Assessment of Malaysian Laterite Aggregate in Concrete

K.Muthusamy and N.W.Kamaruzaman

***Abstract*— Integration of new material as a partial coarse aggregate replacement in local concrete production would be able to reduce the high dependency of concrete manufacturer on granite aggregate supply that may lead to ecological imbalance when this natural material is used excessively. This paper presents the assessment on the characteristic of Malaysian laterite aggregate obtained from several locations before discussing further on the influences of this local material towards engineering properties of normal concrete. Concrete mixes containing 0%, 10%, 20%, 30%, 40% and 50% laterite aggregate replacement level were cast before subjected to water curing for 7, 14, 28 and 60 days. Workability test, compressive strength test, flexural strength and modulus of elasticity were conducted in accordance to the existing standard. Results show that replacement of appropriate laterite aggregate content able to produce workable concrete with satisfactory strength. Addition of 10% replacement laterite aggregate able to produce mix with comparable strength to plain concrete. The targeted strength still can be achieved with addition of 30% replacement laterite aggregate.**

***Index Term* — Malaysian Laterite Aggregate; Aggregate Assessment; Partial Coarse Aggregate Replacement; Laterite Concrete; Engineering Properties.**

I. INTRODUCTION

In Malaysia, efforts towards utilizing other types of material as a partial coarse aggregate replacement in concrete material stems out from the escalating demand of construction industry for concrete material leading to increasing use of local natural granite aggregate exploited from the environment. The issue of natural coarse aggregate depletion has been addressed by [1] who highlighted that the natural resource decreases while the demand for aggregate to be used in concrete production is still high. The diminishing of this material may expose it towards extinction in future thus causing high cost of concrete material. To overcome this issue, modification on the concrete constituents is one of the ways to reduce granite utilization. Concrete that produced from the alternative materials might reduce the usage on the natural aggregate. In Malaysia, availability of laterite aggregate in the states of Malacca, Johore, Negeri Sembilan, Kedah, Pahang, Kelantan and Selangor [2] has open the door for the making use of this material in concrete production. The term laterite was originated by Buchanan to describe a ferruginous, vesicular, unstratified and porous material with yellow ochre [3]. It is formed as a result of a long term tropical weathering process. This material which strength varies upon the weathering process [4] has been used as a construction building material in certain parts of the world. Looking at the integration of laterite aggregate in concrete research, researchers [5], [6] and [7] in other parts of the world have attempted to integrate this material which available in their country as one of the mixing ingredient of concrete. However, potential of Malaysian laterite aggregate as one of the concrete mixing ingredient particularly as partial coarse aggregate replacement yet to be established.

Therefore, the early part of this study presents assessment on the properties of laterite aggregate collected from several locations before selecting the best type to be used for the investigation of fresh and hardened concrete properties. Then, the workability aspect as well as compressive strength, flexural strength and modulus of elasticity of concrete containing various content of laterite aggregate are discussed.

K.Muthusamy
Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan , Pahang

N.W.Kamaruzaman
Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan , Pahang
khairunisa@ump.edu.my

II. EXPERIMENTAL PROGRAMME

A. Material Preparation

A single batch of Ordinary Portland cement (OPC) complies with the Type 1 Portland Cement as in [8] was used in this experiment. Tap water was used throughout the study. Local river sand with fineness modulus of 1.64 was used as fine aggregate. The coarse aggregate integrated in the mix is crushed granite brought from the nearby quarry. The laterite aggregate to be assessed in this study was obtained from several locations namely Site A, B, C and D in the state of Pahang. Fig. 1 and 2 illustrate laterite aggregate which appears to be red brown colour and the greyish granite respectively.

Fig. 1. Laterite Aggregate

Fig. 2. Granite Aggregate

All the aggregate were air dried to ensure it to be in saturated surface-dry condition. The laterite aggregate then tested subjected to the physical and mechanical characteristics following the procedures outlined in the existing standards. Based on that study, the best laterite aggregate was determined to be used partially in concrete mix as coarse aggregate in the next stage of study.

