THE PERFORMANCE OF PALM OIL BOILER STONES (POBS) AND QUARRY DUST AS PARTIALLY SAND REPLACEMENT IN MORTAR

BALKISH BINTI MUHAMMAD ALI

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Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang

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ABSTRACT

Recently there has been a growing trend towards the use of supplementary materials, whether natural, waste or by-product because of ecological, economical and diversified product quality reasons. The compressive strength of mortar is an important property because it usually gives an overall picture of the quality of mortar. Mortar strength development is determined not only by the water-cement ratio but also influenced by many other factor such as the admixtures used and curing condition. One of the many challenges of research work in engineering material is to improve the material in different ways to obtain a better product. The palm oil boiler stone (POBS) and quarry dust are new waste materials and abundantly available has the potential as a replacement for sand in the production of mortar. This study investigates the effects of substitution of POBS and also quarry dust towards the physical properties of mortar which consist of workability and compressive strength. Three types of samples were prepared with the constant water/cement ratio (w/c) of 0.55 and POBS and quarry dust that contains 5%, 10% and 15% in mortar. A total of 63 cube sample specimens 50 mm x *50* mm x 50 mm were prepared for standard testing. The tests that were conducted are flow table test and compression test at curing age of 7, 28 and 60 days. The study also shows that the substitution of quarry dust POBS and improve the workability and strength of mortar until 38.24% which is the highest result for POBS and 17.34% for quarry dust at 28 days. The result of this study indicates that the substitution of POBS and quarry dust aggregates increases the workability and strength of mortar.

ABSTRAK

Baru-baru ini terdapat satu trend terhadap penggunaan bahan tambahan sama ada bahan semula jadi, bahan buangan atau bahan oleh-produk.Kekuatan mampatan mortar adalah satu sifat penting kerana ia memberikan gambaran keseluruhan kualiti mortar. Pembentukan kekuatan mortar ditentukan bukan sahaja melalui nisbah air-simen tetapi juga dipengaruhi oleh banyak faktor lain seperti bahan tambahan yang digunakan dan keadaan awetan. Salah satu daripada cabaran kerja-kerja penyelidikan dalam kejuruteraan bahan adalah untuk meningkatkan kualiti bahan dalam cara yang berbeza untuk mendapatkan kualiti bahan yang lebih baik. Dandang batu kelapa sawit dan debu kuari adalah bahan buangan baru dan kebanyakannya didapati mempunyai potensi sebagai gantian pasir dalam mortar. Kajian adalah untuk mengenalpasti kesan penggantian batu dandang kelapa sawit dan juga debu kuari ke atas sifat-sifat fizikal mortar yang terdiri daripada kebolehkerjaan dan kekuatan mampatan. Tiga jenis sampel telah disediakan dengan pemalar nisbah air/simen 0.55 dan bahan gentian pasir yang mengandungi 5%, 10% dan 15% dalam mortar. Sebanyak 63 kiub spesimen konkrit 50 mm x 50 mm x 50 mm telah disediakan untuk ujian standard. Ujian yang telah dijalankan adalah ujian aliran dan ujian mampatan pada umur pengawetan 7, 28 dan 60 hari. Hasil kajian ini menunjukkan bahawa penggantian POBS dan debu kuari meningkatkan kebolehkerjaan dan kekuatan mortar paling tinggi sehingga 38.24% untuk POBS dan 17.34% untuk debu kuari pada umur 28 hari. Kajian ini menunjukkan bahawa konkrit dengan POBS dan kandungan debu kuari boleh digunakan untuk tujuan galas beban yang disebabkan oleh kekuatan yang tinggi.

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LIST OF ABBREVIATIONS

POBS	Palm Oil Boiler Stones
OPC	Ordinary Portland Cement
PCM	Polymer Cement Mortar
ASTM	American Society for Testing and Materials
BS	British Standard
BSI	British Standards Institution
CO_2	Carbon Dioxide
POC	Palm Oil Clincker
OPS	Oil Plam Shells
PKS	Palm Kernel Shells
EFB	Empty Fruit Bunches
POFA	Palm Oil Fuel Ash
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 Background

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete and mortar works industry needs to be found. River sand is most commonly used fine aggregate in the production of materials for construction poses the problem of acute shortage in many areas. Whose continued use has started posing serious problems with respect to its availability, cost and environmental impact.

