Available online at: http://proceeding.rsfpress.com/index.php/ic-smart/index
**Proceeding on International Conference of Science Management Art Research Technology (IC-SMART)**
Volume 1 Number 1 (2020): 151-159

# Behavior Of Concrete Beam Deflection Framework System

**Pieter Lourens Frans , Hendrie Tahya**
Civil Engineering Department, Ambon State Polytechnic, Indonesia;
E-mail address oncopiet@gmail.com; E-mail address hendritahya29@gmail.com

**Abstract**
*The bar used for concrete beams is generally in the form of shear or stirrups mounted perpendicular to the beam axis. The idea underlying this editorial problem arises from the writer's observation of the use of reinforced concrete beams by changing the configuration of vertical shear reinforcement to less sloping reinforcement related to the theory of its use. This study aims to analyze the deflection behavior of reinforcing beams with a three-quarter spacing distance from the effective height of the beam and produce the bending moment capacity of the skeletal beam reinforcement system. This research is an experimental laboratory study with twelve specimens consisting of three normal beams (BN) as control variable beams and nine reinforcement beams with a frame variation of 0.25d for BTR25, 0.50d for BTR50, and 0,75d for BTR75 each of the three test specimens. Data were analyzed using the strength design method. The results showed that the use of reinforcing frame systems could increase the strength of the beam when the load reaches the ultimate in the BTR25 beam by 10.72% for the BTR50 beam by 7.83% and for the BTR75 beam by 4.82% from the BN beam.*

Keywords: deflection, reinforcement frame system



# I. INTRODUCTION

Plain concrete blocks are generally inefficient to function as a flexible structural component because their tensile strength is much smaller than their compressive strength. As a consequence, unreinforced concrete beams will experience tensile failure at low load levels, long before the concrete reaches its compressive strength. The reinforcement used for concrete beams at this time is generally in the form of shear reinforcement or stirrups installed perpendicular to the beam axis with a certain spacing which functions as a shear force load bearing. Meanwhile, the beam that is subjected to a bending moment is installed horizontal reinforcement along the beam axis, as shown in Figure 1. Along with the development of technology and knowledge, various ideas were developed to increase the flexural strength of reinforced concrete beams, one of which is the use of frame system reinforcement, which changes the configuration of vertical reinforcement to beveled reinforcement, as shown in Figure 2.

Previous research presented a design method for reinforced concrete beams using a modified frame model with diagonal struts at various angles, but there is still a shift (Bing Li, Cao Thanh Ngoc Tran, 2008). The use of frame system reinforcement to flexural strength in styrofoam-coated concrete


DOI: https://doi.org/10.31098/ic-smart.v1i1.36

blocks (BSCTR) shows that the flexural capacity of beams without concrete in the tensile area has decreased and there is an increase in flexural strength (Yasser, Herman Parung, Muhammad W. Tjaronge, and Rudy Djamaluddin, 2015). The flexural capacity of beams without concrete in the tensile section (external reinforced concrete beam, ERCB) increases the flexural capacity and stiffness of the beam (Campinone, G., Colajanni, P. and Monaco, A, 2016). The effect of the geometric and mechanical characteristics of the shear reinforcement of steel-concrete composite beams and slabs increases significantly, thanks to the contribution of shear reinforcement (SNI 2847, 2013).

Figure 1. Beams with vertical stirrups

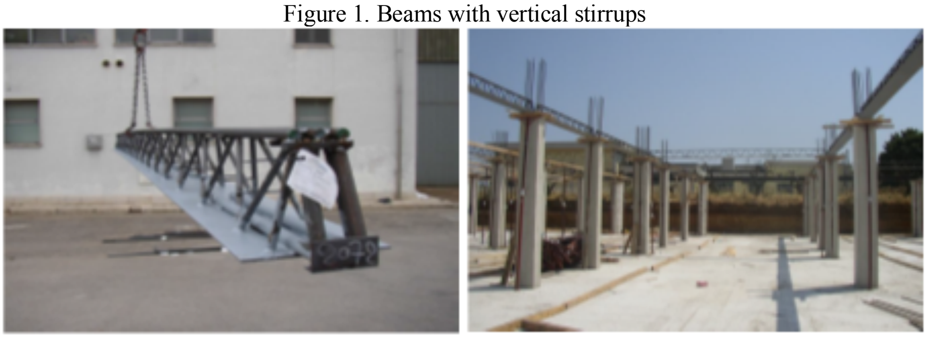


Figure 2. Concrete beam reinforcement frame structure.

