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Strengthand Buckling Analysis of Sliding-Door Housing of Busway

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ABSTRACT--- ***Frame, double H model (DHF) was considered to use as housing of sliding door frame of busway. To insured that this frame is strength and stable enough to support roof weight of busway, an analysis using Ansys program was conducted. The overall dimension of this frame is 3950 mm width and 1850 height. The DHF frame was designed using square hollow pipe 60x40 mm, 2 mm thickness and designed using structural steel with minimal yield strength of about 175MPa. Total vertical load about 5000 N and total moment about 1000 Nm, caused by roof weight were acted on the top of the DHF frame. Two loading conditions namely L1 and L2 were test. In the L1 condition, the total force 5000 N and total moment about 1000 Nm were loaded at four points on the top of DHF frame while in the L2 condition, the total force 5000 N and total moment 1000 Nm were loaded at eight points at the top of the DHF frame. Result showed that, for all loading condition, the DHR frame will unstable at critical load about 23000-27500 N, higher than the applied load. Von Misesstresses about 120Mpa lower than yield strength of materialfor both model were found. These indicated that the DHF Frame was strength and stable enough to withstand roof weight.***

Keywords ---busway, double H model frame, critical load, Von Mises stress.

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1. INTRODUCTION

Now days, City buses, namely busway was being popular in Jakarta and used as Bus Rapid Transit (BRT). In several buswayfleet, there are sliding doors that have large dimension. This door and its door housing needed much space inside the bus. This condition can inhibit the mobility of passenger. However, this sliding door and its housing should be redesigned [1].

A new model of sliding door has been design and its strength have been investigated, both numerically and experimentally and the result shows that that the sliding door is strength enough to withstand the load [1]. However, the sliding door housing is needed to investigate too.

Double H model (DHF) frame was considered to use as sliding door housing and subjected to vertical force and moment, caused by roof weight of busway. It was clearly understood that column strength is somehow related to the column length [2]. These DHF frames are as column and potentially buckle because of the long unsupported length [3-5].

Visual data on column frame of busway have been collected by TonoSukarnoto and some cracks were found (**Figure 1**). The possibility caused is the frame not strength enough to withstand flexural moment or the frame becomes buckle caused by vertical load. Other caused is no good manufacturing condition, particularly on welding joint.

Buckling load of fixed-free single column was based on Euler formula and written as [6]:

$$P_{cr} = \frac{\pi^2 EI}{4nl^2},\; n = 1,2 \ldots. \tag{1}$$

Where E is modulus of elasticity, I is inertia moment and l is column length. This formula was used to predict buckling load of DHF frame whiles its strength and its stability was investigated using Ansys Program.

In this paper, the investigation of strength and buckling of DHF frame using Ansys Program is reported. Stress and displacement in the whole DHF frame was examined in detail.

Figure 1: Crack on column structure at the window corner of Busway

2. THE DHF FRAME

The DHF frame is shown in **Figure 2**. The overall dimension of this frame is nearly the same as dimension of the existing system i.e. 3.95 m width and 1.85 m height and using square pipe 40x60 mm, 2 mm thickness. This pipe was structural steelJIS G3445 STKM 12A with minimum yield strength 175 MPa, modulus of elasticity about 2.0E011 MPa and poison ratio about 0.3.

