مـجلــة جـــامعــة بــــابـل للعلـــــوم الهندسيـة مـجلــة جـــامعــة بــــابـل للعلـــــوم الهندسيـة مـجلــة جـــامعــة بــــابـل للعلـــــوم الهندسيـة
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Investigations on Recycling Methods of Gypsum Plaster Waste (Review)

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Abstract

Humans need to keep on the clean environment in order to refine suitable life for the next generators. Where, the different industries formed by human, cause the environmental pollution by landfill with wastes produced from it and cause the consumption of fresh raw materials. One of these industries, is gypsum plaster industry. Where, a large amount of gypsum plaster waste is produced from different fields that use the gypsum plaster. Therefore, it is necessary to work on reduction of these wastes by reusing or recycling them with the least costs and procedures. This study aims to review the ways used to reduce gypsum waste amount and to figure ant the best among them. It can be concluded that the best ways to reduce the gypsum waste amount are by recycling it with the least costs or reusing it without any additional procedures.

Key words: Plaster of Paris, Recycling, Gypsum waste, Plaster industry.

INTRODUCTION

Reusing of several materials waste in ceramic industry has been largely investigated through the last periods in order to avoid landfilling with these wastes as well as to economically rationalize the great manufacture costs which relate with the ceramics fabrication [1- 7].

Gypsum plaster, which is also commonly named plaster of Paris (POP) and the reason for this nomination as a presence of the great deposits of gypsum on Montmartre in Paris, manufactured with a heating of the gypsum larger than 150°C in presence of air. The resultant gypsum involves just half amounts of hydration water, which is named the gypsum beta hydrate or hemi hydrate [8].

There are another locations for the gypsum, where the foremost deposits are presented in France, Poland, West Germany, Australia and United States. There are also abundant gypsum deposits in Ethiopia [9].

The chemical formula of gypsum hydrated is ($CaSO4.2H2O$), which is sulphur 18.62%, calcium 23.28%, oxygen 55.76% and hydrogen 2.34% . Gypsum hydrated has been utilized largely in many habits in the manufacturing of construction, architecture, medicine, agriculture and art. Cork and Sharp evaluated the amount of gypsum and anhydrite was manufactured in 2004 which was about 102 million tons [10]. The production had developed to 250000000 tons across the world [11].

Hydration and dehydration of gypsum: it can be well recognized three polymorphs of gypsum which are formed as the diverse preparation ways, impurities, crystal morphology, derivatives and supplements. Both the two types of hemihydrates (α and β hemihydrates) suffer the reactions of hydration in slightly diverse mechanisms attended with exothermic variations. Mixing of gypsum with water forms a pastes contained interlocking structures. These structures are responsible for the strength of gypsum setting [12].

Vazquez-Almazan et al. showed that the heating of calcium sulphate dehydrate (gypsum) results in the dissociation of 21% of water from the mineral before the evaporation process, which results in the formation harder calcium sulphate hemihydrate. Endothermic decomposition reactions happen in this process [13]:

$$CaSO_4.2H_2O + heat \rightarrow CaSO_4.1/2H_2O + 3/2\ H_2O \qquad (A)$$

$$CaSO_4.1/2H_2O + heat \rightarrow CaSO_4 + 1/2H_2O \qquad (B)$$

Plaster of Paris preparation: plaster of Paris ($CaSO_4.0.5H2O$) is produced with gypsum heating about (150 ^oC /300 ^oF or 423K) as shown in equation (A). Heating of gypsum about 423 K results in the loss of water molecules from it and converts calcium sulfate hemihydrate, which is called the plaster of Paris. On the other hand, a mixing of dry plaster of Paris with water results in the re-structure of it into gypsum. The hardening and setting process starts about 10 minutes after mixing process and completes in around 45 minutes [9].

Yu and Brouwers stated that in the hydration reaction, the water quantity required to the hemihydrate is critical. The setting and hardening mechanisms of plaster of Paris have been clarified with the theory of crystalline. Using of fine dehydrate generally results in the acceleration of hydration for a required time of setting via varying the rates of nucleation in dehydrate produced. The gypsum hardened contains a large percent of the porosity, thus it is not considered a compact solid. The strength of gypsum develops through setting process due to the rapid formation of linked ground of β-dehydrate needles (crystalline matrix), subsequently the internal stress is relieved and the excessive water is removed [11,14].

