MECHANICAL PROPERTIES OF AFTER-FIRE CONCRETE WITH RICE HUSK ASH (RHA) AS AN ADDITIONAL MATERIAL

Ngudiyono Joedono
Department of Civil Engineering, Faculty of Engineering, Mataram University
Jl. Majapahit 62 Mataram NTB, email: joedono1@yahoo.com

Abstract: *The temperature above 200 °C at fire can cause reducing of the strength of concrete. To anticipate that condition, in order to enhance the strength, the use of rice husk ash (RHA) as an additional material is an alternative. The research would like to know the mechanical behavior and physical changing of after fire concrete with RHA. The specimens are concrete cylinder with 15 cm in diameter and 30 cm height. They are 54 specimens, 30 specimens are used for compression strength of normal concrete at various ages, and the less 24 specimens are used for the compression strength of after fire concrete. The test runs at 3, 7, 14, 28, and 90 days for normal concrete, and 90 days for after fire concrete. The temperatures of fire are 200, 400, 600, and 800 °C respectively with duration one hour. At temperature 200 °C, the compression strength of normal concrete lower than that of RHA concrete. In addition, at 400, 600, and 800 °C, the compression strength of normal concrete less decrease than that of RHA concrete Modulus elasticity of both normal and RHA concrete decrease after firing at 200 to 800 °C. At 400 to 600 °C, they have surface crack and color changing brown to black brown for normal concrete, also white brown for RHA concrete. At 800 ˚C, for normal concrete not only have surface cracks but also spalling. The colors of the concrete become white brown (at 600 °C), and white pink (at 800 °C).*

Keywords: *after-fire concrete, rice husk ash (RHA), spalling*

Abstrak: Pada saat kebakaran, bila suhu yang terjadi di atas 200 °C, kekuatan beton akan menurun. Penambahan abu sekam padi (RHA, *rice husk ash*) merupakan upaya memperbaiki mutu beton. Pada penelitian ini akan dikaji seberapa jauh penurunan kekuatan dan perubahan fisik beton dengan penambahan abu sekam padi 15 % pasca kebakaran. Benda uji berupa silinder beton dengan diameter 15 cm dan tinggi 30 cm. Jumlah benda uji sebanyak 54 sampel, 30 sampel dipakai untuk kuat tekan pada umur yang berbeda, dan 24 sampel dipakai untuk uji kuat tekan beton pasca bakar. Pengujian kuat tekan beton dilakukan pada umur 3, 7, 14, 28, dan 90 hari untuk beton pra bakar, dan 90 hari untuk beton pasca bakar Pembakaran dilakukan pada suhu 200, 400, 600, dan 800 °C, dengan lama pembakaran masing-masing 1 jam. Pada suhu 200 °C, beton normal mengalami kenaikan kuat tekan lebih kecil bila dibandingkan dengan kuat tekan beton dengan abu sekam padi. Pada suhu 400, 600, dan 800 °C beton normal mengalami penurunan kuat tekan lebih kecil dari penurunan kuat tekan beton dengan abu sekam padi. Modulus elastisitas beton normal maupun beton dengan abu sekam padi pasca bakar suhu 200 hingga 800 °C mengalami penurunan. Pada suhu 400 hingga 600 °C, beton normal maupun beton dengan RHA mengalami retak-retak permukaan (*surface crack*), dan perubahan warna, menjadi abu-abu kehitaman (beton normal), dan abu-abu (beton RHA). Pada suhu 800 °C beton normal selain mengalami retak-retak permukaan juga mengalami pengelupasan (*spalling*). Warna beton menjadi putih keabu-abuan (suhu 600 °C) dan merah muda keputih-putihan (suhu 800 °C).

Kata Kunci: beton pasca-bakar, abu sekam padi, pengelupasan

BACKGROUND

On fire, reinforcement concrete structure has raising and decreasing temperature cycle time. That condition will induce not only physical and chemical complex changing of the concrete but the reinforcement.

The higher the temperature of fire, the larger the concrete strength decreases. At 200 °C, the strength of the concrete increase, on the contrary, at 400 °C, the strength decreases until 20 % to the initial condition. The compression strength is extremely decreased at the temperature of 400 to 700 °C. The salvage value strength of the concrete at 700 ^{o}C is 35 %. Above 700 ^{o}C, the concrete has no strength (Partowiyatmo, 1996).

Rising of the concrete temperature will influence the quality. Additionally, bad hydration of Portland cement will cause waste porous substance as $Ca(OH)_2$. The porosity of the concrete will also influence the strength. To minimize the influence of the both factors (the fire and void), the concrete must include with rice husk ash (RHA) as a pozzoland.

