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Effect of Concrete Cover to the Crack Width of RC Beam Burned in High Temperature

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ABSTRACT

Fire disaster on building structure is still happened due to that fire is one of high risk failure of structure. Fire can be as a burden thermal which did not want and be hoped on structure buiding, and the temperature has tendency so high and increasing in a short time. There is influence of the concrete cover will cause the concrete structure crack and become wider until the concrete structure will be collapse at the end. This paper provides the comparison of crack width of reinforced concrete (RC) beam and due to higher temperature of fire with the difference cover depth of concrete. The methodology consisted of experiment using 36 RC beam was carried out by trial kinds temperature of 400°C, 600°C, and 800°C steady in 28 days and then carried out process at the burner which burned and cooled with watering. The beam with the dimension of 750 mm x 150 mm x150 mm ,and the variation of concrete cover are : 15 mm ; 20 mm and 20 mm..The observation of RC beams crack width behavior was using beams bending test and Crack Detector Microscope.The results showed that there was significant difference concrete crack width at every higher temperature, and the different depth of concrete cover but not significantly influence the crack pattern. . On the maximum crack width calculation with many formula is indicated that higher temperature cause smaller allowed the maximum crack width of RC beam.

INTRODUCTION

Many techniques for controlling or decreasing fire influence has developed lately. The development of this phenomena and dynamic of fire influence has carried out as on building protection and prediction of building ability for holding fire. It was intended to observe how far their influence to crack width and in further it was known that the concrete structure can still be used or not after burning process.

Concrete is a composite material and based on previous experiment presented that high temperature of 200^0C did not decrease the compressive strength of concrete because there was fast treatment phenomena or accelerated curing. There was some increasing on compressive stress of concrete if it was heated in the temperature of 200^oC -300^0C, but it was more than 80% increasing of the compressive strength if it was heated until 400^0C and 30% if it was heated until 800^0C.(Setyowati,2013)

The process intended to obtain the recovery of strong burning concrete so that the water gathering in concrete and could be reacted to C_2S and C_3S on cement particle which was not reacted yet eventhough with β C_2S at cement because the concrete had been burned. Result of the reaction was SCH and Ca $(OH)_2$. The watering process was satisfied due to the condition of concrete filling, also presented after treatment process of watering, the recovery degree of concrete strength could reach 100% compared to the concrete before burning. There are two main factors that was very influenced the recovery process of concrete strength burning. The first factor is concrete quality due to the comparison of cooling water and cement (ratio of water and cement: W/C), bigger W/C means as a value of cement which was carried out yet in react by some manners and it was higher and faster on recovery degree of concrete. The second factor was burning process of concrete. The longer time of concrete burning means longer and higher neating and it needs lower recovery degree of concrete. (Kodur, 2008)

The crack would happen inside the mortar (pasta of cement) and around the agregate of particle at the temperature between 300^oC to 500^0C, while temperature of 300^oC was as the limit of crack which happenned around the agregate of particle . The maximum strength betwin cconcrete material andreinforce steel is relevan for the capablelity concrete and steel material. The first fail for the reinforce concrete beam is relevan by the concrete cover depth of concrete beam and the cracking of concrete in the tensile zone has significant effect on

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the ultimate temperature of reinforced concrete flexural members. It is suggested to adopt the effective depth of the concrete cover for reinforced concrete beam for the fire resistant. The influence of concrete cover depth, the temperature and the time burning to have the effective cover on fire resistance of reinforced concrete flexural members (Shi Xudong,2002),(Tan,K.H,2004)

The Influence Of Temperature In Concrete Beam:

Last report about test of building material after burning presented that the breaking structure of concrete element would become worse after burning results if there was spalling or getting peeled of concrete cover. Concrete has increased the temperature for heating, so water is contained in the holes and the concrete capilarry will be stronger at temperature of 100^oC for some water and calcium silicate (CaSi) as the lack of water in cement pasta will disapear. It followed the lack of power. The increasing on number of vapour pressure in the holes caused explosive spalling that is part of concrete segment release from the surface and it happens at the temperature of 300^oC to 600^oC. The next release will gradually be happened because there is formation of concrete that will became weak and brittle at the temperature of 600^0C.

