Experimental Study of Beam-Column Joints Reinforced Concrete with Fiber Concrete and Fly-Ash

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Abstract. Reinforced concrete elements in the beam - column joint (HBK) plays a very important role for maintaining the structure when subjected to the lateral load, despite the presence of many bars in the area often results in imperfections implementation. The use of fly-ash and fiber in the area of HBK can be one of available solutions; both can increase the strength of concrete and reduce the reinforcement. This study discusses the usage of fly-ash in concrete with proportion of 25% by weight of cement and dramix steel fibers and 10 kg for one m³ of concrete. This study uses the specimens of HBK with a variation of the concrete at age of 28 and 90 days. The analysis of 28 days HBK results: specimen with normal and with fly ash have average load of 10.53 kN and 6.97 kN where specimen with Fly-ash + additive has 12.65 kN (20.13% higher than normal specimen). At the age of 90 days, HBK with normal concrete, fly ash and fiber concrete can withstand load at 12.73 kN, 10.87 kN, and 13.15 kN respectively, where HBK with fiber + fly-ash reaches at 13.38 kN or has 5.00% more than HBK with normal concrete.

1 Introduction

Elements of the beam column relationship at a reinforced concrete portal play a very important role in accepting the burden of the structure, especially the lateral loads, such as earthquakes. The mechanism requires that the collapse of the structure failure should occur in the area of the beam, or there exists a ductile flexural failure pattern. But in fact, at the time of the earthquake, many parts of the column element, even the beam column relationships, that have failed, resulting a brittle collapse. The weak point in the power beam column relationship can be caused partly by the improper reinforcement detailing and porous concrete casting due to the difficulty of concrete to enter into the area blocked by a number of bars in the area.

To overcome the weakness in the beam column relationship, one of which could be done by increasing the strength of the concrete. It can be done with the addition of steel fibers [1] and the use of fly-ash concrete, where the right use of steel fibers and fly-ash is able to increase the compressive strength and tensile strength of concrete. The use of steel

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fibers and fly-ash concrete will also reduce the risk of porous concrete in the area of the beam-column relationship, because the use of stainless steel fibers as micro steel will reduce the amount of reinforcement in the beam-column relationship. Improving the ability of beam-column element of the relationship will enhance the capabilities and behavior of the structure, so it will reduce the risk of destruction of a building and prevents loss of material and human lives [2].

Besides increasing the strength of concrete, the use of fly-ash, which in this case is a waste of coal, will also be very helpful in overcoming the problems of environmental pollution. The presence of waste coal fly-ash at the current amount is very large; it is caused by the development of industries that use energy sources of coal. The problem of global warming has yet to be overcome as well, so that the use of fly-ash in the construction industry will be one of the solutions that can be relied upon. Replacement of Portland cement with fly-ash content of 25% by weight of cement, also greatly reduces the use of cement significantly, especially for the production of 1 ton of Portland cement will also produce 1 ton of CO_2 . CO_2 is one of the sources of global warming. Thus reducing the amount of consumption of cement in the construction industry will also reduce the amount of CO_2 in the air.

2 Theoretical

Regional relations beam column is area critical in maintaining the strength and stability of the structure when subjected to the lateral load. As a result of lateral forces acting on the structure, the end of the bending moment on beams at the same joint will rotate in the same direction. This poses a major shear forces on the relationship of column beam. During this time, the area was accounted for strong for their restraint system by reinforcement stirrup. In practice there will be a number of connections of beams and columns as well as the stirrup itself that cause difficulty in implementation. Lack of stirrup bars on the area of main reinforcement that are not unconstrained and forced out due to the high pressure of the concrete core and an error in the installation of reinforcement detailing and implementation of the joint can cause the collapse of a building.

Fig. 1. Effective joint area (a), Calculation of lateral shear force on beam-column joint (b) [3].

From Fig. 1 (b) above, horizontal shear force in the area of relationships beam column (HBK) can be calculated by assuming that the bending elements framed on HBK has

reached the capacity, by setting the beam flexural tensile strength of A_s (1,25 f_y). Lateral shear force on beam-column joint can be calculated as follows [3][4]:

$$V_u = T_{b1} + T_{s1} + T_{s2} + C_{b2} - V_{col\ 1} \quad (1)$$

$$T_{b1} + T_{s1} + T_{s2} = \alpha f_y (A_{s1} + A_{s-s1} + A_{s-s2}) \quad (2)$$

$$C_{b2} = T_{b2} = A_{s2} \alpha f_y \quad (3)$$

where ;

V_u : shear force that occurs in joints (kN)

α : 1.25

f_y : beam longitudinal reinforcement yield strength (MPa)

Shear strength can be provided by HBK depending on the conditions of confinement that work on HBK. HBK shear strength equation can be calculated as follows:

$$V_{jn} = {}^c \sqrt{f'_c} A_j \quad (4)$$

where ;

V_{jn} : nominal joint shear force (kN)

C : 1.7 (HBK bridled at four sides)

: 1.25 (HBK confined on three sides or two opposite sides)

: 1 (for all other relationships)

A_j : effective joint area (mm^2)

Research by the use of fly-ash and steel fiber dramix is expected to improve aspects of strength (f'_c) and aspects of ductility.