OBJECTIVE OF THE RESEARCH

Temperature of concrete and reinforcement steel on fire can cause degradation of the strength and the stiffness of the stucture. On the temperature up to 200 ^{o}C of fire, the concrete strength will get smaller. RHA as Pozzoland to treat the concrete can anticipate the reduction of the strength. The research presented in this paper is aimed to know the gradation of the strength of 15 % RHA concrete after gain a fire. In addition, the reseach also has an aim to know the condition of concrete after fire such as the color, spalling, and crack patern.

BOUNDARY OF THE PROBLEM

There was some limitation during the research, such as:

1. Using RHA from waste brick burning with optimum content 15 % of cement's weight.
2. The temperature variations of the specimen are 200, 400, 600, and 800 ^{o}C.
3. Specimens burning during an hour by using thermocouple furnace at Ceramic Art Working, BTN Gunung Pengsong, Kecamatan Labuapi, Lombok Barat.

REVIEW OF LITERATURES

The compression strength decrease when temperature increases. At temperature higher than 400 ^{o}C, the compresion strength is 90 % than that of normal concrete, and maximum 40 % if is the temperature is 700 ^{o}C. At 400 ^{o}C, the flexure strength decreases to 26% of that of normal concrete (Neville, 1975).

Poh and Bennets (1995) said that there are several factors which influence to behavior of the structure after fire, such as: temperatur variation at time dependent, temperatur variation at the section (cross or, and longitudinal section), non linier material, Loading combination (axial, flexure, and biaxial), initial crack, salvage value of stress, external Restrains.

Durani dan Castillo (1990) said that high strength concrete at 100 to 300 ^{o}C, loss their compression strength untill 15 to 20 %, and that of normal concrete until 6 to 10 % at room temperature. Finally, at 400 to 800 ^{o}C the loss strength more or less depressed up to 30 %. On the other hand, Partowiyatmo (1996) said that at 400 ^{o}C and 700 ^{o}C, the concrete have 20 % and 65 % loss of their compression strength. The compression strenght will worthless at the temperatur greater than 700 ^{o}C.

The compression and split strength of concrete will decrease significantly at the temperature greater than 300 ^{o}C. Al-Shaleh dan Al-Mutairi (1997) had their research at several structural building elements after fire. For column, beam, and plate, the compression strength decreases more or less than 30 to 48 %. Additionally, the structures had surface cracks.

Crozier et al (1998) the color changing and surface cracking occur at high temperature.

At 600 ^oC and 800 ^oC, the beam sample test had cracks at the side, and botom surface. The compression strength will reduce to 35, 60, and 80% at 400, 600, and 800 ^oC respectively.

Teguh (1997) said that the reinforcement concrete beam, after fire at 800 ^oC during an hour 1 hour, had flexure load decrease up to 20 %. In contrast, at the same temperature during 2, 3, and 4 hours, the load decreases more than 40 %.

The decline of modulus elasticity, and increase of the maximum strain of the concrete occur at the concrete fracture (Terro dan Hamoush, 1997).

Hansen (1976) said that concrete modulus elasticty will decline 25 %, if its heated at 500 ^oF, and that of 50 % if heated at 800 ^oF.

Durrani dan Castillo (1990) also said that modulus elasticiy of concrete at 100 ^oC to 300 ^oC will decline 5 to 15%, and at 800 ^oC decline 20 to 25 % than that of at room temperature.

Nurahmah (2000) found the compression strength of concrete cilinder at 300 to 800 ^oC oven, and furnace each 78 to 11 %, and 90 to 27 % from that of the controll concrete (at 28 days). In the same condition, the modulus elasticity were 83 to 28%, and 89 to 47% from that of the controll. The compression strength of core case of reinforcement concrete beam were 96 to 51% from that of controll concrete. Its modulus were 97 to 65% from that of the controll. The Compression strength changing every centimeter core deep changing were 0.4 %, and the modulus elastisity were 1.2 to 2.2% of that of the controll. In addition, there were no significan differences between compression strength of vertical and horizontal core case.

Ngudiyono (2001) said that surface cracking, spalling, and collor changing (to white pink) applied at the concrete beam on fire at 800 ^oC. The flexibility, ductility, and ultimate flexure strength lower such 40.06, 15.65, and 2.09 % respectively than that of the normal concrete of reinforcement concrete beam with Carbon Fiber Strips greater 38.28, 12.37, and 26.51 % respectively than that of normal concrete.

