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Steel Structure Analysis of Workshop Facility in PT Pamapersada Nusantara

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ABSTRACT

Structural planning in every building construction, aims to take into account the ability to withstand the loads that occur. The structural elements must be designed and calculated based on the appropriate combination of standard loads. Workshop facility project at PT. Pamapersada Nusantara uses a steel structure with steel profiles for columns and beams. The function of the steel profile as a cross section of the structure is very important, for that it is necessary to analyse and design the right steel profile for the structural elements of steel columns and beams at the Workshop Facility Project of PT. Pamapersada Nusantara. The method used in this research is based on a case study on the object of research in the project. This building structure planning was analysed using a computer-based structural calculation program, namely the SAP2000 v.22 program, referring to SNI 1729-2020 concerning Procedures for Planning Steel Structures for Buildings and SNI 1726:2019 Procedures for Planning Earthquake Resistance for Building Structures and Non-Building and SNI 1727:2020 Minimum Load for Design of Buildings and Other Structures and Indonesian Loading Regulations for Buildings (PPIUG 2019). The result of structure analysis using SAP2000 V.22, indicates that there are no failed frames/structures with structural susceptibility > 1.0 (red) meaning that they are unable to carry the load that will occur. Meanwhile, frames/structures < 1.0 (grey, blue, green, yellow, orange) mean that they are capable of bear the brunt of what is to come.

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1. INTRODUCTION

The construction of buildings is growing in line with the modern era growth nowadays. The development of building construction such as multi-story buildings as one of the best alternatives in meeting the increasing space needs [1]. Furthermore, the need of office building and workshop for mining companies in handling maintenance of heavy equipment in supporting mining activities is very important. Facilities and infrastructure in the form of buildings are very closely related in the field of structural planning [2]. Structural planning allows construction of a two-story workshop facility and office at PT. Pamapersada Nusantara can meet the needs optimally and have the maximum ability to withstand various kinds of overall loads that can be generated from the function of the building.

Structural planning in building construction aims to measure a building ability in bearing occurred loads. Columns, beams, floor plates themselves are structural elements that are very important in building construction. Thus, the structural elements must be designed and calculated based on the appropriate standard load combination [3]. Therefore, it is necessary to analyze the structure in the construction of workshop facilities at PT. Pamapersada Nusantara. By increasing the coal production targets at Job Site Asmi of PT Pamapersada Nusantara and the demand to prepare a heavy equipment unit that is ready to be used, the orientation of providing workshop/maintenance facilities to support those operations are become crucial.

The resistance of the building structure to planned static loads and or the resistance of the structure to potential disasters such as earthquakes or other working loads is the most important aspect. Thus, proper planning and calculations are needed to find out the resistance of the building structure. The proper and accurate structure analysis is very important to achieve the criteria of strength, safety, serviceability, and durability of the building plan. Workshop facility project at PT. Pamapersada Nusantara uses a steel structure with steel profiles for columns and beams. The function of the steel profile as a cross section of the structure is very important, so it is necessary to analyze using the SAP2000 v.14 application and to design the appropriate steel profile for steel column and beams structural elements at the workshop facility of PT. Pamapersada Nusantara.

1.1. Steel Material

Currently, steel is a very popular material [4]. Steel is an alloy of ferrous metal as a basic element with several elements. Steel material has advantages such as its ductility [4], compared to other materials, namely wood that is easily weathered, stone that requires large volumes, or concrete that is less resistant to tensile forces and too brittle to bend [3]. Steel is often used both as columns and beams of buildings, bridges, towers, roof trusses, and various other civil constructions. The advantages of steel materials among others high strength, ease of installation, uniformity, ductility, etc. Type of steel used in this study is BJ-37 steel. Based on SNI1729-2020 [5] concerning Procedures for Planning Steel Structures for Buildings, steel has mechanical properties that can be used as a planning reference and must meet the minimum requirements given in the table below:

Table 1.1. Mechanical Properties of Structural Steel

Steel Type	**Breaking Voltage Minimum, Fu (MPa)**	**Melting Stress Minimum, Fy (MPa)**	**Minimum Stretch (%)**
BJ 34	340	210	22
BJ 37	370	240	20
BJ 41	410	250	18
BJ 50	500	290	16
BJ 55	550	410	13