Gypsum plaster characteristics: gypsum plaster (plaster of Paris) is generally described as a white dry plaster powder. It can be molded as the desired shapes and can be efficiently made alter with abrasive sheets or even metal devices. When a large amount of plaster of Paris is used, it often needs an external support because of plaster of Paris strength is not as strong as other compounds. It is usually used by a form of the quick-setting paste mixed with water [8].

Applications and uses of gypsum: gypsum plaster is considered a accepted selection in the construction because of the abundant natural presence of gypsum and its characteristics, where it is easy response to heating, water and rehydration. From the gypsum advantages, it is not dangerous to the plants and humans. Due to its union with water, the gypsum is used as an additive to soil because it improve soil chemistry and physics. It is considered the outstanding supply of sulphur and calcium to feed the crops, mainly with crops like peanuts, alfalfa, cotton and wheat [8].

From its medical uses, gypsum has been utilized commonly as a bear to the fractures (broken bones). A cast of gypsum is called an orthopedic cast when it is formed to bear and keep the true place of the broken part of the bone. On the other hand, this usage is gradually being substituted with fibre glass. Also in dentistry, plaster of Paris is utilized in a models of

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مـجلـة جـــامعة بـــابل للعلـــوم الهندسية

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مـــجلة جـــامعة بـــابل للعلـــوم الهندسية مـــجلة جـــامعة بـــابل للعلـــوم الهندسية مـــجلة جـــامعة بـــابل للعلـــوم الهندسية

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the oral tissues. These models easily give the optimum description for the measurements and shapes in the anatomical configuration in the teeth and its structures [15].

While in art, the most of frescos in Europe are made by painting on a fine layer of wet plaster named intonaco, such as Michelangelo's Sistine Chapel ceiling, which considered from the great classical wall painting works in Europe. The way used for the colours sinking into the frescos is the same way used in a formation of the plaster itself. A secco top of the dry plaster might be used in the extra work, however, this work is usually less tough. In this state, plaster is named stucco and it is considered a far simpler material than wood or stone in making reliefs, and it is usually used in the reliefs of building walls in the world [9].

Recycling is the process which uses the materials waste in a production of new products to avoid a landfill with these waste materials that causes the pollution, decrease a consumption of the raw materials, also decrease the energy utilization, in addition to decrease the pollution of air resultant of burning and the pollution of water resultant of landfill with decreasing the needing to general waste disposal, finally, minor greenhouse gas releases in comparison with the origin production. Process of recycling is considered a key constituent of the recent waste reducing, and it is formed the third part of the "Reduce, Recycle and Reuse" chain of command of waste [16].

The aim of this work is to know the best ways to decrease the gypsum waste quantity sent to landfills by reusing or recycling it. Thus, a reduction of the pollution, a decreasing of the raw materials consumption and a decreasing of the energy utilization.

Gypsum is usually found among the wide variety of demolition and construction waste (DCW), this material is being progressively utilized in a many applications of the civil construction, comprising precast moldings (decorative moldings, crown moldings and trim), suspended ceilings (which is plasterboard ceilings), internal wall linings, plasterboard, etc. [17, 18]. There is no economically a possible technology or an application has been improved to allow by recovery or recycling of the construction and demolition waste. However, this waste produces sulfuric gas when wrongly discarded, this gas is flammable and toxic [17]. The gypsum is being reused and the recycling techniques have been developed to decrease a quantity of the waste of gypsum sent to land filling, also in the inert waste land filling [19], increasing the development of new technology for gypsum utilization and companies of its recycling. A great companies have utilized the gypsum recycled for a production of the drywall in Europe [20] and Canada [21]. This procedure is possible since gypsum waste can be separated of additional wastes and can be grinded and burned to recuperate its binding characteristic [18]. New researchs [17, 21, 22] have utilized calcined and recycled gypsum for obtaining the gypsum paste to the interior coatings, and it have explained the influences which may affect the mechanical and physical characteristics of this material.

