weight decreased compared to natural gypsum, and the effect on flexural and compressive strengths was the same as that of natural gypsum. It was stated that phosphogypsum can be used instead of natural gypsum in Portland cement production (Sağlam, 2012).

The effects of the original phosphogypsum of Tugsaş Samsun Fertilizer Plant and refined phosphogypsum purified by various methods on the hydration of different cements were investigated and the conditions for their use as additives in cement production were investigated. It was concluded that the impurities in the original phosphogypsum could not be sufficiently removed by water and lime milk washing, and adversely affected cement hydration. It was also stated refined phosphogypsum prepared by calcining at 150oC for 15 minutes and neutralizing with lime milk had equivalent effects with natural gypsum in cement hydration and phosphogypsum could be used instead of natural gypsum for controlling the setting time in cement production (Ölmez et al., 1987)

In the other study, the optimum anhydrite conversion temperature and time of phosphogypsum from Tügsaş Samsun Fertilizer Plant residue was found to be 1 hour at 650°C and the anhydrite obtained in this way was mixed with appropriate chemical additives and blast furnace slag to produce supersulfated cement. The properties of the prepared supersulphated cement mixtures such as resistance to sulfate water and strength development were investigated and optimum mixing ratios were determined. As a result, it was found that phosphogypsum can be economically utilized in the production of supersulfate cement with high resistance to sulfate water (Erdem, 1989).

The effects of phosphogypsum impurities and purified phosphogypsum on the hydration of Portland cement and trass cement were investigated by electron microscopy observation of hydration products, chemical analysis, setting times and strength determination. It has been stated that phosphogypsum can be used in the hydration of Portland cement, provided that it is washed with lime milk, and that it can be used in the control of the hydration of trass cements without the need for any refining process (Ölmez and Erdem, 1989).

### 3.2. The Use of Phosphogypsum in Block Building Element, Mortar and Brick Production

The potential usability of phosphogypsum, fly ash and lime in the construction industry was investigated. Different proportions of raw and calcined phosphogypsum were used in the production of binder material with fly ash and lime. Lime content was kept constant at 10%, phosphogypsum content was varied as 0, 10, 20, 30, 40, 50 % and fly ash content was varied as 40, 50, 60, 80, 90 %. Phosphogypsum was calcined at 150oC for 2 hours and then cooled to room temperature and used. It was observed that the properties of the binders were effective on the compressive strengths, the compressive strength decreased when the ratio of raw phosphogypsum was increased; the lowest compressive strength was achieved in the 50% raw phosphogypsum addition, whereas the compressive strength value increased when the addition of calcined phosphogypsum was increased. Curing conditions were also effective in the increase of compressive strength. Water cured specimens showed lower strengths than air cured specimens (Figure 1, Değirmenci, 2008b).

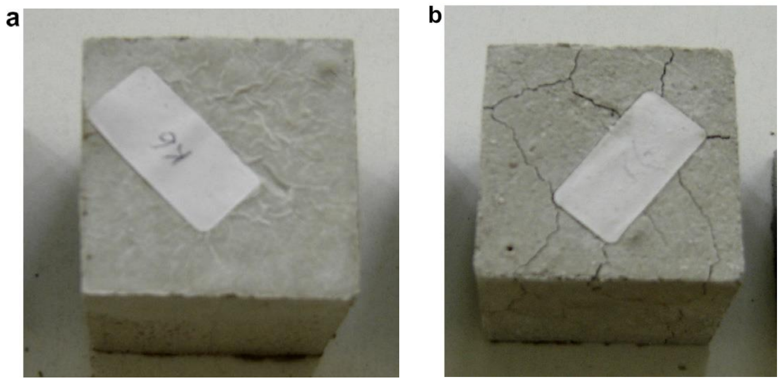


**Figure 1.** Phosphogypsum additive specimens cured in air (a) and water (b) (Değirmenci, 2008b:1861).

Phosphogypsum, a fertilizer factory waste, and perlite, a natural mineral, were added to the plaster as additives. Optimization was made using 24 full factorial design, and which factors were effective by using ANOVA analysis. It was examined whether these factors had a significant effect on the water permeability of the plaster with additives and optimum values were determined. In the experiment conducted to determine the water absorption in the specimens, the phosphogypsum and perlite additives on the water absorption yielded statistically significant results (Oktay et al., 2017).

