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Application of Microscopic Techniques for Studying Microstructure of Concrete Containing Lightweight Aggregate

(Aplikasi Teknik Mikroskopik untuk Mempelajari Struktur Mikro Konkrit yang Mengandungi Agregat Ringan)

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ABSTRACT

The reason for failure in engineering component can be attributed to design deficiencies, poor selection of materials, manufacturing defects, exceeding design limits and overloading, and inadequate maintenance. The behaviour of material depends on the chemical, physical, mineralogical, microstructure characteristics and the interaction between them in the concrete. The aim of this research is to investigate some of the properties on the concrete that is containing the lightweight expanded clay aggregates (LECA). Study the microstructure of concrete be able to understand the relationship between structure and behaviour of concrete. Interaction inside the phase of concrete such as dislocations, grain boundaries, phase interfaces, pores and crack can be identified by a microstructure of concrete. Therefore, a microstructure of concrete has been studied under a digital microscope. The properties of LECA were investigated in order to relate the behaviour of aggregate in the concrete. LECA were used in the production of lightweight aggregate concrete (LWAC) with the size 50 mm × 50 mm × 50 mm. The results show that LECA has several improvements when compared with normal crushed aggregate. The density of LECA was 520 kg/m^3 and its characteristics were round, rough and porous. Besides that, the LWAC shows an excellent strength development, 29.41 MPa compared than normal weight concrete (NWC), 25.57 MPa. The surface of LWAC was darker than NWC due to LWAC experience more hydration of ferrite compound. In addition, the microstructure investigation of the LWAC shows a good bonding between aggregate and mortar at the interface transition zone (ITZ).

Keywords: Lightweight expanded clay aggregates; digital microscope; interface transition zone

ABSTRAK

Punca kegagalan dalam komponen kejuruteraan boleh dikaitkan dengan kelemahan dalam reka bentuk, pemilihan bahan yang tidak baik, kecacatan dalam pembuatan, melebihi had reka bentuk serta beban dan penyelenggaraan yang tidak mencukupi. Tingkah laku bahan adalah bergantung kepada sifat kimia, fizikal, mineral, ciri-ciri struktur mikro dan interaksi antara mereka di dalam konkrit. Tujuan kajian ini adalah untuk mengkaji beberapa sifat pada konkrit yang mengandungi agregat tanah liat dikembang ringan (LECA). Kajian struktur mikro konkrit dapat memahami hubungan antara struktur dan tingkah laku konkrit. Interaksi di dalam fasa konkrit seperti lokasi, sempadan butiran, antara muka fasa, liang dan retak boleh dikenalpasti oleh di dalam struktur mikro konkrit. Oleh itu, struktur mikro konkrit telah dikaji di bawah mikroskop digital. Sifat-sifat LECA telah disiasat untuk mengaitkan tingkah laku agregat dalam konkrit. LECA digunakan untuk menghasilkan konkrit agregat ringan bersaiz 50 mm × 50 mm × 50 mm. Keputusan menunjukkan bahawa LECA mempunyai beberapa penambahbaikan berbanding dengan agregat normal yang dihancurkan. Ketumpatan LECAadalah 520 kg/m^3 dan ciri-cirinya ialah berbentuk bulat, kasar dan berliang. Di samping itu, konkrit agregat ringan menunjukkan ia mempunyai kekuatan yang lebih baik iaitu 29.41 MPa berbanding daripada konkrit berat normal dengan kekuatan 25.57 MPa. Permukaan konkrit agregat ringan juga adalah lebih gelap daripada konkrit berat normal kerana konkrit agregat ringan mengalami lebih penghidratan sebatian ferrite. Di samping itu, kajian melalui struktur mikro konkrit agregat ringan menunjukkan ikatan yang baik antara agregat dan mortar di zon peralihan antara muka (ITZ).

Kata kunci: Agregat tanah liat dikembang ringan; mikroskop digital; zon peralihan antara muka

INTRODUCTION

The demand for the devouring of natural sources may cause the high amount of production of industrial wastes that have to be disposed in landfills and cause an environmental problem (Horvath 2004). In recent years, manufactured lightweight aggregate (LWA) has reached significant interest because it can reduce the environmental problem and new solutions for sustainable development of construction material. The application of LWA is regularly rising in concrete technologies because it helps to diminish the economic problem and environmental problem of the concrete industry by having high durability properties, low costs and eco-friendly concrete (Bentz 2007).