This research focuses on a study of the strength mortar with quarry dust and also palm oil boiler stone (POBS) as partially replacement of sand. For quarry dust, the sources are obtained from the industrial in Malaysia. Presently, in ceramics industries, the production goes as waste which is not under recycle process yet. In this study, an attempt has been made to find the suitability of the quarry dust as possible replacement for sand. Another material used in the formation of foam concrete is quarry dust as partial material replacement. Quarry dust is classified as fine material obtained from the crushing process during quarrying activity at the quarry site. In this study, quarry dust will be studied as replacement material to sand as fine aggregate. Quarry dust has been use for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. (M Safiuddin et al.) Quarry dust is a waste from quarry factory and can be obtain easily .For size specification, quarry dust has been selected since it is finer waste material and by utilizing the quarry dust as sand replacement perhaps could increase the strength to enhance the properties of the mortar.

While for palm oil boiler stones (POBS) which is relatively low cost and abundantly available has the potential as a replacement for aggregates in the production of mortar. This study investigates the effects of substitution of POBS and quarry dust towards the mechanical properties of mortar which consists of density, porosity, compressive strength and flexural tensile strength.

The POBS is a waste material produced from the burning of fiber and shell as a fuel to heat the steam for the generation of electricity and palm oil extraction process. Since the POBS is disposed in landfills, these results are increase every year and now becoming a problem to be disposed of. Since it doesn't have any value, researchers should find the way to utilize this waste material to be incorporated in the production of concrete. In order to -completely evaluate the potential of POBS for new applications, further studies are vital.

Similarly, quarry waste fine aggregate could be an alternative to natural sand. It is a by-product generated from quarrying activities involved in the production of crushed coarse aggregates. Quarry waste fine aggregate, which is generally considered as a waste material, causes an environmental load due to disposal problem. Hence, the use of quarry waste fine aggregate in concrete mixtures will reduce not only the demand for natural sand but also the environmental burden. Moreover, the incorporation of quarry waste fine aggregate will offset the production cost of concrete. In brief, the successful utilization of quarry waste fine aggregate will turn this waste material into a valuable resource (Safiuddin, 2007).

1.2 Problem Statement

Nowadays, development of infrastructure is become number one priority in the world, particularly for developed country. So, there is a great demand for construction industry. Sand is one of vital component for mortar. As the demand of sand was continuously high from time to time, this will become a problem in the production of sand. There might be a shortage of sand in future and the ecological system will be affected.

Hence, a research has to be made to avoid this problem. One of the researches that can be done is by lessening the usage of sand in mortar and replacing it with recycles and secondary aggregates. Thus, a study on the use of quarry dust and also palm oil boiler stones (POBS) by products as alternatives sand with a view of effective utilization of the resources and environment protection is necessary. In order to examine the effective use of quarry dust and palm oil boiler stones aggregate and their applicability to mortar, this study examined the mechanical properties of mortar according to these raw materials content.

1.3 Objective of Study

The objective of this study is to determine the contribution of the waste aggregate type to the improvement of the strength behavior of the mortar:

i. To study the behavior of mortar with quarry dust and palm oil boiler stone (POBS) as partially sand replacement in term of its compression strength.
ii. To compare the properties of conventional mortar with mortar containing 5%, 10% and 15% of quarry dust and palm oil boiler stones at different age of curing days.

1.4 Scope of Study

In this experimental study, the effect of quarry dust and also palm oil boiler stones in mortar in terms of properties of mortar had been focused. Another mix is done using Ordinary Portland Cement (OPC) as a control mix. Workability was tested on fresh concrete using flow table test. For hardened concrete, only compressive strength was tested. Cubes will be tested at the age of 7, 28 and 60 days. There were several numbers of cubes with dimension of 50 x 50 x 50 mm being considered.

This research discusses the following :

1) The difference of mechanical properties between conventional mortar and the mortar with substitution of quarry dust and POBS.
2) The influence of different percentage substitution of quarry dust and POBS toward the properties of mortar.

1.5 Significance of Study

This research will give a further understanding of the effect of quarry dust and also palm oil boiler stones substitution toward the mechanical properties of the mortar. By substituting the quarry dust and palm oil clinker in mortar, a better material with lower cost and higher sustainability can be produced while preserving the characteristic and advantages of mortar.