Other recent study has used the gypsum waste resulted from demolition and construction waste as a substitute material to part of the fine aggregate in the mortar preparation. Where, this work was aimed to decide a substitute way to decrease the using cost for this type of construction and demolition waste, by eliminating the calcination step. In this work, morphology, specific mass, particle size distribution and elemental composition of the gypsum waste powder were examined [3]. Fig. 1 shows some of results for this study. Fig. 1a shows the morphology, where an irregular shape for the porous crystals of the powder of gypsum waste exhibits a β-hemihydrates morphology [3, 23]. While, Figure. 1b displays the chemical composition for the powder of gypsum waste, tested with EDS/SEM, the result of this test was identified a presence of three elements, S, O and Ca, in the gypsum waste powder in agreement with the gypsum formula ($CaSO_4$) [23], indicating there is no a

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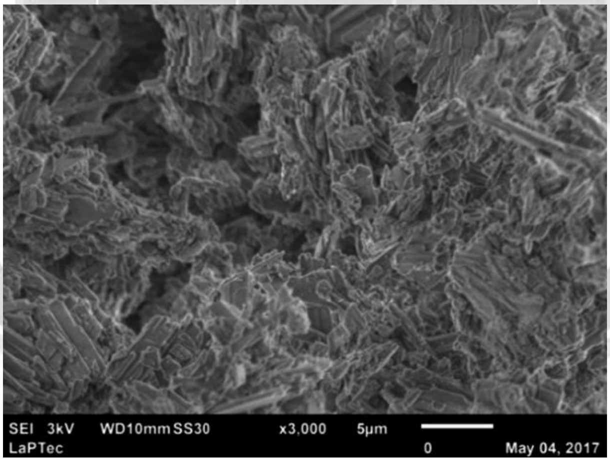
contaminants present in this waste [3]. Finally, Fig. 1c shows the granulometric analysis of the gypsum waste powder. Where, a distribution of particle size of the gypsum waste powder, resulted from the crushing process, was into the range identified by NBR 7214 [24], consequently approving its usage substituting sand in the mortars production. A specific mass of the gypsum waste powder (1.10±0.01 g/cm³) is less than that of sand (2.6 g/cm³) [25], denoted a possibility of the obtain on the lesser density for the mortars contained these wastes. a mixing design with a ratio 1:3 (cement: sand) was used to prepare a test specimens of this study, in addition to the gypsum waste powder as a substitute material of a part of sand in the percent of (30, 20,10 and 0%) in volume. The fresh mortar consistency was assessed, and compressive and flexural strength, water absorption, apparent density, specific mass and voids index of the specimens were determined. The mechanical strength of the specimens after 28 day surpassed the limits identified with NBR 13281 standard, showing that up to the percent (30%) of the ground gypsum waste can be involved in the mortar. While , the apparent density for the samples with (30%) of the gypsum waste powder substituting by sand was about 5% less than that of the samples without the gypsum waste. This use represent an advantage for an utilization of this gypsum waste in the plastering and bricklaying ceilings and walls. Thus, the assumed substitute not only provides the reduction of a discarding of the gypsum waste in land filling but also permits with its use in the practical application without a needing to the calcination, providing of the growth for new material to further environmental value [3].



a)

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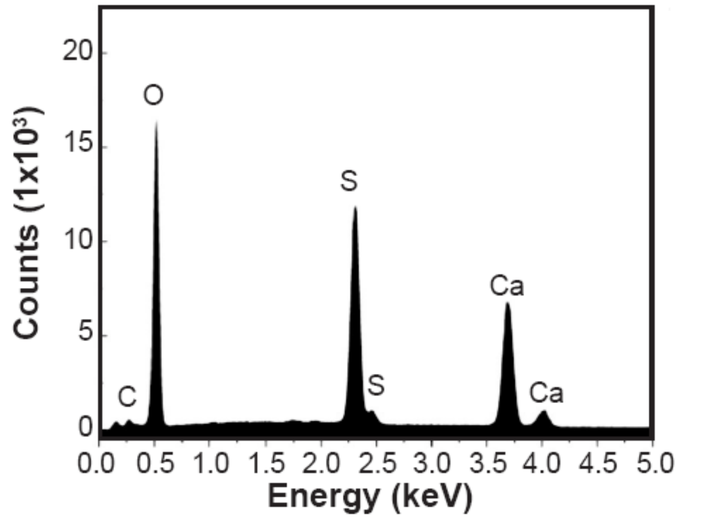