According to the recent study conducted by Baumard and Starbuck (2005), analyses have shown that 800 cases of structural failure in which 504 people were killed, 592 people injured, and millions of dollars of damage incurred. Besides that, the problem that may cause to the failure are due to the manufacturing and selection of material. Georgali and Tsakiridis (2005) stated that failure includes the adverse thermo-mechanical history, material defects, poor microstructure and contamination from foreign particles. In microstructural terms, concrete is a high degree of heterogeneity that has an extremely complex system of solid phases, pores and water. To identify the behaviour, properties and performance of concrete, the knowledge of microstructural features of concrete is beneficial for controlling the properties of concrete.

Concrete consists of cement paste, pore water and aggregate. The application of LWA in concrete has several improvements when compared with normal crushed aggregate (Sagoe et al. 2001). The microstructure of concrete has the various features of the type, shape, size, amount and distribution of phases over a wide range of length scales (Bentz 2008). The features of concrete can completely impact the physical and mechanical properties of concrete such as hardness, toughness, ductility, strength, weight and durability. Many research was related to the interfacial zone has been accomplished on normal weight concrete (NWC). Only a few research has been dedicated to the microstructure of the LWA and cement paste in lightweight aggregate concrete (LWAC) (Vakhshouri 2017).

In 1923, lightweight concrete (LWC) is start protected and specifically long history that mostly used as an insulation material. It is also has a porous which were good in thermal insulation capacity. Besides that, the concrete there contains LWAs are faster in hardening rate because the open pores in a structure of LWAs allow the internal curing effect (Dayalan & Buellah 2014). The open pores of LWAs have raised the capability of water absorption of concrete due to the high porosity of LWAC compared to NWAs (Nemes 2014). The properties of LWC mostly depends on the LWA such as particle density, surface texture, water absorption capacity and shape (Muhit et al. 2013).

The LWAC and NWC are slightly different when it's compared in hardened concrete based on strength and elastic modulus of aggregate. Besides that, the matrix aggregate of an interfacial zone of concrete also different between this two concrete. These dissimilarities were decided the degree of heterogeneity of concrete. While the surface texture of the aggregate, the initial water content of the aggregate and pore structure are determined the properties of the interfacial zone of concrete (Isserman & Bentur 1996). The aim of this research is to identify some of the property on the concrete that is containing light expanded clay aggregates (LECA) under microscopic. There are three specific objectives in this research which are to study the physical, chemical and mineralogical characteristics of lightweight aggregates. Besides that, this study also intends to compare the microstructure of normal concrete with LWC by applying the techniques of microscopic. Lastly, the interfacial zone and bonding between the cement paste with lightweight aggregate in concrete will be investigated.

METHODOLOGY

PHYSICAL PROPERTIES

The physical tests were conducted for each of the aggregates. The density values of light expanded clay aggregates (LECA) and normal aggregate were investigated and observed using a digital microscopic and the output an image of cross-section of the aggregate was captured by the software. The microstructure of aggregate was observed by cutting the aggregate into the half. The shape, surface and pores of aggregate were observed through the cross-section of aggregate. Besides that, the results of normal aggregate were compared with lightweight aggregate.

CHEMICAL AND MINERALOGICAL PROPERTIES

All the raw materials were crushed into a powder. Crucibles were dry for 1 hour at 105°C, it cooled in the desiccator and been weighted. 10 g of each sample powder were placed into a dry crucible and weighted. Weighted crucibles with samples were placed underneath in a ventilated drying oven for 24 hours at 105°C. The powder was cooled and weight after 24 hours. Again the crucibles were placed the in the furnace for 15 minutes at 800°C and had been weighted under the same conditions. The percentage of organic matter content were calculated and all the material were conducted to analyse the basic content of materials.

