PHYSICAL PROPERTIES OF LOCAL PALM OIL CLINKER AND FLY ASH

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Physical Properties of Local Palm Oil Clinker And Fly Ash

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Abstract— **As Malaysia will focus on biotechnology field as indicated in Ninth Malaysian Plan (RMK9) will bring tremendous effects to the local palm oil industry which also produces palm oil clinker as its waste by-product. This paper will studied the suitability of palm oil clinker to be used as coarse and fine aggregate for palm oil clinker concrete production. The parameters studied includes sieve analysis, specific gravity, moisture content, water adsorption, bulk density, aggregate impact value, crushing aggregate value, etc. Another local waste material from coal combustion, pulverized fuel ash (pfa) which react as pozzolanic material which have been proved by previous researchers as cement replacement in concrete mix proportioning to enhance the concrete properties also been studied for its physical properties. This study includes consistency of cement-fly ash paste, initial and final setting of different proportion of cement-fly ash paste as well as the specific gravity of fly ash. All parameters for local palm oil clinker and pulverized fly ash were conducted and measured according to British Standard. All parameters were analyzed and compared to the values that been proposed by British Standard. The results given by the palm oil clinker and fly ash were found to be in good agreement with the concrete testing values for structural use.**

Keywords: Sieve analysis; consistency of binders; specific gravity; Palm oil clinker; pulverized fly ash

I. INTRODUCTION

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As a major manufacturer of palm oil, Malaysia produces lots of palm oil products. Palm oil industry is also an establish business in Malaysia which is still developing and growing. In the palm oil mill, after it is being processed, the palm oil shells are used as burning fuel and as a result, the waste produced by this process is called the clinker. The clinker is normally treated as waste and has no economical value. Therefore, it will be very useful if the palm oil clinker can be recycled as a form of industrial material, thus eliminating waste and providing a cheap option to manufacture concrete. It will be of much benefit to the construction industry as to minimize cost at the same time preserve natural aggregates.

Due the limitation and difficulties in finding strong natural aggregate in certain region, artificial aggregate has been used widely to replace the natural aggregates. Current technologies and discoveries has made it possible to create a strong artificial aggregate that out performs natural aggregates. Many studies and research has been carried out to improve and refine on the aggregate itself. In many cases, natural aggregate has been substituted with artificial aggregate to provide that extra strength that natural aggregate are difficult to provide.

This paper reports the results of an investigation into the physical properties of palm oil clinker and fly ash. Both components are essential to produce stronger and durable lightweight palm oil clinker concrete. Studies by Neville shows that 10% replacement was selected as it gave the optimum reaction.

II. MATERIALS AND EXPERIMENTAL PROCEDURES

Palm oil clinker as aggregate

The Palm Oil Clinker (POC) was taken from the palm oil mill factory from Dengkil. The factory is Sri Ulu Langat Palm Oil Mill. The by-product that is collected from inside the boiler is called clinker. The clinker looks like a porous stone which is gray in color. The process of producing palm oil clinker in palm oil mill is shown in Table 1.

Table 1
Production process of palm oil clinker

Process	Activity	Remarks
1	Sterilize	- The raw palm oil is transferred from the farm to the factory and is boiled in hot water to sterilize the palm oil. - This sterilization process also softens the palm oil to make it easier for stripping later on.
2	Stripping	- The trunk of the palm oil is stripped in a rotating drum "stripper" and the palm oil fruits are separated from the tusk. - The tusk is thrown away and regarded as waste.
3	Extraction	- A process where the palm oil is crushed so that the palm oil in the fruit section will be extracted. - This process will extract the juice (palm oil) and leaves the skin, seed and the remaining fibrous material.
4	Separation	- This separation process separates the seed with the skin and the fibrous material because the seed is useless. - The fibrous material still contains some palm oil and is ideal for burning to regenerate power.
5	Burning	- The remaining fibrous material is sent to a furnace where it is burnt in temperature more than 500 degrees Celsius to power the steam engine which in turns generates power. - The burning process can last for more than 24 hours to give a complete burn.
6	Collection	- After the burning process, the fibrous material is now transformed into a hard and solid compound which we called the "Clinker". - The Clinker is then collected at the base of the furnace where it is either disposed of as landfill or being recycled for better usage.

All the clinkers are prepared to be crushed into required size. Clinker with nominal size of 20mm is used as coarse aggregate and size below 5mm is used as fine aggregate. The clinkers were flaky and irregular shaped. The broken edges were rough and spiky.