B. Concrete Mix Design

Two types of mixes have been used in this study that is plain concrete and laterite concrete which produced using a range of laterite aggregate content. Plain concrete, (100% natural granite aggregate) of Grade 30 acting as control specimen was designed using DOE method. The mixing of laterite aggregate as partial coarse aggregate replacement was based on a simple approach of direct replacement. Partial replacement of aggregate is limited only up to 50 % to produce blended aggregate which grading falls within the lower and upper limit of the requirement for aggregate from natural resources as stated in [9]. The value of proportion on the coarse aggregate replacement is from 10% to 50% with 10% interval leading to the formulation of mix identified as LC10, LC20, LC30, LC40 and LC50 in Table I.

TABLE I
CONCRETE MIX PROPORTION

Material (kg/m^3)	Designation					
	Ctrl	LC10	LC20	LC30	LC40	LC50
Cement	365	365	365	365	365	365
Granite	1170	1053	936	819	702	585
Laterite	-	117	234	351	468	585
Sand	660	660	660	660	660	660
Water	164	164	164	164	164	164

C. Testing Procedure

A total of 216 samples comprising cubes (100 x 100 x 100 mm), cylinders (100 x 200 x 400) mm were cast. All samples were demoulded after 24 hrs of the casting and then subjected immediately to water curing until the date of testing. The testing on workability aspect, compressive strength, flexural strength and modulus of elasticity were conducted in accordance to [10], [11], [12] and [13] respectively. The engineering properties of the concrete specimens were determined at the age of 7, 14, 28 and 60 days.

III. RESULTS AND DISCUSSION

A. Properties of Laterite Aggregate

Based on the results presented in Table II, it can be observed that chemical element content of laterite aggregate vary from one location to another. All laterite aggregate except granite contain carbon element. On the other hand element such as natrium and magnesium that exist in granite can be found in any laterite aggregate samples. Knowing the granite which is categorised as igneous rock formed from magma and laterite is a resultant of tropical weathering and leaching of rocks, it can be deduced that the differences existing between these two types of aggregate are probably due to variation in the factors causing its formation. Comparing the percentage of element content between the laterite aggregates of various sources, there is noticeable variation in the percentages for all element content in laterite aggregate originating from difference sources. Degree of weathering and variation in parent rock which varies from one place to another could be one of the contributing factors. This issue has been highlighted by previous researcher [14] who identified factors namely climate, geology and the degree of weathering play role in shaping the properties of this soil. Of all the samples, laterite from Site A demonstrates the closest similarity in the percentage of element content to granite aggregate.

TABLE II.
ELEMENT CONTENT OF GRANITE AGGREGATE AND LATERITE AGGREGATE FROM DIFFERENT LOCATION

Element (%)		Sources of Laterite Aggregate			
	Granite	Site A	Site B	Site C	Site D
C	0	1.32	5.59	7.65	20.75
O	58.01	62.24	57.16	44.15	47.42
Na	0.89	0	0	0	0
Mg	1.26	0	0	0	0
Al	6.91	15.98	19.19	8.18	7.37
Si	17.76	11.38	2.88	7.16	5.96
K	3.01	0.77	0	0.89	0.43
Ca	0.92	0.23	0	0	0
Ti	0.96	0.9	1.54	0.6	0.33
Fe	10.28	7.18	13.64	31.39	17.74

Table II shows the physical characteristic of laterite aggregate from different sources compared with granite aggregate. Looking at the value of water absorption, the higher porous texture of laterite aggregate of Site C causes it to have higher water absorption which may affect the bond between the aggregate and cement as well as the fresh concrete properties. However, all aggregates exhibit less than 3% of water absorption complying to the requirement in [9] indicating it can be used as coarse aggregate in concrete work. The flakiness and elongation index of the laterite aggregate is within the value outlined in [15]. Of all the samples, laterite aggregates from Site A exhibit closer value to granite aggregate.

In terms of better denseness which represented by higher value of specific gravity, laterite aggregate from Site A demonstrate closer value to granite aggregate indicating its harder and stronger characteristic of this material as compared to the rest of samples collected from other locations. Similar trend is observed from the result of aggregate crushing value test, aggregate impact value and moisture content determination. Finally, the testing on the ten percent fines of the samples has clearly draws a line between aggregate from Site A and other laterite aggregates when it fulfilled specification in [16] as compared to the latter. As a result, aggregate belonging to Site A has been utilized for further experimental study in the next stage.