MANUFACTURING OF CONCRETE

The block of concrete 50 mm × 50 mm × 50 mm was produced for all samples. Coarse aggregate consisted of crush stone size 12.5 mm maximum in diameter and fine aggregate, a well graded natural sand of maximum 2 mm were used for normal weight concrete (NWC). The ratio of the mixture of mortar using the volume proportions of 1 cement: 2 fine aggregate: 3 coarse aggregate and water ratio was used 0.55. However, for lightweight aggregate concrete (LWAC) used light expanded clay aggregate (LECA). LECA is rounded in shape and light in weight were used as coarse aggregate with the size 4 mm to 10 mm. The proportion mixture of mortar was same as NWC but the proportion in volume 1 ml cement: 2 ml fine aggregate: 3 ml coarse aggregate. The water ratio used in the production of LWAC is 0.52. Lastly, the mortar was put into mould and compact using vibrate for 3 seconds. The concrete cubes were removed from the mould after 24 hours after casting. The concrete was removed carefully to make sure it is not damaged because at this stage the concrete cube not accomplished adequate quality of strength. After that, the concrete was weight and recorded as the weight before curing. All the concrete samples were put into curing tank for 28 days.

ANALYTICAL METHODS

The sample of concrete was observed the changes in the colour of a concrete surface for every 7 days, 14 days, 21 days and 28 days of curing. Besides that, the concrete also was weighted to determine the density of the concrete. All the concrete cubes were tested using a compression testing machine after 28 days curing by referred to ASTM C109 / C109M – 16a of the standard test method for compressive strength of hydraulic cement mortars. Three of concrete cubes from each sample were tested and an average of the results of compressive strength was recorded. The concrete cubes from each specimen are cut into half to observe the cross section of concrete by using the digital microscope. The surface of cross-section was polished to become flatted and smooth. The cross-section of concrete were investigated focus on the bonding between aggregate and cement paste. The properties of aggregate which were open or close porous and its outer surface investigated in order to prove the strength of the bond formed. Besides that, the interfacial transition zone (ITZ) between cement paste and aggregate also being investigated.

RESULTS AND DISCUSSION

PHYSICAL PROPERTIES OF LECA

In this study, the size 4 mm to 10 mm of coarse aggregate; LECA was used and it is in the dry form. Based on the experiment, the properties of LECA were recorded in Table 1. The density of LECA is 520 kg/m^3 proved that it is considered as a lightweight aggregate when compared with normal aggregate with density 1800 kg/m^3. Due to internal cellular pore system, LECA has a low density.

The hard and strong or fragile or weak of aggregate are depending on the shape, size and surface of aggregate. The characteristics of the material used in the concrete give effect to the workability, so consideration of the characteristics of the material is important to form strong concrete. Strong concrete is necessary to avoid failure of the structure because of the material used.

Figure 1 shows the feature of LECA under the digital microscope. The shape of LECA in Figure 1 is ball-shaped granulate and ceramic shell around a porous core due to circular motion in a rotary kiln at the high temperature during production of LECA. The rounded shape of LECA advantage in a given weight or volume. It has less surface compared to angular aggregate, it gives better lubricating effect because the excess paste is available. Besides that, it provided the less friction resistance and high workability.

TABLE 1. Properties of LECA

Component	LECA Coarse
Density (kg/m^3)	520
Bulk Density (kg/m^3)	327

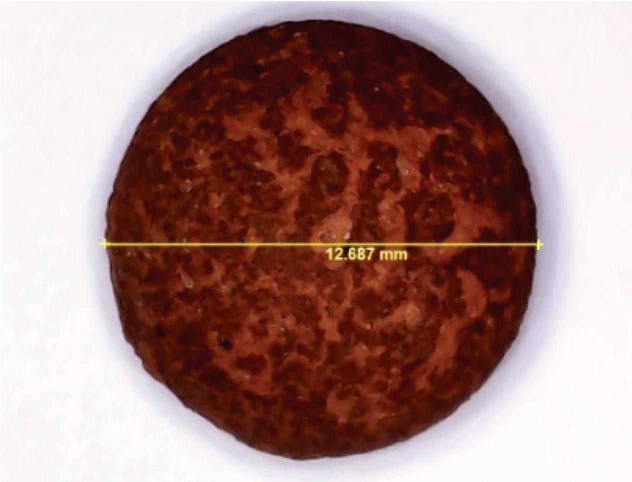

FIGURE 1. Shape of LECA

Figure 2 shows the surface texture of the LECA aggregate with magnified 60X under a digital microscope. It is observed that the LECA aggregate is a rough surface texture with porous. Cement paste is bond strongly with the rough surface of the LECA aggregate and generate high strength. The surface texture has small porous which is good in forming a mechanical bond with the surrounding mortar enhancing the aggregate and cement paste interface. By considering inside the concrete matrix, it also helps in reducing the formation of micro-cracks.

