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Original Article

Retrofitting Analysis of Steel Roof Frame to Preserve Heritage Building 1921

Nusa Setiani Triastuti[1*], Rico Turnando[2], Indriasari[1]

[1,2]*Krisnadwipayana University, Indonesia.*

[*]*Corresponding Author: nusasetiani@unkris.ac.id*

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Abstract *- The spirit of preserving heritage buildings as they originally became a big challenge during design analysis, ensuring they remain in their original state without damaging the construction process. The objective of this research was to maintain the authenticity of the structure. Roof covering, strengthening and detailing the roof by analyzing the structure on the roof's strength, stability, and deflection with Indonesian code 1729-2015 based on the American Steel concept. Analysis of dead loads, live loads, and the wind load, because only the roof was on the 3rd floor and the roof slope is 30o. The case study method was carried out with surveys and secondary data results from the investigation consultant in 2016. The analysis results of two truss members' roof, 2L 70.70, need to be replaced with a double profile 2L 80.80, bolt connections with the provision that steel profiles, bolts, and rust anchors were replaced. Analysis of the 3-dimensional roof structure with software by calculating the compressive wind load of 75.82 kg/ m2 and the suction wind load of 57.37 kg/m2 according to the wind speed of 40 m/s. Conclusion Steel roof truss meets strength stability and retains the original structure shape, accessories, roof, and tile roof.*

Keywords *- Fixed heritage roof, Steel roof truss structure retrofitting, Bolt connection roof frame, Profile dimensions maintained, Tile roof preserved.*

1. Introduction

The heritage building is protected by the Regulation of the Minister of Public Works and People's Housing of the Republic of Indonesia Number 19, the Year 2021, concerning technical guidelines for the implementation of cultural heritage buildings to be conserved Article 6. (1) b. Article 6. (4) c.

It needs to be repaired or strengthened so that it functions properly and can be enjoyed by the younger generation to explore the history of the Indonesian nation. Damage to the roof structure as a building protector can cause overall damage to heritage buildings. The research team identified the overall damage, but only roof damage is discussed in this paper.

The Heritage Building was a construction building started in February 1921 in Jakarta. After the building was not used for office operations, the Heritage Building was less maintained than 100 years old; it needs to be retrofitted.

A small part of the roof truss elbow profile is porous in areas not protected by the roof, so it must be replaced. The roof beam WF profile, which is porous, is still good and is considered to have been replaced according to the dimensions of the existing roof truss. The input software is assumed to be non-roten and non-hollow because it will be replaced with a new steel profile.

Analysis of the roof structure from the software's output shows that the load-receiving results are smaller than the allowable stress of the steel. The purpose of this study was to analyze the reinforcement of the steel roof truss, including bolt connectors and anchors so that it achieved strength, stability, and stiffness in the 1921 Heritage Building. Reinforcement analysis using SNI 1729-2015 regulations with the help of software. The author tried to simply analyzed the big impact on the old and young generation that heritage buildings were in accordance with the original, retrofitted with a simple construction non-sequential that was easy for young engineers or workers to understand for build and scientific journal easy implementation. Historic earth structures are an important part of a worldwide heritage, with similar structural characteristics and performance levels. (Lourenço P.B 2018)

This manuscript focuses on two main aspects: the urgent knowledge of construction engineering at the time the work is constructed and the ongoing linkages required between the various aspects involved in the process. (Gutiérrez A.C, Imenez M.B,2018). The diaphragm is built on top of the existing structure without significantly changing the overall layout of the roof. The proposed retrofitting engineering is primarily defeasible, minimizes damage to the integrity of the building, and can be easily implemented in constructing earthquake-resistant wooden roofs in new buildings. (Giuriani E., Marini A, 2008)

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Fig. 1 (source Mandiri Bank)1a. Picking tobacco leaves, 1b, Pounding rice, 1c, Carrying sugarcane stalks, 1d Picking coffee, 1e Tapping rubber trees

The roof structures were an integral part of the architecture and should be treated with care because of their historical significance. Wooden structures are important sectors of historical relevance, architectural technology, and construction materials. (Cestari. C.B, Marzi T 2018)

Assessing the early stages of iron roof construction and the evolution of iron roof structures, four case studies of churches located in Brussels, Antwerp, and Gent from the 1840s to the 1860s through in-depth analysis. (Wibaut. R et al., 2019)

Long-span truss profiles require less material than structure profiles roofs to relate to the required width of the truss Rambhau (P. R, Wakchaure M.R. 2017)

An alternative design to reduce the footing size avoids shearing the integrated rigid frame in the floor between the foundations in the tension tie beam (Mangaluru, Karnataka, 2018).

A rigid frame structure spans longer or is equal to 30m cheaper without calculating the foundation cost compared to the span of a 20m rigid frame. (Martínez J.M et al, 2004).

A function of the average wind speed in the area under study. It is an estimate of the number of damaged schools per area. The risk assessment proposed in this paper (Acosta T.S, 2021).

The risk assessment proposed in this paper. The average wind speed in the studied area. Estimated number of damaged schools per region (Acosta T.S 2021).

Both trusses are designed and compared to all internal forces, are economical, and evaluate the moments and shear forces present along the critical sections with the same configuration area, keeping all other parameters constant (Bláha. 2018).

Damage caused by aging and neglect. Construction The structure's life cycle here is investigated through the various stages of the building's life, built-in 1902 and abandoned in 1984. The periods analyzed are from construction to disuse and from disuse to the present day. The second phase of life significantly accelerates the ongoing degradation. (Basso N, Sgambi L 2018).

The design process consists of determining first the exact shape of the original roof, taking into account different types of evidence, and secondly, the necessary modifications to meet the structural standards. Such a design choice is far from a simple solution; a thorough multidisciplinary investigation involves the participation of different experts (Piazza M, Riggio M, 2017).

In this paper, two main aspects contribute to the achievement of broader sustainability goals during the restoration and renovation of historic buildings, exploring the relationship between structural rehabilitation of historic architecture and cultural sustainability (Bertagni S. et al., 2018)

Two types of steel truss roof structures – K-series steel beams and arch trusses as prototype roof trusses. Nonlinear dynamic analysis that considers the material and geometric nonlinearity was carried out for this simulation study.

Installing the steel truss roof structure prototype device in the intentionally attenuated force zone helps to reduce the displacement of the truss structure due to wind stress, thereby reducing the risk of dynamic failure Zhang. LBY (2012). Helps reduce displacement of the truss structure from wind stress by installing force-limiting devices in the intentionally attenuated zone of the prototype steel truss roof structure, thereby reducing the risk of dynamic failure (Yong Y.X et al.,2017).

Four representative locations in China were investigated. Steel roof structure exposed to snow load. The studied roof reliability index was not sufficient to reach the target value. In addition, a large partial factor for various snow loads (Kozak D.L, Lief A.B, 2015)

2. Implementation

Retrofitting the steel roof structure with the shape, profile, and shape of the existing roof covering so that the authenticity of the heritage building is maintained. The layout and shape of the roof are below.

The layout of the existing steel structure is maintained as it is, with the following data:

1. 102 m elongated roof.
2. Roof structure is 21.6 m long.
3. The span of the roof structure is 7.4, 4.35 m, 2.1 m.
4. Roof slope 30o
5. Roof Truss 2L elbow profile 80.8.8; 2L.70.70.7, 2L60.60.6, L 50.50.5, L 40.40.4.

In this analysis, the connection tool used bolts of 13 mm for steel profiles, and for anchors using 19 mm, the anchor length is 15 cm with A325 quality (high-quality HTB bolts).

According to Figure 5,6,7,8, the load entered in the structural software is:

1. Dead Load 157,64 kg/m2
2. Live Load 135 kg/m2
3. Push Wind Load75,82 kg/m2

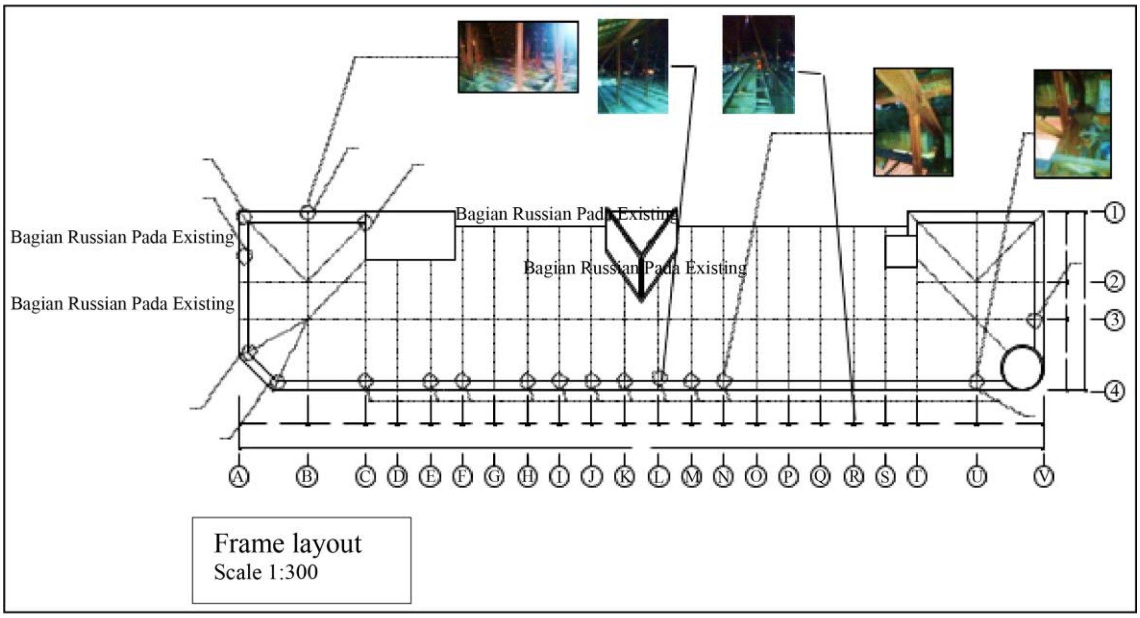

Fig. 2 Roof length of 102 m, width 21.6 m, height 5 m, with a distance of 7.4 m and 4.1 m truss