Source: SNI 1729-2020

1.2. Columns and Beams

The column is an upright compression rod that works to hold the beam, roof truss and loads above it which is then channelled to the foundation [3]. Straight rods that are stressed due to the action of axial forces are known as columns. The strength of the short column is determined based on the yield strength of the column material. Meanwhile, the strength of the long column is determined from the elastic buckling factor that occurs. Furthermore, the strength of the medium-sized column is determined by the plastic buckling factor that occurs. Therefore, a good or a perfect column is a column made of isotropic material, free from side stresses, loaded at the centre and has a straight shape, will shorten due to compressive strain in its cross section. If the load on the column is gradually increased in size, it can trigger the column to experience lateral flexion, resulting in collapse. The load that triggers the lateral bending of the column is referred to as the critical load and is the maximum load that the column can safely withstand [6].

Beams are structural elements that are used as floor stands and upper floor column binders that function as horizontal reinforcing frames of the building against loads [3]. In this study, the floor plate beam serves as a holder that will be used for the ground floor, then for the steel beam it functions as a horizontal reinforming of the building from the load transmitted from the column, frame, and roof itself. In analysing the strength of the beam, it is necessary to pay attention to two elements, namely checking the effect of working moments on the beam and examining the effects of shear forces (latitude forces).

1.3. Bolted Joints and Welded Joints

Steel structures are composed of elements that are combined with one another using a connection system. Bolted joints and welded joints in this study are used to connect among steel elements. According to Saputra et al [4], the design of steel structure connections using bolt type moment has to concern to the strength of the bolts among others, bolt carry tensile forces, strong focus, determine the number of bolts, the force of the latitudes carried together by the bolts, the normal force shared by the bolt, and tensile force due to moment. One of the fasteners that can be used to unite the components of the rod in any steel structure is a high-quality bolt. Bolt connection is one of the fasteners besides welding which is quite popular by using high quality bolts. In the installation of high-strength bolts, sufficient initial tensile force is required which is obtained from the initial tightening [1]. Installation of high-strength bolts requires sufficient initial tensile strength which can be obtained from the initial tightening. The initial tensile force provides friction so that it is strong enough to carry the working load.

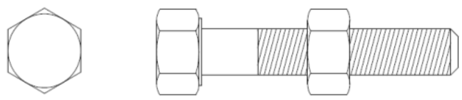

Figure 1.1 Bolt Joint
Source: Senggasi, 2016

According to Oemar [1], welded joint is a process of combining metal materials by heating to a certain temperature in order to melts those materials into one material. There are four types of welded joint namely, groove, fillet, slot, and plug. Each type of welded joint has its own advantages that can determine the range of use. In general, those type of welded joints have the following weld construction percentage: groove welding (blunt welding) 15%, fillet (angle welding) 80%, and the rest is divided for slot and plug welding.

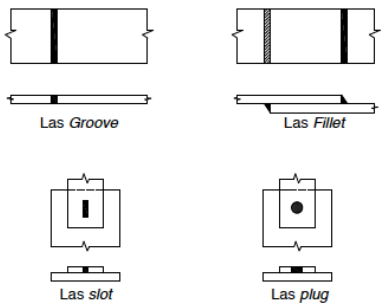

Figure 1.2 Bolt Joint
Source: Oemar, 2010

1.4. Structural Planning

Structural planning defined as a combination of science, art, with a structural expert's intuition about structural behaviour and basic knowledge in statics, dynamics, mechanics of materials, and structural analysis in order to obtain a safe and economical structure during its service life. The building structure consists of upper building structure planning or upper structure, and lower building structure planning or substructure. The upper structure is a building structure which position is above the ground level, while the substructure is a building structure which positions is below the ground surface. Structural planning has purpose based on the Procedures for Steel Structures Planning for Building (SNI 1729-2020) which is to obtain a structure that is stable, strong, enough, serviceable, durable, and fulfils other objectives such as tilted over, or displaced during the building design life. Another objective is to minimize the risk of structural failure and the risk of serviceability failure during the design life to an acceptable limit. Structural planning is a process to obtain optimal structural results in order to generate durable structure and minimize maintenance costs during its service life. The optimum structure must meet the following criteria:

a. Minimum cost
b. Minimum weight
c. Minimum construction time
d. Minimum workforce
e. Minimum manufacturing cost
f. Maximum benefits during the service period

