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The effect of mixing rice husk ash and palm oil boiler ash on concrete strength

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Abstract: Physical properties such as compressive strength and tensile strength of concrete can be changed by adding a mixture of rice husk ash and palm oil boiler ash in concrete. The rate of absorption of water by the concrete mixed with rice husk ash and mixed with palm oil boiler ash was further tested. Levels addition of the mixture to be tested is 5%, 10%, 15% , and 20% by long immersion for 7 days, 14 days, 21 days, 28 days, and 60 days. Tests on the compressive strength and modulus of elasticity of concrete from a wide variation in the mixture, analyzed by XRD (X - ray diffractometry). Analysis of the surface morphology and content of elements contained in the sample of natural bentonite, used Scanning Electron Microscopy (SEM). The test results showed the addition of a mixture of rice husk ash, palm oil boiler ash , and the addition of a mixture of both, ideal on concrete that has the addition of a mixture of 5% composition. With the addition of the concrete mix results in a SiO_2 content of the concrete is reduced. Significant content of SiO_2 is with a mixture of 5% rice husk ash. Compressive strength and modulus of elasticity of concrete with rice husk ash mixture 5% higher than the others.

Keywords: Concrete, Compressive Strength, Modulus of Elasticity

1. Introduction

Concrete is a building material that is most widely used in the world. Global production is around 4 billion m^3 annually, with about 1.25 billion tons of cement a year [1]. Concrete is a mixture of fine and coarse aggregate cement, sand and water, in the presence of air cavities. As the composite material properties of concrete is very dependent on the interaction between the constituent materials. Cement is the key ingredient in concrete, although there were only 7-15% of the mixture.

The use of partial cement replacement material through an innovative mix composition will reduce the amount of cement used in order to reduce greenhouse gas emissions and use of fossil energy consumption of the earth in the cement industry [2]. The use of adhesive or ceramic or inorganic matrix for natural fibers, developed in various countries including the use of natural fiber rice husk ash and palm oil boiler ash. Mortar that use palm oil boiler ash as a partial replacement of cement, showed that the maximum compressive strength obtained in the palm of boiler ash content between 20% - 30% [3]. Rice Husk Ash fiber properties can reduce the density of the concrete making it possible to make a lightweight concrete [4].

Rice husk ash is a residue of agricultural rice milling process. Indonesian Central Bureau of Statistics (2011) reports that paddy production in 2011 by 1st Forecast Figures (FF I) - 2011 is estimated at 67.31 million tons of paddy rose 895.86 thousand tons (1.35 percent) than in 2010 amounted to 66.41 million tons of paddy. Approximately 20 % of the total production of the resulting rice husk ash. This means that Indonesia produced 13,462 tonnes of rice husk ash in 2011.

North Sumatra has oil palm plantations of about 855,333.00 hectares, with a total production of about 12,070,507.81 FFB (Fresh Fruit Bunches). With the palm oil boiler ash is formed in large quantities. Use of rice husk ash on cement composites can provide several advantages such as increased strength and endurance, reduce the cost of materials, reducing the environmental impact of waste materials, and reduce CO_2 emissions [5]. With the addition of palm oil boiler ash in a certain percentage of the weight of cement is expected to improve the quality of the mortar, the compressive strength and good water absorption.

Rice husk ash is a material that has yet lignosellulosa like other biomass containing high silica. In the form of crystalline silica (quartz and opal) and amorphous concentrated on the outer surface and a bit of surface in [6]. Chemical content owned consists of 50% cellulose, 25-30% lignin and 15-20% silica [7]. Very high porosity causes can absorb large amounts of water [8].

Reactivity between silica in rice husk ash with calcium hydroxide in the cement paste can be influential in improving the quality of concrete [9]. Rice husk ash increasingly fine would increase the strength of the concrete mix, due to increased activity and therefore pozzolanik rice husk ash acts as mikrofiller in the concrete matrix [10].

