PERFORMANCE OF RED GYPSUM AS CEMENT REPLACEMENT IN MORTAR

TONY CHONG SOON FUNG

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Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

More than 400 hundred tons of red gypsum (RG) has been produced in Bukit Besi,Terengganu every year. Currently, the utilization of industrial by product in mortar or concrete is priority due to environmental and economical concerned. The goal of this study is to investigate the perfornance of the Red Gypsum as cement replacement in mortar. There are 4 different mixtures of RG weight proportions were prepared and tested (0%, 5%, 10%, 15%). All specimens were cured in water and air at 3,7,14, and 28 days. The density, compressive strength, water absorption and porosity values were recorded. The results showed that 5% of the RG mixture is nearest and a comparable result with the control specimen. The replacement of cement with RG in the mortar mixture leads to reduction of the industrial waste deposit to the landfill. With the reduction of cement usage there would be less release of CO_2 into the atmosphere in equivalent proportion. The usage of waste material will also reduce the cost of the project.

ABSTRAK

Lebih daripada 400 ratus tan gipsum merah telah dihasilkan di Bukit Besi, Terengganu setiap tahun. Penggunaan produk dalam mortar atau konkrit adalah diutaman untuk menjaga alam sekitar dan ekonomi di industri. Matlamat kajian ini adalah untuk menyiasat keberkesanan Gypsum Merah sebagai pengganti simen dalam mortar. Terdapat 4 campuran yang berbeza perkadaran peratus RG telah disediakan dan diuji (0%, 5%, 10%, 15%). Semua spesimen diawet di dalam air dan udara di 3,7,14, dan 28 hari. Nilai ketumpatan, kekuatan mampatan, penyerapan air dan keliangan telah direkodkan. Hasil kajian menunjukkan bahawa 5% daripada campuran RG adalah terdekat dan hasil setanding dengan spesimen kawalan. Penggantian simen dengan RG di dalam campuran mortar membawa kepada pengurangan deposit sisa industri ke tapak pelupusan. Dengan pengurangan penggunaan simen akan ada pembebasan kurang CO_2 ke atmosfera di bahagian yang sama. Penggunaan bahan sisa juga akan mengurangkan kos projek.

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RG	Red Gypsum
ASTM	American Society Fot Testing and Material

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

More than 400 hundred tons of red gypsum (RG) has been produced in Bukit Besi,Terengganu every year. Currently, the utilization of industrial by product in mortar or concrete is priority due to environmental and economical concerned. The goal of this study is to investigate the performance of the RG as cement replacement in mortar.

Red gypsum is a kind of waste product that produced during the production of titanium dioxide in the industry. Red gypsum is a waste from industrial process for titanium dioxide industry(Fauziah, Zauyah, & Jamal, 1996). Chemical process is required for the processing of red gypsum in industry. Waste product Red gypsum is produced by illuminate of sulphuric digestion and neutralize of spending acid with calcium carbonate in extraction of titanium dioxide (Fauziah et al., 1996).

Red gypsum had become one of the waste materials that used for partial replacement of cement in the industry nowadays. Red gypsum is being used as substitute for natural gypsum in cement production nowadays(Conference, Recycling, & Madrid, 2009). Red gypsum also can help to lower the production quantity of cement in industry. Moreover, the use of red gypsum as raw material for construction will also lower the production cost since the waste product able to mix well with the cement. The low cost of titanium's waste is a strong motivation to consider in manufacturing cement because it will lower the cost production(Potgieter, Horne, Potgieter, & Wirth, 2002). In tern of safeness, red gypsum is a very safe and good material for construction even it is a chemical waste product. Red gypsum can be used as the component for the

construction material because it doesn't contain any radiological consequence (Conference et al., 2009).

Malaysia has become part of development country in 21th century. The overconsumption of natural resources will be contributing greatest problem to the environment. This is because the mining process during the production of natural resources will bring large impact to the environment. Mining of natural resources bring impact to the environment problem based on GIS technology and probability integration method (Song et al., 2012).