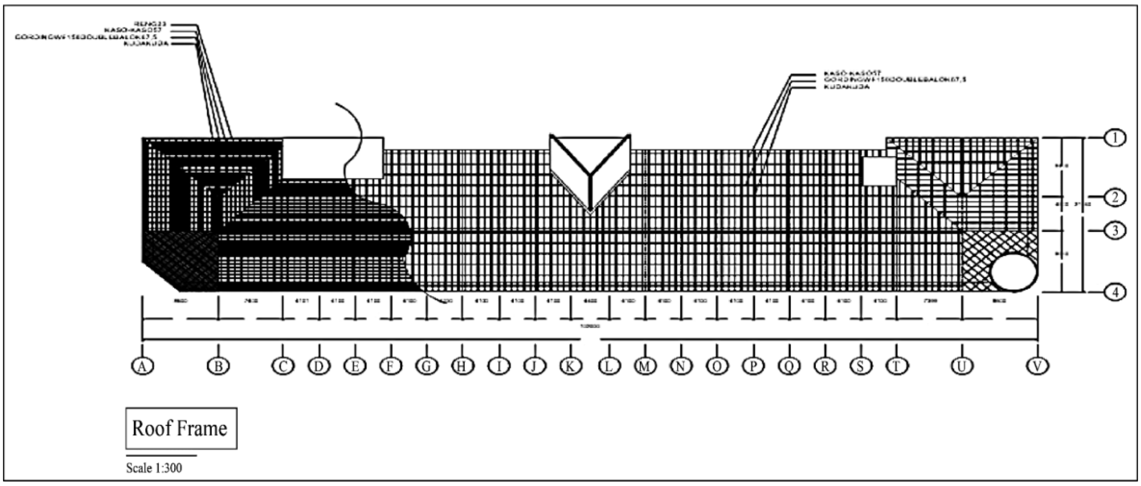

Fig. 3 Roof frame

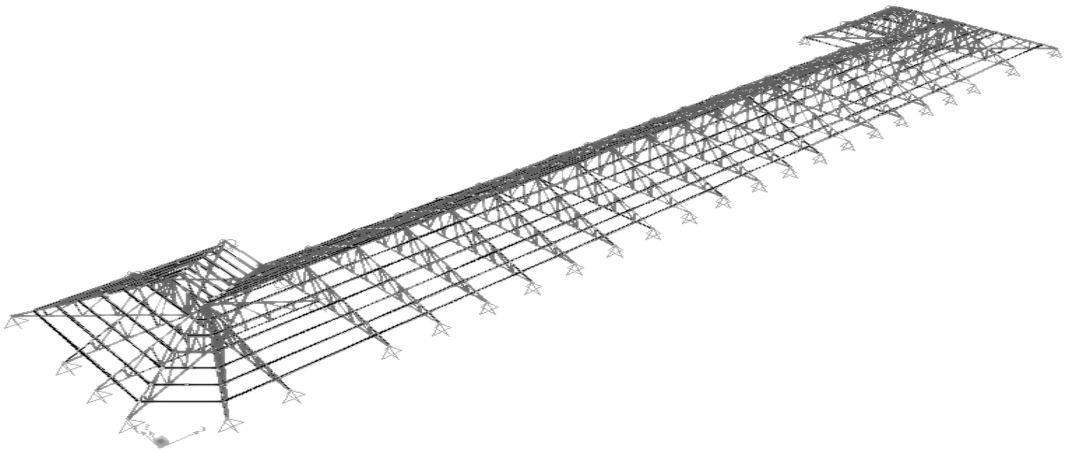

Fig. 4 Three-dimensional space layout sources (Researchers Team)

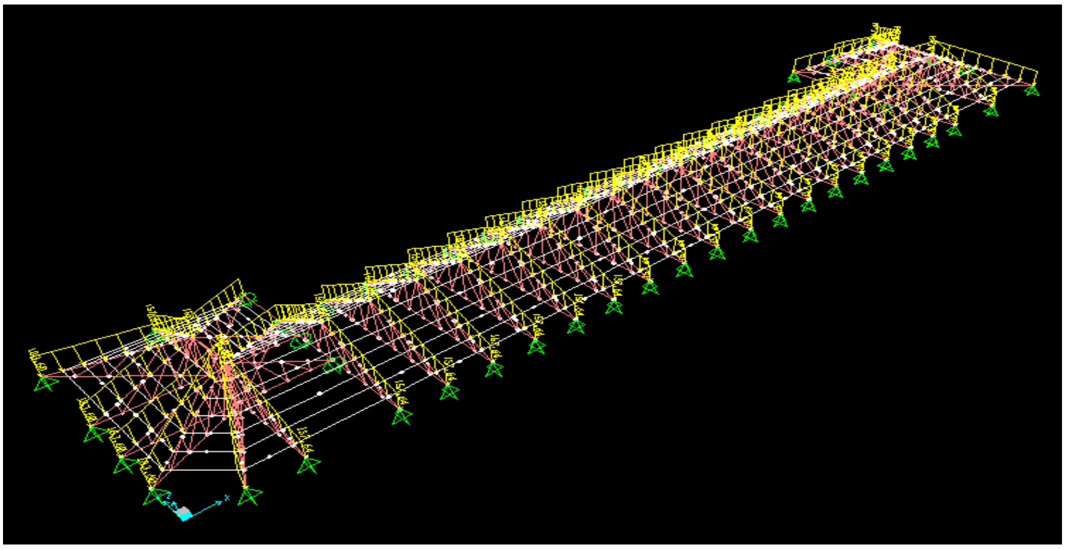

Fig. 5 SAP2000 Program, dead load input (Researchers Team)

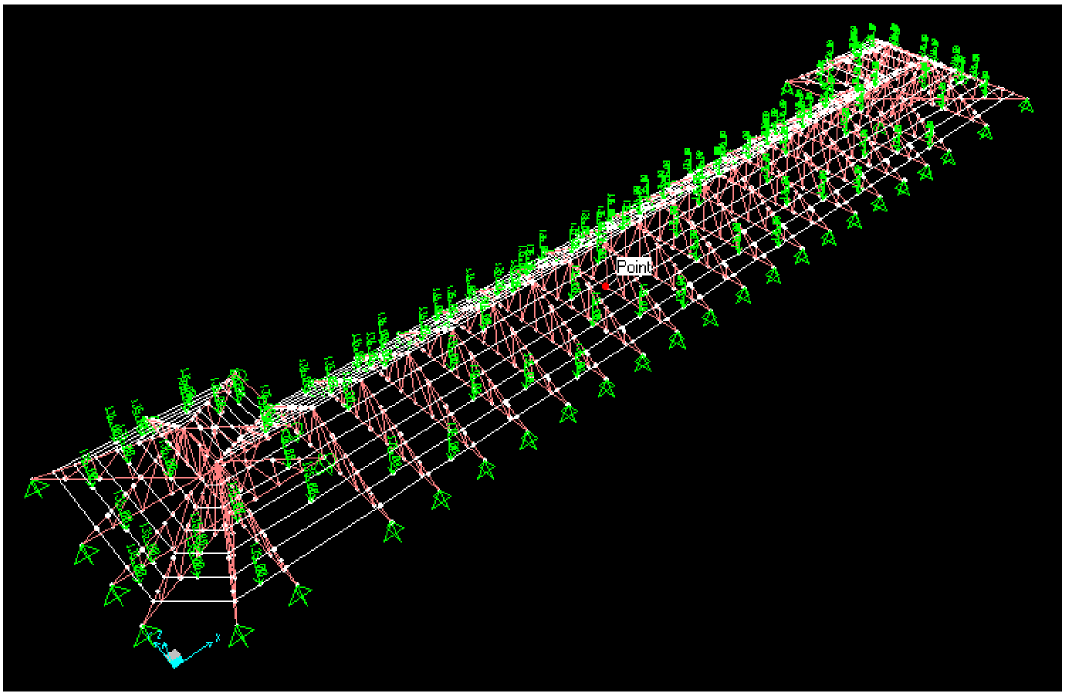

Fig. 6 SAP2000 Program, live load input (Researchers Team)

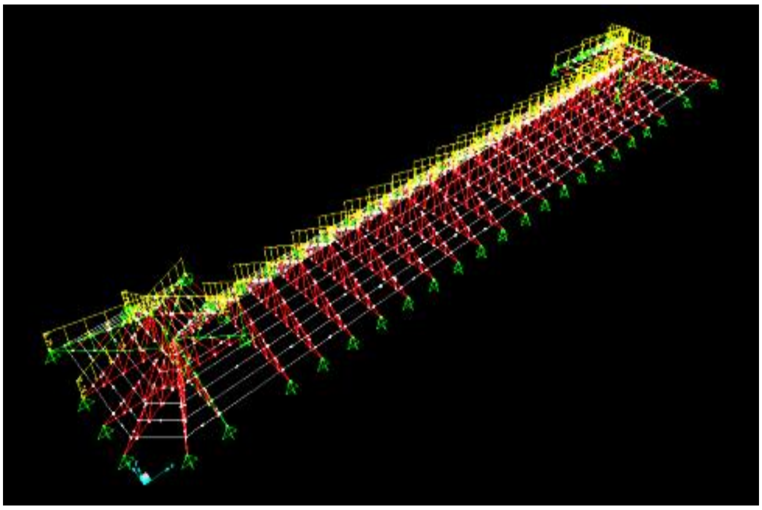

Fig. 7 SAP2000 Program, push wind load input (Researchers Team)

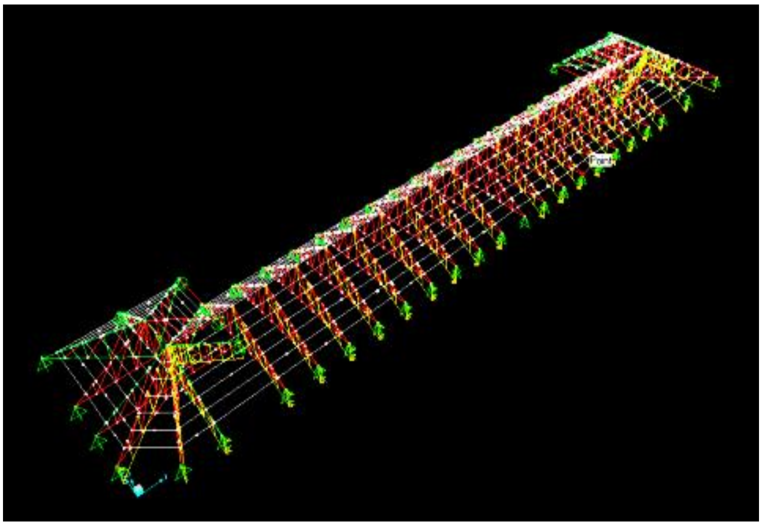

Fig. 8 SAP2000 Program, pull wind load input (Researchers Team)

2.1. Overview

Fig. 9 Existing visual

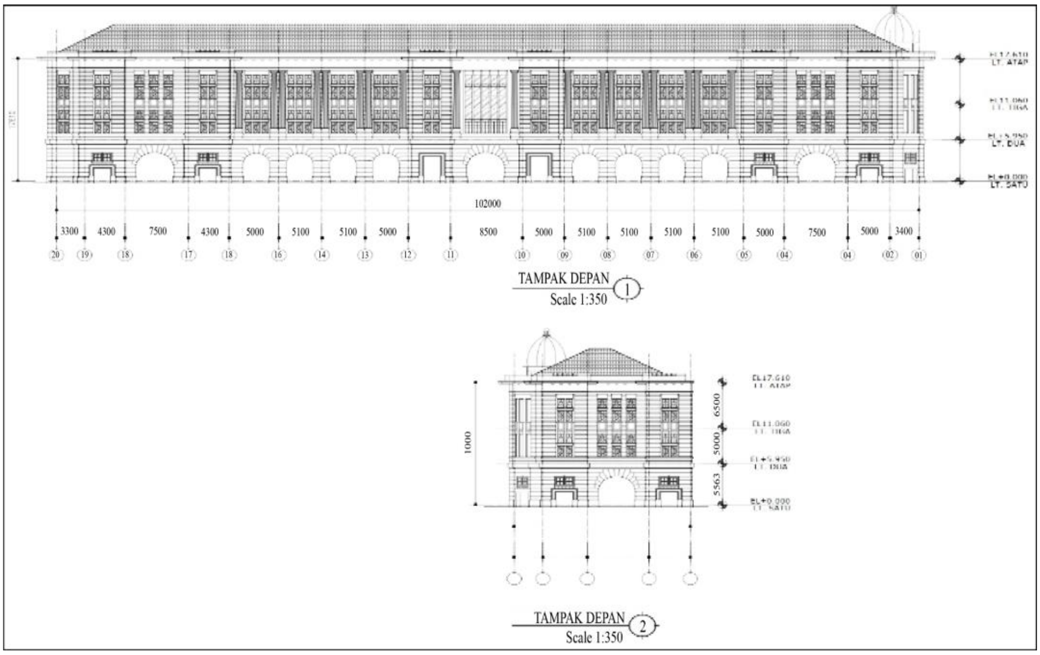

Fig. 10 In front and side view

Maintaining the visuals and finishing heritage buildings must be done. This was, of course, without neglecting the structure's strength, stability, and rigidity. The heritage building was located in the old city of Jakarta, about 6 km away. The influence of seawater was quite high, and the elbow steel with the roof covering did not exist and was easily porous. The implementation must be replaced with an elbow profile according to the existing dimensions. In addition, the weak structural steel dimensions are replaced with larger steel dimensions. Gap Research: There was no condition of the heritage building where the roof covering was damaged or not maintained; the steel truss roof and upper structure were damaged but still maintained as original with retrofitting. The research team has to be careful when surveying and analyzing the profiles that can be maintained and those that can't. The steel roof truss from 100 years ago was of high quality; it was proven that the WF profile for the curtains beam was still good.