Generally, the pore space of aggregate has affected the movement of water, void, transport and reaction of chemicals especially in concrete. For the cross-section of LECA aggregate in Figure 3, they have more porous with the size range from 0.1 mm to 0.4 mm. The size of the porous may cause the difference in absorption of water and asphalt (Lee et al. 1990). Theoretically, the interaction between cement paste and LECA aggregate become stronger due to the mechanical interlocking between LECA aggregate and cement paste (Bajare et al. 2012).

FIGURE 2. The surface texture of LECA

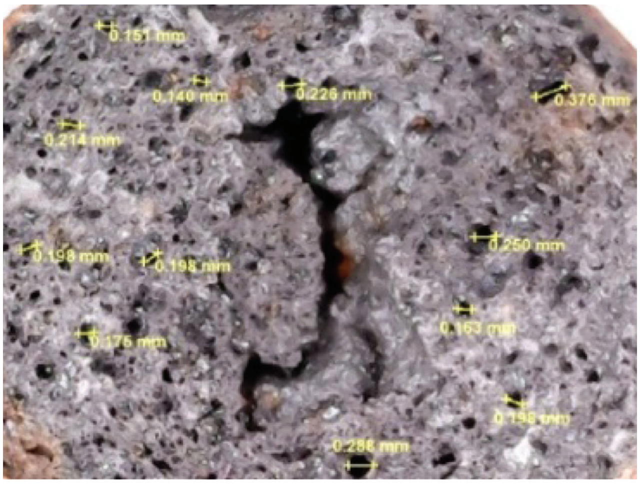

FIGURE 3. Pore distribution of LECA

CHEMICAL AND MINERALOGICAL PROPERTIES OF MATERIALS

In this study, LECA aggregate was used in the production of lightweight concrete. Table 2 shows the chemical composition of raw materials that were used in this experiment. Chemical and mineralogical of aggregate can give effect to the interaction of aggregate and cement paste due to the reaction of a compound in the mortar. Besides that, it affects the workability of concrete. On the other sides, some of the substance may cause distress the concrete and make the concrete an unsightly appearance.

The organic compound of cement in Table 2 shows that 65.50% silicon dioxide, SiO_2 is the highest value contained in cement. Cement used in the laboratory is Portland cement which is CEM II/B-M(S-L) 32.5 R. The production of cement commonly requires a source of silicon (such as clay or sand) and source of calcium (generally limestone). Cement has been heated with very high temperatures to formed clinker. Therefore, carbon emissions are high in the production of cement.

From the data of loss of ignition (L.O.I), the percentage of organic matter content of sand is 0.92%. Table 2 shows that silicon dioxide (SiO_2) is the major organic compound of sand, which is 77.50%. The high substance of silica is great in the purity of silica sand. The substance of sand differs, depending on the rock sources and conditions, but the most widely recognized constituent of sand in inland continental settings and non-tropical coastal settings is silica (SiO_2), usually in the form of quartz.

Crushed stone is natural resources and basic raw material. The rocks and minerals from which these materials are limestone or chalk, are contain primarily of calcium carbonate. From the previous data of L.O.I, the percentage of organic matter content of crushed stone aggregate is 3.10%. Table 2 shows the highest organic compound of crushed stone aggregate is calcium oxide (CaO).

The term LECA is derived from Light Expanded Clay Aggregate. Usually, raw materials to make these lightweight aggregates are formed from sedimentation of the natural materials like clay, shale, and slate that contain a lot of silica. From the previous data of LOI, the percentage of organic matter content of LECA is 0.12%. Table 2 shows that silicon dioxide, SiO_2 is the major organic compound of sand, which is 48.70%.