The idea that was developed was to conduct experimental research on several types of truss system reinforcement with variations in diagonal reinforcement spacing to determine deflection behavior. This study aims to analyze the deflection behavior of the reinforcing concrete beam in the frame system. During the test, the applied loads, the strain in the concrete compressed area, the tensile steel at the mid-span, and the deflection at the mid-span is measured up to failure. The beam response is examined and discussed in terms of deflection, strain, load capacity, crack pattern, and failure mode. .

## II. LITERATURE REVIEW

The load-deflection relationship of reinforced concrete beams can be idealized into a trilinier form as shown in Figure 3.

In area I is the precast stage, where the structural rods are free of cracks. This can be written with equations (SNI 2847, 2013).

$$M_{cr}= f_r \frac{I_g}{y_t} \quad (1)$$

With Mcr is the moment of cracking of the beam section moment of crack in the beam section, Ig is the gross moment of inertia of the beam section, fr is the modulus of crushed concrete and yt is the distance from the compressive surface of the beam section.

In region II is the post-layered stage, where the structural rods experience acceptable control cracks, both in distribution and in width. This condition can be calculated by the equation:

$$M_y = \frac{f_s.I_t}{n.(d\text{-}c)} \quad (2)$$

With My is the is the melting moment, fs is the tensile stress of the steel, It is the inertia of the transformation section, n is the modulus radius, d is the effective height of the beam and c is the height of the neutral axis.

In area III there is a post-serviceability level, where the stress on the tensile reinforcement has reached its yield stress. The basic assumptions for the equilibrium condition, given by Whitney, with the compressive force C on the concrete and the tensile force T on the reinforcement:

$$Mn = T\,(d - ½\,a) \quad (3)$$

With Mn is the flexural strength of the beam, and a is the height of the blocking voltage. The calculation of instantaneous deflection with the following equation:

$$\Delta = \frac{5}{384}\frac{qL^4}{E_c.I} \quad (4)$$

$$\Delta = \frac{1}{24}\frac{P.a}{E_c I}\left(3L^2 - 4a^2\right) \quad (5)$$

With q is the load evenly, P is the load centered, L is the beam span length, and $E_c$ is the elastic modulus of concrete.