The physical properties such as water adsorption, moisture content and bulk density are shown in Table 2. Palm oil clinker and conventional coarse aggregate, i.e., gravel used in saturated surface dry condition.

Table 2
Physical properties of POC and gravel

Physical properties	Coarse aggregate POC	Crushed stone
Specific gravity (SSD condition)	2.17	2.60
Moisture content (%)	0.08	0.05
Water adsorption (%)	4.65	1.79
Bulk density (kg/m^3)	863.65	1815.23
Fineness Modulus (Fine aggregate)	2.84	2.65

Fly Ash

Fly Ash was taken from TNB Kapar in Selangor. It is by-product from power generator which broadly used as pozzolans in concrete technology. The fly ash used for this experiment belongs to type "F". It is grey in color and can be directly used upon collection.

Other concrete mix components

River sand was used as fine aggregate which has a fineness modulus of 2.56. Fly ash and Malaysian Ordinary Portland Cement was used as binders. Superplasticizers also been used as an admixtures for water-reducing agent.

Standard Code of Practice

For palm oil clinker test, there is a few test was taken; i.e., sieve analysis, moisture content, water adsorption, specific gravity, bulk density (bulk and loose), aggregate crushing value (ACV) and aggregate impact value (AIV). On the other hand, fly ash which used as partial binder was undergoing few tests, i.e., specific gravity, consistency of binders paste, initial and final setting of binders paste and Blaine surface area.

There is 2 major code of practice was implemented; i.e.; British Code of Practice which is mostly similar to Malaysian code of Practice and American Standard Testing Material (ASTM). Table 3 shows the code of practice been done for each type of test.

Table 3
Code of Practice for Aggregates Testing

No.	Testing	Code of Practice taken
1	Sieve Analysis	BS 812: Part 1: 1975
2	Moisture Content	BS 812: Part 109: 1990
3	Water Absorption	BS 812: Part 107 (Draft)
4	Specific Gravity	BS 812: Part 107 (Draft)
5	Bulk Density	BS 812: Part 2: 1975
6	Aggregate Crushing Value	BS 812: Part 110: 1990
7	Aggregate Impact Value	BS 812: Part 112: 1990
8	Aggregate Abrasion Value	BS 812: Part 113 (Draft)

Table 4

Code of Practice for Binders Testing

No.	Testing	Code of Practice taken
1	Specific surface (Fineness)	ASTM C 115-93
2	Initial and Final setting	ASTM C 191-92
3	Specific Gravity	BS 4550: Part 3: 1978

III. RESULTS AND DISCUSSION

PALM OIL CLINKER MATERIAL TEST

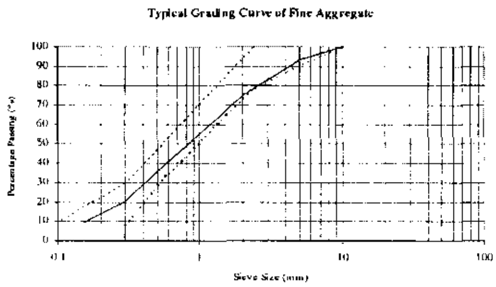
Visual Inspection

Particle shape and surface texture classification of aggregates is given by BS 812: Part 1: 1975. Since palm oil clinker come in a big size and it is crushed to a maximum size of 20mm to be used as coarse aggregates. We can see a possessing of well-defined edges at the intersection of roughly plane faces and rough fracture of medium-grained rock containing no easily visible crystallium constituents, we can classify that palm oil clinker aggregate is angular and rough.

Visual inspection of both properties follows to BS812: Part 1: 1975 to reduce the misunderstanding the classification. External features of the aggregates, especially particle shape and surface texture are essential of fresh and hardened concrete properties. Rough plane faces and rough textures of palm oil clinker aggregates can contribute to good bonding with the mortar constituents.

Size Classification

Palm oil clinker (POC) aggregates has a range of size up to a maximum size of 20 mm. The massive size of POC taken from palm oil mill is crushed to the desired shape with a maximum size of 20mm. To determine the range of sizes particle aggregate used, sieve analysis is carried out using vibrator shaker which the results are shown in Figure 1. From the graph in Figure 1, coarse aggregate has beyond its lower upper case for 10mm and 14mm sieve size. However, the fall is not significant and acceptable. The fine aggregates show the well grading as its entire particle sizes falling within the specified grading.