In addition, this study can help to promote these replacement materials and therefore will be able to reuse the agricultural waste in the country as a natural source of construction materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Mortar is one of the constituents of the anisotropic masonry material. It is responsible for creating a more uniform stress distribution, for corrections of irregularities of blocks and accommodation of deformations associated to thermal expansions and shrinkage. In spite of this, mortar has been often neglected in terms of structural analysis of masonry structures, it is well known that it influences the final behavior of masonry such as compressive and bond strengths, and deformability (Edgell and Haseltine, 2005).

Mortar is a mixture of sand and cements that is most often used to build brick or block walls and it is a paste used to bind blocks together while filling the spaces between them. It is used most commonly in the masonry trade to bind stone, brick or concrete blocks during building construction. It can also be used to repair when the original application has crumbled or washed away.

Mortar is a combination of sand, a binder such as lime or concrete, and water. It is applied as a thick paste and sets hard. It creates a tight seal between bricks to prevent the entry of air and moisture into the structure. It bonds with any joint reinforcements, anchor bolts or metal ties, and compensates for size variations in the bricks to create an aesthetically pleasing and structurally sound building.

2.2 History of Mortar

The first mortar used by man was nothing more than mud or clay combined with water. The ancient Egyptian pyramids, dating back to 2600 BCE, were made of limestone bricks bound together with mud and clay. Eventually, concrete mortar came into popular use. Today, there are several different kinds of mortar available for all types of building and construction.

Portland cement mortar (OPC) is a mixture of Portland cement, sand and water. Joseph Aspdin created OPC in 1794 and received a patent for the mixture in 1824. It was used heavily in the late 19th century and by 1930, it was used exclusively in new construction. It sets quickly, requires less skill to use, and increases construction speed.

Polymer cement mortar (PCM) is created by replacing cement binders of traditional mortar with polymers. These include latex, emulsions, powders, liquid resins, water-soluble polymers and monomers. PCM reduces shrinkage cracking and is primarily used for repairing concrete construction.

Lime mortar is created by placing impure lime stones in a kiln. The resulting dust is a hydraulic lime that sets almost instantly upon contact with water. It is used as a binder in the mortar mixture instead of concrete or polymers. Lime mortar is breathable when set, and allows moisture to move freely and evaporate from the surface.

Mortar is hard wearing and typically lasts a very long time, even without repair. The standard lifespan of modern mortar is around 20-30 years. It may need replacing or refreshing if it easily scraped out with a sharp knife.

2.3 Mortar Properties

ASTM C 270 focuses on three masonry properties to define the quality of mortar: water retention, air content, and compressive strength. These parameters by themselves, however, present only a limited view of the characteristics of cement-lime mortar. Brown and Robinson (1986) write "The most rigorous mortar requirements are to provide adequate and uniform bond strength and to prevent wall leakage." Other parameters, such as workability of the mortar and durability are also important. Two types of properties should be considered. Plastic mortar properties pertain to the mortar from the time of mixing until it chemically hardens in the wall. Hardened mortar properties develop as the mortar cures after the initial chemical set. Both types of properties are important in determining the quality of the masonry application.

2.3.1 Plastic Mortar Properties

2.3.1.1 Workability (Plasticity)

Brown and Robinson (1986) write "The most rigorous mortar requirements are to provide adequate and uniform bond strength and to prevent wall leakage. Workability of mortars plays an important role on the construction process of masonry structures. The workability may be considered one of the most important properties because it influences directly the bricklayer's work. It is important to mention that the quality of the workmanship can influence considerably the mechanical properties of masonry. The definition of workability is somewhat subjective as it depends on the person who evaluates the mortar. Panarese (1991) considers the workability as an assembly of several properties such as, consistency, plasticity and cohesion. Given the fact that plasticity and cohesion are difficult to measure in situ, consistency is frequently used as the measure of the workability. Hydrated lime particle shape, that can influence workability as measured by plasticity.

The hardened properties of mortar that is most often tested for is the strength. Although mortar very rarely fails in direct compression, the compression strength is the most specified of all of the hardened properties. This is probably primarily because the test procedure is convenient to carry out. Additionally it is the one that is familiar in principle to many engineers and technologies who are used to the testing of concrete in compression. In addition, there is clearly a relationship between strength and binder content so the procedure sometimes used to provide a convenient surrogate for the latter where prescribed mixes are specified.