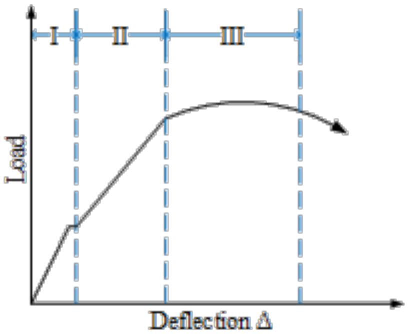



Figure. 3. Load-deflection relationship in the beam

# III. RESEARCH METHODOLOGY

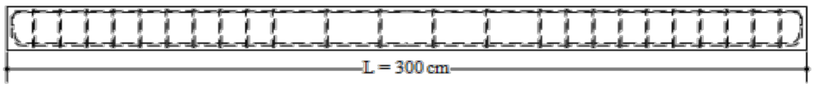
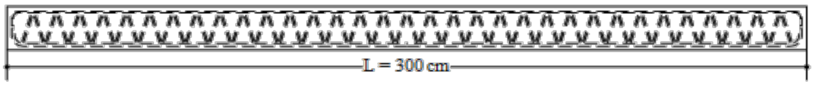
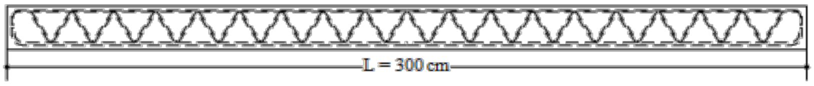
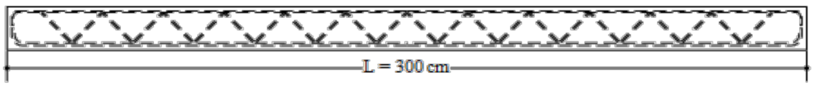
## III.1. Specimens

Specimen preparations were divided into the preparation of the truss reinforcements and the casting of the concrete beams. The concrete beams specimen dimensions are 300 cm length with 15 x 20 cm of cross-section, respectively. The detail of the specimen is presented in Figure. 4. The specimens prepared in this study were three beams for the normal reinforced concrete beams (BN), nine beams using truss reinforcement (BTR). The space of the diagonal bars on the truss reinforcement was varied in 0.25d (BTR25), 0.5d (BTR50), and 0.75d (BTR75), where d is the effective depth of the beam. The variation and number of the specimens summarize in Table 1.

## III.2. Test setup

Figure 5 shows a test piece setup where a load is applied to the hydraulic jacks on an attached steel contrast frame. The jack is controlled by a hydraulic control unit at a rate of 0.2 mm / sec. A load cell with a capacity of 200 kN is placed between the jack and distributor beam to measure the precisely applied force. During loading, it is recorded through a data logger. A linear variable differential transducer (LVDT) is used to monitor the vertical displacement of the specimen.

Table 1. The specimens

| No. | Code | Specimens |
|---|---|---|
| 1 | BN-01 |  |
| 2 | BN-02 | |
| 3 | BN-03 | |
| 4 | BTR25-01 |  |
| 5 | BTR25-02 | |
| 6 | BTR25-03 | |
| 7 | BTR50-01 |  |
| 8 | BTR50-02 | |
| 9 | BTR50-03 | |
| 10 | BTR75-01 |  |
| 11 | BTR75-02 | |
| 12 | BTR75-03 | |

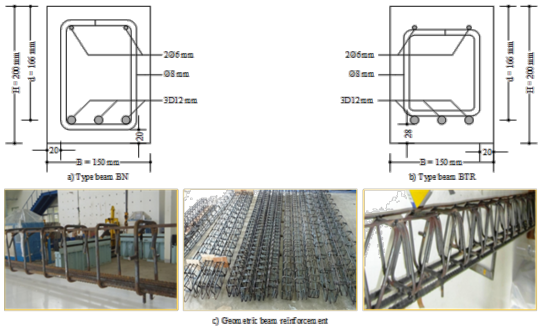



Figure 4. Detail of concrete beams

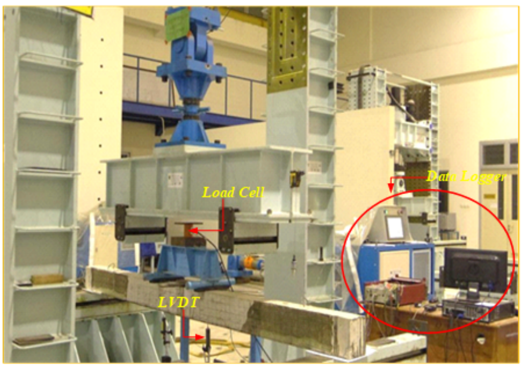



Figure 5. Tool settings

### III.3. Material properties

Concrete material is fresh, ready-to-use concrete mixed entirely in a mixer. The compressive strength of concrete is obtained after 28 days of age, with an average compressive strength of f'c = 18.50 MPa.