Proof Of Strengthening Concrete Due To High Temperature:

Concrete was proved having ability for keeping its integrity and strength from time to time . At burning temperature, hot condition that was received by concrete in the surface was different with in the middle one. So the breaking degree of concrete sometimes only happens in the surface which is signed by hair crack. In this research, the temperature of concrete will be homogen so the temperature in every concrete is so good. And the concrete will be through a process of heating and cooling one by one. Heat in the concrete will be directly accepted by concrete surface in every side, while the temperature inside the concrete (or middle) still be cool and it will cause damage in concrete.(Kodur, 2008)

Decreasing Crack Due To The Change Of Temperature:

The concrete will cause crack inside in less of volume and the other is caused by steel reinforcement in part of construction, when there is cracking, the concrete that is not crack has tendency to be tide so the steel is covered in presser condition. Therefore the steel is in crack area. This case is followed by cracking near the every one in pushed condition The balance between concrete and steel reinforced was presented in figure 1.

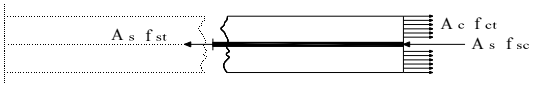

Fig. 1: The balance between concrete and steel reinforced

If the strength caused by decreasing and change of temperature due to compressive strength of concrete,there will be cracked. To control the crack width, the steel must be placed near with concrete surface and it was decided number of minimum reinforce in part of construction due to particle guidance. Creep is a continuous deformation on part of construction when there was burden. The influence of creep is important especially in beams, where can be added for opening the crack, breaking the finished part and placing not the same lines from mechanic tool. Redistribution thigh between concrete and steel which was the first happening in press area does not crack and it has small tendency to push beside reinforce than down to decrease tight in some circumtances. The stock of reinforcement in pressing area from bend part would help standing the trimble because of creep (W H Mosley,1984).

Effect of fire on concrete beams causes evaporation of free moisture in the concrete,with a continued exposure to fire, the temperature inside the beam increases and the strength of concrete decreases,it may be to reduction in concrete compressive strength. Effect of fire on concrete beam also making the residual bearing capacities.The residual shear strengths and ratios provided by concrete and shear reinforcement have predicted by models.The modeling results revealed that the shear reinforcement provided the main shear strength in common states but decreased quicly when yielding strength has influenced by high temperature (Tan,K.H,2003)

For concrete structures subjected to normal service load, most of their bending members have craks due to low concrete tensile strength.To accurately astimate the fire resistance of reinforced concrete bending member,the effect of flexural cracks on temperature distribution of the cracked section must be considered and depend on many factors, and it is difficult to accurately determine .Though several factors effect the durability, it was thought that by controlling the crack widths, found by many formulas and in controlled laboratory tests.

Considering multiple factors that give influence to the crack width on reinforced concrete as an effect from high temperature, as such the factors are : steel strength, concrete strength, temperature, steel elasticity modulus, steel dimension, and concrete dimension, and also concrete cover depth,then the maximum reinforced concrete cracks width that caused by high temperature can be formulated, as:

$$W = [\varepsilon_s(1 - (\Delta_t.\gamma.Lu)/(n.A)].[f_t.\theta/(2.(As/Ac).fb)] \quad (1)$$

A C I give the formula for the maximum crack width is :

$$w = 11 \times 10^{-6} \beta fs (dc . A)^{1/3} \quad (2)$$

SVKM. Rao dan WH Dilger. give the formula for the maximum crack width is :

$$w = 2{,}55 \times 10^{-6} fs\ dc\ (At/As)^{0,5} \quad (3)$$

Annex F ,2000, give the formula for the maximum crack width is :

$$w = [3.a . \varepsilon_m] / [1+(2(a - C_{min})/(h-x)] \quad (4)$$

MATERIALS AND METHOD

The purpose of this study was to observe the concrete crack width which was caused by normal temperature or high temperature on cooling condition with watering in certaint time. The variety temperature was 400°C, 600°C, 800°C and the concrete was observation on 28 days.This research was carried out for testing of burden when crack width was maximum on concrete beams condition before falling down because there was high temperature of 400°C, 600°C, and 800°C. This research conducted during 28 days and it would be carried out watering process before concrete burning on stated temperature.