2.1.1. Decomposition Forces

The dead load, live load, and wind load, the most important of which must be accepted by the frame roof structure, it is hoped that the roof structure will not be damaged for decades to come.

2. 1.2. Internally Computed Parameter

Parameters as a reference are strength, stability, rigidity according to engineering standards, and small deformation of the allowable deformation. This is the concern of the research team, in addition to the profile of the existing bolt condition and the rust profile that needs to be replaced.

2.1.3. Detailing

Detailing of the shape of the roof truss and material is attempted not to be different from the original condition, both roof structure work, roof covering truss, roof covering as well as vertical gutters. All of this is for the sake of preserving the heritage building.

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2.4. Detailing

Detailing of the shape of the roof truss and material is attempted not to be different from the original condition, both roof structure work, roof covering truss, roof covering as well as vertical gutters. All of this is for the sake of preserving the heritage building.

The facade must be retained in its original form. The details of the roof knick-knacks are also made as before; namely, bolt connections made according to the supporting structure, namely bracing, ceiling hangers, roof beams, roofs, and gutters; the principle is that even though the roof structure is strengthened by replacing the porous and damaged but the shape of the roof, the structure of the roof and the details are retained.

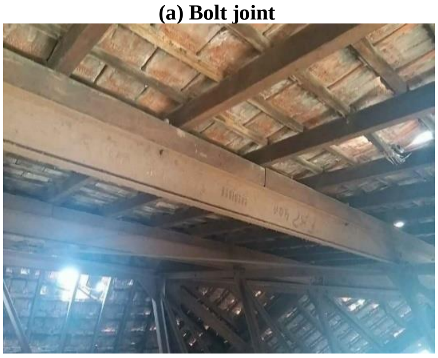
2.5. Choice of Output

The main thing is to analyze the retrofitting of the heritage building so it doesn't collapse. When replacing bolts, profiles are porous and rusty. The roof truss structure support sits not only in the existing building but the base in given a steel plate base that supports the structure to the ground floor because it cannot rely on a low-quality concrete structure smaller than fc 14.53 mpa.

(a) Bolt joint

(b) Bracing

(c) Plafond hanger



(d) Roof beam

(e) Roof and survey team

(f) Horizontal rainy gutter

Fig. 11 (a), (b, (c), (d), (e), (f), (g) Existing detail roof structure and roof

2.6. Internal Regulation

Regulation of the Minister of Public Works and People's Housing of the Republic of Indonesia Number 19 the Year 2021 Concerning Technical Guidelines for The Implementation of Cultural Heritage Building Be Conserved.

Article 6. (1) b. As much as possible, maintain authenticity.

Article 6. (4) c. Careful and responsible use is based on the use of non-destructive techniques, methods, and materials.

3. Result/ Preliminary Analysis

The steel roof truss structure of the Heritage building that was researched has an age of more than 100 years and can still be used. The shape of the roof, roof structure, and roof details that need to be replaced are made according to the original. This retains the glory of the building in its time; changes to the roof structure for strengthening do not prevent its authenticity from being retained. This can be an eternal history of the building, even though generations change, and the descendants of the previous generation can be nostalgic, considering their parents used to work.

Based on the results of the SAP2000 analysis, it was found that the profile replacement on the roof truss type K2 members 161 and 214 with the number of bolts 2 pcs (existing installed 3 bolt) on the 2L 80.80 profile, 3 pcs on the 2L profile 70.70, 2 pcs on the 2L profile 60.60, 2 pcs on the 2L profile 50.50, 2 pcs on 2L 40.40 profile and 4 anchors. With a deflection of 0.25 cm at a distance of 7.4 m and a distance of 4.1 m, the roof truss obtained a deflection of 0.11 cm. Of the many elbow profiles on the roof truss and curtain beam, the results of the computer output show that 2 members exceed the stress limit, so the dimensions that need to be enlarged from the existing 70.70.7 profile dimensions of the double elbow can be seen in the image below:

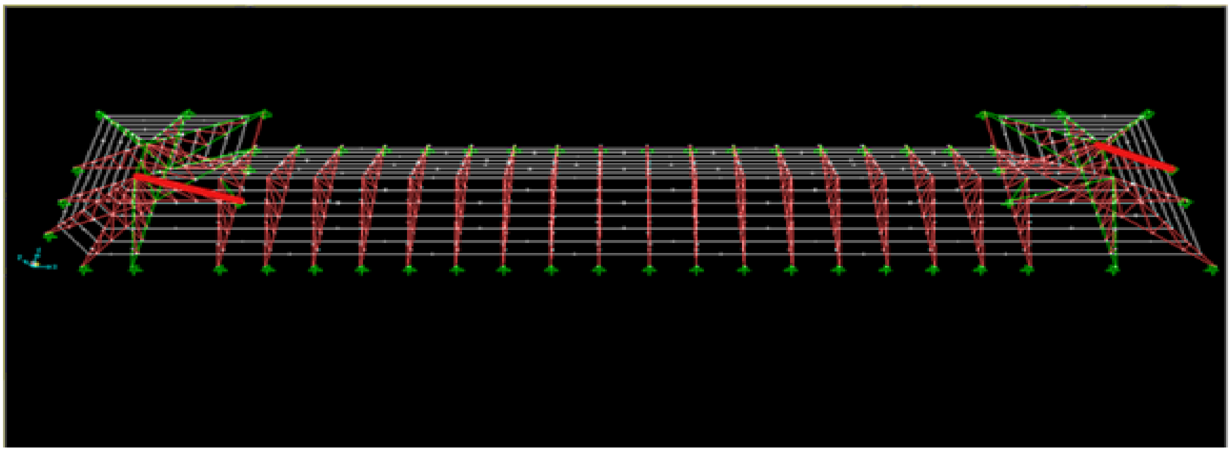


Fig. 12 Two profile members 70.70.7 need to be replaced with double elbows 80.80.8. Two profile members 70.70.7 need to be replaced with double elbow 80.80.8 on type K2 as per Figure 16

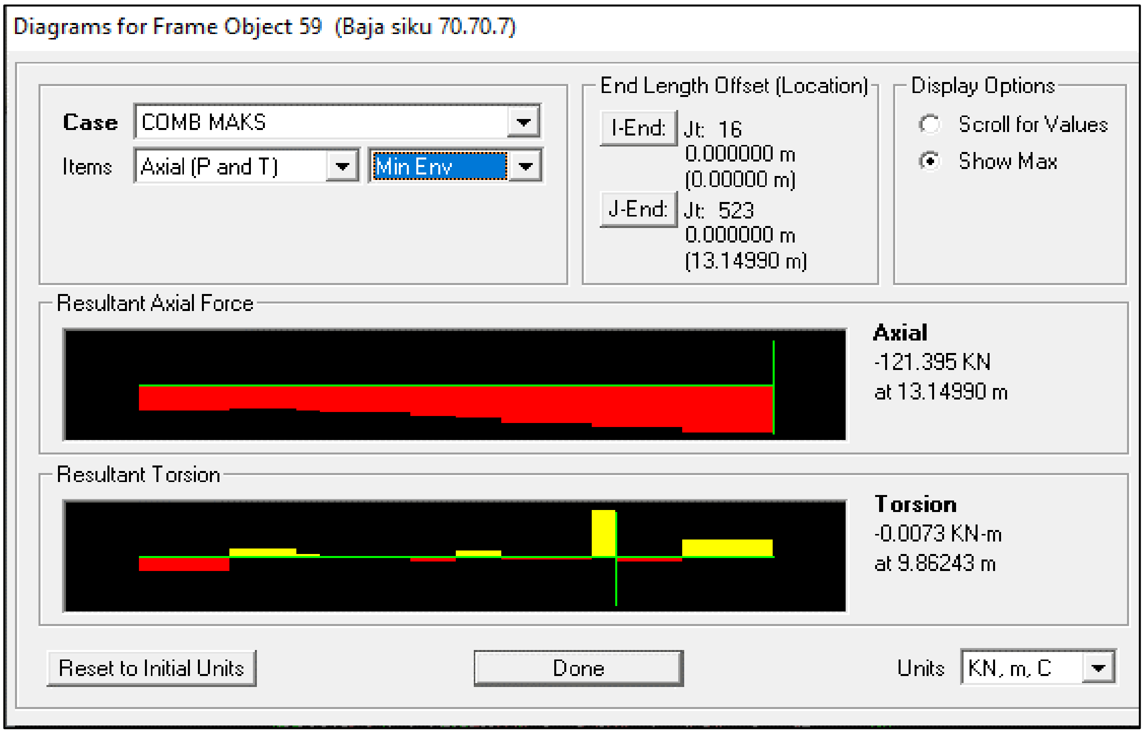


Fig. 13 The output of the software shows that the compression member is not strong enough to stand axial loads; the profile needs to be replaced with steel profile 2L 70.70.7 to 80.8.8 member 59 and member 2 Mpa Elastic buck uncritical stress:

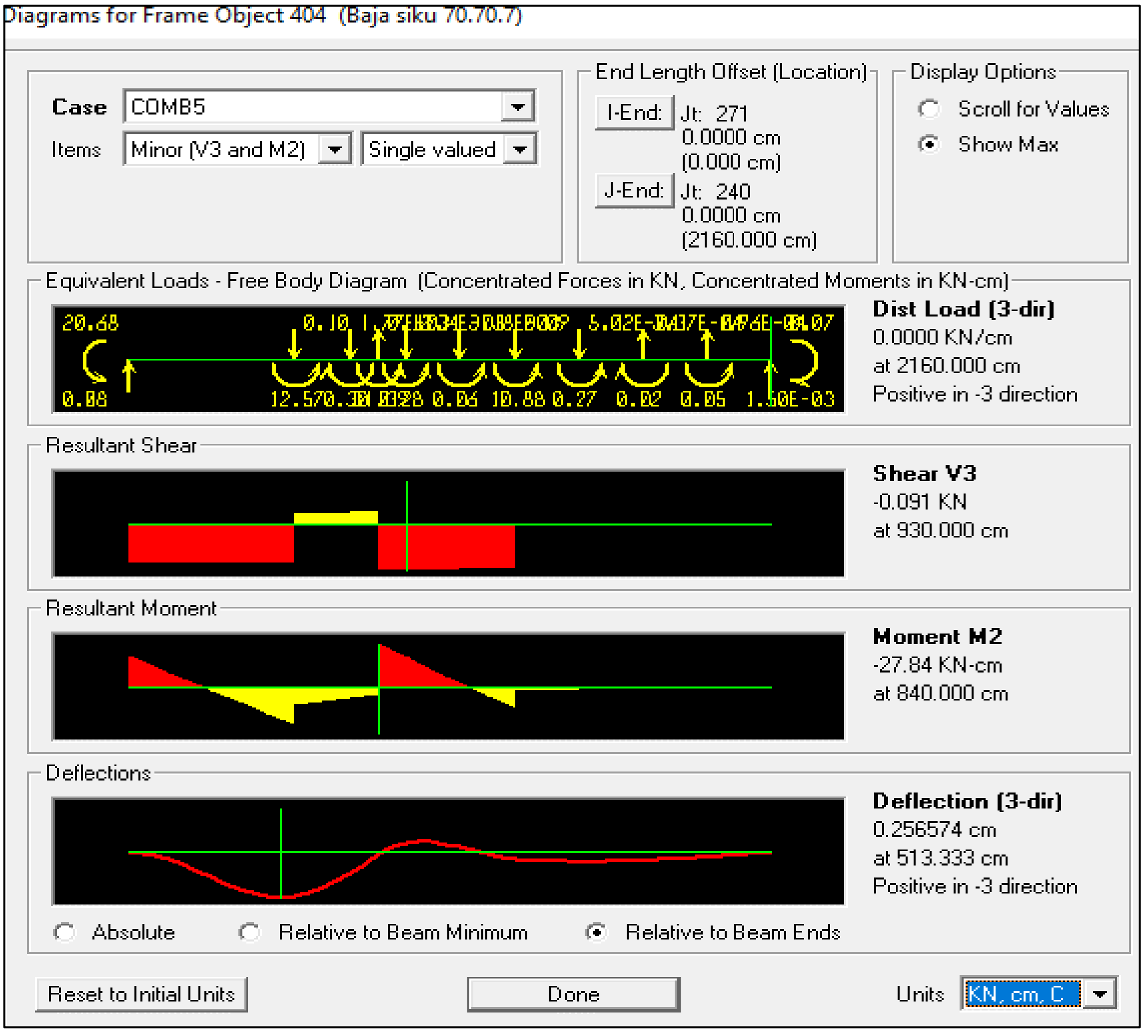


Fig. 14 Deflection 0.256574 cm with a span of 2160 cm L to the inter-roof frame 7.4 m

According to the output of structure roof software below, Figure 13, the software's output shows that the compression member is not strong enough to withstand axial loads; the profile needs to be replaced with steel profile 2L 70.70.7 to 80.80.8 member 59 and member 284.

$$\text{Fex} = \frac{\pi^2 \, . \, E}{(\frac{KL}{rxg})^2} \quad (1)$$

Fex = 192,42 Mpa

$$\text{Fcry} = (,658^{\frac{fy}{fex}})$$

fy = 189,85 Mpa

Fy/Fe < 2,25

Other elbows 70.70.7 still meet the requirements.