Through several studies have been conducted to examine the feasibility of using POFA in construction materials . palm oil boiler ash is a agro waste resulting from the burning of palm oil residues which is known as POFA (Palm Oil Fuel Ash) [11]. Palm oil boiler ash formed from the combustion of shell and palm oil boiler ash of fruit fibers contains a chemical element silica (SiO_2) as much as 31.45 % and elements of Lime (CaO) as much as 15.2%. If the element silica (SiO_2) was added to the concrete mix, then the element silica will react with the free lime Ca (OH)2 which is a weak element in the new concrete into the CSH gel. CSH gel is the main element that affects the strength of cement paste and concrete strength. 40% replacement of cement with rice husk ash can be made with no significant changes in compressive strength compared to the control mix (concrete without rice husk ash)[12]. Maximum compressive strength of mortar with the addition of a mixture of Abu Boiler Palm Oil from Malaysia is 20 % [3], while the use of the addition the mixture Abu Boiler Palm Oil derived Thailand produces a maximum compressive strength of 30 % [3].

Strong need for the concrete to reach the level of ultra high compressive strength is reached 120Mpa [13].Nature is resistant to pressure, and weather resistant. Must avoided the water - resistant properties (permeability of concrete is Relatively high), the low tensile strength, easy terdesintegrasi by sulfate contained by ground [14]. This is determined by the properties of its constituent materials, mixing ratio, and the method of implementation of the work [15]. Concrete can be distinguished based on the unit weight of concrete and strong of concrete. Contents concrete are classified in three general categories items, namely, (1) Lightweight concrete (light weight concrete / LWC) weighing 1800 kg/m^3, (2) Normal concrete (Normal weight concrete) weighing 2400 kg/m^3, and (3) concrete Weight (Heavy Weight concrete) with greater than 3200 kg/m3. properties of hardened concrete has an important meaning during its lifetime associated with the concrete compressive strength and split tensile strength of concrete .

The main function of the cement is as an adhesive on the concrete. Semen is composed of limestone (limestone), which is the compound calcium oxide (CaO), clay (clay) are compounds Oxides Silica (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3) and magnesium oxide (MgO). The raw material is burned to melt to produce cement. Partly to form a clinker. Clinker is then crushed and added to the gypsum. Cement that binds the aggregate particles apart to become one entity. The composition of the cement-forming material is (a) 3CaO.SiO_2 (tricalcium silicate) abbreviated C3S (58% - 69%), (b) 2CaO.SiO_2 (dicalcium silicate) abbreviated C2S (8% - 15%), (c) 3CaO. Al_2O_3 (tricalcium aluminate) abbreviated C_3A (2% - 15%), (d) 4CaO.Al_2O_3.Fe_2O_3 (tetracalcium alummoferrit) abbreviated C_4AF (6-14%).

Setting and hardening is binding and hardening of cement hydration reaction that occurs after. Cement hardening reactions are written as below.

$$C_2S + 5H_2O \longrightarrow C_2S.5H_2O$$
$$C_3S + 18H_2O \longrightarrow C_5S6.5H_2O + 13Ca(OH)_2$$
$$C_3A + 3CS + 32H_2O \longrightarrow C_3A.CS.32H_2O$$
$$C_4AF + 7H_2O \longrightarrow C_3A.6H_2O + CF.H_2O$$
$$MgO + H_2O \longrightarrow Mg(OH)_2$$

With this, the need to find an ideal composition to improve the quality of concrete by mixing with rice husk ash and boiler ash mixing with oil palm and mixing both the constituent materials.

2. Methods and Materials

Material consisting of Concrete (coarse aggregate, fine aggregate, cement), rice husk ash, and palm oil boiler ash are mixed in the mortar according to design separate plots. Mix composition for rice husk ash in concrete, and palm oil boiler ash in concrete, respectively, are 5% : 95% , 10% : 90% , 15% : 85% and 20% : 80% . Composition of mixing the three together (rice husk ash , palm oil boiler ash, and concrete), was 2.5% : 2.5% : 95% , 5% : 5% : 90% , 7.5% : 7.5% : 85 % and 10% : 10% : 80%. The sample is formed by mold shaped cube and cylinder. Tests conducted by the length of drying, ie 7 days, 14 days, 28 days and 60 days. Tests on concrete compressive strength, modulus of elasticity, water absorption and density of concrete was analyzed by XRD (X- ray Diffractometry), SEM and EDX. XRD technique was used to identify crystalline phases in the material by determining the parameters of the lattice structure, as well as to obtain particle size. Characterization (XRD) were used in the room temperature by using a Shimadzu XRD 600 X - ray Diffractometer (40 kV, 30 mA). To filter CuKα radiation used nickel. The rate of scanning used is from 0,010 / CPS in the range 2θ = 50-600. Analysis of the surface morphology and content of elements contained in the sample of natural Bentonite, used Scanning Electron Microscopy (SEM).