Observation was performed on crack behavior of 36 RC beams 150 x 150 x 750 mm^3 with variety of concrete cover (15mm, 20mm, and 25mm) that have been 28-day-old. The samples are burned in 400 ^oC, 600^o C, 800 ^oC temperature and are cooled by watering, as a comparison is the sample that is not burned. Reinforced concrete beams testing was done in accordance with the ASTM standard by flexure testing for each treatment is given 3 x recurrence with the aim to get bending loads with the observation of maximum crack width.The test is done after concrete beam cooling ,until room temperature reachs 27°C. The burner is presented in figure 2 for burning and figure 3 presented the diagram of research working.

Fig. 2: The Burner

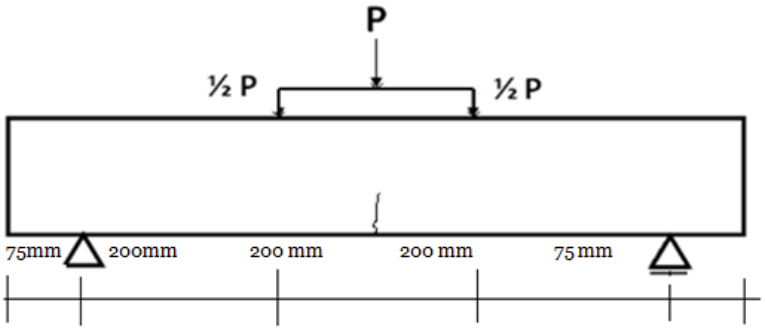

Fig. 3: Arrangement of Bending test

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Material test for each 3 beams is burned as control of beam. Maximum crack width of concrete beam is as condition before falls down. Then there is tried to compare the crack width of concrete beam with variety : 1.5 cm; 2 cm and 2.5 cm of the depth of concrete cover. Test of normality is used for knowing the identification of variables which is obtained from data result of observed normal distribution due to normal approach.

RESULTS AND DISCUSSION

Test Of Strength For Concrete And Steel:

Concrete is tested by using compression testing machine, the test of strong press in material test cylinder is carried out on the day of 28^{th} and the results is : 35.42 MPA.

Steel is tested by using the tention testing machine and the result are : Fy = 411 MPa

Data Processing Of Crack Width:

As an ease on data processing, crack width is measured between concrete cover and burning temperature as described in figure: 4 – figure: 9

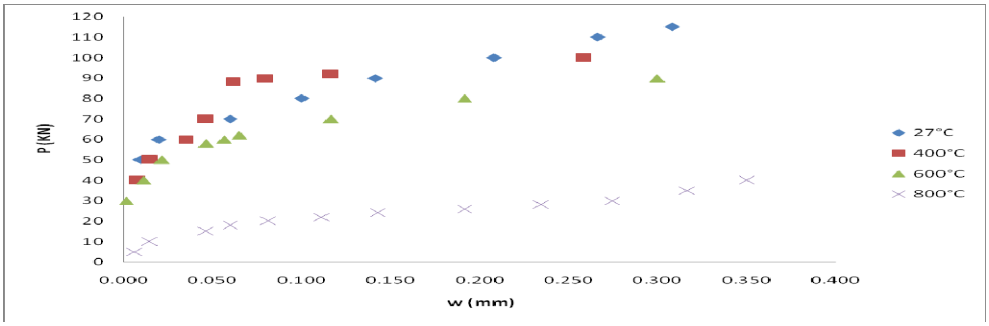

Fig. 4: The relation of crack width and loading at temperature variation in 15 mm concrete cover