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TABLE 2. The chemical composition of the raw material

Chemical Compound	Conc. Unit (%)			
	Cement	Sand	Crushed Stone	Leca
Al_2O_3	13.00	12.60	4.96	19.80
SiO_2	65.50	77.50	14.70	48.70
SO_3	-	-	0.84	0.45
K_2O	9.25	6.82	1.90	4.43
CaO	-	-	72.73	3.46
TiO_2	0.50	0.63	0.38	1.45
V_2O_5	0.10	0.02	0.03	0.07
MnO	0.49	0.04	0.06	0.28
Fe_2O_3	8.75	1.60	3.21	20.38
CuO	0.08	0.03	0.04	0.06
ZnO	-	-	0.21	0.33
Rb2O	-	0.06	0.02	0.05
SrO	-	-	0.13	0.05
ZrO_2	0.08	0.19	0.02	0.08
RuO_2	-	0.26	0.32	0.27
BaO	0.79	0.11	0.39	0.09
L.O.I (%)	4.35	0.90	3.10	0.12

DENSITY OF CONCRETE

The density of lightweight concrete is affected by the mixture proportions, water demands, particle density, contents of air and contents of moisture of the lightweight aggregate. Concrete is considered as the lightweight when its density is not more than 2400 kg/m^3. In this case of study, Table 3 shows the lightweight concrete using LECA aggregate has an in-place density after 28 days of curing is 1608 kg/m^3 compared to normal weight concrete a density is 2298.67 kg/m^3. The density of both concrete was shown the differences between types of concrete in term of weight.

Table 3 also shows the density of concrete was increased by the days of the curing process. Normal weight density was 2202.67 kg/m^3 and its density started to increase slowly during the curing process until 28 days with final density 2298.67 kg/m^3. However, the lightweight LECA concrete drastically increased in density from 1498.66 kg/m^3 at first day until 1608 kg/m^3 at 28 days of curing. This is due to the particle of the aggregate and pore structure of the aggregate.

From the previous data of LECA aggregate in Figure 3 shows more porous of LECA aggregate and its function as movements of water as well as absorption of water. It is proven that the more porous of LECA aggregate helped more water pass through concrete than crushed aggregate that was used in normal weight concrete. During the curing process, water is helped the cement bind with aggregate. The porous structure of aggregate is helped they bind and formed strength concrete.

TABLE 3. Density of concrete

Concrete	Day 0	Day 7	Day 14	Day 21	Day 28
Normal Weight (kg/m^3)	2202.67	2277.33	2293.33	2296.00	2298.67
Lightweight (LECA) (kg/m^3)	1498.66	1589.33	1599.99	1605.33	1608.00

COLOUR CHANGE OF CONCRETE

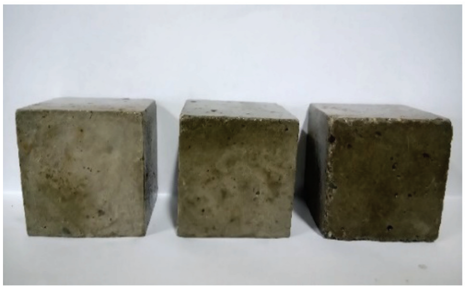
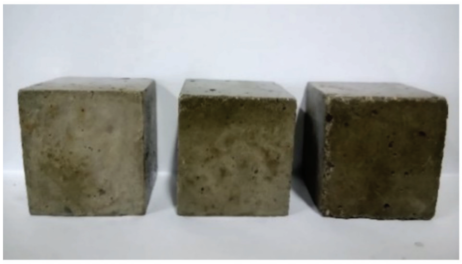
The changes colour of the surface of concrete can be seen very soon after put into curing tank. The surface of concrete looked like speckled light or dark smudge or light patches of efflorescence. The aspect that effects the changes colour of concrete is types of cement used which is cement alkalis, admixtures of calcium chloride, a wet substrate, hard-troweled surfaces, inadequate or inappropriate curing, water-cement ratio and concrete mixture. The changes in the colour of concrete also may be the result of organic staining in simply term is the concrete is dirty.

Table 4 shows the changes in the colour of concrete days by days of curing. Day 0 is the day of concrete take out from the mould before replace it into curing tank. Normal weight concrete shows the light in colour which is grey same goes to lightweight LECA concrete. However, both of the concrete started changes in colour during the curing process. Normal weight concrete slowly shows the changes of colour from grey to the dark spot and some of the surface look like mossy. However, lightweight LECA concrete changes the colour from grey to darker spot and its surface mostly covered by muddy.