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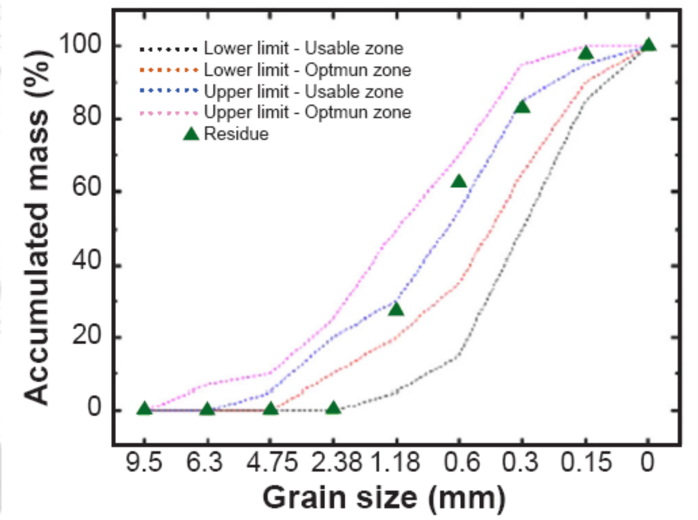
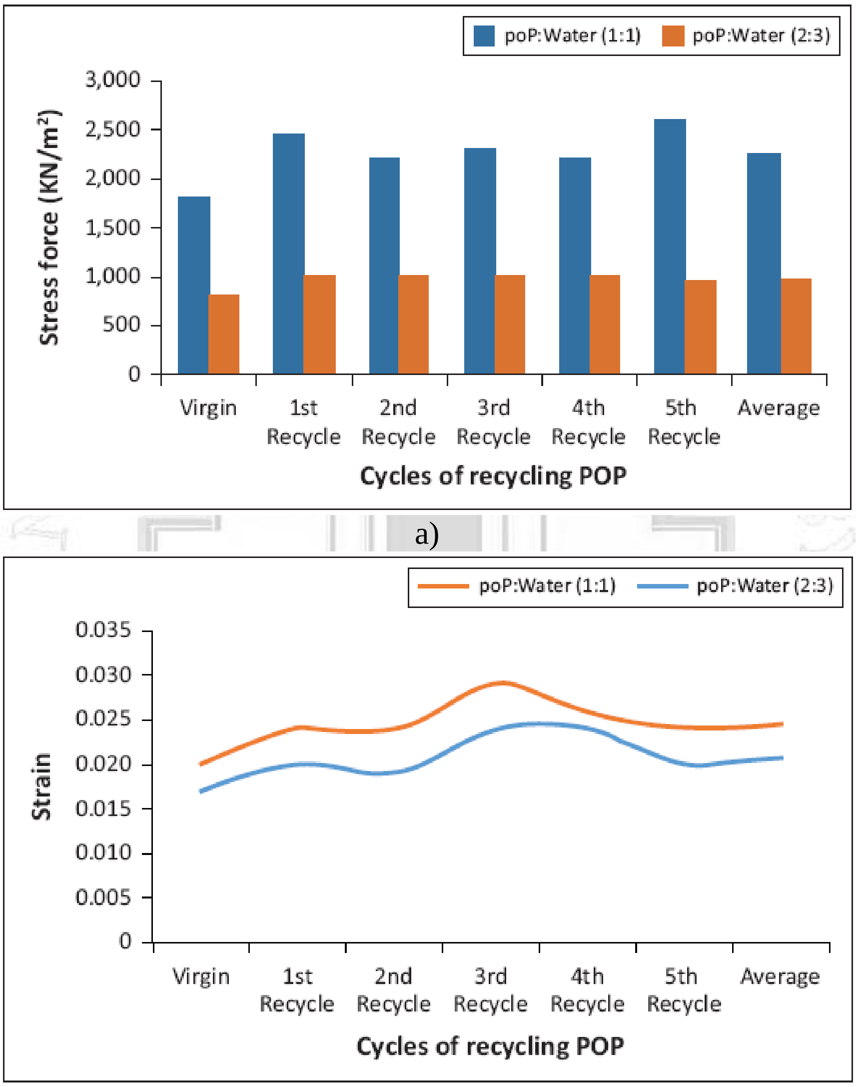


c)

Figure 1: (a) SEM Micrograph, (b) EDS Spectrum of the Gypsum Waste Powder, and (c) Curve of Particle Size Distribution [3].