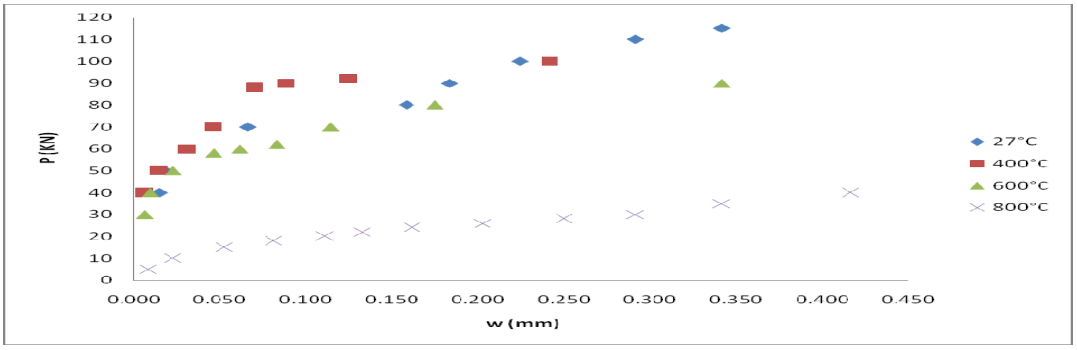

Fig. 5: The relation of crack width and loading at temperature variation in 20 mm concrete cover

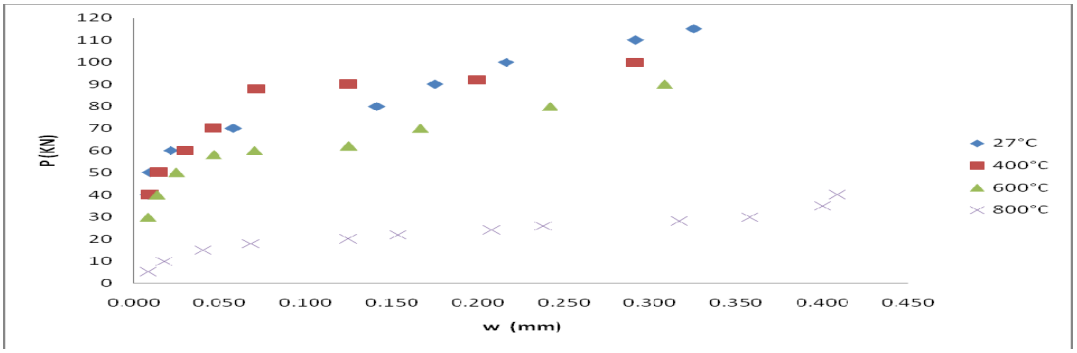

Fig. 6: The relation of crack width and loading at temperature variation in 25 mm concrete cover

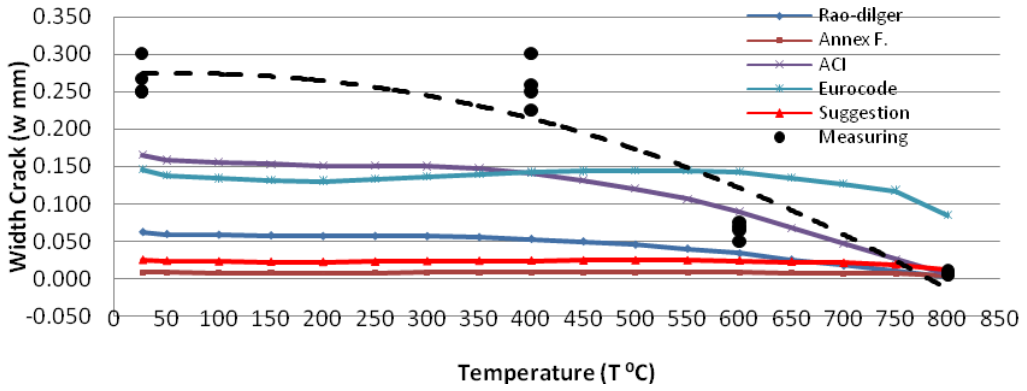

Fig. 7: The relation of crack width and temperature at 15 mm concrete cover in many formula