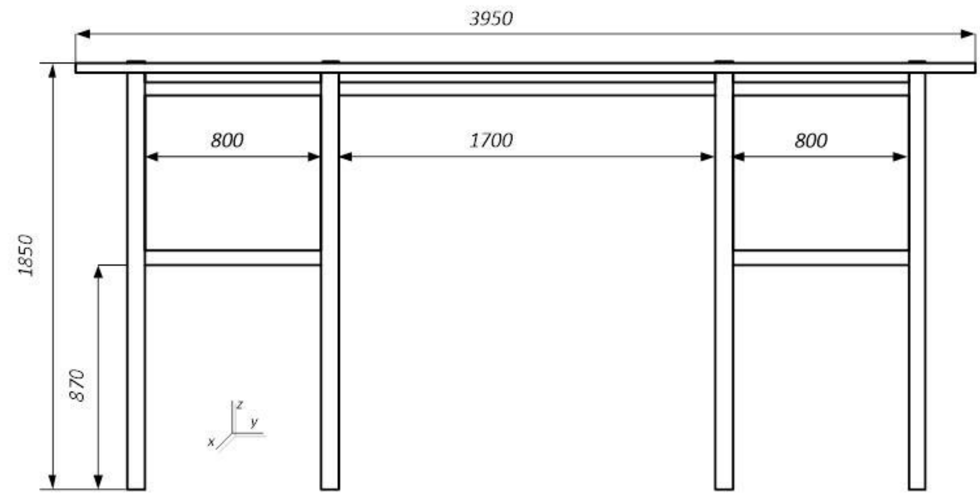

Figure 2: The DHF Frame

All frame column of Busway should support vertical load including roof load, air conditioning load and total window load. Approximately, this total vertical load is about 7800 N [7]. In case of calculating the strength of frame column, the vertical load was based on Concession Contract for Urban Mass Transport Public Services (26 Mei 2002): the whole column frame of the Busway should be support 50 % of the maximum admissible weight of the Busway. Assumed that the admissible maximum weight of Busway is 50000 N. This mean that all structure in each side of Busway should support admissible weight about 12500 N.The dimension of Busway is 11 m length and 2.5 m width while the total length of DHF frame that support vertical load is about 3.95 m. The total load on DHF Frame can be calculated using classical mechanics resulting force about 4488 N and moment about 944 Nm should be support by the DHF frame. For convenient, this load could increase to force about 5000 N and moment about 1000 Nm

3. FINITE ELEMENT MODELLING

Finite Element solution (including modelling, stress and stability analysis) using Ansys program was conducted by many researchers. Comparing to analytical and experiment analysis, the result of Ansys programis accurate enough [8-11]. However, Ansys program was used to analysis strength and stability of this DHF Frame.

Ansys modelling of DHF Frame is shown in **Figure 3**. The structure was fixed at the bottom of the structure while force and moment were applied at the top of the frame. Two supporting system of the DHF Frame to Busway roof were conducted. In the first system, the frame support the Buswayroof at point A, C, F and D while in the second system, the frame support theBusway roof at point A to H. Depending on these supporting system, two loading system were modelled, namely L1 and L2. In the L1 model, force about F=1250 N and moment about M=250 Nm were applied at point A, C, F and H. In the L2 model, force about 625 N and moment about 125 Nm were applied at point A to H. Do to simplicity and accuracy;tetrahedral elements were used as mesh for both models. Comparing to maximum shear stress theory (Tresca theory), distortion energy theory (Von Misestheory) is generally better predictor of failure. Hence, it is the most widely used theory and is recommended for design problems [12].

However, Von Mises stress was used to investigate the strength of this frame. On the Ansys program, statics structural was used to investigate the strength including Von Mises stress and displacement of DHF Frame while linier buckling was used to investigate the stability of the DHF Frame.

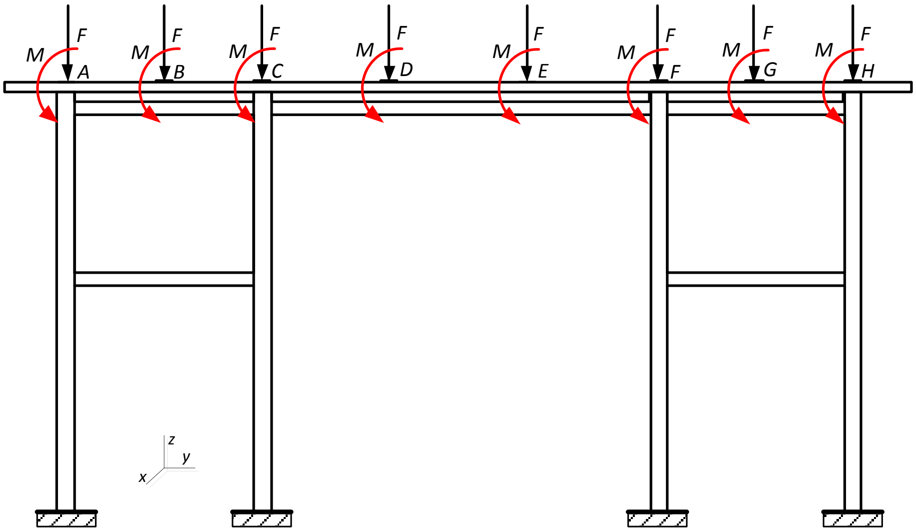

Figure 3: Finite Element Modelling of DHF Frame

4. RESULT AND DISCUSSION

Von Mises stresses of both model is shown in **Figure 4** (L1 model) and in **Figure 5** (L2 model). These stresses in every column for both models nearlyhave the same value around 55 MPa. Maximum Von Mises stress was happen at the top of the column. Again, these maximum Von Misses stress of L1 and L2 at the top column for both model nearly have the same value around 120 MPa. This maximum stress was caused by flexure moment acted on the top horizontal member of the frame.