Base on Lianasari (1999), cement paste will swell at 100 ^oC, and shrink at 500 ^oC due to dehidration. Up to 700 ^oC, the strength will lose, and cause no tighting between cement paste and agregate.

Sabuni (in Lutfi, 2000), rice husk from Tanzania at 350, 400, 500, 600, and 900 ^oC on six to sixty seven hours give RHA. At 500 ^oC belong to 20 hours will give optimum result. The chemical contains are SiO_2 (88.61 %), Al_2O_3 (0.28 %), CaO (0.49 %), MgO (1.98 %), Na_2O (0.05 %), K_2O (3.56 %), Fe_2O_3 (0.19 %), and loss of igmition (4.56 %).

The compression strength of concrete with 5, 8, 10, and 15 % RHA, w/c = 0.4 greater than that of the controll concrete (0 %). The optimum compression strength is founded at 15 % RHA. Modulus elastisity of concrete at 28 days are equal between the RHA and normal concrete (Zhang and Malhotra, 1996).

RESEARCH METHOD

Description of the specimens

Fifty-four 15 x 30 cm cylinders of specimens were included in the investigation. The detail specimens were shown in Table 1 and Table 2.

Table 1. The Specimens for Normal Concrete and 15 % RHA at Different Age

Specimen code	Ages (Days)	Total Number of Specimens
BN	3, 7, 14, 28 & 90	3 each
BN+RHA	3, 7, 14, 28 & 90	3 each
	Total	30

Table 2. The Specimens for Concrete After Fire

Specimen code	Temperature (^oC)	Duration (Hours)	Total Number of Specimens
BNPB	200, 400,600, & 800	1	3 each
BN +RHAPB	200, 400,600, & 800	1	3 each
	Total		24

BN = Normal Concrete
BN + RHA = RHA's Concrete
BNPB = After Fire Normal Concrete
BN + RHAPB = After Fire RHA's Concrete

RESULTS AND DISCUSSION

Compression Strength of After Fire Concrete

The compression strength of normal concrete at the age of 3, 7, 14, 28, and 90 days are presented in Figure 1.

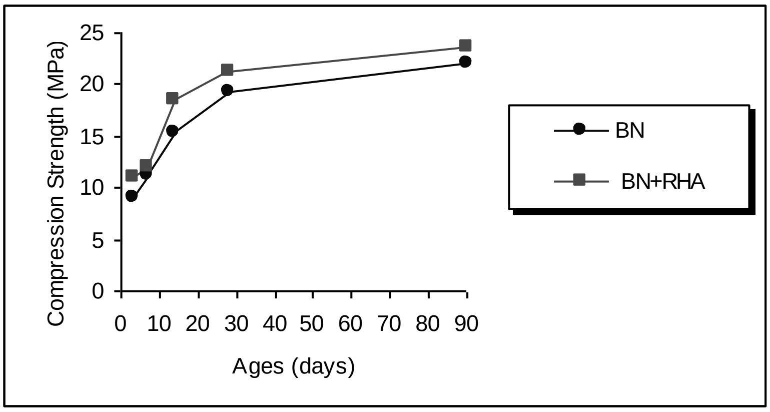

Figure 1. The Ages versus the Compression Strength of Concrete

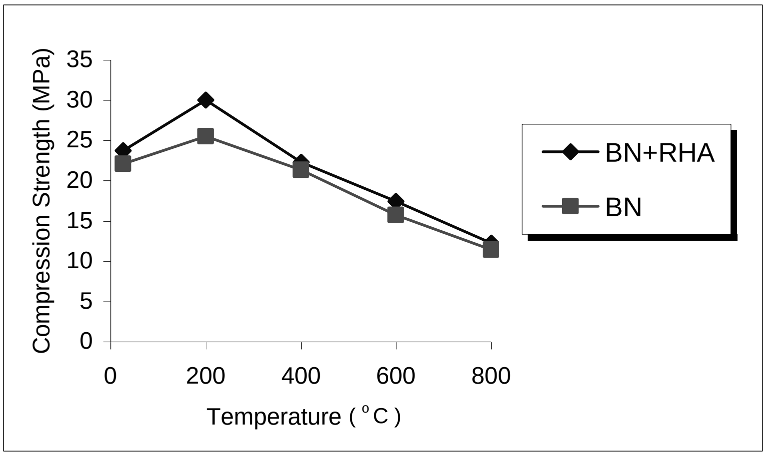

Figure 2. The Temperature versus Compression Strength

The compression strength of after fire concrete

Figure 2. shows the compression strength increase to maximum at 200 ^oC, then decrease when the temperature raise up. The phenomena take places because of dehydration process. The process repair of thigh ting among Calcium Silica Hydrate (C-S-H) particle toraise the compression strength.