3 Method

3.1 Material

Additional components in the concrete material are as follows:

- i) Fly-ash originating from ready mix concrete plant in the town of Sukoharjo. See Fig. 2 (a).
- ii) Steel fibers Dramix RC-80/60 – BN with a length of 60 mm; diameter 0.75 mm; tensile strength of 1225 N / mm^2 and an aspect ratio of length to diameter of 80 . See Fig. 2 (b).
- iii) Additive from SikaCim®Concrete, added on fresh concrete at a dosage of 250 mlper sack of cement (50 kg).

(a) Steel fiber Dramix

(b) Fly-ash

Fig. 2. Additional materials research.

3.2 Test specimen

There are two types of test specimen, namely :

- i) The cylinder specimen, diameter of 150 mm and a height of 300 mm.
- ii) Elements of beam-column joint (HBK) with column dimensions of 150 mm x 150 mm height 2000 mm and the beams with dimensions of 150 mm x 200 mm with a length of 1500 mm with a shape as shown in Fig.3. Concrete Repair held only in the meeting of the beam and fields, which are all 500 mm in the central part of the column and 150 mm on the beam in front of the column. The specifications of the test specimen HBK is presented in Table 1 below.

Table 1. Specifications of the test specimens HBK

Sampel	A day of test (day)	Amount	Information
HBK N	28	3	Normal
HBK F	28	3	Fly-ash
HBK AD	28	3	Fly-ash+ Additive
HBK N	90	3	Normal
HBK F	90	3	Fly-ash
HBK S	90	3	Fiber
HBK SF	90	3	Fiber+Fly Ash

3.3 Setting test HBK

Details of the test specimen HBK, setting tools and testing methods of HBK specimen can be seen in the Fig. 3.

Fig. 3. Setting test and specimens.

4 Result and discussion

4.1 Cylinder

Cylindrical specimen test results on 28th day and 90th day can be seen in the Table 2 and Table 3. From Table 2, it is known that the use of fly-ash concrete with additive at the age of 28 days, can increase the strength of concrete from 18.40 MPa to 23.16 MPa, an increase of 25.86%. Being on a 90th day test from Table 3, the use of fly-ash concrete and fiber will increase from 25.70 MPa to 29.91 MPa, an increase of 16.38%. From of the Table 2 and

Table 3 can also be seen that the use of fly ash on 28th day and 90th day has not provided maximum strength because it is still in the process of reaction.

Table 2. Compressive strength of cylinder on 28th day.

No.	Specimens	Pmax (kN)	f _c (MPa)	f _{cr} (MPa)	Comparisons (%)
1	S-N1 ₂₈	340	19,24	18,40	0,00
2	S-N2 ₂₈	340	18,99		
3	S-N3 ₂₈	300	16,98		
4	S-F1 ₂₈	160	8,93	9,56	-48,04
5	S-F2 ₂₈	150	8,56		
6	S-F3 ₂₈	200	11,17		
7	S-AD ₁₋₂₈	350	19,59	23,16	25,86
8	S-AD ₃₋₂₈	410	22,31		
9	S-AD ₆₋₂₈	500	27,59		

Table 3. Compressive strength of cylinder on 90th day.

No.	Specimens	Pmax (kN)	f _c (MPa)	f _{cr} (MPa)	Comparisons (%)
1	S-N1 ₉₀	460	25,46	25,70	0,00
2	S-N2 ₉₀	450	24,91		
3	S-N3 ₉₀	470	26,72		
4	S-F1 ₉₀	480	26,80	25,65	-0,19
5	S-F2 ₉₀	460	25,57		
6	S-F3 ₉₀	450	24,58		
7	S-S1 ₉₀	480	27,53	27,15	4,11
8	S-S2 ₉₀	540	30,83		
9	S-S3 ₉₀	410	23,10		
10	S-SF1 ₉₀	580	31.82	29.91	16.38
11	S-SF2 ₉₀	510	28.86		
12	S-SF3 ₉₀	510	29.05		

4.2 Test of specimens HBK – at 28 days

HBK testing at 28 days presented in the table of load and deflection relationship as shown incFrom Fig. 4 and the obtained value of the maximum load HBK on several conditions as follows:

The average maximum load on HBK-Normal concrete is

$$P_{\max \text{ rt-rt}} = \frac{10.70 + 10.80 + 10.10}{3} = 10.53 \text{ kN}$$

(5)

The Average maximum load on HBK-Fly ash is

$$P_{\max \text{ rt-rt}} = \frac{6.90 + 7.00 + 7.01}{3} = 6.97 \text{ kN} \tag{6}$$

The average maximum load HBK-AD (fly-ash + additive) is

$$P_{\max \text{ rt-rt}} = \frac{12.86 + 12.20 + 12.89}{3} = 12.65 \text{ kN} \tag{7}$$

Fig. 4. Relationships of load – deflection of HBK specimens at 28 day.