3. Results and Discussion

Concrete compressive strength test results shown in Table 1. Compressive forces are greatest at the age of 60 days in a mixture of Rice Husk Ash 2.5% + Boiler Palm Oil

Ash 5% in the amount of 567.55 kg/ m^2, and followed by a mixture of Rice Husk Ash 5% at 560 kg/cm^2 followed by a mixture of Palm Oil Boiler Ash 5% at 448 kg/ cm². As for the concrete without mixture over low at 445.78 kg/cm^2.

Table 1. *Results Analysis of Concrete Compressive Strength.*

Time (days)	Sample type												
	Concrete (kg/cm²)	RH5% (kg/cm²)	RH10% (kg/cm²)	RH15% (kg/cm²)	RH20% (kg/cm²)	PO5% (kg/cm²)	PO10% (kg/cm²)	PO15% (kg/cm²)	PO20% (kg/cm²)	RHPO5 % (kg/cm²)	RHPO 10% (kg/cm²)	RHPO 15% (kg/cm²)	RHPO 20% (kg/cm²)
7	319.56	399.56	317.78	315.56	307.56	356.45	328.89	308.00	277.33	401.78	342.22	324.00	288.89
14	386.67	514.22	375.56	379.55	364.00	398.67	386.87	346.22	299.56	478.67	389.54	395.56	368.00
21	405.33	527.99	398.67	397.78	380.00	417.78	392.44	357.78	321.33	520.87	403.56	415.56	379.56
28	414.67	550.22	432.45	411.11	391.11	431.11	405.78	378.22	327.11	547.56	415.56	418.67	376.44
60	445.78	560.00	444.47	425.33	403.05	448.00	416.44	395.11	329.33	567.55	434.22	434.22	383.56

RH = Rice Husk Ash; PO = Palm Oil Boiler Ash; RHOP = Rice Husk Ash and Palm Oil Boiler Ash

This is thought to occur because the RH and PO containing amorphous SiO_2. At the time of hydration of cement with water, hydrolyzed resulting hydrochloric calcium ($Ca(OH)_2$) and Calcium silicate hydrate (C-Si-Hgel), in which the CS - Hgel is a binder in concrete. Calcium Hydroxide ($Ca(OH)_2$) reacts with the amorphous SiO_2 from rice husk ash (RH). Palm oil boiler ash (PO) generates C-Si-Hgel that add new power tie on the concrete so that the concrete is better.

For the modulus of elasticity of the largest concrete mix contained in Rice husk ash 2.5 % + Palm oil boiler ash 2.5% (LoA) 5 % at 26848.18 MPa followed by a mixture of Rice husk ash (RH) 5% at 27311.65 MPa while for the concrete mix without more low at 26131.78 MPa. Tendency of increase in modulus of elasticity occurs on the addition of a mixture of rice husk ash (RH) or a mixture of palm oil boiler ash (OP), at a certain position in line with the increase in compressive strength of concrete on the addition of a mixture of rice husk ash (RH) and palm oil boiler ash (OP). This means that the concrete is more brittle. So it can be concluded that the value of the modulus of elasticity of concrete will rise along with increasing the compressive strength of concrete. Shown in Table 2

Table 2. *Results Analysis of Modulus of Elasticity.*

Time (days)	Saple Type												
	Concrete (MPa)	RH5% (MPa)	RH10% (MPa)	RH15% (MPa)	RH20% (MPa)	PO5% (MPa)	PO10% (MPa)	PO15% (MPa)	PO20% (MPa)	RHPOS5 % (MPa)	RHPO 10% (MPa)	RHPO 15% (MPa)	RHPO 20% (MPa)
7	22838.71	24654.34	21468.83	21466.58	21180.56	23382.17	22401.84	21435.50	20886.05	24771.46	22556.62	21864.64	20914.69
14	25380.56	28352.24	24635.77	23819.02	23243.50	24938.26	24274.74	23117.37	22494.41	27342.39	24712.28	24503.78	23765.52
21	26109.86	29394.35	25528.96	25143.75	24401.18	26330.03	24957.57	24122.71	22842.83	29265.50	25486.36	25842.35	24606.35
28	26428.14	30358.53	26730.78	26003.43	25322.67	26789.11	26075.30	24883.46	23309.84	30224.21	26292.08	26207.87	24918.82
60	26131.78	29192.03	27095.75	26438.67	25681.32	27311.65	26364.29	25569.22	23361.29	30780.45	26848.18	26773.43	25130.10

Analysis by XRD in the palm oil boiler ash, obtained an element that has the greatest Wt%, is a Calcium Titanium Oxide ($CaTiO_3$) with a 0.859, followed by Silicon Oxide (SiO_2) with a 0.831, and Aluminum Silicate Hydroxide ($Al_2Si_2O_5(OH)_4$) with 0,703 such shown in Figure 1.