The deflection that occurs meets the requirements and is still smaller than what is allowed, meaning that the roof truss structure can support it. The deflection that is used with the load of the installed tile. The existing connection uses bolts; the need for bolts is recalculated according to the package program output.

The elbow profile roof frame is by the existing dimensions, except for 2 members that must be replaced 80.80.8; the other profiles still meet the stress requirements that do not exceed the allowable stress.

Deflection analysis on the roof frame with a distance between horses of 7.40 m was obtained from structural analysis with software for the deflection of 0.25 cm, and the following is a picture of the deflection at a distance of 7.4 m that occurred and a deflection of 0.21 cm at a distance of 4.1 m roof frame.

4. Discussion

This discussion explains in a way that is easily understood by young engineers and serves as an example that scientific papers are easy to apply. The rods need to be replaced if they cannot match or are insufficient with the accepted force, the number of bolts and anchors that need to be added, and the required anchor length. The authors explain this so that it becomes a reference for readers who work in the building sector.

The analysis carried out is simple, as an example. Authors have the principle that the manuscript can be useful not only for academics but also for professionals. The principle of repairing old buildings that must be maintained is not easy because construction must also be not sequential; the bottom roof structure must be supported to the ground floor because the concrete quality of the heritage building is very low. It is necessary to analyze the implementation not sequentially when designing the roof structure; the implementation is not sequential so that there is no weakening in adjacent areas, which can result in tilting or collapsing.

Replacement of damaged or less strong roof details is replaced by paying attention to the authenticity and strength of roof details and roof structure. Everything must be done carefully, and pay attention to the weak parts; replacing doesn't have a fatal impact.

According to the Roof plan, the placement of the roof frame plan, K1, K2, K3, K4, and K5 roof frames, and details of the explanation according to the figures 16,17,18,19,20,21.

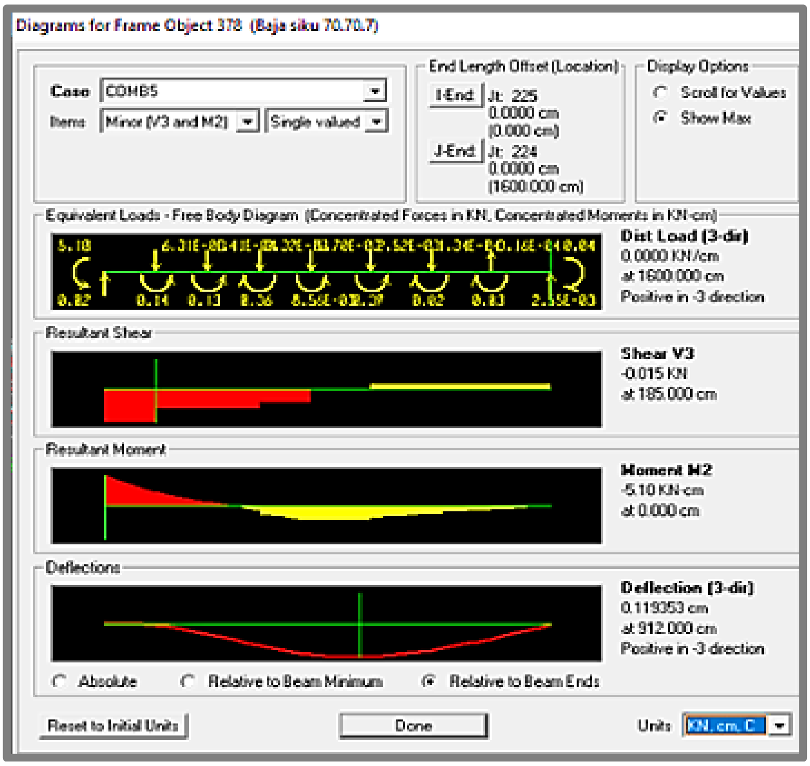


Fig. 15 Deflection 0.119353 cm length of 16 m to a distance of frame 4,1 m Member 378

The entire roof structure from the floor plan and roof frame details as below:
1. Figure 16 Roof frame layout
2. Figure 17 Roof frame 1
3. Figure 18 Roof frame 2
4. Figure 19 Roof frame 3 and Roof frame 5
5. Figure 20 Roof frame 4
6. Figure 21 Details I, II, II

We include all plans for retrofitting the roof truss structure to be applied throughout the world to be a reference for repairing old buildings, especially roofs.