The compressive strength has also been related empirically to other parameters that are more difficult to test for particularly masonry strength and is thus often used to calculate an empirical assess net of that property. Compressive strength is tested for either by using cubes or by making prisms and producing specimens for testing as equivalent cubes. Cubes of many different sizes are used, BS 4551 (1998) covers 70.7mm and 100 mm sizes, whilst 150 mm cubes are sometimes used. Much smaller cubes have also been used, including specimens as small as 10 mm sq. taken from mortar bed joints, currently specified in a DIN standard (DIN,1999). More recently, prism have been loaded in flexure and the two equivalent cubes so produced tested in compression. This method was adopted in BS 4551 (1999) in the CEN test for 40 x40x160 mm specimens (CEN,1999) although an earlier RILEM recommendation was for prism of 40 x40x80 mm (RILEM,1982). The determination of bond strength of bond strength for mortar is generally accompanied either by high variability in the case of simple tests, or high costs in the case of test on larger specimens. Many years successful experience lie behind the method given in the BS 5628 part 1 Code of Practise (BSI,1992). Unfortunately this test is uses a relatively large number of bricks and to carry out a determination using the a significant number of replicates is costly. A simpler test has been developed within CEN and involves the uses of testing for initial shear strength as a proxy test (BSI, 2002). However , this test also shows a high variability . a simpler test still uses a bond wrench. This is an arm or similar which is clamped onto a brick after the perpendicular joints have been progressively cut through, usually with a diamond saw. It is loaded to produce a bending moment that causes the joint to fail. This method has also been proposed as a CEN test (BSI,1998).

In summary the situation with respect to mortar and masonry strength is that bond strength determination is generally relatively complex and costly and often with high variability. For this reason, compressive strength is usually used as a surrogate but may not relate directly to practical service condition s. many other tests for hardened mortar properties have been proposed but most are for specialist applications although recently adopted CEN test (BSI,1999) include those for water absorption due to capillary action , water vapour permeability (BSI,1999) adhesive strength (BSI,1999) and compatibility of one coat renders. The water absorption test (BSI, 1999) is a simple one based on immersing pre-weighed mortar prisms in 5-10mm of water and then weighing again after a period of immersion. It appears to be easy an reliable. The water vapour permeability (BSI,1999) is a requirement for plastering and rendering mortars and uses a basic permeability cell. There is not a great deal of international experience of this test but again, it is simple and robust. The adhesion of plastering and rendering mortar is determined using a pull-off test as defined in EN 1015-12 (BSI, 1999). This test uses normal pull off testing equipment and is easy and reliable although, in common with pull off tests, attention to bonding the specimen to the disc is required. The test must be carried carefully and the failure mode must be precisely reported.

The compatibility of one-coat rendering systems maybe assessed bt the used of tests developed in Frence (BSI,1999). In this test sample panels are rendered and then subjected to cycles of heating to 60C by infrared radiation, freezing at -15C and immersing in water for 8 hours. The adhesive strength and mortar permeability are determined after a number of cycles of heating , freezing and saturating. This test is little known outside France.

Workability significantly influences most other mortar characteristics. Workability is not precisely definable in quantitative terms because there are no definitive tests or standards for measurement. Workability is recognizes as complex rheological property including adhesion, cohesion, density, flowbility, plasticity and viscosity wwhich no single test method can measure. A workable mortar has a smooth, plastic consistency is easily spread with a trowel and readily adheres to vertical surfaces. Well-graded smooth aggregates enhances workability as do lime air entraiment and proper amounts of mixing water. The lime imparts plasticity and increases the water-carrying capacity of the mix. Air entraiment introduces minute bubbles which act as lubricant in promoting flow of the mortar particles, but maximum air content is limited in mortars to minimize the reduction of bond strength. When structural reinforcement is incorporated in the mortar cement lime mixes are limited to 12% air content and masonry cement mixes to 18%. Unlike concrete mortar requires a maximum amount of water for workability and retempering to replace moisture lost to evaporation should be permitted.