In a study investigating the possibilities of using phosphogypsum with other industrial wastes, phosphogypsum-fly ash-lime based binder was produced by using phosphogypsum supplied from Bağfaş and fly ash together, and the water absorption, dry unit weight, compressive and tensile strengths of the specimens produced from this binder were determined. It was stated that phosphogypsum decreased the compressive and tensile strength fly ash increased the compressive and tensile strength. The curing conditions were also effective on the strengths, and the phosphogypsum-fly ash-lime based binder gained strength after 28 days. Due to the strength requirement, it was stated that the phosphogypsum ratio should be kept constant at 20%. According to the test results, the water absorption and thermal conductivity of the specimens increased with the phosphogypsum ratio, at the same time, the increase in phosphogypsum ratio caused a decrease in unit weight. It was reported that the developed binder can be used in the production of block building elements, mortar and low strength materials (Değirmenci and Okucu, 2007).

In another study, the sulfate resistance of cement mortars prepared with phosphogypsum from Bandırma Bagfaş Fertilizer Plant waste was investigated. In the study, phosphogypsum was used as an additive in cement mortars at the rates of 0%, 5% and 10% of the cement weight, instead of cement. The weight loss, compressive strength and length changes of cement mortar specimens with and without phosphogypsum additives kept in 5% and 10% sodium sulfate solution were investigated. Although there was a decrease in the weight of the specimens in the first weeks, the weight of the specimens increased in the following weeks. In terms of compressive strength, it was observed that the mixtures with phosphogypsum additives gave better results in sulfate solution than the control mixtures without phosphogypsum additives (Değirmenci and Okucu, 2002).

Phosphogypsum from Bagfas Fertilizer Plant waste was also used in brick production with fly ash and the firing temperature was kept constant at 1000oC. It was stated that phosphogypsum was more effective than fly ash on the properties of brick specimens and phosphogypsum additive decreased water absorption values while increasing the unit weight and strength (Türkel and Aksın, 2012).

### 3.3. Use of Phosphogypsum in Adobe Production

The weakness of adobe is its low compressive strength and water resistance. Phosphogypsum (PG) and natural gypsum (NG) were used to improve the properties of adobe soil.. Addition of more than 10% phosphogypsum and natural gypsum increased the compressive strengths (Figure 2). The highest compressive strengths were obtained with 25% phosphogypsum and natural gypsum addition. Phosphogypsum addition also reduced the drying shrinkage values. The adobe specimens prepared with phosphogypsum showed sludge in more than 45 minutes as specified in the standard (TS 2514, 1971). The specimens produced without phosphogypsum were completely destroyed in water in less than 45 minutes (Figures 3 and 4). It was stated that the mixtures used in the production of adobe can also be used as plaster for mudbrick walls. It was concluded that the use of phosphogypsum in adobe production would not only be effective in solving the waste problem, but would also be useful in improving the weak properties of adobe (Değirmenci 2008b).

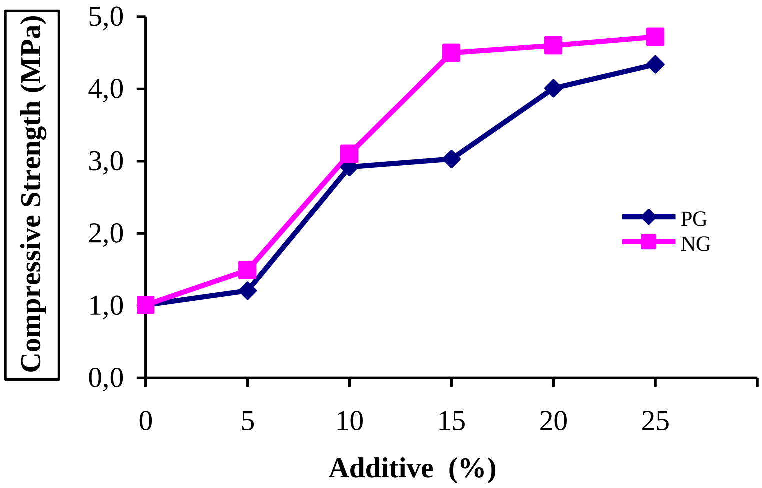



**Figure 2.** Compressive strengths of adobe specimens produced with phosphogypsum (PG) and natural gypsum (NG) additives (Değirmenci 2008b:1222).