TABLE III.
PHYSICAL PROPERTIES OF GRANITE AGGREATE AND LATERITE AGGREGATE FROM DIFFERENT LOCATION

Physical Properties	Granite	Sources of Laterite Aggregate			
		Site A	Site B	Site C	Site D
Water Absorption (%)	0.92	1.070	1.69	1.34	2.32
Flakiness Index	6.3	8.5	8.8	9.2	8.9
Elongation Index	6.1	8.0	8.2	9.6	12.3
Specific Gravity	2.69	2.54	2.49	2.53	2.5
Agg. Crushing Value (%)	28.8	30.7	31.6	33.9	35.2
Ten Percent Fines (%)	8.4	10.2	19.7	18.5	12.8
Agg. Impact Value (%)	26.2	28.7	30.8	32.9	34.5
Moisture Content (%)	0.45	0.52	0.71	0.64	0.69

B. Effect of Laterite Aggregate on Workability

It can be observed in Fig. 3, that the slump decreases as the percentage of laterite content replaced becomes higher. This result indicates that concrete become less workable as the amount of laterite aggregate added increases, thus implying the need for larger amount of water required to make the mixes more workable. Reduction in the laterite concrete mix workability is probably due to the higher rate of water absorption of this aggregate which possess higher porosity as compared to granite aggregate. The effect of coarse aggregate properties and proportion of constituent materials towards concrete properties has been highlighted by [17]

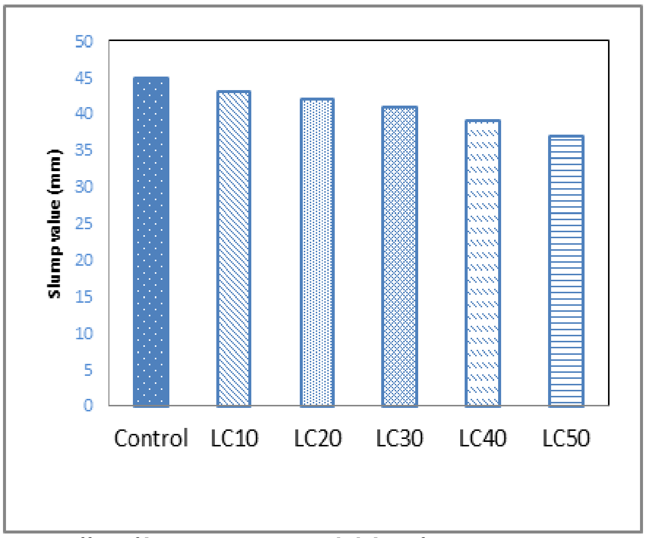

Fig. 3 Effect of laterite content on workability of concrete

C. Effect of Laterite Aggregate on Engineering Properties

Fig. 4, 5 and 6 shows the results of compressive strength, flexural strength and modulus of elasticity of specimens at various age stages; 7, 14, 28, and 60 days. All the samples exhibit continuous strength development as the curing age become longer. The availability of water supply promotes more complete hydration process leading to larger amount of Calcium Silicate Hydrate gel thus assisting towards improvement of the concrete internal structure which in turn enhances the concrete strength performance. Integrating 10% laterite aggregate in concrete mix results in concrete exhibiting compressive strength comparable with plain concrete. Replacement of laterite aggregate up to 30% produces laterite concrete with the targeted strength of 30 MPa at 28 days.

However, replacement beyond 30% causes significant strength reduction. Addition of too much laterite aggregate which possesses lower density compared to granite leads to lower strength. Substituting natural aggregates, at different replacement levels, by Malaysian laterite aggregates definitely have influence on the mechanical behavior of the concrete. This is probably due to variation in the physical characteristic of laterite aggregate compared to granite in term of denseness, surface texture and shape. This fact has been highlighted by [18] who stated that the type of coarse aggregate properties have influence towards the concrete strength.