1.2 PROBLEM STATEMENT

Cement is one of the very important raw materials in construction industry. Malaysia is one of the countries which undergo development in Asia. The higher rate of the construction had caused the increase rate of demand for production of cement in factory. Cement factory emitted Carbon dioxide during the production to the surrounding. Carbon dioxide (CO_2) is a by-product of chemical conversion process during the production of clinker in cement factory (Guidance, n.d.). Almost 5-7% of CO_2 is contributed by the cement industry in global (Benhelal, Zahedi, Shamsaei, & Bahadori, 2013). The amount of CO_2 emitted to surrounding is based on the amount tonnage production in factory. The production of one tonnages of cement will caused released of 900 kg of CO_2 to the atmosphere (Benhelal et al., 2013). From the latest cement production record, Malaysia had produced 19,500 thousands metric tons of cement in 2010 (Indexmundi, 2013). Hence, Malaysia had produced 17.55 million of CO_2 to the atmosphere. The emission of CO_2 will cause to serious greenhouse effect to the global.

In addition, the demand output of red gypsum increased year by year due to long term productivity of Titanium Dioxide by the industry. Malaysia had produced 340,000 tons of red gypsum in a year (Kamarudin & Zakaria, 2007). If the waste cannot dispose in a proper way, it would lead to social and environmental problem. Moreover, the red gypsum which contains the chemical material will cause dead to the plantation and will cause pollution to the water. Red gypsum contain the heavy materials that will absorb

by the plant or flow into groundwater (Fauziah et al., 1996). Hence, by using RG as cement replacement in the mortar mixture leads to reduction of the industrial waste deposit to the landfill. Furthermore, with the reduction of cement usage there would be less release of CO_2 into the atmosphere.

1.3 OBJECTIVES OF STUDY

The goal of this study is to investigate the performance of the Red Gypsum as cement replacement in mortar. The specific objectives of this study are:

1.3.1 To determine the workability, consistency and stability of fresh properties of RGM mixes

1.3.2 To determine the oven dry density, water absorption and porosity of RGM mixes

1.3.3 To determine the compressive strength of RGM mixes

1.4 SCOPE OF STUDY

The goal of study is to investigate the performance of red gypsum (RG) as cement replacement on the properties of mortar. It is focused on the influences of red gypsum on the workability, density, compressive strength, water absorption and porosity of mortar due to water and air curing at 3,7,14 and 28 days. The study is divided into four main stages as follow:

i. Stage 1 is to prepare the RG for the XRF and sieve analysis test. It is to examine the chemical content (CaO, SiO2 and Al2O) and the particle size of RG. All the RG used is provided by UMP Green Technology Sdn. Bhd.

ii. Stage 2 is to prepare the RG for the cement replacement in the mortar mixtures as stated in Table 1.1. The percentage of RG used based on

total mass of cement which Mix I was 100% cement used as control sample, Mix II was cement replaced with 5% RG, Mix III was cement replaced with 10% RG, and Mix IV was cement replaced with 15% RG.

iii. Stage 3 is to prepare and analyze the mortar and RG mixtures workability by using flow table test

iv. Stage 4 is to prepare and analyze the hardened properties of the mortar and RG mixtures. All the testing has been performed according to density test; ASTM C513-11, Compression test: ASTM , Porosity test; ASTM C642-13 and Water Absorption Test; ASTM C1403-00.

All the material and specimens preparation are conducted based on standard code of practice design requirement of ASTM at FKASA Laboratory, Universiti Malaysia Pahang, Gambang Malaysia.

Table 1.1: Number of Samples and Test For Laboratory Work

	Mixtures	2.5% RG + OPC (Mix A)			5% RG + OPC (Mix B)			5% RG + OPC (Mix C)			OPC (Control)		
	Days	7d	14d	28d	7d	14d	28d	7d	14d	28d	7d	14d	28d
Number of Sample	**Oven Dried Density Test**	6	6	6	6	6	6	6	6	6	6	6	6
	Porosity Test	6	6	6	6	6	6	6	6	6	6	6	6
	Water Absorption Test	6	6	6	6	6	6	6	6	6	6	6	6
	Compressive Strength Test	6	6	6	6	6	6	6	6	6	6	6	6
Total Sample		108 samples(100mm x 100 mm x 100 mm) 36 samples(50mm x 50 mm x 50 mm)											

1.5 SIGNIFICANCE OF STUDY

The replacement of cement with RG in the mortar mixture leads to reduction of the industrial waste deposit to the landfill. This can avoid waste deposit that could effect on the fertility of the land. Moreover, usage of RG in mixture of mortar can avoid the waste deposit into the river which will cause dead to the aquatic life and water pollution. Hence, the advantage of using RG in the mortar mixture is can be used as part of replacement for cement without affecting the environment.