If the temperature rises between 200 to 600 ^oC, the strength of the concrete will decrease. The decrease because of there is no water already in the pore. The pore fills with air. In addition, the raise of temperature changes the composition of $Ca(OH)_2$ to CaO that It has already had strengthless. At 600 ^oC or 700 ^oC, decomposition process of C-S-H particle to free CaO, SiO_2, and steamed water H_2O. The decrease of C-S-H that is the main particle for the strength of the concrete will cause concrete strength decline.

Figure 2. also shows the compression strength of 15 % RHA concrete under temperature fire gerater than 200 ^oC, higher than that of normal concrete. The addition of RHA in concrete mix will make new particle that cause more comprehensive reaction. The reaction are between silica (SiO_2) in RHA and Calcium Hidroxide ($Ca(OH)_2$) to $3Ca.2SiO_3.3H_2O$ or Calcium Silica Hydrate (C-S-H). It increases the strength and and dense of the concrete.

The compression strength of 0 % RHA concrete at room temperature (27 ^oC); 200, 400, 600, and 800 ^oC were 22.0803, 25.477, 21.325, 15.7115, and 11.417 MPa respectively. The compression strength of 15 % RHA concrete at room temperature (27 ^oC); 200, 400, 600, and 800 ^oC were 23.6375, 30.0065, 22.269, 17.4566, and 12.2665 MPa respectively. Based on the data, normal concrete on temperature of 200˚ C increases the compression strength to 15.633 %. On the same temperature, its compressions strength increases to 26.945 % for 15 % RHA concrete. On the other hand, at the temperature of 400, 600, and 800 ^oC, the compression strength for normal concrete decline as 2.564, 28.843 and 48.293 % of control sample respectively. The compression strength for 15 % RHA concrete on the same temperature declined as 5.988, 26.304, and 48.215% of the sample respectively.

The declining and extending of after fire concrete compression strength shows at Figure 3. Based on the Figure 3, the compression stength of 15 % RHA concrete greater that that of no RHA.

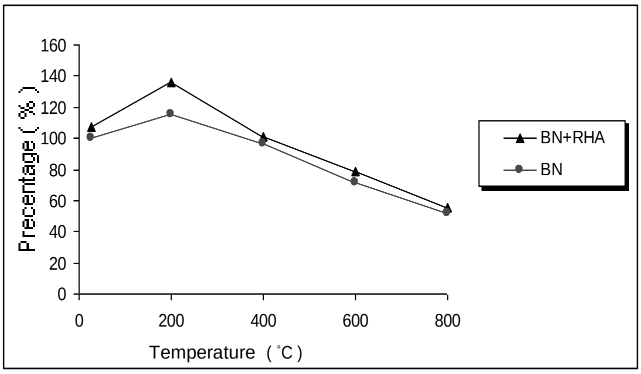

Figure 3. The Precentage of Declining and Increasing of Compression Strength at High Temperature

On the conclusion, 15 % RHA concrete has greater durability than normal concrete.

Elasticity modulus by using modulus secant formula (0,4 $f'c$) for Pre-fire/normal concrete at 28 and 90 days were 8403.5963 and 10520.8197 MPa. On the same condition, the RHA concrete were 8005.8324 and 10124.5260 MPa. They were lower than that of the standart (14000 till 31000 MPa). The result is cause of several factors such as loading velocity, uneven of loading surface, mankind, and the apparatus. At 28, and 90 days, elasticity modulus of pre-fire RHA concrete decrease of 4.733 % and 3.766 % to that of normal concrete.

Figure 4. shows elasticity modulus of concrete without or with RHA at room temperature (27 ˚C), 200, 400, 600, and 800 ˚C. The elasties modulus of RHA's concrete are 10124.526, 8602.628, 6089.4, 2126.12, and 1126.119 MPa.

Figure 4. also shows elasticity modulus for normal concrete at the same temperature were decrease 3.766, 18.233, 42.121, 79.792, and 89.297 %. Elasticity modulus of normal concrete at room temperature (27 ˚C) was 10520.8197 MPa, and at 200, 400, 600, and 800 ˚C were 9782.2219, 7881.4126, 2220.7507, and 1296.359 MPa respectively.