1.5. Structural Loads

The external forces working on the structure are called loads. The load working on the structure cannot be certainty calculate and can only be estimated, but it is still carried out with assumptions and approaches [3]. The number of structural loads can refer to the SNI 1729-2020 with the following load categories:

a. Dead loads
   Dead loads are the weight of all parts of the building or building with fixed properties during the service life of the structure. However, it also includes additional elements, finishing, machines, and fixed equipment which are an integral part of the building. For example, structural loads, pipes, power lines, air conditioners, lights, ceilings, and floor coverings.
b. Live loads
   Gravity loads working on the structure in its service life and arising from the use of a building. Example of live loads are human weight, movable furniture, vehicles, etc. Determining the live load is difficult to be certain since the weight of the live load is always changing.
c. Wind loads
   Loads working on the structure due to pressure from wind movement. The wind loads depend on the location and height of the structure. The minimum wind pressure that must be taken is 25kg/m^2.
d. Earthquake loads
   All equivalent static loads working on the structure due to ground movement by an earthquake, both vertical and horizontal ground movements. In general, the effect of horizontal earthquakes is more decisive than vertical earthquakes because the horizontal direction of land is greater than the vertical direction. The magnitude of the basic shear strength (static equivalent) is determined by the equation $V = \frac{C\,x\,I}{R}\,Wt$, where C is an earthquake response factor that depends on the location of the building and the type of soil; I is a building priority factor; R is an earthquake reduction factor that depends on the type of structure concerned; and Wt is the total weight of the building including live load.

2. METHOD

This research used case study method, which was done in this case is review and plan back the condition of the building that has been or is being worked on to become the object of research. The redesign of this structure uses the sap 2000 v.14 application. Furthermore, steel structure calculation analysis refers to SNI 1729-2020. This study was conducted at Workshop facility project in Barunang City, Kapuas Regency, Central Kalimantan. The structure of the building steel profile uses 1 floor for workshop building, and 2 floor for office building. Kalimantan is an area that has relatively low seismic activity, but seismic calculations are still reviewed referring to SNI 1726:2019. Data needed as a reference material to facilitate the process of planning and compiling the research. Data used in this study namely primary data and secondary data. The primary data obtained from field observations in the form of project technical data including soil data, planning location maps, project drawings, and material quality. Primary data can be used as a basis for planning of this research. Then secondary data used in this research obtained from literature sources such as books, papers, journals, and previous research which can be reprocessed. The secondary data used in this study are in the form of regulations, graphs and tables which are needed as a basis for research planning. The data needed in this study are:

a. General description of the building which include the function of the building and its location. The function of the building is to plan the loading and the location of the building is to determine the characteristics of the soil and the risk of earthquakes.

Table 2.1 Structure Specification

Project Name	Workshop Facility
Project Owner	PT. Pamapersada Nusantara
Function of Building	Workshop
Location	ASMI – Kalimantan Tengah
Number of Floor	2 Floors
Material's Quality	Steel BJ 37
Upper Structure Materials	
Beam, Plate	Concrete K.250
Column	Concrete K.250 dan Steel ST.37
Ground Floor Plate	Slab on Ground
Substructure Materials	
Pile	Pile 25 x 25 cm
Pile Bearing Capacity	40 tf
Pole Length	To hard ground
Quality of Concrete Piles	Minimum K.450
Non-Structural Materials	
Wall	Half Brick Wall

Source: PT Pamapersada Nusantara, 2022

b. Picture of floor plans and views which include roof structure plans, portal structures for planning calculations

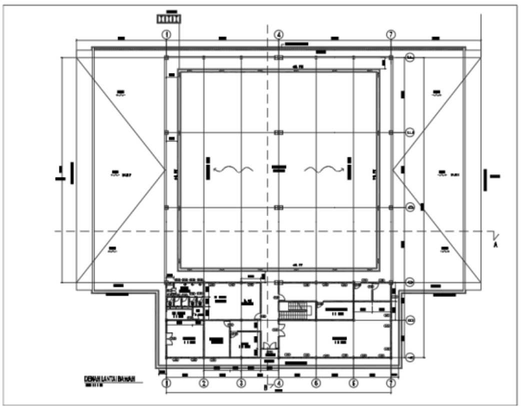

Figure 2.1 Blueprint of Workshop Facility PT. Pamapersada Nusantara
Source: PT. Pamapersada Nusantara