All these results of changes colour of concrete in this study may due to very hard troweling that because the surface of the concrete is lower in water-cement ratio. This may inhibit the hydration of the ferrites compound that is composed of iron (III) oxide (Fe_2O_3) and its cause spots or smudges of dark discolouration. From the previous data in Table 2 shows that the LECA aggregate contains the higher compound of Fe_2O_3 which is 20.38% while the crushed stone that was used in normal weight concrete only contain 3.21% of Fe_2O_3. It is proven that lightweight LECA concrete experience more hydration of ferrites compound and cause the concrete surface darker compared than normal weight concrete.

TABLE 4. The colour change of concrete

Days	Normal Weight Concrete	Lightweight Concrete (LECA)
Days 0		
Days 7		

Days	Normal Weight Concrete	Lightweight Concrete (LECA)
Days 14		
Days 21		
Days 28		

COMPRESSIVE STRENGTH

The strength of aggregate affected the strength of concrete. The advancement of concrete is conceivable just when the aggregate has enough strength. From this case of study, concrete has tested the strength after 28 days of curing. The 28 days period is an arbitrary specimen age though chosen for many good reasons for testing the compressive strength of concrete. Kosmatka et al. (2011) preferred 28 days as the standard specimen age to establish consistency for testing in the industry. It is estimated that concrete reaches 75% at 28 days of concrete to undergo compressive strength and its strength will remain stable. This tested is conduct to relate the strength of the concrete with their physical properties of the aggregate that were used. However, the strength of the concrete can be achieved depends on the method of casting, mix proportion, water-cement ratio, material, and compaction.

Table 5 shows the result of the compressive strength of concrete. Normal weight concrete is designed in grade M30 using 50 mm × 50 mm × 50 mm cubes. After 28 days of curing, normal weight concrete shows the strength of concrete well over 90% of its total strength which is in average 25.56 MPa. The compressive strength of light expanded clay concrete is 29.41 MPa which is more strength than normal weight concrete. However, the concrete does not reach targeted strength. This is impossible to achieve a blowhole-free surface while compaction of mortar into mould because the size of concrete is too small.

TABLE 5. The compressive strength of concrete

Compressive strength			
Normal Weight Concrete		(MPa) Lightweight Concrete	
Sample	Average	Sample	Average
23.426		30.080	
28.161	25.567	28.731	29.412
25.103		27.212	

According to ASTM C 330 (2005), the compressive strength of this structural lightweight concrete must be more than 17 MPa with the density of aggregate in dry form is not more than 1840 kg/m^3. It is proved the compressive strength of lightweight concrete is achieved according to the standard.

Figure 4 shows the observation on the failure shape of concrete were conducted. For comparison, the normal weight concrete is shown in Figure 4 started the failure from the interfacial transition zone (ITZ) and no failure found in aggregate. The shape of failure under compression strength is steep diagonal cone and as expected this may cause by the shear failure of crushed stone. The initial formation of ITZ and cement paste is related to the shear failure.

FIGURE 4. The shape failure of NWC

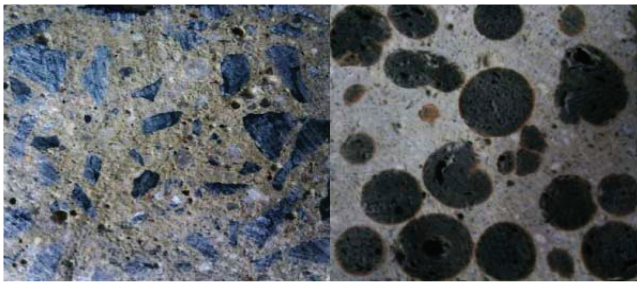
On the other hand, the shape of failure lightweight concrete containing LECA is a less steep diagonal cone. Besides that, it shows that a lot of LECA were destroyed in Figure 5. LECA were split into the half on the fracture surface signify that the failure was started from the inside space of aggregate. The fraction of lightweight concrete makes the LECA experiences the splitting tensile failure when compression test were conducted. Besides that, the LECA were connected and the results are the shape is like column shaped of failure.

FIGURE 5. The shape failure of LWAC

MICROSTRUCTURE OF CONCRETE

From this study, the cross-section of concrete can easily be observed under a microscope based on the aggregate particle size, shape, porous and cement paste. The microstructure of concrete is being considered the dispersed a matrix of cement paste with aggregate. The bonding between cement paste and aggregate in the concrete were depended on the mechanical properties of aggregate.