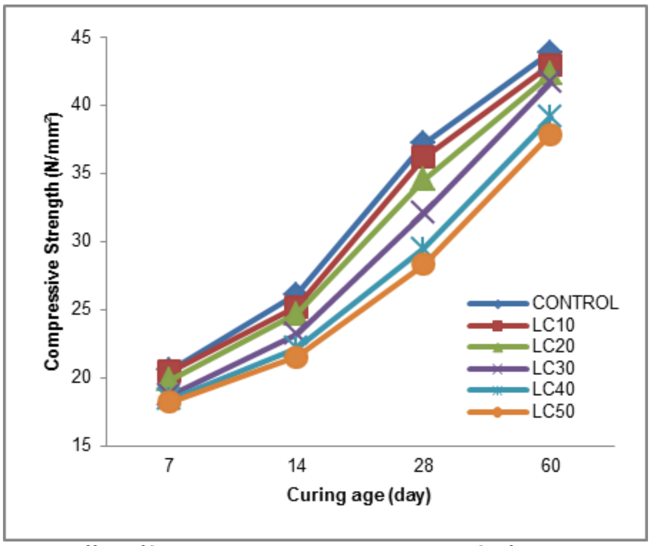

Fig. 4. Effect of laterite content on compressive strength of concrete

Flexural strength test was conducted in order to measure the specimens' ability to resist deformation under load. The flexural strength value was approximately 14 to 15% of the specimens' compressive strength. Since flexural strength of concrete is about 10 to 20% of compressive strength depending on the type, size and the volume of aggregate used [19], the value obtained in the testing is within the range. On overall, performance of concrete specimens produced using 10 to 50% of laterite aggregate exhibit good flexural strength. The results obtained for the flexural strength performance of concrete as shown in Fig. 5 demonstrates a similar trend to that observed in the compressive strength development. The slight declination of the flexural strength is probably due to the characteristic of laterite aggregate which has lower stiffness and more pores compared to granite aggregate. This factor causes lower bonding strength between aggregate and cement as well as increase water requirement for workable concrete which in turn reduce the ability of concrete to sustain larger load.

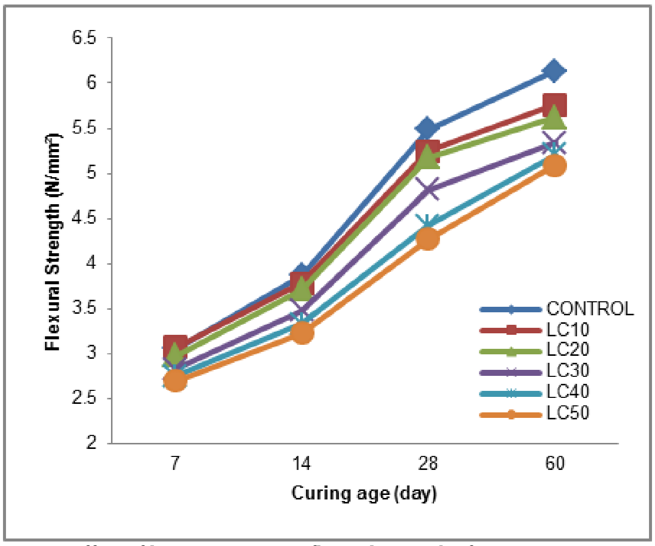

Fig. 5. Effect of laterite content on flexural strength of concrete

Modulus of elasticity test was conducted to examine the influence of laterite aggregate towards concrete elasticity in various replacement percentages. The modulus of elasticity result as shown in Fig. 6 follows a similar trend to development of compressive strength and flexural strength. Increase in the laterite aggregate replacement cause the concrete to be less stiff. The low values of the elastic modulus of concrete made with the laterite aggregate might be because of the corresponding low strength characteristics of the laterite aggregate when compared to the granite.