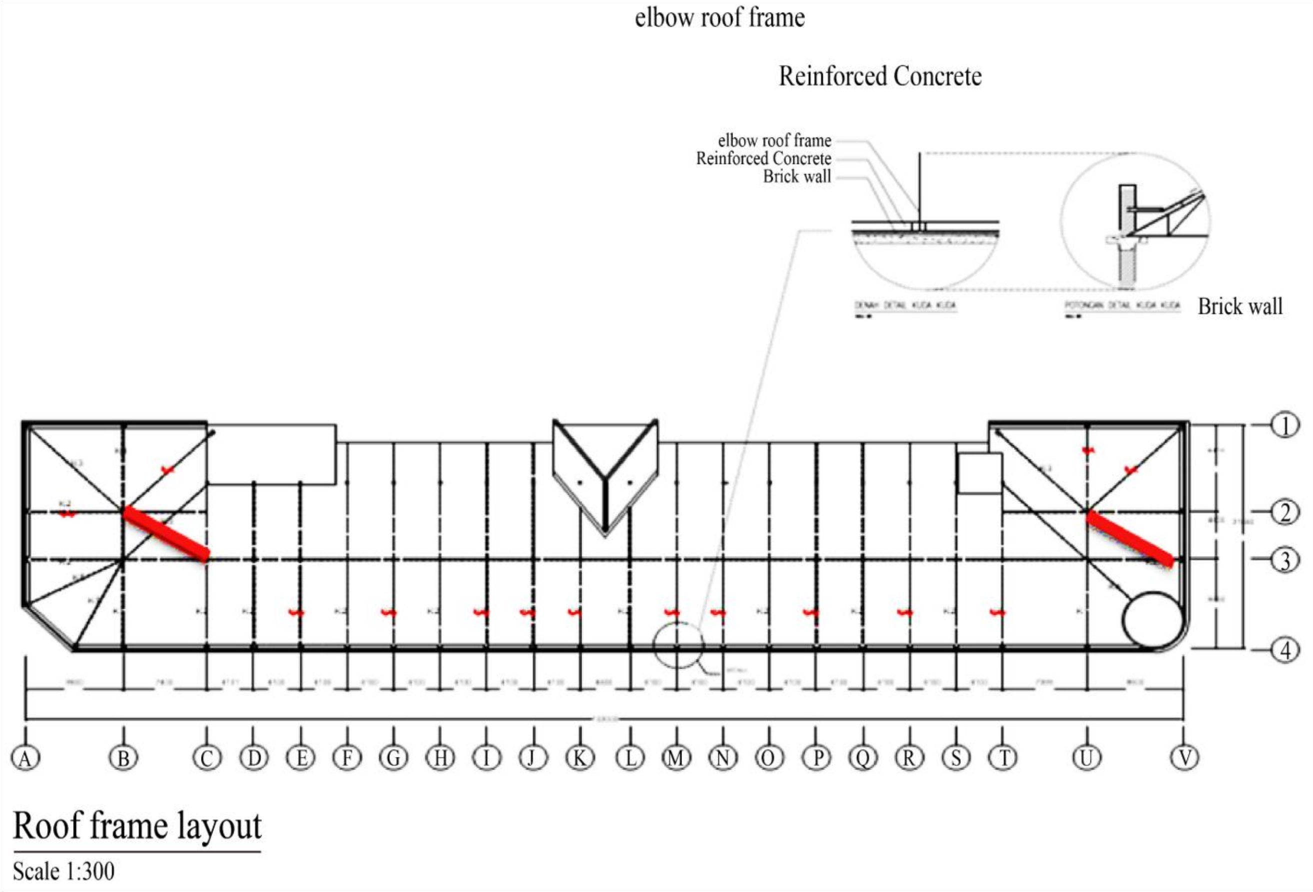


Fig. 16 Roof frame layout

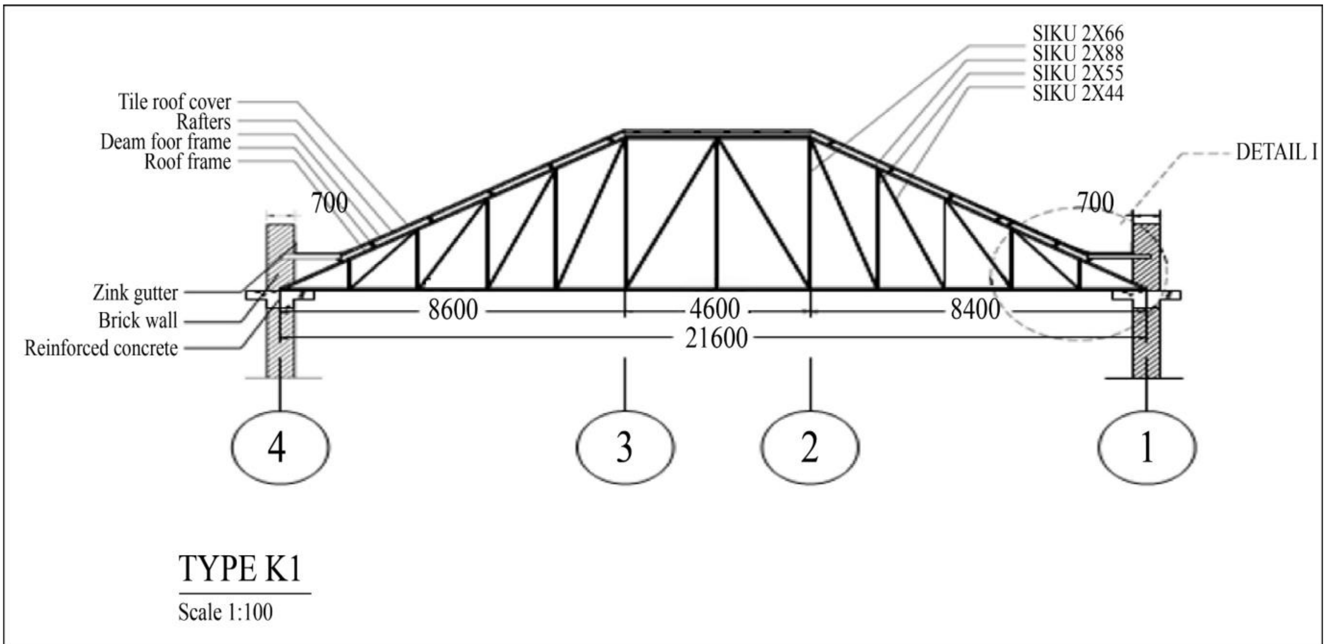


Fig. 17 Truss K1

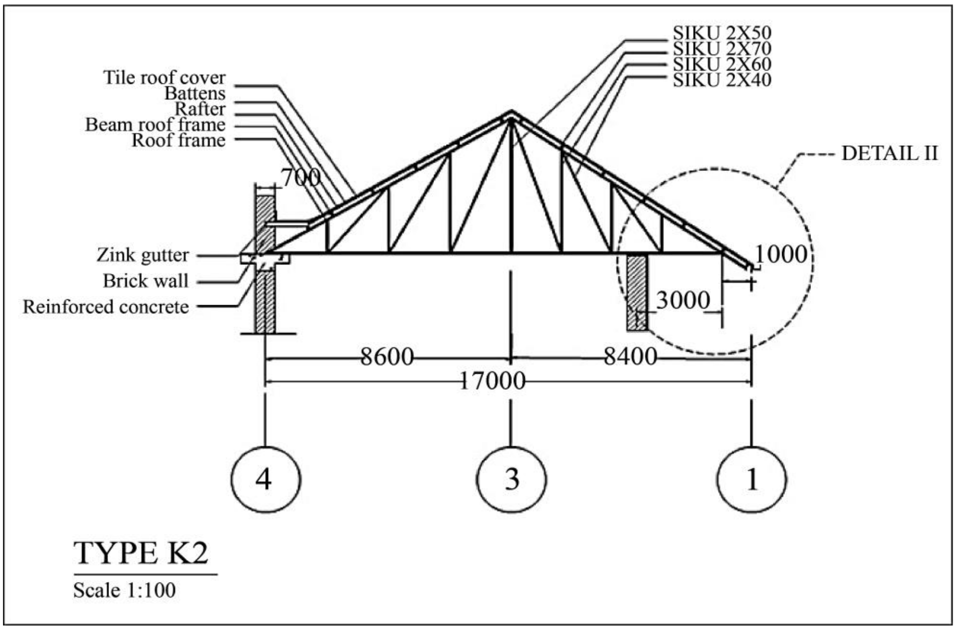


Fig. 18 Truss K2

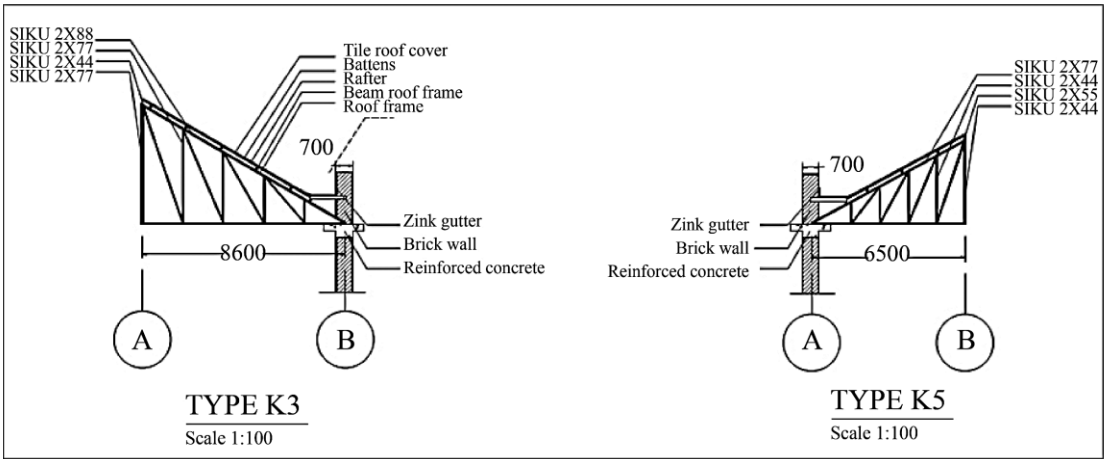


Fig. 19 Truss K3 and K5

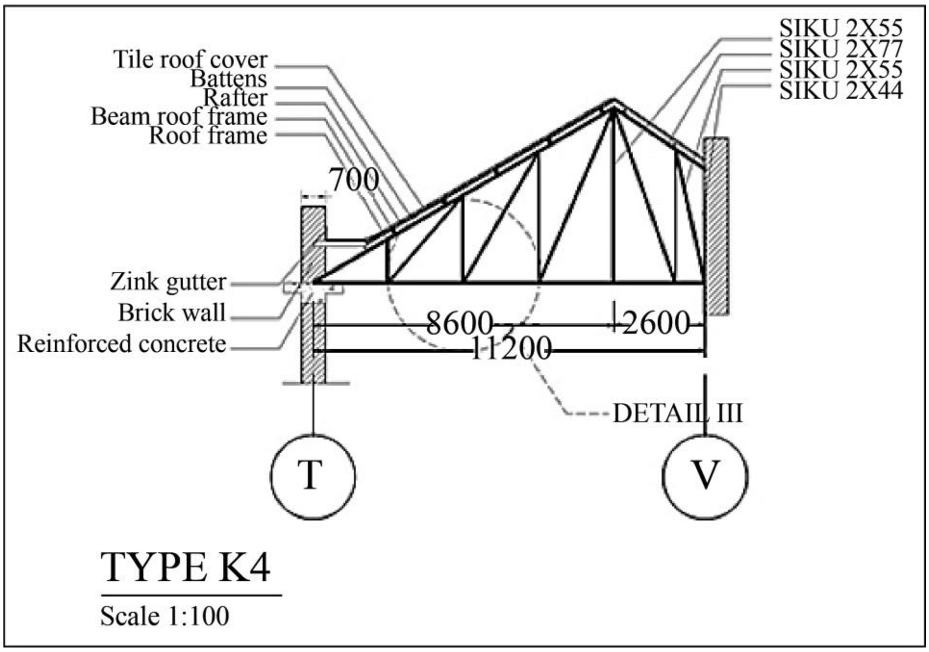


Fig. 20 Truss K4

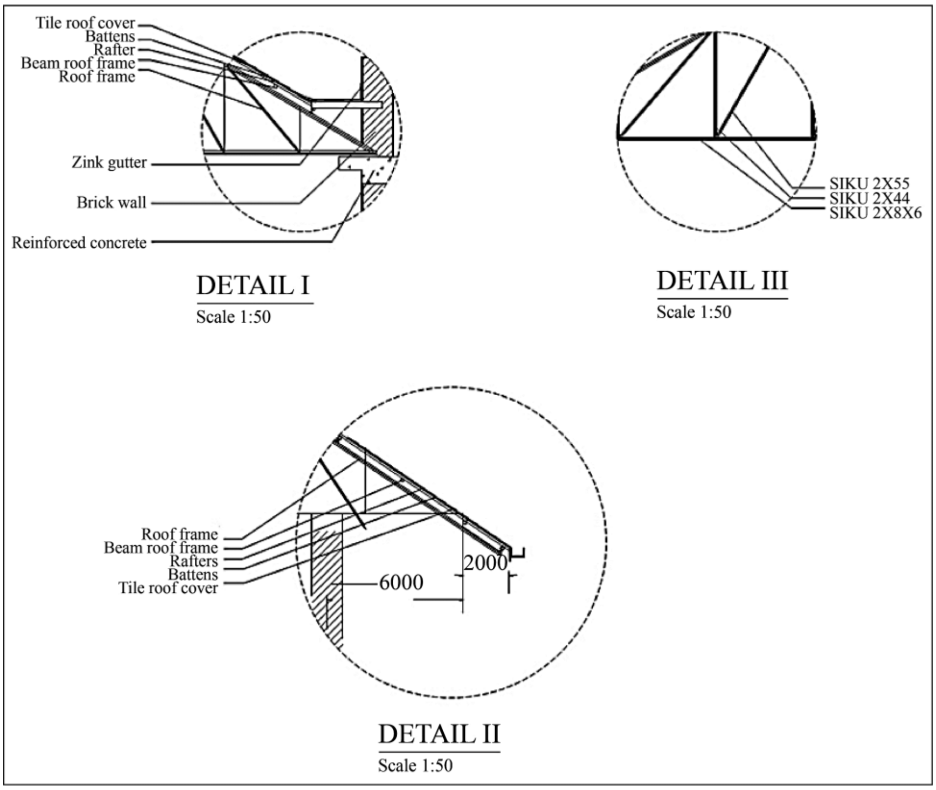
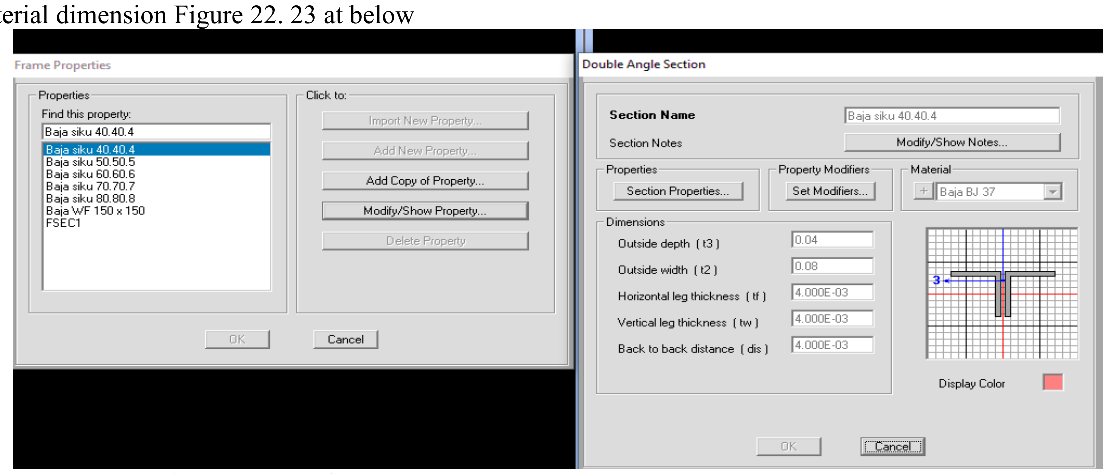


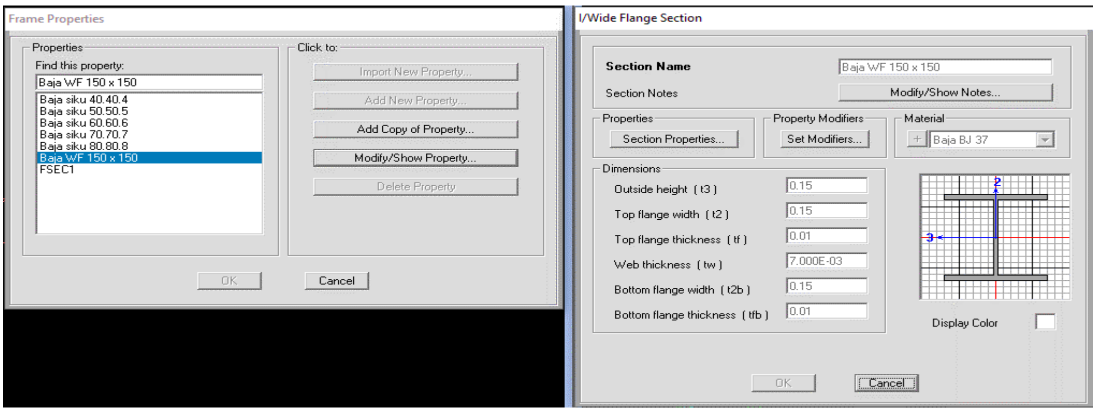
Fig. 21 Detail I, II, III

Input material dimension Figure 22. 23 at below



Sources Researcher Team: Input of SAP2000 Program

Fig. 22 Dimension of steel material double elbow



Sources Researcher Team: Input of SAP2000 Program

Fig. 23 Dimension of steel material IWF

Figure modeling the geometry can be seen in Figure 24 below.