S. Shiyo and et al. researched to recycle plaster of Paris models which use in the field of medicine (body segments in prosthetics and orthotics), also evaluated a reuse of these models in production of new models with the same qualities, subsequently reduction of the environmental pollution. The followed method was by breaking the waste of unwanted models for the small parts, and removing the impurities and dirt from these waste; then milling, washing, drying and crushing from these waste. The plaster of Paris powder was heated in order to remove the crystalline water for determining the number of times for its recycling with retaining the wanted strength, working characteristics and setting time. The mixing ratios used in this work for the plaster of Paris and water were (1:1) and (2:3). Results of this study showed that the recycled plaster of Paris was stronger in terms of the compressive strength and strain, and has upper setting temperatures than the virgin plaster of Paris as shown in Fig. 2, and there was no variance in the properties of working between the virgin and recycled plaster of Paris. From the distinct conclusions for this study is in controlled circumstances, like heating temperature, time, avoidance of contamination and grinding size, utilized plaster of Paris could be recycled continuously, exhibiting the workable and stronger casts [8].



b)

Figure 2: The Effect of Mixing Ratios for Plaster of Paris with Water on (a) Compressive Strength and (b) Strain for Cycles of Recycling Plaster of Paris [8].

Other study has investigated the microstructural description for two kinds of the recycled gypsum plaster (which are marked with RGP-1 and RGP-2) in addition to commercial gypsum plaster (CGP) to evaluate the formation of crystals for these types of the recycled gypsum plaster which have diverse particle sizes developed from the recycling process and also for commercial gypsum plaster. Where, SEM was used to observe morphology of these crystals in both commercial and recycled gypsum plasters as shown in Fig. 3. Results of this study showed a presence of the obvious similarities among these crystals of different plasters types. This similarity in the microstructure for the different plasters types denoted the correspondence of the chemical composition in these types, formed by β-hemihydrate. Thus,

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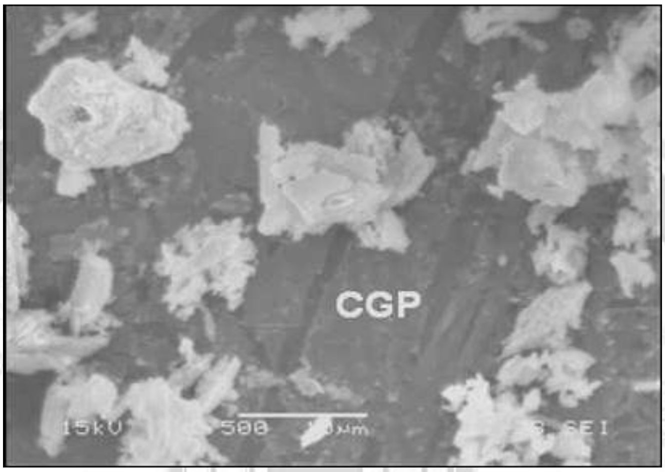
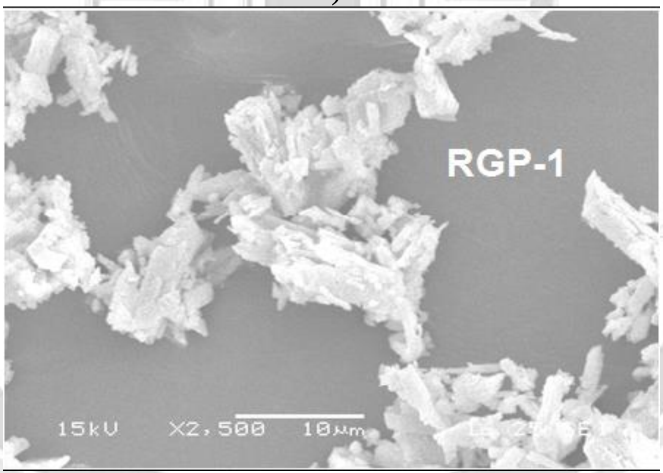
these different plasters types (commercial and recycled gypsum plaster) exhibit a similar performance and subsequently show the possibility of reusing it for the recycled gypsum plaster in the same purposes in which the commercial gypsum plaster is used, and thus, a reduction of the consumption of gypsum ore [26].



a)