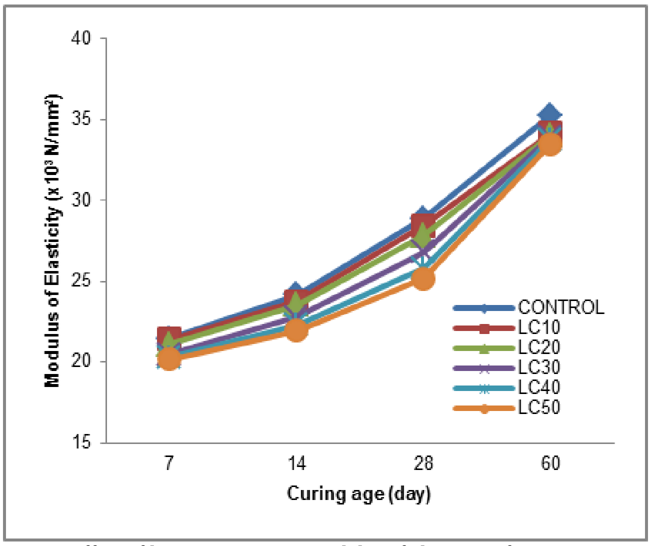

Fig. 6. Effect of laterite content on modulus of elasticity of concrete

IV. Conclusions

Based on the study, it can be concluded that:

1. The use of laterite aggregate as partial coarse aggregate replacement has influence towards engineering properties of concrete.
2. The study discovered that replacement of 10% laterite aggregate can produce laterite concrete exhibiting comparable strength with normal concrete.
3. Replacement of laterite aggregate up to 30% able to produce laterite concrete exhibiting the targeted strength which is 30 MPa.

Acknowledgment

This research was financially supported by Ministry of Higher Education of Malaysia and Universiti Malaysia Pahang.

References

[1] R.B.A. Alshahwany, "Effect of partial replacement of sand with limestone filler on some properties of normal concrete," *Al Rafidain Engineering Journal*, 19(3): pp.37-48. 2011.

[2] G. West, and M.J. Dumbleton, "The mineralogy of tropical weathering illustrated by some west Malaysian soils," *Quarterly Journal of Engineering Geology*, 3: pp.25-40. 1970.

[3] J.A. Osunade, "Effect of replacement of lateritic soils with granite fines on the compressive and tensile Strength of laterized concrete," *Building and Environment*, 37: pp 491-496. 2002.

[4] K. Raju, "Properties of laterite aggregate concrete," *Materiaux et Construction*, 5(5): pp 307-314. 1972.

[5] D. Adepegba, "A comparative study of normal concrete with concrete which contained laterite instead of sand," *Building Science*, 10(2), pp.135-141. 1975.

[6] F.F. Udoeyo, U.H. Iron, and O.O. Odim, "Strength performance of laterized concrete," *Construction and Building Materials*, 20(10): pp.1057-1062. 2006.

[7] E. Ikponmwosa, and M.A. Salau, "Effect of heat on laterised concrete," *Journal of Science and Technology*, 4(1): pp. 33-42. 2010.

[8] ASTM C150 (2012) "Specification for Portland Cement" American Standard And Testing Materials.

[9] *Specification for Aggregate from Natural Resources for Concrete* British Standard 882, 1992.

[10] *Testing Fresh Concrete* BSEN12350-2, 2009.

[11] *Testing Hardened Concrete* BSEN12390-2, 2009.

[12] *Flexural strength of concrete (Using simple beam with center point loading)* American Standard and Testing Materials C293, 2010.

[13] *Static Modulus of Elasticity and Poisson's ratio of concrete in compression* American Standard and Testing Materials C469, 2010.

[14] M.D. Gidigasu, "Mode of formation and geotechnical characteristics of laterite materials of Ghana in relation to soil forming factors," *Engineering Geology*, 6(2): pp.79-150. 1972.

[15] *Methods for Determination of Particle Shapes* British Standard 812 Part 105, 1990.

[16] *Methods for Determination of Ten Percent Fines Value* British Standard 812 Part 111, 1990.

[17] E.G. Nawy, (1985) " Reinforced Concrete" Prentice-Hall

[18] M. Abdullahi, "Effect of aggregate type on compressive strength of concrete" International Journal of Civil and Structural Engineering. 2(3) pp791-800. 2012.

[19] CIP 16 "Flexural Strength Concrete," *National Ready Mix Concrete Association*. 2000