With the reduction of cement usage there would be less release of CO_2 into the atmosphere in equivalent proportion. The production of 1 tonnage cement will cause emission of 900 kg of CO_2 to the atmosphere. With amount of RG used as replacement for cement, it will lead to less production of cement in the factory and directly proportional reduce the emission of CO_2 to the atmosphere. Hence, using of RG in cement industry can help to reduce amount emission of CO_2 which could cause the thickness of ozone layer in atmosphere.

The usage of waste material will also reduce the cost of the project. With reduce quantity of cement and replace with RG during the production of cement, it will reduce the cost of the cement. This is because the cost during the process of clinker to cement is very high.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed the previous study of cement replacement in mortar. It is important to understand the mortar in term of its materials, production and properties. Figure 2.1 shows the literature review process of this study. However, the reviewed focused on the Red Gypsum potential as cement replacement. It is stated that the best percentages of RG replacement for Portland cement provide better performance in physical properties as well in mechanical properties of fresh and harden state of mortar. Perhaps, using of RG in cement industry can help to reduce amount emission of CO_2 which could cause the thickness of ozone layer in atmosphere and reduce the cost of the project.

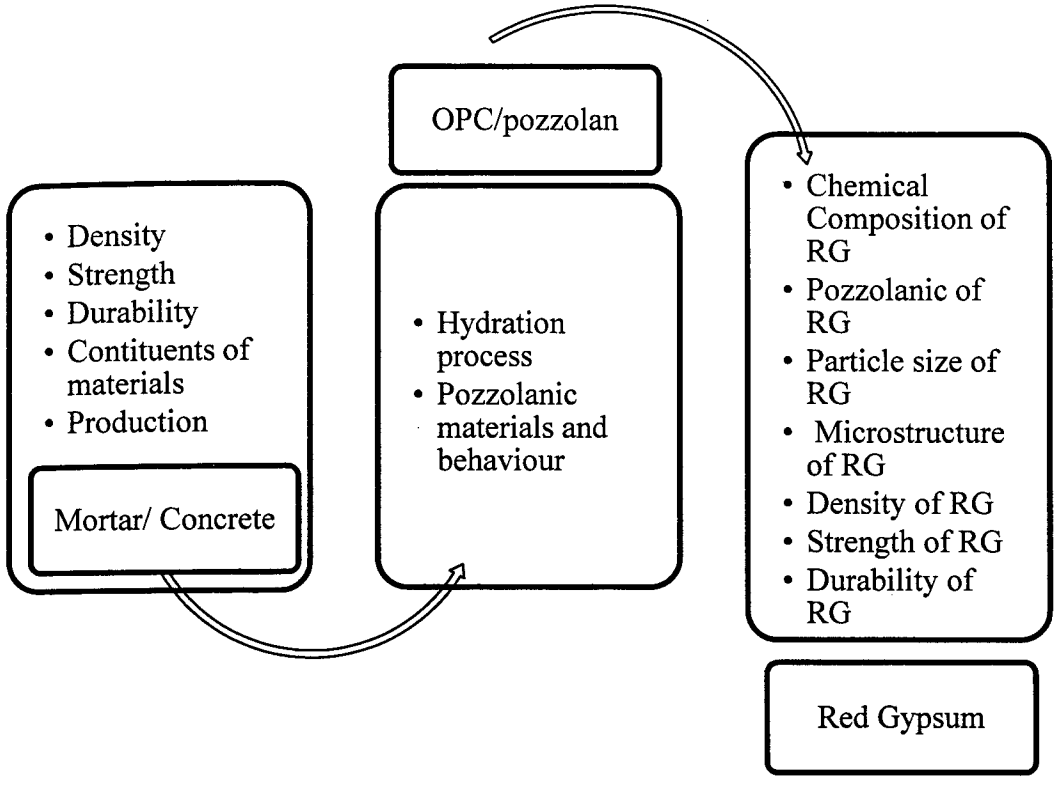

Figure 2.1: Literature review process.