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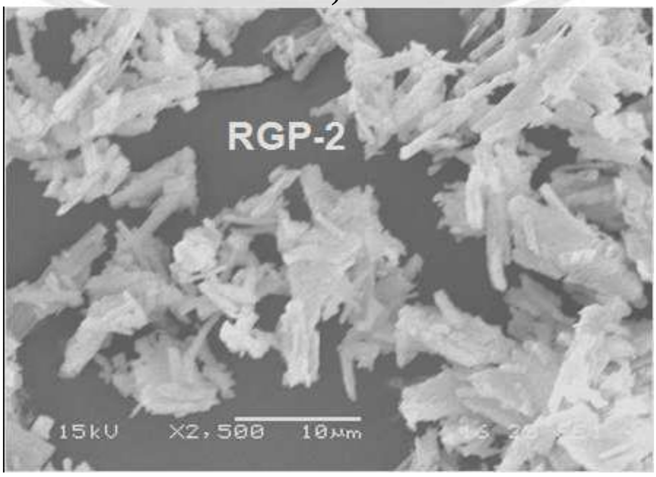

c)

Figure 3: SEM Images of a) Commercial Gypsum Plaster (CGP), b) Type 1 of Recycle Gypsum Plaster (RGP-1), and c) Type 2 of Recycle Gypsum Plaster (RGP-2) [26].

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In thesis research, T. A. Bekele studied an effect of the calcinations temperature and time for recycled plaster of Paris from the waste of gypsum moulds on some of its properties, such as the compressive strength, the time of setting, the water absorption and other physical characteristics. A results of this work showed that there was a big possible for recycling plaster of Paris from the waste of gypsum moulds and utilizing it in the process of casting for the ceramic manufacture mostly since it reductions the cost of production for buying virgin plaster of Paris, and also showed that the recycling plaster of Paris from the waste of gypsum moulds exhibits the improvement of process of environmentally friendly with reducing the waste of gypsum moulds which go to an open air removal [9].

Other thesis research investigated a ceramic pottery body produced by the use of a diverse composition of the waste plaster of Paris, beginning with (0 % wt.) to (12 % wt.). The specimens were examined by viscosity test and its green body was experiential, in addition to the physical properties, the mechanical properties and the description of the raw material utilized through analysis of particle size, analysis of thermal, and recognition of its purity. From the results obtained of this research, it can be completed that the waste plaster of Paris can be successfully utilized as a filler to improve the characteristics of ceramic pottery body [27].

CONCLUSIONS

Although the studies of recycling of the gypsum plaster waste were limited, it can be concluded from the studies above that the gypsum plaster waste can be recycled or reused in many fields after a few procedures for this waste. Where, the gypsum plaster can be shaped via a thermal treatment for recycled powder of gypsum, and the gypsum plaster could be recycled frequently by the same way without changing the working characteristics and required setting time of it, in addition to improve the compressive strength of recycled gypsum plaster casts. Consequently, the recycling of gypsum plaster waste could reduce the environmental pollution by landfill with these wastes, the consumption of gypsum ore and the importing cost of new gypsum plaster. The best ways to decrease the quantity of gypsum waste sent to landfills is by recycling it with the least costs or reusing it without any additive procedures. However, further studies on reusing or recycling the gypsum plaster waste in the different fields are needed.

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تحريات عن طرق إعادة تدوير مخلفات البورك

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4 كلية هندسة المواد, جامعة بابل, بابل, عراق

الخلاصة

يحتاج الإنسان إلى الحفاظ على البيئة التي يعيش فيها من أجل أن تبقى مناسبة للحياة للأجيال القادمة. حيث تتسبب الصناعات المختلفة التي يشكلها الإنسان في تلوث البيئة من خلال الطمر بالمخلفات التي تنتج عنها وتتسبب في استهلاك مواد أولية جديدة. من هذه الصناعات، صناعة البورك. حيث يتم إنتاج كمية كبيرة من مخلفات البورك من مجالات مختلفة يتم فيها استخدام البورك. لذلك من الضروري العمل على الحد من هذه النفايات عن طريق إعادة استخدامها أو إعادة تدويرها بأقل التكاليف والإجراءات. تهدف هذه الدراسة إلى مراجعة الطرق المستخدمة لتقليل كمية مخلفات البورك ومعرفة أفضلها. يمكن الاستنتاج أن أفضل الطرق لتقليل كمية مخلفات البورك بإعادة تدويرها بأقل التكاليف أو إعادة استخدامها بدون أي إجراءات مضافة .

الكلمات الدالة: البورك، إعادة تدوير ، نفايات جبسية, صناعة البورك.

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