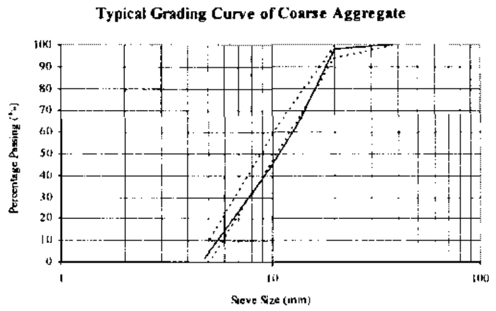


Figure 1: Typical grading of Palm oil clinker (top) fine aggregates (bottom) coarse aggregate

Fineness modulus is calculated for fine aggregates to detect a slight variation in the aggregates from the same sources, which might affect the workability of the fresh concrete. In this case, the fineness modulus for palm oil clinker is 2.84. Typical values ranging from 2.2 (very fine type of aggregates) and 3.2 (very coarse type), showing the palm oil clinker has coarse grading. This might due to the crushing work by lab crusher produce more coarse rather than fine particles.

By right, the bigger size of aggregates requires less water requirement of the wetted per unit mass. In this case, water-cement ratio can be reduced and this will increase the strength of the concrete. However, bigger size gave lesser bond area hence gives lesser strength. Normally, the nominal size used is 10, 20 and 40 mm. 20mm is chosen as it is the average size and commonly used in construction practice.

Specific Gravity

BS 812: Part 107 expressed specific gravity as "particle density" in kg/m^3. There are few types of specific gravity, namely bulk specific gravity (saturated surface dry which filled the pores with water) and absolute specific gravity. Conventional aggregates have an apparent specific gravity between 2.6 and 2.7. Since lightweight aggregates introduce air in its density, it will fall below this range.

POC shows its values of specific gravity as shown in Table 5. This value gave the requirement for designing the mixture of lightweight concrete. Minimum density always applies especially in designing structures required less load like dams, bridges as well as embankment for stability purposes.

Table 5
Specific gravity of palm oil clinker

Physical Properties		Coarse palm oil clinker	Fine palm oil clinker
Specific Gravity (SG)	Apparent SG	1.78	2.17
	Bulk SG (Dry)	-	1.61
	Bulk SG (SSD)	1.64	1.87

Bulk Density

The bulk density shows how dense the aggregates are packed and roughly show size distributions and shape of particles. As specified in BS812: Part 2: 1975 recognize two types of bulk density, loose and compacted. The values of bulk density and void ratio for palm oil clinker sample are shown in Table 6. For structurally satisfactory, density of aggregates lies between 700-1400 kg/m^3.

Table 6
Bulk Density for palm oil clinker aggregates

Physical Properties		Coarse palm oil clinker	Fine palm oil clinker
Bulk Density	Loose	742.20	-
(kg/m^3)	Dry Roded	863.659	1040.76
Void ratio (%)		0.47	-

As we know coarse aggregates constituent filled about 60% of concrete matrix. Void ratio indicates volume of mortar required to fill the space between the coarse aggregate particles. Bulk density shows roughly the information for the design purposes as commonly used in concrete mix design. Void ratio shows the required mortar to bind together. Within the concrete matrix, ratio between loose and compacted bulk density is 0.87 which prescribed by ASTM C29-91a.

Adsorption and Moisture Content

Since POC is a porous aggregate, it will allow high amount of water to fulfill the pores compared to solid aggregates. For design purposes, this value is important to determine how much water is required to assure the aggregates are in SSD state when in use. This value is quite critical because if POC in used, the water in design mix will be adsorbed by the aggregates and there is not sufficient water for workability and consistency and therefore, insufficient the hardened concrete properties especially strength and durability.

Moisture content of an aggregate depends on the humidity of the environment where the aggregate is placed. As the aggregates stored in the lab, there will no exposure to rain which collects moisture not only on the surface but also inside the aggregates as the pores will adsorbed water inside the particles. This amount gave a considerable important since it will be calculated in water requirement in concrete mix design as it is impossible to oven-dry huge amount of aggregates on-site.

Table 7
Moisture content and water Adsorption of palm oil clinker aggregates.

Physical Properties		Coarse palm oil clinker	Fine palm oil clinker
Moisture Content (%)		0.084	0.383
Water Adsorption (%)	5 minutes	2.97	-
	1 hour	3.38	-
	24 hours	4.65	16.17

Aggregate Crushing Value (ACV)

Since coarse aggregates comprises of 60% of concrete constituents, strength of the aggregates will imply on the strength of the hardened concrete. The measuring principle for this test is the fines produced by slowly increasing load to a specified maximum. The selection of a suitably high characteristic concrete strength alone is normally taken to assure a sufficient potential resistance to abrasion and attrition.