Due to vertical force and moment acted on themiddle top horizontal frame of L2 model, the Von Mises stresses on this middle frame of L2 model was higher than Von Mises Stresses on the top middle frame of L1 model i.e. 46 MPa at L2 models compare to 33 MPa at L1 Models.

It's clear that the maximum Von Stress in whole DHF Frame (120 MPa) is lower than the yield strength of material (175MPa), so that no other reason of crack on DHF Frame but bad manufacturing processes particularly brittle fracture on welding joint.

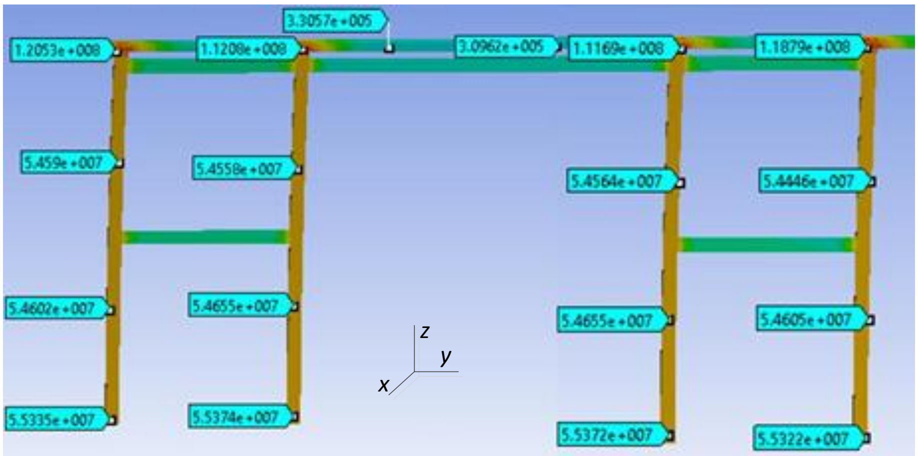

Figure 4: Von Mises stress of L1 model

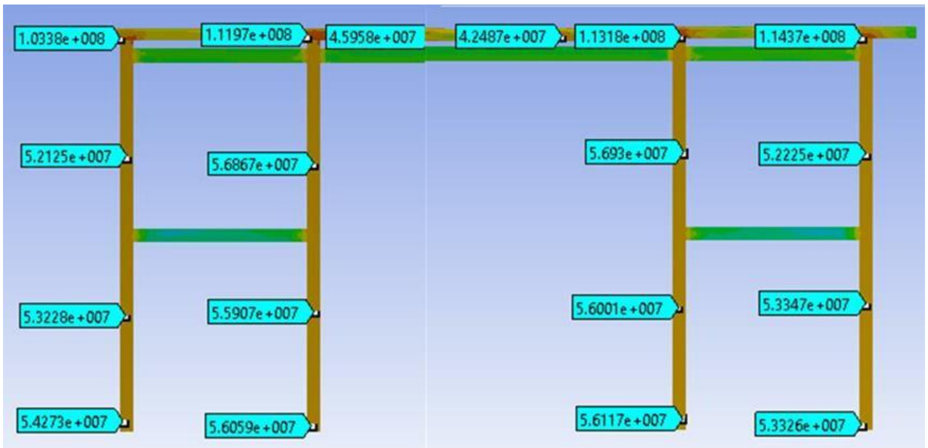

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Figure 5: Von Mises stress of L2 model

Deformation in x direction is shown in **Figure 6**(L1model) and in **Figure 7**(L2 model).This x deformation was primarily caused by moment.**Figure 6** and **Figure 7**showedthat deformation in x direction for all columns and for both models was nearly the same i.e. around 0 cm at the bottom and increased to 2.18 cm at the top of the column. In the top member of the frame, the deformation in x direction was also have the same value around 2.18 cm even additional moment was given to point D and E in L2 model