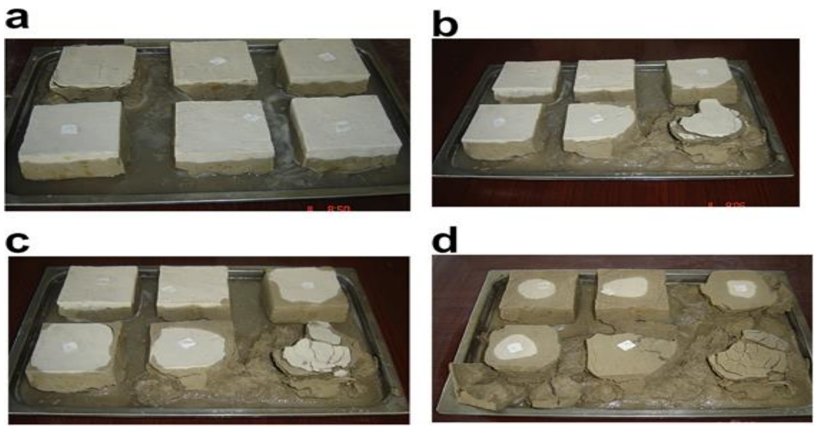



**Figure 3.** Visual appearance of adobe specimens produced with phosphogypsum additives after 30 min. (a), after 45 min. (b), after 60 min. (c), and after 145 minutes (d) in the sludging test (Değirmenci 2008b:1223).

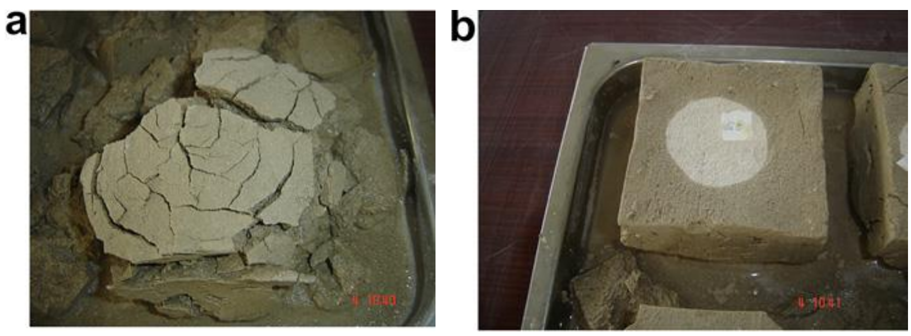



**Figure 4.** Visual appearance of adobe specimens without phosphogypsum additive (a) and with phosphogypsum additive (b) after 145 minutes in sludging test (Değirmenci 2008b:1223).

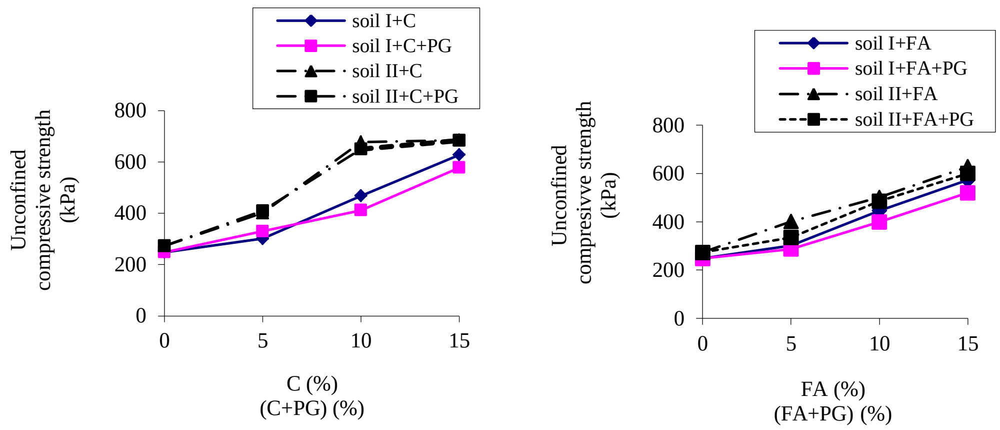
In another study, Bağfaş Fertilizer Factory waste phosphogypsum was used in the production of adobe with thermal power plant waste fly ash and lime. Slaked powdered lime at the rate of 10% and fly ash at the rate of 20% of the total dry mix weight were used and the phosphogypsum/soil ratios were chosen between 0.25 and 2.50. Compressive strength, dry unit weight and capillary water absorption values of the prepared specimens were determined. In addition, the compressive strength test was applied on the specimens kept in water for 24 hours and it was observed that the compressive strength values in both cases met the values predicted in the standard (Değirmenci, 2005).

### 3.4. Use of Phosphogypsum in Road Construction

The physical and mechanical effects of industrial wastes such as phosphogypsum, marble dust, fly ash, and glass dust on asphalt concrete wear layer were investigated. Marshall's method was applied to the specimens prepared using varying bitumen content and the optimum bitumen content was determined as 4.9%. In order to determine the effect of water on the cohesion of compacted bituminous mixtures prepared with fixed bitumen amount and 0% stone dust-7% industrial waste filler, Marshall test was performed and the variation of stability and yield values were investigated. The test results show that phosphogypsum can be used as an industrial waste filler in bituminous hot mixtures at a rate of 7% instead of stone dust filler (Üstünkol and Turabi, 2010).