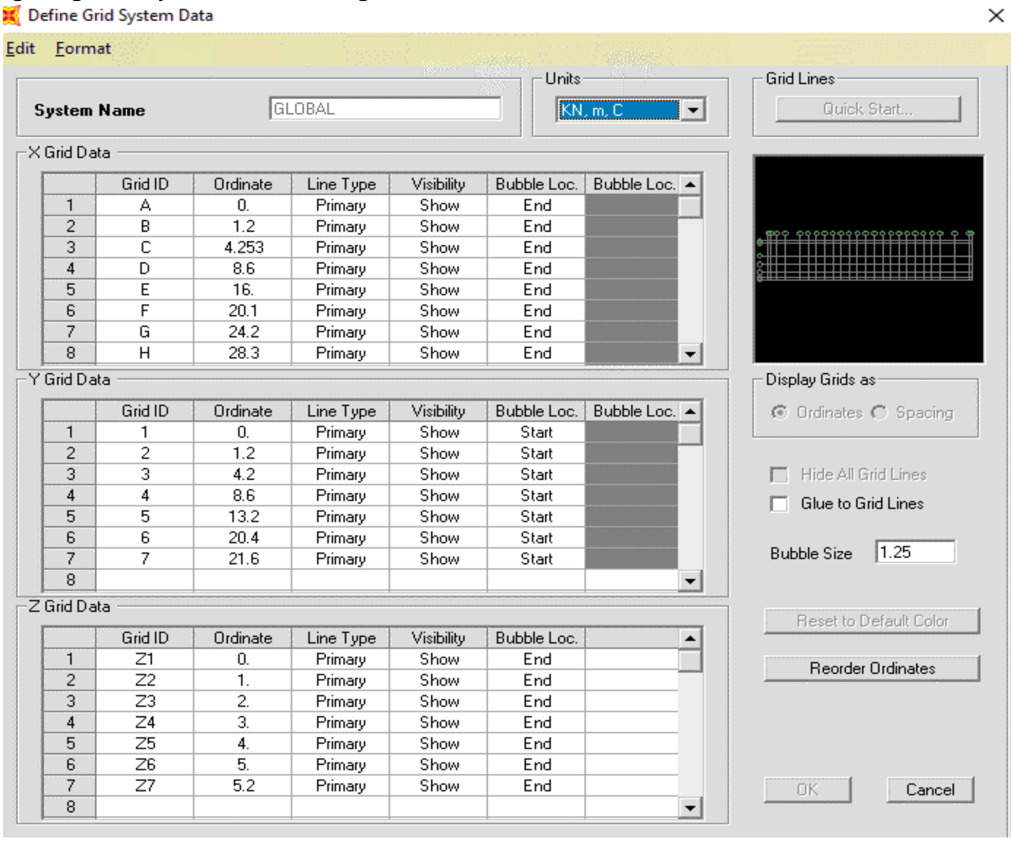


Fig. 24 Input of grid frame roof structure sources researcher team: Input of SAP2000 program

The tensile strength of the member is compared to its value between the tensile strength based on the cross-section and the net section; the smaller value will determine the tensile strength. Gross cross-sectional tensile strength (Pnb): tb. Pnt1 = 406.08 kN.

Net cross-sectional tensile strength (Pnn)
ϕtn Pnt2 = ϕt Ae. (2)
Fu = 451,77 kN Pnt = 451,77 kN

For other profiles, the output diagram meets the requirements according to Figures 25, 26, and 27 below.

- Double elbow steel profile 60.60.6 member no 560 Span L- 5.50364 P max elbow 60.60.6 member no 426-output software = 41,89 kN, yes it safe.

Figure 25 Axial force. Double elbow steel profile 60.60.6 L 5.44256 KN TENSION

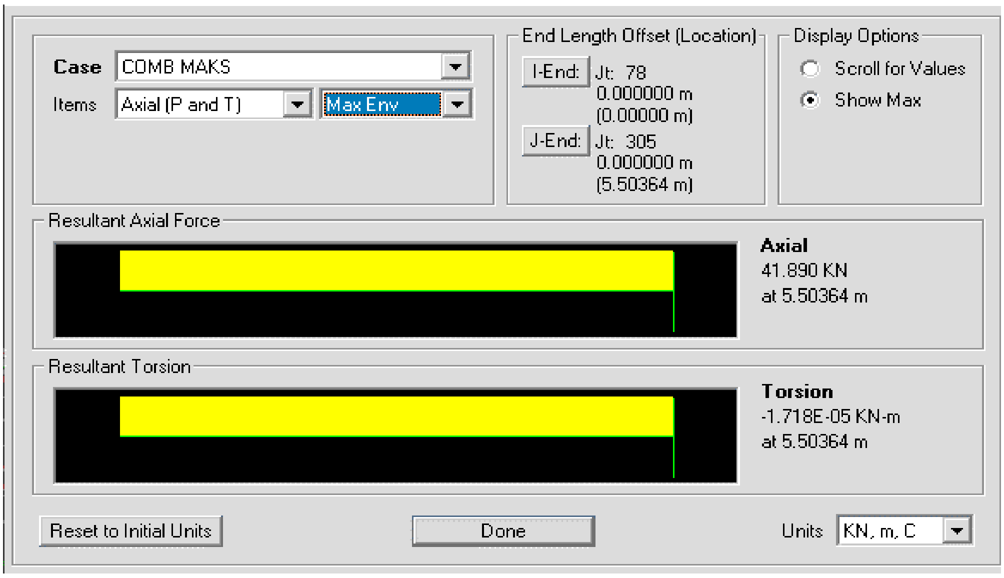
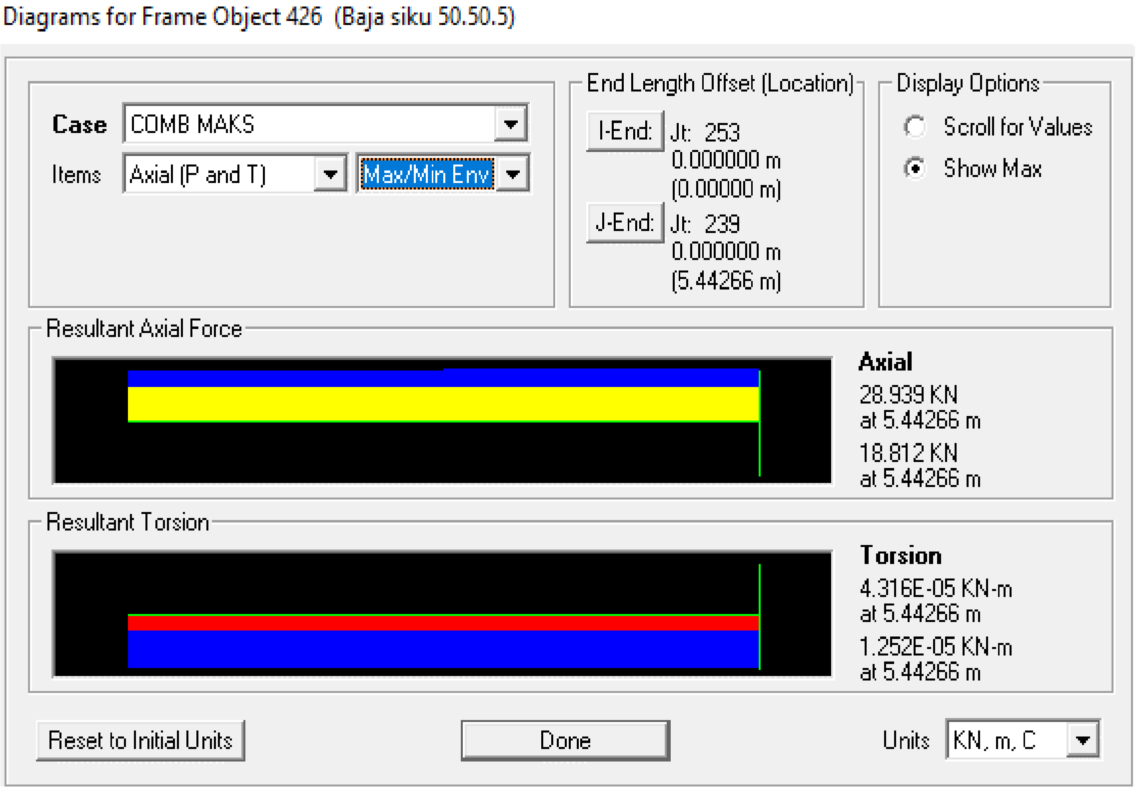


Fig. 25 Axial force. Double elbow steel profile 60.60.6 L 5.44256 KN tension

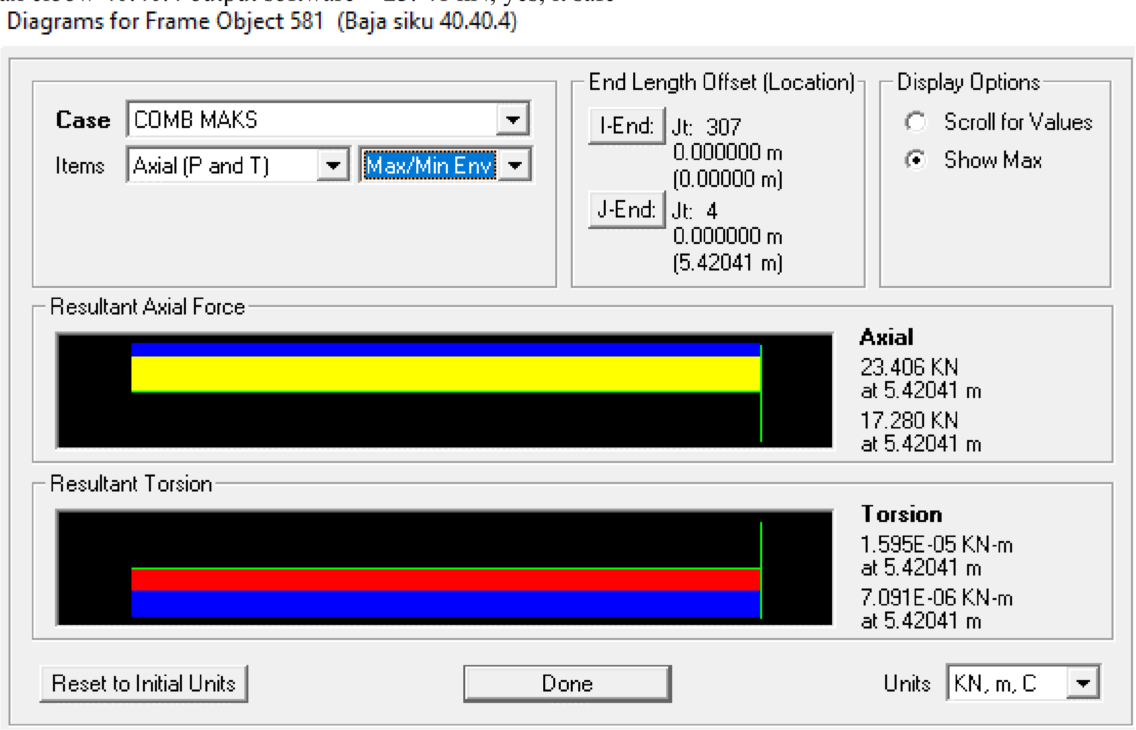
- Double elbow steel profile 50.50.5 Span L=5.44256
  P max elbow steel profile 50.50.5 member no 426-output software = 28.93 kN, yes it safe



Source : Author: output software SAP2000

Fig. 26 Axial force. Double elbow steel profile 50.50.5 Span L=5.44256

- Double elbow steel profile 40.40.4 span L=5.42041 tension
  Double elbow 40.40.4 Member no 581 biggest force
  P max elbow 40.40.4 output software = 23. 41 kN, yes, it safe



Source: Author: output structure software SAP2000

Fig. 27 Axial force. Double elbow steel profile 40.40.4

In the design of compression elements, the strength will be taken into account in the following conditions:

A. Two compression members, 127.95 kN and 121.39 kN, in members 284 and 59 must be replaced. 2L profile 80.80.8 : Compression member 59 lengths 13.14990 m supported by another member so that the span length is 2.452 M and the slenderness value is small.