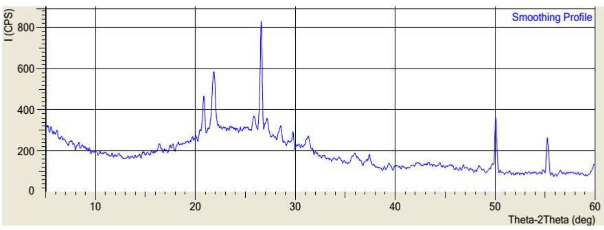

Figure 1. *XRD palm boiler ash.*

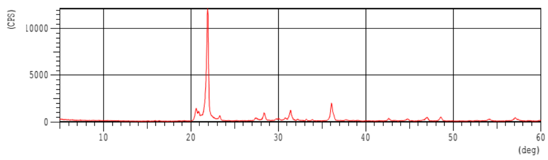

Figure 2. *XRD rice husk ash.*

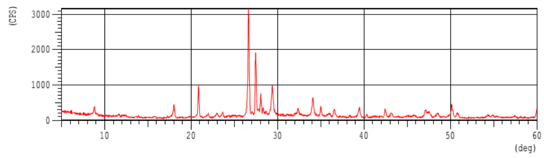

Figure 3. *XRD Concrete.*

Testing with Rice husk ash XRD to provide results, that element which has the largest Wt%, is Silicon Oxide (SiO_2)

with a 0.842, followed Tantalum Oxide (Ta_2O_5) with 0.678, and Calcium Carbonate ($CaCO_3$) with 0.669 as shown in Figure 2. Concrete testing with the XRD, giving results that element that has the greatest Wt%, is Calcium Carbonate ($CaCO_3$) with 0.942 followed by Silicon Oxide (SiO_2) with a 0.918 as shown in Figure 3. Figure 4 shows the XRD testing on Rice Husk Ash 5%. The element that has the greatest Wt%, is Calcium Carbonate ($CaCO_3$) with a 0.946, followed by Calcium Hydroxide ($Ca(OH)_2$) with a 0.922, and Silicon Oxide (SiO_2) with a 0.910.

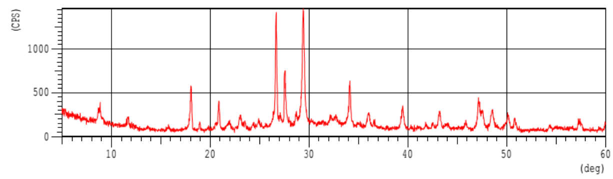

Figure 4. *XRD rice husk ash 5%.*

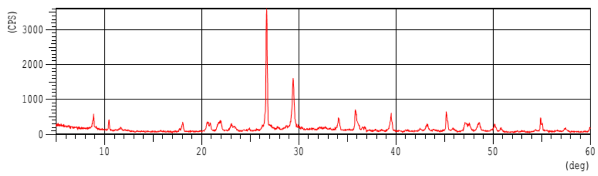

Figure 5. *XRD abu boiler palm oil 5%.*

Testing by XRD palm oil boiler ash against deliver results, that element which has the largest Wt%, is Calcium Carbonate ($CaCO_3$) with a 0.938, followed by Silicon Oxide (SiO_2) with 0,885, and Calcium Hydroxide ($Ca(OH)_2$) with 0.764 as shown in Figure 5. Testing by XRD to mix rice husk ash and palm oil boiler ash provide results, that element which has the largest Wt%, Calcium Hydroxide is ($Ca(OH)_2$) with 0.785 followed by Calcium Carbonate ($CaCO_3$) with 0.752 out second and Silicon Oxide (SiO2) ranked third with 0.694 seen in Figure 6.