Variations in units materials and in environmental condition effect optimum mortar consistency and workability. Mortar for heavier units must be more dense to prevent uneven settling after unit placement and or excessive squeezing of mortar from the joints. Warmer summer temperatures require a softer wetter mix to compensate for evaporation. Although workability is easily recognized by the mason the difficult in defining this property precludes a statement of minimum requirements in mortar specifications.

Workability of a mortar is determined by its uniformity, cohesiveness and consistency. A mortar is considered workable when the mix does not segregate easily, is easily spread, supports the weight of units makes alignment easy, clings to vertical faces of masonry units and is easily forced from mortar joints without excessive smearing the wall (Marotta, 2005). The workability of mortar is affected by:

i. The time elapsed since mixing
ii. The properties of the fine aggregate such as the particle size, shape, porosity and surface texture
iii. The properties of the cement
iv. The presence of any cement replacements such as POFA,POBS and quarry dust.
v. The presence of any admixtures such as superplastizer, retarder or air-entraining agent and
vi. The relative proportions of the mix constituents.

2.3.1.2 Water Retention

The fine particle size of Type S hydrated lime particles enhance the ability of plastic mortar to retain water when applied to an absorptive base. Water retention is important, not only to enhance workability (plasticity), but also to extend board life and assure that adequate water is available to hydrate cementitious components of the mortar. Though research has shown that plasticity is a good predictor of water retention, water retention by itself is not a predictor of plasticity (Levin et al 1956). Water retention of the mortar becomes more important as the absorption rate of the masonry increases or the temperature during installation increases (Palmer et al 1934).

Other mortar characteristic that influences general performances such as aggregate grading, water retention and flow can be accurately measured by laboratory test and are included in ASTM Standards. Water retention allows mortar to resists the loss of mixing water evaporation and the suction of dry masonry units to maintain moisture for proper cements hydration. It is the mortar's ability to retain ability to retain its plasticity so that the mason can carefully align and level the units without breaking the bond between mortar unit.

Highly absorptive clay units may be prewetted at the job site but concrete products may be moistened thus requiring that the mortar itself resist water loss. Conversely if low-absorption units are used with a highly retentive mortar. They may float. Less retentive mortars may also bleed moisture reduce bond strength. Water retention generally increases as the proportion of lime in the mix increases. At one extreme the mortar made with only lime and sand without Portland cement, would have a high compressive strength but high water retention. High suction unit especially if laid in hot or dry weather should be used with a mortar that has high water retention. Low suction units especially if laid cold or wet weather should be used with a mortar that has high water retentivity. ASTM C91standard specification for masonry cement includes a water retention test which simulates the action of absorptive masonry units and mortar cement are tested for water retention in accordance with ASTM C1906, standard test method for water retention of hydraulic cement based mortar and plaster.

Under laboratory conditions, water retention is measured by flow tests. And is expressed as the percentage of flow after suction to initial flow. The flow test is similar to a concrete slump test but is performed on a flow table that is rapidly vibrated up and down for several seconds. Suction is applied by vacum pressure to stimulate the absorption of the masonry units and the mortar is tested a second time on the flow table.

Although they accurately predict the water retention characteristics of mortar laboratory values differ significantly from field requirements. Construction mortars need initial flow values of the order of 130 to 150% while laboratory mortars are required to have an initial flow of only 105 to 115%. The amount of mixing water required to have an initial flow of only 105 to 115. The amount of mixing water required to produce good workability proper flow, and water retention is quickly and accurately adjusted by experienced masons. Results produced from masonry assemblages prepared in the field reliably duplicate the standards set by laboratory researchers. Dry mixes lose too much water to the masonry units and will not cure properly. Excessively wet mixes cause units to float will decrease bond strength. The proper amount of mixing water is universally agreed upon as the maximum compatible with workability and workability is best judged by mason. Project specification should not dictate water/cement ratios for masonry mortar or grout.

Mortar is subject to water loss by evaporation, particularly on hot, dry days. Retendering (the addition of mixing water to compensate for evaporation) is acceptable practice in masonry construction. Since highest bond strength are obtained with moist mixes having good flow values, partially dried and stiffened mortar is less effective if the evaporated water is not replaced. Mortar which has begun to harden is result of cement hydration however should be discarded. Since it is difficult to determine by either sight or touch whether mortar is stiffening is due to evaporation or hydration it is customary to determine the suitability of mortar based on the time elapsed after initial mixing. Evaporative