Fcrx=192,42 Mpa Fcry=189,85 Mpa

Slenderness value 2L 80.80.8 (127.95 KN)

Table B4.1a of SNI 1729-2015.
The slenderness of the rods: = 10 < r, then it is a non-slender element
Element slenderness : = b/t = 10
Slimness limit: r = 0.45. E/Fy = 12.98
because < r it is a member, a non-slender

The compressive strength of the member is compared to its value between the strength based on the view of flexural buckling and flexural torsional buckling, and the smaller value will be determined as the compressive strength.

Maximum compressive stress
Overview of flexural buckling: Fcr1 = 142.82 Mpa
Overview of torsional buckling and flexural torsional buckling: Fcr2 = 193.32 Mpa
Stress used Fcr = 142.82 Mpa
Compressive reduction factor c = 0.90

member compressive strength:
ϕc . Pnc = ϕc .(3)
Fcr . Ag = 316,203 N. Ratio of strength to compression force Pu/ϕPnc = 0,40 < 1,0

B. Overview of flexural buckling, Article E.3 SNI 1729 2015)
Connecting plate thickness: tp = 8 mm

Effective length factor (Appendix no. 7.2.3.a SNI 1729-2015) K = 1.0

Limit ratio : (KL/r). max = 135.96

Slenderness Ratio $(\frac{\boldsymbol{KL}}{\boldsymbol{rxg}})$ =. max = $4{,}71.\sqrt{\frac{\boldsymbol{E}}{\boldsymbol{fy}}}$ (4)

C. Torsional buckling dan Flexural-Torsional Buckling, clause E.4 1729 2015)

Plastic buckling critical stress: Fex = $\frac{\pi^2 \ . \ E}{(\frac{KL}{rxg})^2}$ = 192,42 Mpa (5)

$\frac{fy}{fex} = \frac{240}{192{,}42}$ = 1,24 < 2,25

Critical

$$\begin{cases} 0{,}658\ .\ \frac{fy}{fex}\ .fy \rightarrow \frac{KL}{rxg} \leq 4{,}71\ .\ \sqrt{\frac{E}{fy}}\ atau\ \frac{fy}{fex} \leq 2{,}25 \\ 0{,}877\ .fex \rightarrow \frac{KL}{rxg} \leq 4{,}71\ .\ \sqrt{\frac{E}{fy}}\ atau\ \frac{fy}{fex} \leq 2{,}25 \end{cases} \quad (6)$$

→ because $\frac{KL}{rxg}$ < 4,71 $\sqrt{\frac{E}{fy}}$ and $\frac{fy}{fex}$ < 2,25 then (7)

658 $^{\frac{fy}{fex}}$) . fy 142,83 Mpa

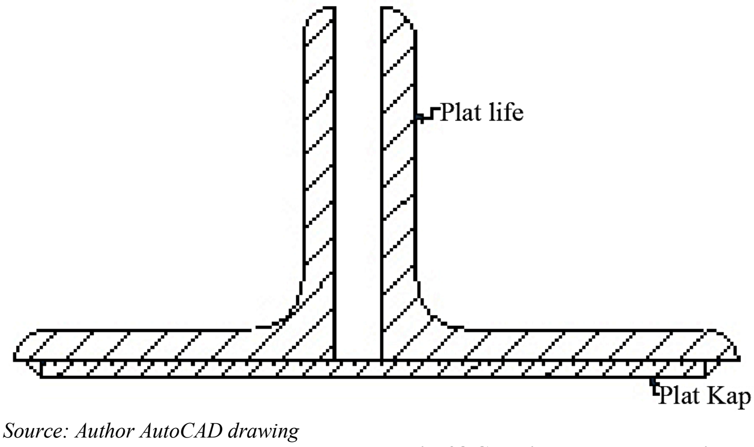
The double elbow joint profile (installed on all members) can be seen in Figure 28 below:

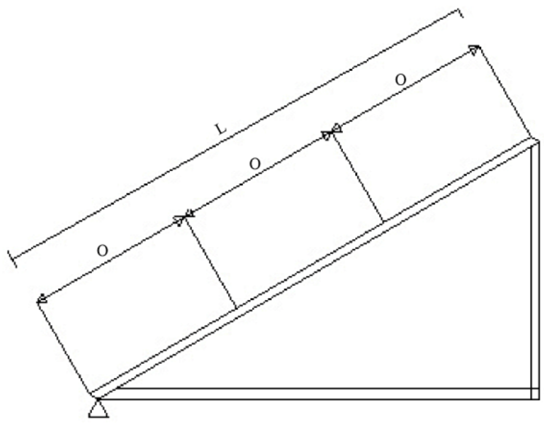
Slenderness ratio: Ki = 0,50 (Pasal E6.1b SNI 1729 2015, for back-to-back elbow profile

$$(\frac{KL}{r})o = \frac{KL}{ryg}\frac{KL}{r})m \begin{cases} \left(\frac{KL}{r}\right) o \rightarrow \frac{a}{ri} \leq 40 \\ \sqrt{(\frac{KL}{r})^2\ o + \left(\frac{Kia}{ri}\right)^2} \rightarrow \frac{a}{ri} > 40 \end{cases} \quad (8)$$

→ because $\frac{a}{ri}$ < 40 then:

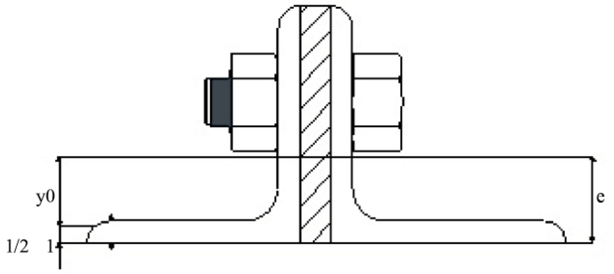
$(\frac{KL}{r})$ m =$(\frac{KL}{r})$o = 67,60 < $(\frac{KL}{r})$max





Source: Author AutoCAD drawing

Fig. 28 Coupling plate and coupling plate position pieces



Source: Author AutoCAD drawing, diameter bolt 13 mm
Fig. 29 Double elbow profile sliding center position

shear center coordinate: x0 = 0

y0 = c - $\frac{1}{2}$. t = 19 mm

The radius of polar shear center to shear center:
ro = $\sqrt{Xo^{2} + yo^{2} + (\frac{Ixg+Iyg}{Ag})}$ = 47,59 mm

Torsion (Dewobroto W, 2015)
J = $\frac{2}{3}$. (2b - t) t 3 = 51882,66 mm4

Critical Stress (clause E.4 SNI 1729-2015):

Fcry

$$\begin{cases} \left(0{,}658.\frac{fy}{feym}\right).fy \rightarrow \left(\frac{KL}{r}\right)m \leq 4{,}71.\sqrt{\frac{E}{fy}}\ atau\ \frac{fy}{feym} \\ 0{,}877.\ feym \rightarrow \left(\frac{KL}{r}\right)m > 4{,}71.\ \sqrt{\frac{E}{fy}}\ atau\ \frac{fy}{feym} \end{cases} \tag{9}$$

→ because $(\frac{KL}{r})$m < 4,71 $\sqrt{\frac{E}{fy}}$ and $\frac{fy}{feym}$ < 2,25 then:

Fcry = $(0{,}658^{\frac{fy}{fex}})$. fy = 189,85 Mpa

Fcrz = 2 . G. $\frac{J}{Ag}$. Ro² = 1434,08 Mpa

H = 1 - $\frac{xo^2+yo^2}{ro^2}$ = = 0,84

$$cr2 = \left(\frac{fcry+fcrz}{2.H}\right) x\ 1 - \sqrt{1 - \frac{4.fcry.fcrz.H}{(fcry+fcrz)^2}} \tag{10}$$

= 193,32 Mpa

Tensile
a. Overview of the tensile strength in the net cross-section and the bolt connection is reviewed

Tensile strength (Put) 110,7 kN member no 89

Profile	: 2L.70.70.7
Area (Ag)	: 1880 mm2
Member span (L)	: 2000 mm (the most)

Tensile strength profile 2L.70.70.7

Pnt1 = Ag. Fy = 451200 N → 451,2 kN
Tensile strength reducing (Pnb) :
ϕtb . Pnt1 = 406.08 kN
Connection eccentricity: x = c = 20 mm
Shear lag factor : U = 1 – ($\frac{x}{lb}$) = 0,80

Overview of tensile yield conditions in net cross sections This review bases tensile strength on net cross sections and the tensile strength of the material reviewed in the case of bolted connections (Chapter D.2.b SNI 1729-2015).

Connection eccentricity: x = c = 20 mm
Shear lag factor: U = 1 – ($\frac{x}{lb}$) = 0,80

The connection bolts reviewed in this analysis are all types that exist in the steel truss profile, while the profile member under review takes the largest axial force on each steel profile; the connection plate is 8 mm. The results of the analysis can be seen below.

The shear strength of the bolt is calculated according to the provisions of Article J3.6 of SNI 1729-2015 as follows. Strength reduction factor: s = 0.75

Bolt cross section (cross section without thread)
Ab = $\frac{\pi}{4}$. db 2 = 132,66 mm.

$$\text{Shear strength} = \phi\text{Rnv} = \phi\ \text{Fnv. Ab} \tag{11}$$

Shear strength = 45469 N→ 45,47 kN. Bolt bearing strength 2,4. ϕ . db. T. fup = 60606 N → 60,60 kN

Steel profile 2L 80.8.8
The highest number of bolts required in the profile 2L 80.8.8 J 127.95 kN 2L 80.8.8 : : (127.95)/(45.47) = 2.813943 = 3 bolts. There are a maximum of 3 installed existing ones, while the others only need 2 bolts with a diameter of 13.

Steel profile 2L 70.70.7
Several bolts are required for profile 2L 70.70.7: = 2.67 → 3 bolts Existing bolts 3 bolts for each connection. Several other bolts are required on 2L profile 70.70.7:= 1,958 → 2 bolts. The number of bolts required for the 2L profile is 70.70.7:= 1.689 → 2 bolts. BT 161 (89. 03 KN), BT 214((76.81 KN).

Steel profile 2L 60,60,6
Number of bolts required for profile 2L 60.60.6: (41.89)/(45.47) = 0.92 → 1 piece, min 2 bolts. Review member no 560 P max = 41.89 kN → SAP2000 output. Span length=5.5036m.

Number of profile bolts needed 50.50.5 rods 426 L=5.4425628.93 kN SAP2000 output: (28.93)/(43.29) = 0.66 → 1 piece, min 2 bolts

Number of profile bolts needed 40.40.4: (23.41)/(34.63) = 0.67 → 1 piece min 2 pcs, tensile bolts.