The modulus of collapse obtained the magnitude of the flexural strength fr an average of 2.59 MPa. The tensile strength of steel is obtained according to SNI 03-686.2-2002 for plain reinforcement Ø8 yield strength f'y = 382.81 MPa and threaded reinforcement D12 with yield strength f'y = 373.94 MPa.

## IV. FINDING AND DISCUSSION

The deflection behavior of BN and BTR beams based on this test is assumed to be an instantaneous deflection, where the load is applied continuously with a momentary time until flexural collapse occurs and is trilinear as shown in Figure 6.

Deflection with Pcr first crack load

Load-deflection in area I for beams BTR25, BTR50, and BTR75 tend to be perpendicular to the line of the BN beam. The theoretical assumption that the first crack occurs in the BN beam and the BTR beam is that when the compressive load reaches Pcr = 2.96 kN, which is the same as the magnitude of the modulus of collapse fr = 2.59 MPa. In Table 2, the results of the load-deflection test on BN beam obtained Pcr = 2.94 kN while the BTR25, BTR50, and BTR75 beams experienced an increase in the compressive load Pcr and the moment Mcr was greater than the BN beam.

Deflection with melting load Py

Table 3, the results of the load-deflection test at the time of melting reinforcement show that the geometric changes of vertical stirrups into diagonal stirrups with a spacing of 0.25d for beam BTR25, spacing 0.50d for beam BTR50, and spacing 0.75d for beam BTR75 provide strength addition to the Py load level. Based on the percentage of the value of the Py load on the BTR25 beam increased by 12.22%, the BTR50 block increased by 8.38%, and the BTR75 block increased by 6.88% from the BN block. Furthermore, the increase in Py load capacity is analyzed on the moment value when the melting reinforcement of My on BTR25 beam increases by 11.60%, for BTR50 beam increases by 7.95%, and for BTR75 beam increases by 6.53% from BN beam.

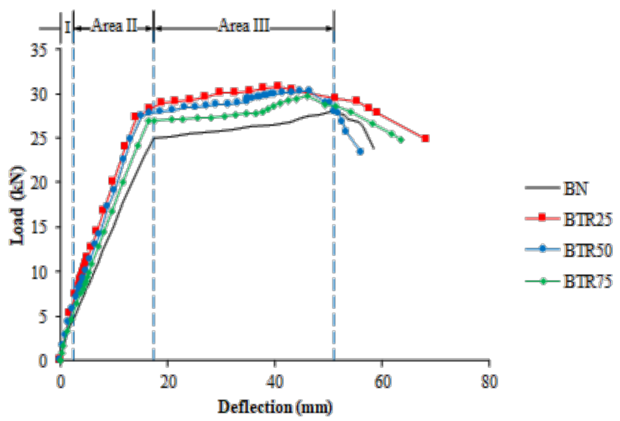



Figure. 6. BN and BTR beam deflection behavior

Table 2. Percentage moment of cracking $M_{cr}$

| Beam | Test result | | Percentage | |
|---|---|---|---|---|
| | $P_{cr}$ (kN) | $M_{cr}$ (kNm) | $P_{cr}$ (%) | $M_{cr}$ (%) |
| BN | 2,94 | 2,57 | - | - |
| BTR25 | 4,45 | 3,48 | 51,52 | 35,29 |
| BTR50 | 3,94 | 3,17 | 34,09 | 23,36 |
| BTR75 | 3,25 | 2,76 | 10,61 | 7,27 |

Table 3. Percentage melting moment $M_y$

| Beam | Test result | | Percentage | |
|---|---|---|---|---|
| | $P_y$ (kN) | $M_y$ (kNm) | $P_y$ (%) | $M_y$ (%) |
| BN | 25,18 | 15,92 | - | - |
| BTR25 | 28,26 | 17,77 | 12,22 | 11,60 |
| BTR50 | 27,29 | 17,19 | 8,38 | 7,95 |
| BTR75 | 26,92 | 16,96 | 6,88 | 6,53 |