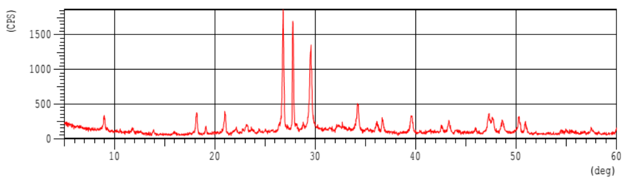

Figure 6. *XRD ash rice husk ash + palm oil boilers ash 5%.*

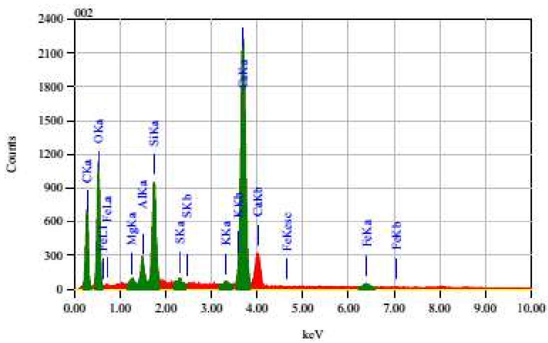

Figure 7. *Concrete spectrum.*

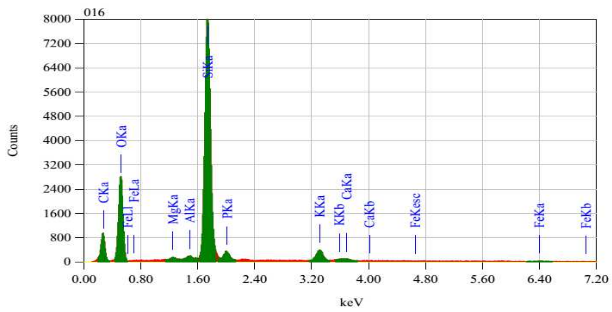

Figure 8. *Spectrum of rice husk ash.*

The results of morphology by SEM EDX Concrete, obtained an element that has the largest peak, is the mass amount of Calcium with 37.56%, followed by the element Oxygen in second place with 37.38% shown in Figure 7. Figure 8 shows the results of the morphology by SEM EDX Rice Husk Ash. Looks element that has the greatest peak, is oxygen with a mass number of 44.35% followed by the element Silicon in second place with 24.82%. The results of morphology by SEM EDX Palm Oil Boiler Ash, obtained an element that has the greatest peak, is oxygen with a mass number of 43.48% followed by the element Silicon in second place with 12.18% shown in Figure 9. The results of the SEM morphology and EDX Concrete Rice Husk Ash, obtained an element that has the largest peak, is oxygen with a mass number of 43.74% followed by the element Silicon in second place with 16.75% shown in Figure 10.