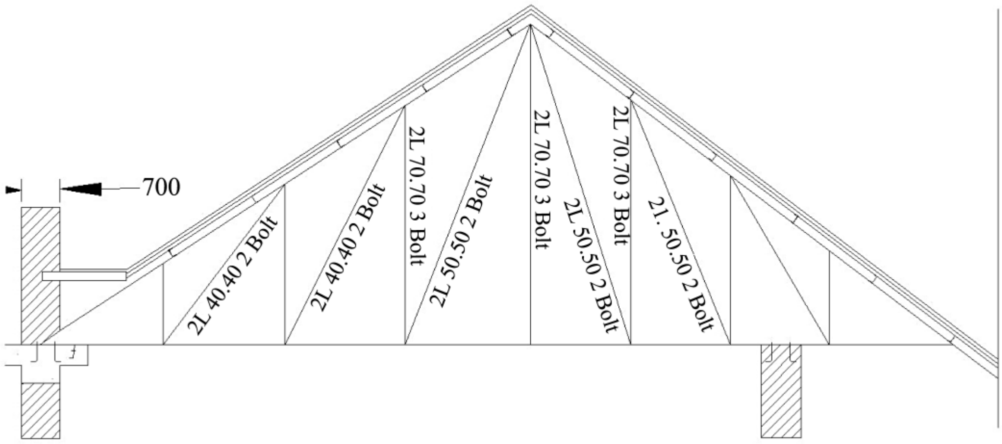
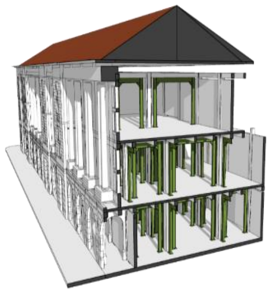


Fig. 30 Bolt requirement on profile

(a) Heritage building view,1921

(b) Heritage building roof



(c) 3D building

(d) Survey team at roof

(e) Rooftop

(f) Roof gutters

Fig. 31 Documentation survey team

4.1. Base Plate and Anchor

Some of the input data that will be used in calculating the base plate design are as follows:
Anchor diameter 19 mm.

The anchor shear strength is 84.18 kN. Anchor bearing strength is 126.5 kN. Horizontal reaction (RH) = 70.35 kN. Vertical reaction (RV) = 116.72 kN

R result in = $\sqrt{(RH)^2+(RV)^2}$ = 136.28 kN 4 anchors are used. Allowed anchor strength 84.18 KN
Number of anchor requirements: (136.28) / (84.18) = 1.61 →2 anchors
A minimum of 4 pieces of the anchor are used. Force on 1 anchor = 34.08 KN

4.2. Anchor Length

Based on the split tensile test against the compressive strength of 6.323%, the split tensile strength of the concrete = 1.58075 mpa (Pandaleke RE Wndah RS 2017.) Shear strength of the anchor is Vsa= 3 . Ab. Fnv = 84.18 kN. Anchor support strength is 2.4. .db .t.fup = 126.54 kN

Bolt cross section (cross section without thread)
Ab = /4. Db 2 = 283.39 mm2.

For a review of shear loads with ductile quality, 3 = 0.65
The length of the anchor is calculated when getting tensile force so that the anchor is not uprooted.
The vertical force is divided by the anchor blanket and the concrete stress.

$$Pa = RV/(\pi \cdot da \cdot fc\ concrete) \qquad (12)$$

= (34080/(3.14*19*12.3) = 46.42841mm plus base plate and grout thickness s2 = (3 . Pa) + tp = (3. 46.42) + 13 =152.2852 mm Anchor length used is 16 cm.

5. Conclusion

The author analyzed the calculation of the continued non-sequential construction, but it needs to be executed properly and supported by strengthening. If the retrofitting was successful, it would become a heritage building that was very useful for the younger and older generations. The roof is the crown of the building; if the roof is strong, has the same shape, and returns to a similar original, it will be seen from a distance as an icon of the building. It will be more attractive to tourists of all generations; the older generation is nostalgic, while the younger generation is to understand the history of the era when the building was built and triumphed.

Heritage buildings, especially roofs, can be used after retrofitting the entire roof structure, up to the roof details, as strengthening and complementing the function of the roof has been carried out on roof frames subjected to bending, tensile, buckling, torsion, and deflection. The deflection of the roof structure of the heritage building meets the requirements. Then, the roof frame structure meets strength, stability, and stiffness, provided that rusty steel profiles, bolts, and anchors are replaced, and the software output calculates the amount. Note that the design was based on the construction that was not sequential but alternating; if carried out sequentially, it will weaken in certain areas, which could cause it to collapse and the supporting roof installed until the ground floor. The research team had to check the bolts, make sure the anchors were in their proper position and not loose, and ensure nothing was rusted.

The research team tried the original roof, which had to be retained. Besides our manuscript, we hope to publish a simple guide for young engineers to construct heritage buildings and academies to understand the philosophy of repairing or strengthening old buildings or heritage buildings.

Author Contributions and Acknowledgments

Thank you to the team of building owners and managers who provided survey opportunities and the team of investigative consultants who provided data on 2016 the results of testing the roof structure of a heritage building. Nusa Setiani Triastuti created heritage building research and retained the choice of structural system, detailed roof, and roof material. Rico Turnando was the survey leader and the input of structure software. Indriasari rechecked the output software and rechecked the manuscript.

Conflict of Interest

The authors got a chance to do a roof survey together with handymen who usually install roofing materials on other heritage building projects; the authors felt fortunate.

Competing Interest

The research team tried to prove that the building was by the level of very severely damaged, even though it was difficult when the survey entered the building, they were worried that the material would be dropped and injure the research team, danger, especially when monitoring the roof so that the footing was with assistive devices without existing footing. Design must be careful with attention to implementation to not continue the work area but alternating (jump) sequences the work area before the overall roof structure is dismantled. The level of difficulty and danger during the survey, design, and implementation are still high heritage buildings; however, it is easier to dismantle, as the structure and roof covering are similar to the existing ones.

Highlight

The original shape of the roof remains, including the steel profile material. The research team must be careful by paying attention to the existing material to avoid falling on the survey team because the heritage building was not well maintained. At the same time, the design paid attention to construction to be retrofitted safely and retained as much as possible. The design can achieve stability, rigidity, and small deflection.

Statements and Declarations

The research team declared and fought for the 1921 building to be as original as possible, even though the level of difficulty and risk was high.

Background

Architect of the Fermont & Cuypers building: The building was built in 1921 to function as the Banking and Trade Office of the Chartered Bank of India, Australia, and China in Batavia (source Mandiri Bank). The sum of 475 to 1993. Glass Patri by J. Sabel's en Co, Holland depicts Nusantara Plantation Commodities, namely the activities of picking tobacco leaves, pounding rice, carrying sugarcane stalks, picking coffee, and tapping rubber trees.

References

[1] Timothy S. Acosta, “Risk Assessment of Low-Rise Educational Buildings with Wooden Roof Structures against Severe Wind Loadings,” *Journal of Asian Architecture and Building Engineering*, vol. 21, no. 3, pp. 973-985, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[2] Clara Bertolini Cestari, and Tanja Marzi, “Conservation of Historic Timber Roof Structures of Italian Architectural Heritage: Diagnosis, Assessment, and Intervention,” *International Journal of Architectural Heritage*, vol. 12, no. 4, pp. 632-655, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[3] “Procedures for Planning Steel Structures for Buildings,” *Standar Nasional Indonesia*, pp. 1-215, 2002. [Publisher Link]

[4] Wiryanto Dewobroto, “SNI 1729:2015 and the New Era of Computer-Based Steel Planning,” *Seminar Nasional Inovasi Struktur dan Rekayasa Bahan dalam Teknologi Konstruksi*, pp. 1-30, 2015. [Google Scholar] [Publisher Link]

[5] Ezio Giuriani, and Alessandra Marini, “Wooden Roof Box Structure for the Anti-Seismic Strengthening of Historic Buildings,” *International Journal of Architectural Heritage*, vol. 2, no. 3, pp. 226-246, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[6] Angel Candelas-Gutiérrez, and Milagrosa Borrallo-Jimenez, "Methodology of Restoration of Historical Timber Roof Frames Application to Traditional Spanish Structural Carpentry," *International Journal of Architectural Heritage*, vol. 14, no. 1, pp. 51-74, 2020. [CrossRef] [Google Scholar] [Publisher Link]
[7] Ramakrishna Hegde, G. Yogesh, and S. Suraj Chavhan, "Comparative Study on Analysis of Steel Truss Structure and Rigid Frame by Using STAAD PRO," *International Research Journal of Engineering and Technology*, vol. 5, no. 9, pp. 1308-1314, 2018. [Publisher Link]
[8] "Specifications for Structural Steel Buildings," *Standar Nasional Indonesia*, pp. 1-289, 2015. [Google Scholar] [Publisher Link]
[9] "Minimum Design Loads and Related Criteria for Buildings and Other Structures," *Standar Nasional Indonesia*, pp. 1-323, 2018. [Google Scholar] [Publisher Link]
[10] Derek L. Kozak, and Abbie B. Liel, "Reliability of Steel Roof Structures under Snow Loads," *Structural Safety*, vol. 54, pp. 46-56, 2015. [CrossRef] [Google Scholar] [Publisher Link]
[11] Paulo B. Lourenço et al., "Traditional Techniques for the Rehabilitation and Protection of Historic Earthen Structures: The Seismic Retrofitting Project," *International Journal of Architectural Heritage*, vol. 13, no. 1, pp. 15-32, 2019. [CrossRef] [Google Scholar] [Publisher Link]
[12] J. Montero et al., "Comparative Study between Rigid Frames and Truss Steel Structures," *International Commission of Agricultural Engineering*, vol. 6, pp. 1-13, 2004. [Google Scholar] [Publisher Link]
[13] Rio Mulyadi, Sucitra Wijaya, and Suwarjo Suwarjo, "Analysis of the Roof Frame Structure of Muara Bungo University Rectorate Building (Single Frame Beam Type Truss Frame)," *Jurnal Komposits*, vol. 1, no. 1, pp. 1-29, 2020. [CrossRef] [Google Scholar] [Publisher Link]
[14] Phatangare Roshani Rambhau, and M.R. Wakchaure, "A Review Paper on Alternate Design Of Roofing Sysytem," *International Journal of Engineering Sciences and Research Technology*, vol. 6, no. 2, pp. 761-765, 2017. [Google Scholar] [Publisher Link]
[15] Regulation of the Minister of Public Works and People's Housing of the Republic of Indonesia Number 19 Year 2021 Concerning Technical Guidelines for the Implementation of Cultural Heritage Building be Conserved Article 6.(1)b, Article 6.(4)c. [Online]. Available : https://peraturan.bpk.go.id/Details/216956/permen-pupr-no-19-tahun-2021
[16] Ronny E. Pandaleke, and Reky S. Windah, "Comparison of Direct Tensile Test and Concrete Split Tensile Test," *Jurnal Sipil Statik*, vol. 5, no. 10, pp. 657-662, 2017. [Google Scholar] [Publisher Link]
[17] Charles G. Salmon, and John E. Johnson, *Steel Structures: Design and Behavior, Second ed*., Penerbit Erlangga, Jakarta, vol. 1, 2, 1986. [Google Scholar] [Publisher Link]
[18] Afti Suhajri, and Sri Hartati Dewi, "Evaluation of Steel Truss Structure Planning for the Sultan Syarif Kasim II Pekanbaru Airport Cargo Building," *Jurnal Saintis*, vol. 16, no. 1, pp. 76-93, 2016. [Google Scholar] [Publisher Link]
[19] Romain Wibaut, Ine Wouters, and Thomas Coomans, "Hidden Above Church Vaults: The Design Evolution of Early Iron Roof Trusses in Mid-Nineteenth-Century Belgium," vol. 13, no. 7, pp. 963-978, 2019. [CrossRef] [Google Scholar] [Publisher Link]
[20] Yang Xiang et al., "Vertical Ductility Demand and Residual Displacement of Roof-Type Steel Structures Subjected to Vertical Earthquake Ground Motions," *Soil Dynamics and Earthquake Engineering*, vol. 104, pp. 259-275, 2018. [CrossRef] [Google Scholar] [Publisher Link]
[21] Linjia Bai, and Yunfeng Zhang, "Nonlinear Dynamic Behavior of Steel Framed Roof Structure with Self-Centering Members under Extreme Transient Wind Load," *Engineering Structures*, vol. 49, pp. 819-830, 2013. [CrossRef] [Google Scholar] [Publisher Link]