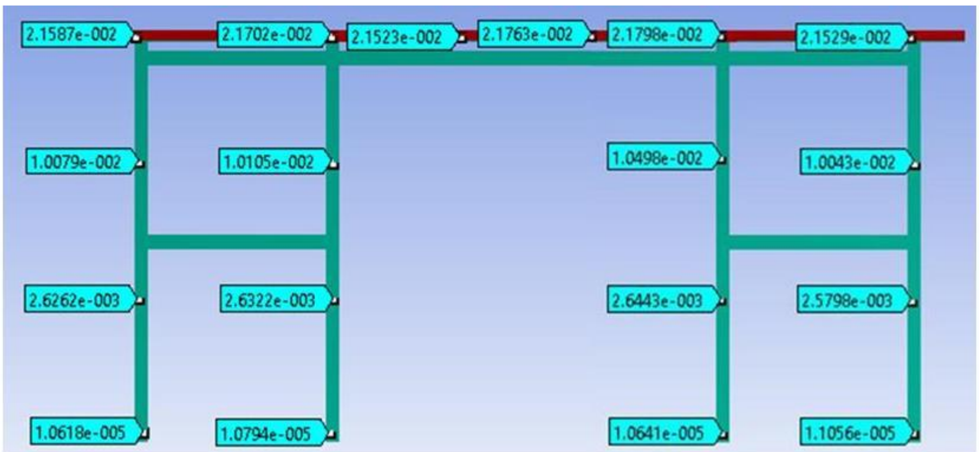


Figure 6: deformation of L1 model in x direction

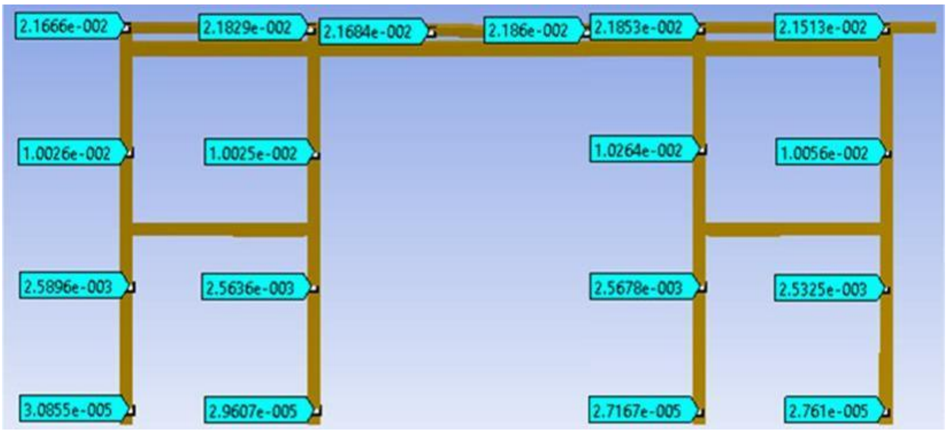


Figure 7: deformation of L2 model in x direction

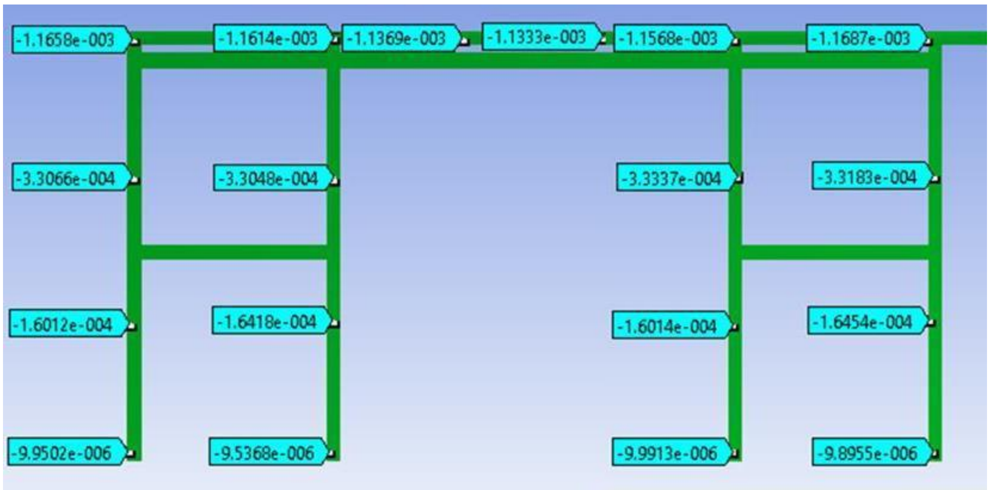


Figure 8: deformation of L1 model in z direction

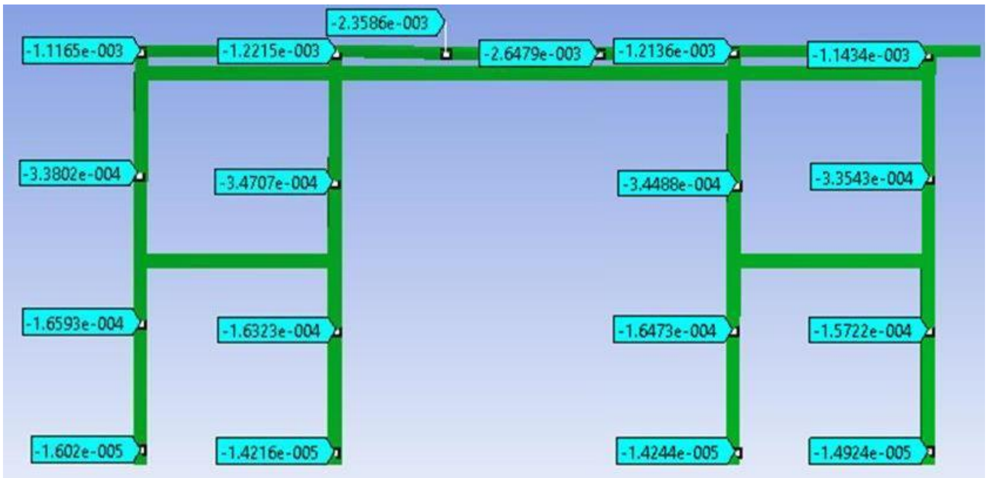
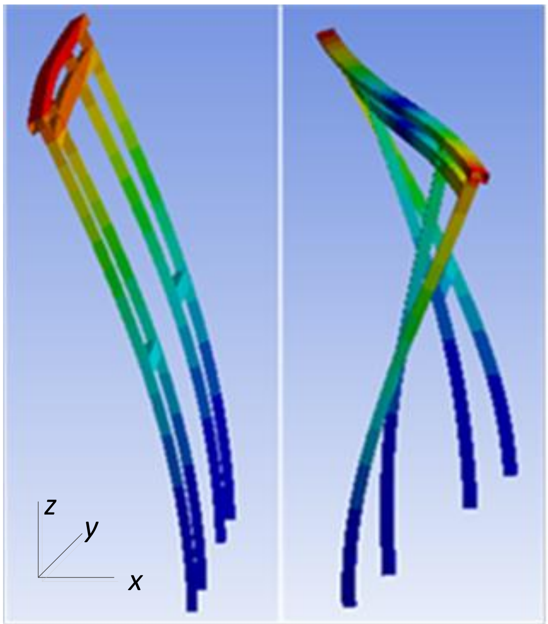


Figure 9: deformation of L2 model in z direction

Deformation in z direction is shown in **Figure 8** (L1model) and in **Figure 9** (L2 model).This z deformation was primarily caused by vertical force.**Figure 8** and **Figure 9** showedthat deformation in z direction for all columns and for both models was nearly the same value. In the L1 model, the z deformation was 0 mm at the bottom and increased to -1.16 mm at the top of the column. In the L2 model, the z deformation was 0 mm at the bottom and increased to -1.2 mm at the top of the column. Due to vertical force at the middletop horizontal member of L2 model, the deformation in z direction of L2 model was higher than deformation in z direction of L1 model. In the L2 model, the deformation in z directional on the middle top horizontal member of the L2 model was around -2.6 mm compared to -1.13 mm at the middle top of L1 middle.

All deformation, both in z direction and in x direction for both model was acceptable because buswaydoor can be slide in the DHF Frame freely



(a) (b)

Figure 10: Buckling deformation, (a) First mode (b) second mode

Using equation 1, buckling force for first mode of single column was found about 14132 N, higher than vertical force on single column of DHF Frame. Ansys program showed that buckling force for first mode in L1 model of each column about 14129 N while buckling load of each column in L2 model was about 7301 N. In the second mode, buckling load of each column in L1 model was about 27625 N while buckling load of each column in L2 model was about 22364 N.Mode shape for both models has the same graph as shown in **Figure 10**. In the first mode, the all column of DHF Framewas deformingas single column in x direction. In the second mode, Dou to elasticity of horizontal member of the frame the left side of the frame was deforming in opposite to the right side in x direction.

The buckling data showed that the applied force for both model is lower than the buckling force. This conclude that crack on DHF Frame was not caused by buckling load and DHF Frame was stable enough to withstand roof weight

5. CONCLUSION

The above discussion can be concluded as:

a) Strength investigation showed that the DHF Frame was strength enough to withstand vertical load caused by roof weight
b) The DHF Frame is stable enough to withstand vertical load without buckle
c) Roof weight was not primarily caused of crack on DHF Frame. The primarily possibilities caused of these crack was bad manufacturing processes, particularly brittle fracture on welding joint.

6. ACKNOWLEDGEMENT

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