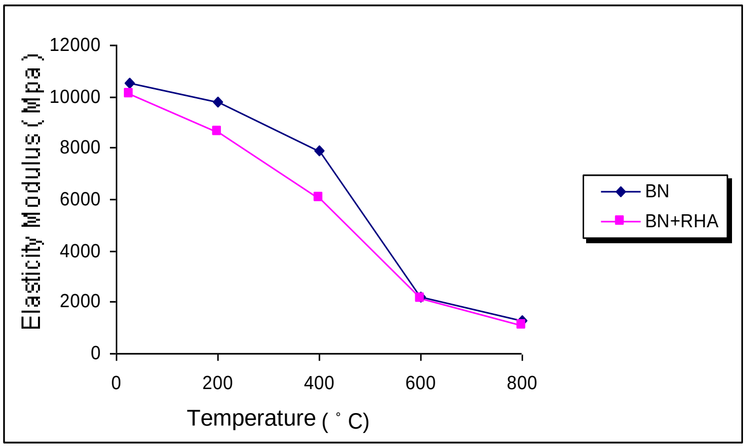

Figure 4. Temperature versus Elasticity Modulus of Concrete

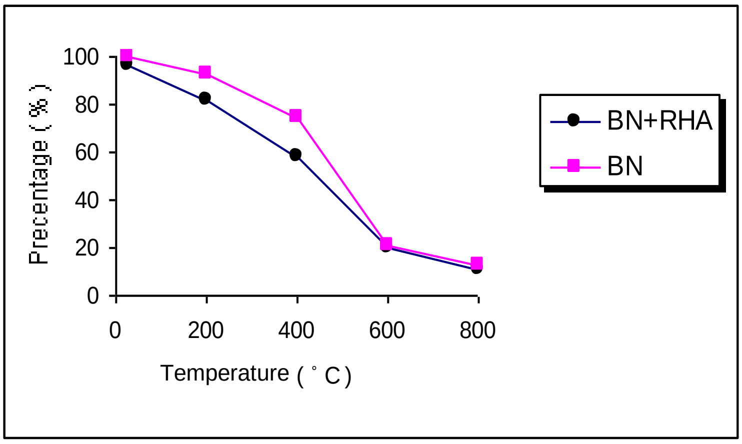

Figure 5. Decline Precentages of Elasticity Modulus of After-Fire Concrete

Figure 5. shows that the decline percentage of elasticity modulus of post fire 15 % RHA concrete is greater that of no RHA concrete.

Color Changing, Cracking Pattern, and Spalling

There was no color changing and surface cracking of normal and RHA concrete at 200 ˚C. On the temperature of 400 ˚C, its color changes to dark brown. There were no spalling for both normal and RHA concrete, but smooth cracking on the entire surface.

At 600 ˚C, the color of both normal and RHA concrete change to white brown. The normal concrete have more obvious cracking pattern than that of RHA concrete. In adition, the smooth crack see-through to the whole surface. At the same temperature, the normal concrete had their 2 cm in diameter and 1 cm depth of circle spalling, but RHA concrete had not.

The colors of the concrete change to white pink. The cracking patern for both concrete were smooth crack. Its spread out through out the surface. Spalling with 3 cm in diameter and 1 cm depth took place only on normal concrete.

CONCLUSIONS

Based on the result and discussions, the following conclusion can be drawn:

1. The compression strength of normal concrete on temperature 200 ˚C was increase 15.633 %. They were lower than that of RHA concrete. It's reached to 26.945 %.
2. The compression strength of normal concretes was decrease 2.564, 28.843, and 48.293 % at 400, 600, and 800 ˚C. In accordance with the same temperature, the decrease was lower than that of RHA concrete. They were after all 5.944, 26.304, and 48.2153 %.
3. The elasticity modulus of on post-fire normal concrete at 200, 400, 600, and 800 ˚C declined until 7.021, 25.087, 78.892, and 87.679 % compare with that of normal concrete. The modulus for post-fire RHA concrete on the same temperature were obtained to 18.223, 42.121, 79.792, and 89.297 % compared with that of no post-fire RHA concrete.
4. For normal concrete, at 400 ˚C, had their surface crack, and color change to dark brown. In addition, at 600 ˚C, concrete not only had surface crack but spalling, and changing the collor to white brown. The surface cracking, spalling, and color changing of the concrete took place at 800 ˚C. The color became white-pink. On the contrary, at 600 ˚C and 800 ˚C RHA concretes only had their surface cracking but no spalling. The colors became white-brown and white-pink.

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