Figure 6 is the image under the digital microscope with magnification 20X of microstructure of cross-section of concrete. From the Figure 6, the bright area is referred to the mortar while the dark area is aggregate particles. The matrix of the mortar complex has some dark spot which is pieces of unhydrated cement paste.

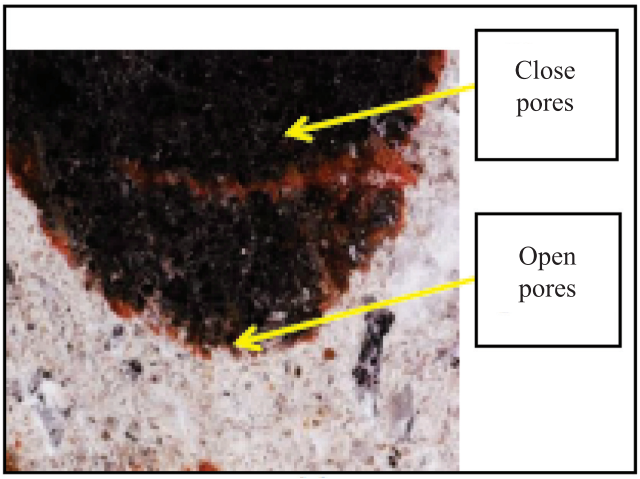


(a) (b)

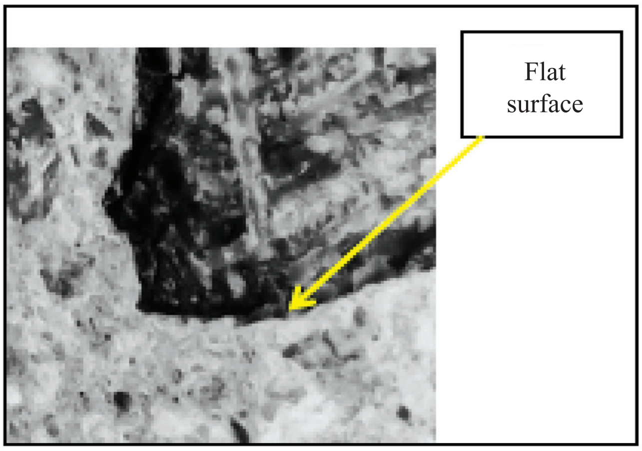
FIGURE 6. Microstructure of concrete (a) NWC and (b) LWAC

The results of an experiment, LECA shows clear interaction in the concrete and good in bonding between them. The structure of LECA in Figure 7 (a) is porous on the surface that helps cement bond with LECA and forms stronger due to interlocking between them. During mixing of LWAC, cement paste can flow through open pores of an outer layer of LECA. Besides that, it clearly is seen open pores of LECA were susceptible to water absorption. Moreover, LECA also has a closed porous structure that can help concrete increase development of the strength.

On the other hand, the solid structure of normal crushed stone in Figure 7 (b) shows rough surface, angular and elongated aggregate needed more water to form the workable concrete compared with the smooth and rounded shape of LECA. The larger size and high proportion of crushed stone which are elongated and flat aggregate cause the higher tendency of water films to accumulate at aggregate surface known as bleeding.



(a)



(b)

FIGURE 7. Interaction between cement paste with (a) LECA and (b) Normal aggregate