2.2 MORTAR

Mortar and concrete are made of different ingredient. Mortar is a mixture of sand, cement and water for the construction purpose use. A mortar is a mixture material which resulting mainly of cement, sand and water (Palomo, Puertas, & Fortes, 1981). Mortar is a mixture of binder, sand and water which in plastic state and can be trowelled into place and set in-situ (David, 2007). Meanwhile, the main ingredients that made of concrete are water, sand, cement, fine aggregate and rough aggregate. Concrete is formed when chemical reaction happen by adding water into the mixture of cement, various sized of sand and gravel which cause harden (Bjorn Johannessen, 2008).

2.2.1 History

Old mortar is the traditional mortar that exists since several thousand years ago. The first gypsum based mortar was used since 10,000 years ago meanwhile the lime base mortar was started operation since 6,000 years ago (European mortar Industry

Organization, 2013). The first lime mortar was used by the Romans. The lime which functions as binder was obtained from burning limestone or sea shell(Age & Monster, n.d.). In this case, the use of lime mortar are weaker, take longer to set and required higher of skill but lime mortar also has advantages including great compatible with soft material, good workability, increase initial adhesion, flexibility, greater porosity, and better weathering properties. Old mortar is function as gasket or separator between the individual masonry block (Age & Monster, n.d.).

Modern mortar purposed as the veneer construction for brick and stone building nowadays. New modern mortar are design to a specific performance and proportion criteria that known as ASTM C-270. ASTM C-270 allowed the cement manufacture use the exact blend of material in order it meet the specific requirement. Besides that, the additives used was improved the workability, extend or shorten the set time, and achieve the ultimate strength earlier. This proportion had improved compare to tradition mortar..

2.2.2 Application in Construction

Mortar has variety functions in the construction industry. The primary function mortar is as binder between the brick. The cement content in the mortar with water form chemical reaction cause it harden and set to bond with brick during construction (David, 2007). With the presence of mortar as the bonding for the brick wall, it provided the stability and strength to the wall. Mortar has function as important role for joining masonry and providing stability to the masonry structure in construction world. According to (Kubica & Gąsiorowski, 2010), mortar serves the purpose as joining masonry to create durability and stable to the masonry structure. Besides that, mortar also provided smooth finish and protect against weathering to the structure building (European mortar Industry Organization, 2013).

In this case there are various types of mortars for the construction's purpose which is, ordinary surface mortar, waterproof mortar and decorative mortar (Zhang, 2001). Hence, different type of the mortar consist its own using purpose. Ordinary surface mortar is normally used as the surface for the building and it smooth and clean

in surface. Ordinary surface mortar doesn't provide strength to the wall. Hence few layer have to apply on the surface of the building in order to provide smooth and uncrack surface (Zhang, 2001). Waterproof mortar is normally mortar which used in the building which are appear in moisture area Moreover, water proof mortar also used in the building deform greatly and sink unevenly. Water repellent will added in the normal mortar to improve it impermeability (Zhang, 2001). Meanwhile decorative mortar is used for plastered the internal and exterior of the building wall. Therefore, colorful cementing or dyes will be mixed in the mortar so that the surface can reveal colorful wall. (Zhang, 2001)

2.3 PROPERTIES OF MORTAR

2.3.1 Density

Density is a unit for weighing the weight of the mortar. The density can be identify based on the fresh state and harden state for mortar. A sample of fresh mortar of minimum volume 50 times greater than the maximum aggregate size (or 1.5 times the quantity needed to perform the test) whichever is the greater is required. Three test samples of regular shape are prepared from the fresh mortar to be tested and cured in accordance with ASTM. Meanwhile for the harden stare of mortar, it required to be cure either by water curing or air curing before density test conduct..

2.3.2 Compressive strength

Compressive strength is a physical criteria used to determine the type of the mortar. According to ASTM C109, mortar type are categorize based on it compressive strength. Mortars are divided into type N, S, and M. Table 2.1 shows the physical requirement of the mortar based on it type. Compressive strength of the mortar are affecting by several factors such as cement content, sand grading entrained air content and water content . Increased of cement contain will give higher strength, meanwhile increase of sand, water and air content will reduce the strength of the mortar ("Educational Guide To Properties of Masonry Mortar," n.d.). Moreover, the minimum

compressive strength for the mortar is design based on the calculation of the mix design concrete.