Table 8
Aggregate crushing value

Physical Properties	Palm oil clinker
Aggregate Crushing Value (ACV) (%)	18.44

Generally, the lower compressive strength, the higher is the crushing values. However, there is no explicit relationship and test on the relationship need to be obtained for verification.

Aggregate impact value (AIV)

Impact value will determine the toughness of the aggregates which is the resistance of aggregate to failure by impact. The value and BS882 classifications are summarized in Table 9.

Table 9
Aggregate impact values

Physical Properties	Palm oil clinker	BS882 Classification (not exceeding)
Aggregate Impact Value (AIV) (%)	38.6	25 (heavy duty concrete floor finishes) 30 (pavement wearing surfaces 50 (others)

Palm oil clinker is not a solid particle. It is a porous material which has air within its particles to make it lightweight. In aggregate crushing value which the aggregate is subjected to impact, it gave quite a high value which is 38.6%. Based on classification by BS 882, this type of aggregates cannot be applied on heavy duty concrete floor finishes and pavement wearing surfaces. But it passes for other applications.

Deleterious substances

Since POC is made from well-burnt residue of palm oil high-temperature furnaces, fused or sintered into lumps, there will be some amount of carbon appears on the surface of the POC. The carbon should be cleaned from the surface of the aggregates which might interference the hydration process of cement, preventing the good coating between aggregates and cement paste; and carbon will make the aggregates unsound and weak.

Fineness of binders

The fineness of 'binders' give the total surface area of cement ready for hydration rate. The finer the cement particles, the better for hydration process, hence the strength will be increased. However, there is limitation, which too fines will increase the cost of production and made the low workability of fresh concrete. As more fines, the rapid hydration will not produces from the concrete matrix to be developed properly, leaving pores behind. The fineness of OPC and Fly ash is shown in Table 10.

Table 10
Fineness of binders

Physical Properties	Ordinary Portland Cement (OPC)	Pulverized Fly Ash (FA)
Blaine Specific Surface (cm^2/g)	3200	1800

From Table 10, the fineness of fly ash is higher than OPC. The more fineness of fly ash makes the rapid process of hydration rather than OPC.

Initial and Final Setting

Before the initial and final setting times can be done, consistency of standard paste has to determine first which gave the amount of water required for any given cement to produce a paste of standard consistence. Water content required which expressed as a percentage by mass of dry cement lies within 26-33 for conventional Ordinary Portland Cement (OPC). Table 11 shows the results of initial and final setting mixed of water content that give the consistency of cement paste.

Table 11
Initial and Final setting of cement

Physical Properties		Water content (%)	Initial Setting (h:m)	Final Setting (h:m)
Binders mix	100% OPC	25.6	2:15	4:05
	90% OPC + 5% fly ash	28.3	2:45	4:22
	90% OPC + 10% fly ash	28.1	3:14	4:25
	90% OPC + 15% fly ash	29.0	2:17	3:08

Basically, water percentage increased when the ratio of pozzolans was increased. When the ratio of substituted materials increased, the specific surface of the mixtures also increased. As specified in Table10, value for Blaine specific surface for fly ash is around 3200 cm^2/g and OPC is 1800 cm^2/g.

Setting times decreased when water percentage increased. When the ratio of substituted materials was increased, setting time decreased. When fly ash is ground with OPC, the fineness of the cement increases; hence, the hydration process becomes faster, and reduces setting time. ASTM C191-92 specifies that initial setting of binders should be more than 45 minutes and final setting time less than 10 hours.

This however, different from observing the mixture of 10% fly ash replacement. It requires less water content from 5% replacement of fly ash. As the requirement of water increased, the setting times increased as well. We know that increasing the setting times will increase the time thus increasing the cost of production. However, research by Neville shows that optimum strength was obtained by using fly ash replacement by 10%.

IV. Conclusions

The following conclusions can be drawn from this investigation:-

1. Palm oil clinker is a lightweight material that can save up to 40% when batched. This can reduce the cost of production due to lesser dead load.
2. High water adsorption should be taken a serious place when designing palm oil clinker mixtures.
3. High specific surface of fly ash than OPC can enhanced the hydration rate; thus produced a stronger and durable concrete.
4. Both palm oil clinker and fly ash have a great potential to be developed in future.

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