Table 4.Percentage flexural strength $M_u$

| Beam | Test result | | Percentage | |
|---|---|---|---|---|
| | $P_u$ (kN) | $M_u$ (kNm) | $P_u$ (%) | $M_u$ (%) |
| BN | 28,11 | 17,67 | - | - |
| BTR25 | 31,12 | 19,48 | 10,72 | 10,23 |
| BTR50 | 30,31 | 18,99 | 7,83 | 7,47 |
| BTR75 | 29,46 | 18,49 | 4,82 | 4,60 |

The ultimate load-deflection $P_u$

The results of the load-deflection test at the ultimate limit show that when the additional load is applied to the ultimate limit of Pu, there is a maximum deflection in the middle of the span according to the amount of stiffness of the effective inertia section Ie in the beam. The effect of the geometric change in vertical stirrups into diagonal stirrups shows that at 0.25d spacing for BTR25 beams, 0.50d spacing for BTR50 beams and 0.75d spacing for BTR75 beams gives additional Pu additional load capacity on BTR25 beams increases by 12, 14%, the BTR50 block increased by 7.83% and the BTR75 block increased by 6.76% from the BN block, seen in Table 4.

Simulation

The simulation of beam deflection that occurs in the middle of the beam span using the Finite Element Method (FEM) analysis method. In modeling the test object into FEM, there are several mathematical models that can be used, namely isotropic, orthotropic, and anisotropic. Steel and concrete reinforcing materials are modeled as line elements and analyzed by using 2D elements by:

a. Model geometry
   Describe the geometric attributes of concrete with a concrete cross-sectional height of 200 mm and a concrete cover height of 20 mm. With 3D12 tensile reinforcement, compression reinforcement 2Ø6, and stirrup reinforcement Ø8 for vertical and diagonal according to beam variation. Next, do the grouping to make it easier to give attributes to the model for each beam element.
b. Defines the material properties of concrete and steel reinforcement
   Material properties include the elastic modulus of concrete 20,222.37 MPa with concrete stress of 18.50 MPa. The elastic modulus of steel is 200,000 MPa with steel for stirrup 382.81

MPa and for tensile reinforcement 373.94 MPa. Poisson ratio for concrete 0.20 and 0.30 for steel. In defining the selected material is an isotropic model. For the concrete model chosen is concrete (model 94), and for steel reinforcement, the model is the stress potential von misses.

c. Defining Support or Support
For the selection of pedestals in this modeling, joint and roller placement types are used based on experimental testing in the laboratory.

d. Loading
In accordance with the planning model, the load given is the point load with the definition of a point load of 1 kN. This is meant because the load increase adjustment is carried out in nonlinear control where the loading automatically occurs until the beam collapses. In nonlinear control, the loading is carried out automatically with the number of iterations that is 100 with the initial load being 1000 and the increase in each load is 1000 without limiting the maximum total load factor that is entered so that the load occurs in the collapsed beam condition so that the initial load that will occur on the beam is 1 N x 1000 = 1 kN for each incrementation. Furthermore, the interpretation of the results for load-deflection is as shown in the following figure:

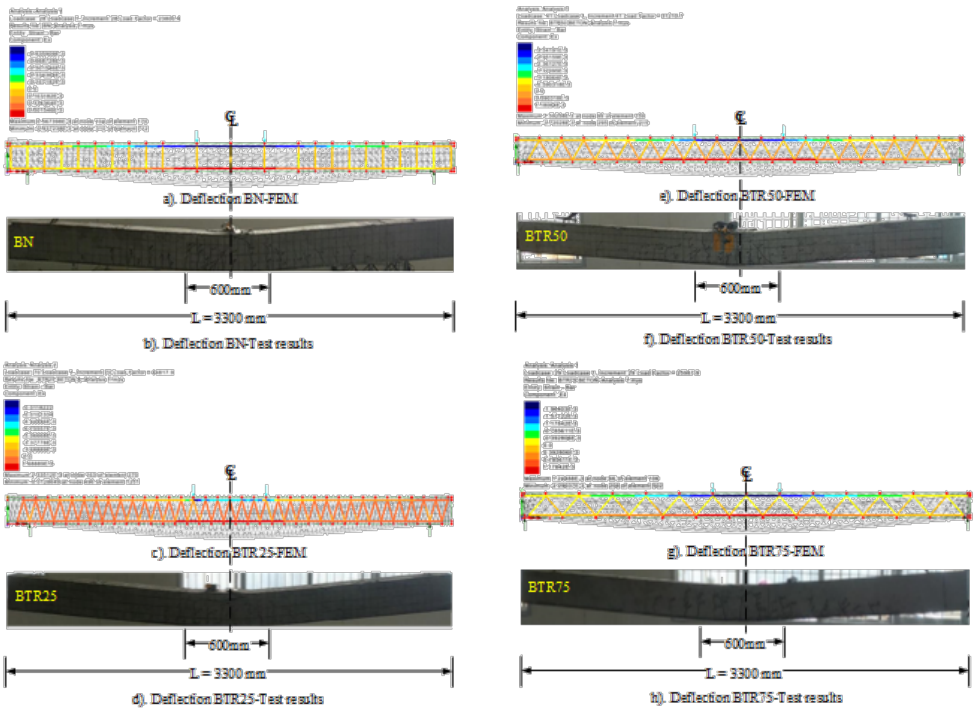



Figure.7. Simulation of deflection of BN and BTR beams

Figure7, shown the results of the load-deflection simulation using the FEM method and the experimental test results in the laboratory for BN beam, BTR25 beam, BTR50 beam, and BTR75 beam. These results show that the FEM analysis and test results for BN and BTR beams have a similarity to the maximum deflection in the mid-span area that experiences bending. The maximum deflection varies according to the amount of stiffness of the effective inertia section Ie on the beam. Whereas in the BTR beam, the geometric changes of the vertical stirrups into diagonal stirrups with 0.25d spacing for BTR25 beams, 0.50d spacing for BTR50 beams, and 0.75d spacing for BTR75 beams have an impact on increasing loads at the ultimate time of Pu at the time the occurrence of maximum deflection is better than BN beams with vertical stirrups.

Figure8, shown a diagram of the load-deflection relationship results of the FEM analysis. The analysis produces a trilinear graph of the load and deflection relationships for BN, BTR25, BTR50, and BTR75 beams according to the stages of the initial load conditions for Pcr crack, the current load of Py steel reinforcement, and the ultimate limit load Pu. FEM analysis shows that the geometric changes of vertical stirrups on BN beams into diagonal stirrups on BTR beams based on variations in spacing 0.25d for BTR25 beams, 0.50d spacing for BTR50 beams, and 0.75d spacing for BTR75 beams contributes to strengthening Tensile to the longitudinal tensile reinforcement As to the equivalent area of replacement concrete (nAs) can provide additional beam capacity and reinforcement of the bending behavior of the BTR beam when the load reaches the ultimate better than the BN beam.

Table 5 shows the load-deflection analysis of BN and BTR beams for the ultimate load capacity of Pu and the amount of deflection using FEM in comparison with the laboratory test results obtained by a ratio between 0.99 to 1.07. This ratio by the general formula with a ratio scale of 0.90 - 1.0 is categorized as very good.