Table 2.1: Compressive strength of mortar based on the ASTM C-109.

Mortar Type	Minimum Compressive Strength (psi)	Minimum Compressive Strength (Mpa)
N	750	5.2
S	1800	12.4
M	2500	17.2

2.3.3 Water Absorption

According to ASTM, water absorption is the test to determine the relative water absorption by capillary uptake characteristic of mortar. The absorption of water is measure the amount of water absorb by harden mortar. Mortar can be good resist of chemical attack and straining, if it less absorbent (International Mansory Instituate's, 1997). This proved the requirement of mortar specimen in low water absorption condition for the potential of mortar to resist the chemical attack on its surface. Moreover, the higher rate of water absorption of mortar will lower the ability resistance of chemical attack by the mortar itself. The water absorption for mortar effect on the durability of the mortar samples characteristic. Besides that, the water absorption rate will also affect the compressive strength of the specimen as well. The lower the water absorption rate will give a good compressive strength to mortar (Thokchom, Ghosh, & Ghosh, 2009). Table 2.2 show the minimum water retention of the mortar according to type of mortar based on ASTM C1039.

Table 2.2: Water absorption of Mortar based on ASTM C1039.

Mortar Type	Water Retention Minimum (%)
N	75
S	75
M	75

2.3.4 Porosity

Porosity test is the test used to identify the durability of the mortar specimen. The porosity test identifies the percentages air void which consists in the specimen. Porosity test important for identify the durability level of the specimen, because it can identify the rate penetration of water into the specimen.

For the specimen which have high porosity rate result low durability. Hence, reduce porosity of the specimen will increase the durability of the specimen (Syeda, 2012). This happened because the air void consisted in the specimen is higher. Therefore, the liquid will easily penetrate into the specimen.

2.4 CONSTITUENTS OF MATERIALS

The materials that include in production of mortar are water, sand, and cement. In this case, cement play important role as binder for the sand to form mortar. In this case, cement bind with water and turn harder by chemical reaction ("Mortar For Concrete Masonry," 2004). Cement have place in the place which away from water because it very sensitive to water. Cement will turn harden once it near water (Davison, 1977).

Fine aggregate or sand consists of natural and manufactured sand according to ASTM C 144. Manufactured sand is produce through crushing of big stone or gravel. The characteristic of the manufactured sand is sharp and hard. Gradation limit is based on ASTM C 144. According to ASTM C270, water should be clean and free from any deleterious acid or alkali or organic material. In this case the ratio for cement to sand ratio should consider before the designation of mortar. Table 2.3 shows the mix design ratio for mortar based on ASTM.

Table 2.3: Classification type of Mortar based on constituent of materials.

	M	S	N
Strength	5.2	12.4	17.4
Volume Ratio	1:1/4:3	1:1/2:4	1:1:6
	Proportions by Volume		
Cement	0.33	0.22	0.17
Water	0.08	0.11	0.17
Sand	1	1	1

2.5 PRODUCITON OF ORDINARY PORTLAND CEMENT

There are a few steps for production of cement in the factory. In this case, it divided into 4 steps which are extraction and pre-processing of raw material; preprocessing to produce clinker; blending and grinding of clinker to cement; and storage and delivery of cement.

In extraction and pre-processing of raw material, the material for production cement id prepared. The raw materials for cement production are those mineral which containing calcium oxide, silicon oxide, aluminum oxide and ferrous oxide. Meanwhile the raw materials are including limestone, chalk, marl, and shale clay.

For the preprocessing to produce clinker, the mineral of the raw mix are transformed at high temperature into new material with hydraulic properties. The production of clinker takes place in a kiln system in which the minerals of the raw mix are transformed at high temperatures into new minerals with hydraulic properties. This results in an efficient transfer of heat and energy to the raw mix and an efficient removal of pollutants and ash from the combustion process. During the passage of the kiln system the raw mix is dried, pre-heated, calcined and sintered to clinker, which is rapidly cooled with air and stored.

During the blending and grinding of cement clinker process, the portland cement is produced by inter-grinding cement clinker and sulphates such as gypsum and