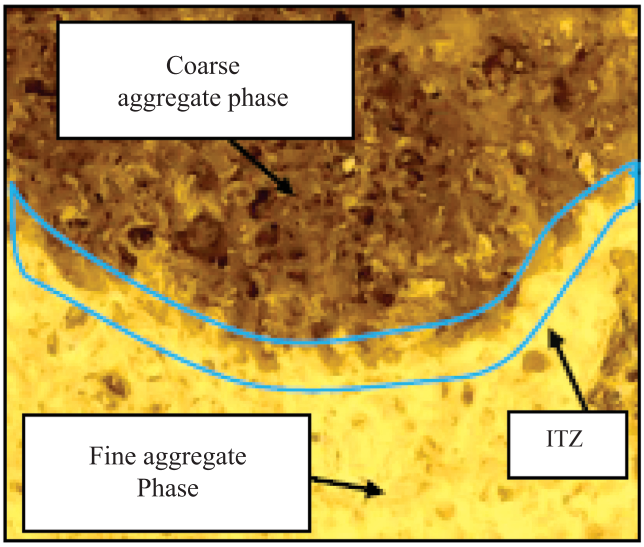


FIGURE 8. Interaction between cement paste with LECA

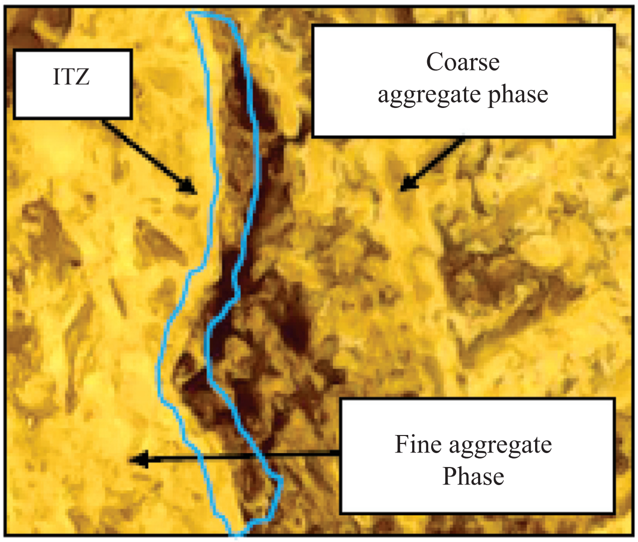


FIGURE 9. Interaction between cement paste with normal aggregate

INTERFACIAL TRANSITION ZONE (ITZ)

The unique characteristics of concrete based on microstructure are be observed under a microscope. From the microscope, the interfacial transition zone shows the small area next to the aggregate. The thin shell existed around the aggregate known as interfacial transition zone is the weaker part whether aggregate or bulk hydrated cement paste. Second, there have multiphase in character for each of the three stages. For example, each aggregate may have a few minerals for micro cracks and voids.

It can be observed that the digital microstructure in normal concrete in Figure 8 and lightweight concrete in Figure 9. From Figure 8 under a microscope, the properties of LECA is containing very dense outer shell and pores are help the development of interfacial transition zone (ITZ). While in Figure 9, the rough surface of normal aggregate created less strength of ITZ because of less interlocking between aggregate and cement paste. Besides that, LECA contains nature porous in the surface which contributes to interlocking sites for mortar and formed the stronger bonding between LECA and cement paste at the ITZ. In addition, the more pores of aggregate are effect 'wall effect' at ITZ area created stronger ITZ. Its help to increase the concrete strength since the microstructures are denser packed to each other.

However, flat surface of aggregate in Figure 9 does not help the development of strength of aggregate. This is due to the flat surface of aggregate do not have good bonding between aggregate and cement paste. These experiments explain the development of the larger ITZ of LWAC than the NWC due to reduces of wall effect at ITZ and large interlocking of a porous aggregate of LECA and cement paste. It is obviously different in the microstructure of the ITZ for normal weight concrete.

These experiments explain the development of the larger ITZ of LWAC than the NWC due to reduces of wall effect at ITZ and large interlocking of a porous aggregate of LECA and cement paste. It is obviously different in the microstructure of the ITZ for normal weight concrete.

CONCLUSIONS

The experiments show that the properties of aggregate effect the mechanical properties of concrete. The rough in surface, rounded shape and porous structure of LECA are good in the production of high strength of concrete. In addition, lightweight aggregate concrete (LWAC) contains of LECA is darker in colour of concrete surface due to hydration of ferrite compound and it helps the interaction of cement paste and aggregate to create stronger bond between them. Apart from hydration, this process bind the individual particles of the mixture to make "concrete" and forming a solid mass. It proves that, the behaviour of the material can be determined by investigating the microstructure of concrete.

The microstructure can be easily observed under microscope and proven that the cement paste-aggregate bonding have relied on the nature external shell of aggregate. The open and close porous of LECA in the concrete are helps the development strength of concrete while NWC with the rough surface of aggregate has improved the workability. Besides that, the characteristics of interfacial transition zone of concrete are rely on the physical, chemical and mineralogical of structure aggregate. From the result of experiment, the ITZ of LWAC have more pores and denser structure because the properties of LECA with porous surface is help to better strength of concrete.

ACKNOWLEDGEMENT

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