Then the value of the average load that can be accepted by normal concrete HBK is 10.53 kN and a maximum load average HBK fly ash concrete is 6.97 kN or decreased by 33.81%, while the HBK-Fly ash + additive capable of withstanding the load amounted to 12.65 kN or an increase of 20.13% when compared to normal concrete HBK, HBK while if compared with fly ash concrete increased by 81.49%. Increased ability to withstand the burden shows that the addition of Concrete Additive SikaCim® is able to make fly ash concrete at 28 with more dense so that stronger in the weight-bearing.

4.3 Test of specimens HBK – at 90 days

HBK testing at 90 days presented in the table of load and deflection relationship as shown in Fig. 5, and the calculated mean of the maximum load as follows:

- i) The average maximum load on HBK-Normal is 12.73 kN
- ii) The average maximum on HBK fly ash concrete is 10. 87 kN

Based on the above calculation, it shows that the capacity load of HBK fly ash concrete is still below normal concrete. The average maximum load - average which can be held by HBK fly ash concrete is 10.873 kN, which is 14.59% below normal HBK concrete that can withstand at 12.730 kN. Increased load obtained HBK fly ash concrete is not maximized due to the slow hardening concrete.

From Fig. 6, it can be seen that the calculated mean of the maximum load average on HBK- concrete fiberis 13.15 kN. So that the fiber-reinforced concrete HBK maximum load increased by 3.27%. The increase in the maximum load of the HBK is a result of the increase of the quality of concrete. The rise of all concrete deflection is caused by the change in style that resulted a shake on the side of the column.

Fig. 5. Relationships of load – deflection of HBKN – HBKF specimens at 90 days.

Fig. 6. Relationships of load – displacement of HBKN – HBKS specimens at 90 days.

From Fig. 7, then the calculated mean of the maximum load average on HBK- concrete fiber + fly-ashis 13.38 kN. Based on the above analysis it is known that the average maximum load HBK fiber + fly ash concrete is higher than the normal concrete and HBK test specimens fiber + fly ash concrete experience longer deflection of the test specimen HBK normal concrete. The addition of fly ash + fiber provides maximum expenses increased by 5.08% of normal concrete.

Fig. 7. Relationships of load – displacement of HBKN – HBKSF specimens at 90 days.

4.4 Summary of results

From Table 4, it can be seen that, the use of fly-ash and additives in concrete at 28 days will be able to increase the capacity of the HBK of 20.13% against the normal concrete, while the use of fly-ash and fiber in the concrete life of 90 days will be able to increase capacity by 5.11% compared to normal HBK and increased by 27.07% compared to HBK concrete at 28 days. The use of fly ash at 28 days and 90 days has not been an effective outcome for fly ash is still the process of reaction and should be used additive substances.

Table 4. Summary of testing specimens

Specimen	Load (kN)	Comparisons (%)
Results of the test at 28 day		
HBK N – 28	10,53	0,00
HBK F – 28	6,97	-33,81
HBK AD - 28	12,65	20,13
Results of the test at 90 day		
HBK N – 90	12,73	0,00
HBK F – 90	10,87	-14,61
HBK S – 90	13,15	3,30
HBK SF - 90	13,38	5,11

5 Conclusion

From the testing and analysis conducted drawn conclusions as follows:

- i) The use of fly-ash 25% by weight of cement and additive in concrete cylinder at 28 days can increase the strength of concrete from 18.40 MPa to 23.16 MPa, an increase of 23.16%. where at age of 90, the use of fly-ash concrete and fiber will increase from 25.70 MPa to 29.91 MPa, an increase of 16.38%.
- ii) The use of steel fibers Dramix and fly-ash in concrete HBK 28 days will improve the ability of concrete 10.53 kN to 12.65 kN, with an increase of 20.13%.
- iii) The use of steel fibers Dramix and fly-ash in concrete HBK at age of 90 days will improve the ability of concrete from 12.73 kN to 13.38 kN amounted to an increase of 5.11%. HBK compares to 28 days increased by 27.07%
- iv) The use of fly-ash with additive materials and steel fibers effective for increasing load capacity at a time can be a solution to overcome the coal waste in the form of fly-ash.

References

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