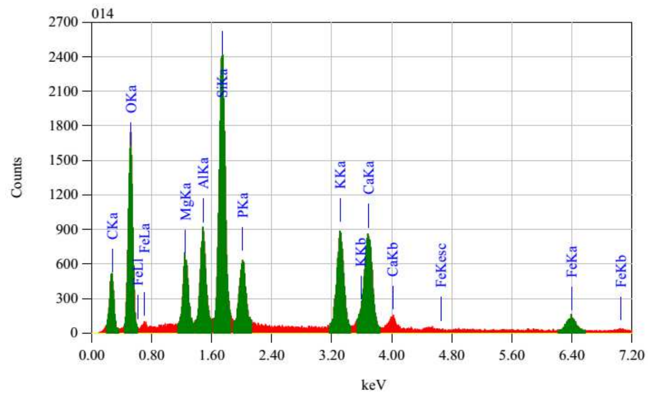

Figure 9. *Spectrum palm oil boiler ash.*

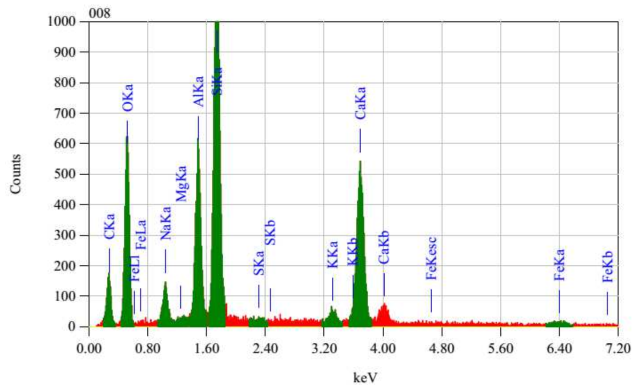

Figure 10. *The spectrum of concrete and rice husk ash.*

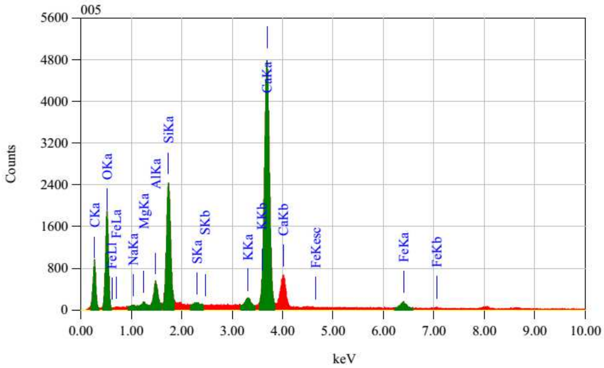

Figure 11. The spectrum of concrete and palm oil boiler ash.

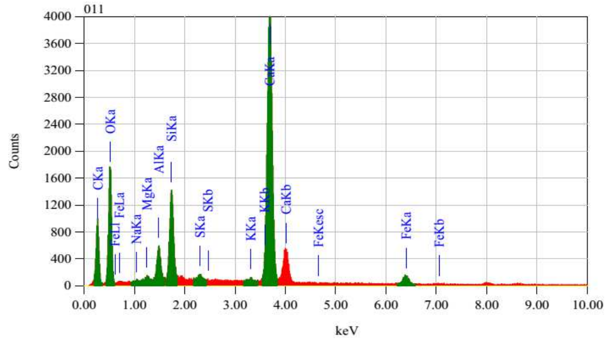

Figure 12. The spectrum of concrete with a mixture of rice husk ash and palm oil boiler ash.

The results of the SEM morphology and EDX Concrete Abu Boiler Palm Oil, obtained an element that has the greatest peak, is the mass amount of Calcium with 25.78% followed by the element Oxygen in second place with 46.33% as shown in Figure 11. The results of morphology by SEM EDX Concrete Mixed With Rice Husk Ash and Boiler Abu Palm Oil, indicates elements with the largest peak is Calcium with mass amounts of 24.93% followed by the element Oxygen in second place with 48.12% as shown in Figure 12 . Distribution of particles with a magnification of 750 times, it seems the average particle size is 20µm, shown in Figure 13.

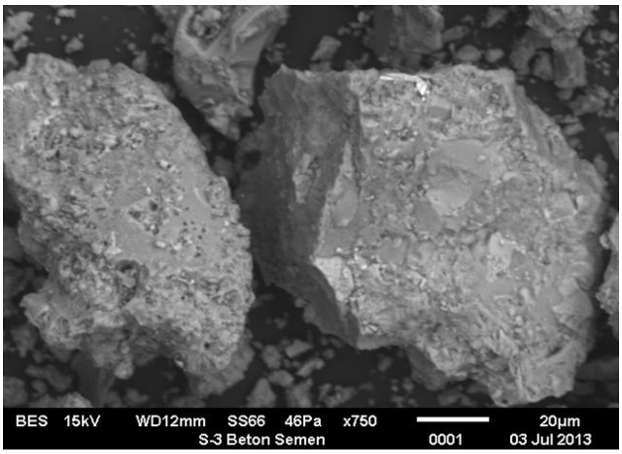

Figure 13. Concrete morphology.

4. Conclusion

The addition of a mixture (Rice Husk Ash, Palm Oil Boiler Ash, and Both together) on concrete, are ideal additions to the composition of the mixture of 5%. This is based on Mechanical and Physical Test results on a wide range of composition and duration of immersion. XRD results SiO_2 at Palm Oil Boiler Ash, Rice Husk Ash, Concrete, Concrete with a mixture of Rice Husk Ash 5%, Concrete with a mix Palm Oil Boiler Ash 5%, with a Concrete mixture Rice Husk Ash 2.5%, Palm Oil Boiler Ash 2,5 %, respectively are 0.831 Wt %, 0.842 Wt %, 0.918 Wt %, 0.903 Wt %, 0.885 Wt % and 0.695 Wt %. This is based on the mixing of rice husk ash , palm oil boiler ash in concrete resulted SiO_2 content of the concrete is reduced. Significant addition to approaching the value of SiO_2 content in concrete, is concrete content to the mix Rice Husk Ash 5% . Concrete with Rice Husk Ash mixture of 5%, has a compressive strength and modulus of elasticity which is the highest compared with other compositions that are considered to improve the quality of concrete.

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