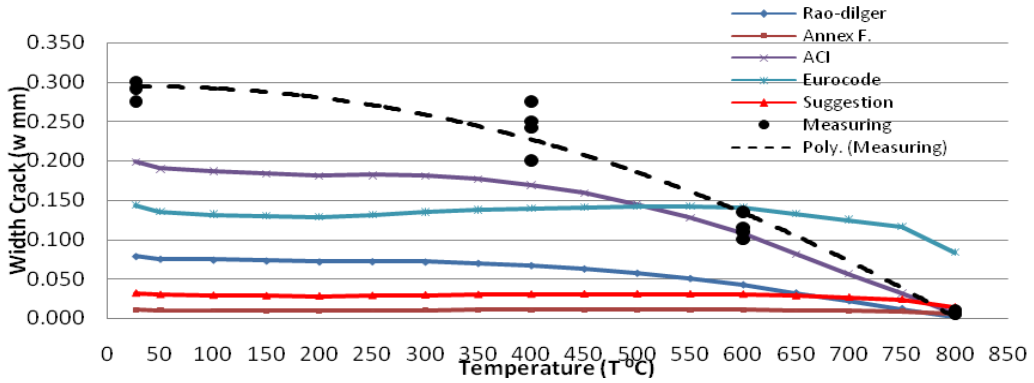

Fig. 8: The relation of crack width and temperature at 20 mm concrete cover in many formula

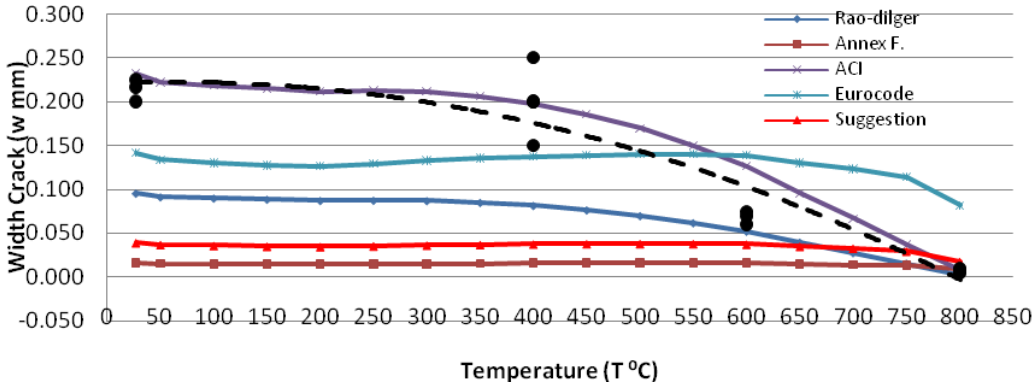

Fig. 9: The relation of crack width and temperature at 25 mm concrete cover in many formula

Based on figure 3, above known that the surface of loading burden is biggest is surface on spot where the burden centered, because on the spot of surface of moment on burdening and move power on the same time. So it can be said on the spot on crack first and may wide crack is big on spot is crack width is biggest.On the reality the crack happen on concrete beam, first time shown on spread between two centered burden. It explained that crack of first shown up is because of bent. But the bigger past of beams test, the crack of first time shown on centered burden point and the biggest of wide crack. Followed by graph of biggest wide crack on crack width before fall down.Based on figure: 4 in upper known as test result on concrete beam with variation temperature (400°C, 600°C and 800°C) shown on biggest wide crack on burning a concrete beam on 800°C. It

is because of the decreasing compressive strength of the concrete material than 70%, and creasing of the yield strength of the steel is more than 80%.

Wide crack comparation on reinforce concrete beam on temperature variation on actual can be seen on different on figure : 4 – 9, there is difference between the width crack on every variation of concrete cover thickness. The wider concrete caver on the same load and on the same temperature is the shorter for the crack width.On the calculation maximum crack width that using different formula shows that higher temperature causes smaller allowed crack width of RC beam. It is indicated that the more compressive strength of the concrete material and the yield strength of the steel , the more crack width is allowed after the concrete beam having high temperature.The depth of concrete cover of RC beam are not significantly influence the crack pattern, but it influence to the measure of allowed maximum crack width for RC beam.

It is according to the result of calculation by many formulas of the maximum crack width and the result of the real test for the reinforced concrete beam in burned in high temperature.

Conclusion:

Based on analysis as above, it is concluded that

1. The greater difference of temperature will be affect for the crack width of RC beam that occur on pressured.
2. The difference of concrete cover depth for the concrete beam after burning will be different crack width of the RC beam that accur on pressured.
3. The wider concrete cover on the same load and on the same temperature is the shorter for the crack width.
4. On the maximum crack width calculation with much formula is indicated that higher temperature cause smaller allowed maximum crack width of RC beam.
5. The concrete cover depth did not significantly influence the crack pattern, but effected the maximum crack width of RC beam in high temperature.

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