### 3.5. Use of Phosphogypsum in Geotechnical Applications

It is necessary to take precautions in advance for the problems that may arise in the engineering structures (highway, airport and railway pavements, water structures, retaining walls, etc.) to be built in the layers with cohesive soils. Many stabilization works are carried out to control the behavior of such soils with liquefaction potential, excessive settlement problem, insufficient bearing capacity and swelling potential. Chemical additives such as cement, lime, bitumen and fly ash are used as one of the most economical methods for stabilization of such soils. In recent years, the use of waste materials as chemical additives has gained importance due to environmental impacts. Considering that the use of waste materials in soil stabilization will contribute both to the economy and to the solution of environmental pollution problem. Phosphogypsum was used as an additive material with cement and fly ash in the stabilization of two different cohesive soils with high clay and silt content (soil class CH and MH). It was reported that the use of phosphogypsum with cement and fly ash decreased the plasticity index of the soils, increased the dry unit weight, decreased the optimum water content and increased the free compressive strength (Figure 5) (Değirmenci et al., 2007).




(a) (b)

**Figure 5.** Compressive strengths of soils stabilized with cement (C) and cement+phosphogypsum (C+PG) (a), fly ash (FA) and fly ash+phosphogypsum (FA+PG) (b) (Değirmenci et al., 2007:3397).

In another study, phosphogypsum was used with boron wastes at 0%, 5%, 10% and 15% for stabilization of cohesive soils. 10% and 15% phosphogypsum additives decreased the plasticity indices, increased the maximum dry unit volume weights and water requirements, caused lower deformations at the same stresses and increased the free compressive strengths (Tülek et al., 2014).

## 4. CONCLUSION AND DISCUSSIONS

The need for food is increasing in direct proportion to the increasing population in the world. In order to meet the increasing food demand, the use of fertilizers in agriculture is inevitable. As a result of increasing fertilizer production every year, the amount of waste material obtained is also increasing and the storage or disposal of these wastes has become a major problem. These wastes are usually stored on agricultural lands or dumped into the sea and rivers. The open storage of such wastes damages agricultural crops, is spread by rain and wind, and has harmful environmental impacts such as dusting, leaching into the soil and thus carrying toxic substances. Due to these environmental problems, the quality of water and air deteriorates and negative consequences arise in terms of the economic status of the region.

The phosphogypsum waste product, which is the subjected of this study, resulting from the production of phosphorus fertilizer from the Bandırma Bağfaş Fertilizer Factory, is stored in the open and this situation causes environmental pollution. In our country, there are phosphoric acid factories in Samsun, Bandirma, Mersin and Iskenderun and phosphogypsum is produced as waste around 3 million tons per year. It is very important to reuse waste materials, prevent losses in agricultural areas and contribute to the economy by eliminating wastes that may harm human health. One of the areas where phosphogypsum from Bagfas Fertilizer Plant waste can be utilized in large quantities is the construction sector. In the construction sector, phosphogypsum has been used as an additive material in cement production to adjust the setting time, in brick and block element production, in road and soil stabilization, and in adobe production. The phosphate industry is investigating the beneficial use of phosphogypsum in different fields to reduce the amount of phosphogypsum piles, which are released as a large amount of waste during the production of phosphoric acid, and at the same time to prevent environmental damage.

Considering that the $^{226}$Ra concentration of fertilizer factory wastes can sometimes exceed international limits, it should be preferred to use phosphogypsum in combination with other conventional or industrial wastes instead of using it alone in the production of building materials. Considering the radionuclide concentrations in the content of phosphogypsum used as an additive in the preparation of building materials, the amount of phosphogypsum substance to be used should be reduced as a percentage, so that radionuclide concentrations can be reduced below the permissible limits and phosphogypsum can be used in the production of building materials. It should not be ignored that people may be directly exposed to radioactive substances as phosphogypsum is present in building materials at very high rates as raw material.

One third of our fertilizer consumption belongs to phosphorus fertilizers and therefore the importance of phosphate as a raw material in production is obvious. Due to the low grade of phosphate reserves in our country and high production costs, phosphate rock used as raw material in fertilizer production is mainly imported from countries such as Tunisia, Morocco, Jordan and Israel. The natural structure and properties of phosphogypsum depend on the composition and quality of phosphate rock. Phosphogypsum contains various pollutants in varying concentrations depending on the region where the phosphate rock is mined. It is thought that by importing phosphate rock with the lowest concentration of radioactive substances, environmental pollution that may occur can be prevented.

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