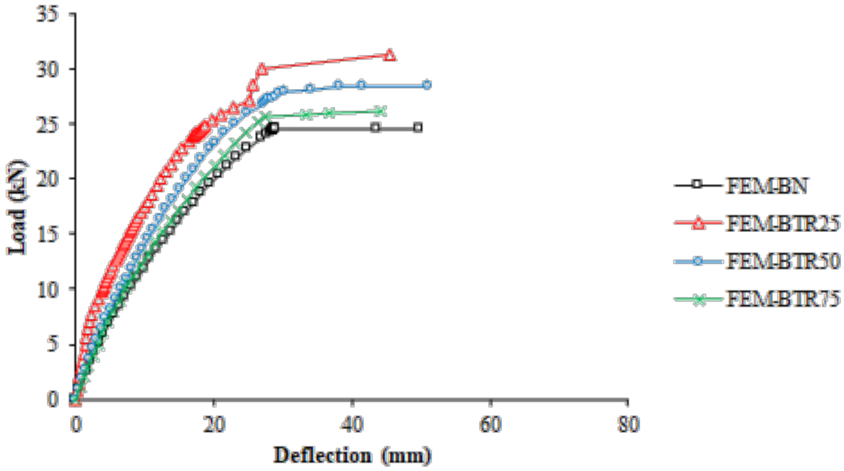



Figure 8. Load-deflection of the FEM results

Table 5. Rasio beban-lendutan hasil uji dan FEM

| Beam | Test result | | FEM | | Ratio | |
|---|---|---|---|---|---|---|
| | $P_u$ (kN) | $\Delta_u$ (mm) | $P_u$ (kN) | $\Delta_u$ (mm) | $P_u$ (%) | $\Delta_u$ (%) |
| BN | 28,11 | 38,01 | 28,93 | 32,23 | 1,02 | 0,85 |
| BTR25 | 31,12 | 42,55 | 33,58 | 38,51 | 1,07 | 0,91 |
| BTR50 | 30,31 | 39,11 | 31,21 | 34,57 | 1,03 | 0,88 |
| BTR75 | 29,46 | 37,81 | 29,43 | 32,09 | 0,99 | 0,85 |

# V. CONCLUSION AND FURTHER RESEARCH

The use of frame system reinforcement is able to increase the strength of the beam when the load reaches the ultimate in BTR25 beam by 10.72%, for BTR50 beam by 7.83%, and for BTR75 beam by 4.82% from BN beam.

# REFERENCES

Bing Li , Cao Thanh Ngoc Tran 2008. Reinforced concrete beam analysis supplementing concrete contribution in truss models. Journal Engineering Structures, 30 (2008), Elsevier 13 June 2008, 3258-3294.

Campinone, G., Colajanni, P. and Monaco, A. (2016). Analytical evaluation of steel-concrete composite trussed beam shear capacity, Materials and Structures, Vol. 49, pp. 3154-3176.

Leopoldo Tesser, Roberto Scotta 2013. Flexural and shear capacity of composite steel truss and concrete beams with inferior precast concrete base. Journal Engineering Structures, 49 (2013), Elsevier 25 December 2012, 135-145.

Rudy Djamaluddin 2013. Flexural Behaviour of External Reinforced Concrete Beams. Procedia Engineering 54 ( 2013 ) Elsevier 23 March 2013, 252 – 260.

Rudy Djamaluddin, Yasser Bachtiar, Rita Irmawati, Abd. Madjid Akkas, Rusdi Usman Latief 2014. Effect of the Truss System to the Flexural Behavior of the External Reinforced Concrete Beams. World Academy of Science, Engineering and Technology International Journal of Civil, Structural.

SNI 2847: 2013 Requirements for Structural Concrete for Buildings based on BSN 2013 - ICS 91.080.40., Jakarta.

Trentadue, F., Mastromarino, E., Quaranta, G., Petrone, F., Monti, G., and Marano, G. C. (2014), Bending stiffness of truss-reinforced steel-concrete composite beam, Open Journal of Civil Engineering, Vol. 4, pp. 285-300.

Vis. W.C and Kusuma.G.H. 1994. Basics of Reinforced Concrete Planning (based on SK SNI T-15-1991-03). Erlangga, Jakarta.

Yasser, Herman Parung, Muhammad W. Tjaronge, and Rudy Djamaluddin 2015. Flexural Characteristics of Reinforced Concrete Beam Using Styrofoam Filled Concrete (SFC) in Tension Zone. IACSIT International Journal of Engineering and Technology, Vol. 7, No. 1, February 2015.