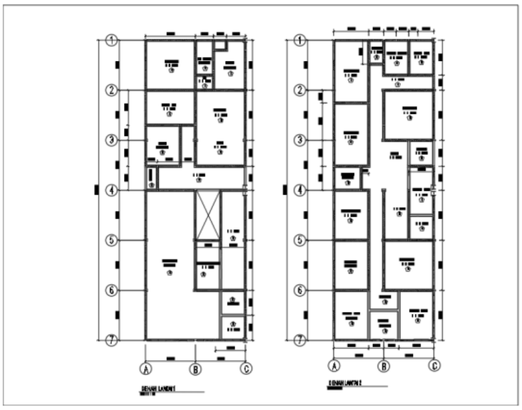

Figure 2.2 Blueprint of Office 2 Floors
Source: PT. Pamapersada Nusantara, 2022

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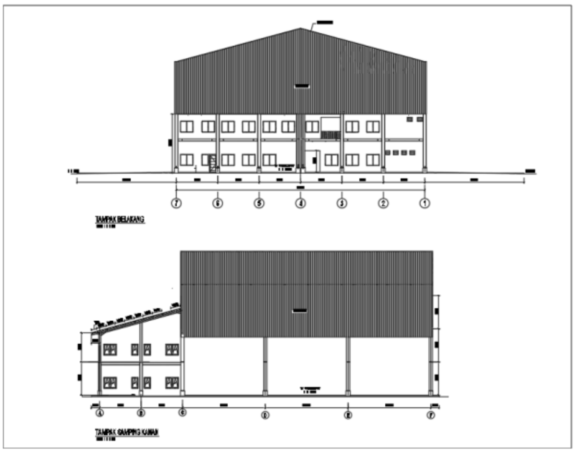

Figure 2.3 View of Workshop Facility
Source: PT. Pamapersada Nusantara, 2022

c. Quality of the materials to be used as well as the dimensions of the planned structure, such as concrete (fc) and steel (fy)
d. Regulations used in structural planning among others:
   1) Minimum design load and related criteria for buildings and other structures (SNI 1727-2020)
   2) Procedures for planning steel structures for buildings (SNI 1729 – 2020)
   3) Procedures for planning earthquake resistance for buildings (SNI 1726 – 2020)

This study used structural analysis as an evaluation of the building that is used as the object of the case study. Using SAP 2000 V.22 program and the calculation of the steel structure using LRFD method with the following stages:

a. Collecting building data and literature studies, such as shop drawings, structural plans, geometry, structural modelling and loads to be used.
b. Calculating the occurred dead load and live load
c. Calculating earthquake load parameters. These parameters will be used to calculate the force distributed by the earthquake load on the building structure.
d. Modelling a 3-dimensional structure in accordance with the shop drawings of the building used as the object of this research by using SAP 2000 V.22 including specification detail and material type contained.
e. Comparing the results of the SAP2000 V.22 calculation with manual calculations on the under review column.
f. Drawing conclusions based on the result of data analysis and discussion in accordance with the objectives of the research conducted.

3. RESULTS AND DISCUSSION

Analysis of steel structure in this building was carried out using 3-dimensional structural modelling with SAP 2PPP V22 software. Columns and beams structure of the building are modelled as frame elements. For the analysis of earthquake loads, the building structure is modelled as a shear building structure. After the structure was designed, it was checked against the working loads whether they meet the requirements or not. If the structure doesn't meet the requirement for resistance to the working loads, the structure will be redesigned with a stronger and more economical cross-section. From the structural analysis, the result of the cross section of the building structure are strong and in accordance with the sorking forces. Moreover, it was designed the connection to the profile of the steel structural elements. If the structure designed is in accordance with the planning concept, then the designed structure is ready to be built by carrying out the correct method.

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3.1 Structural Loading

a. Dead load

The self-weight of the structural elements consists of the weight of the columns, beams, and roofs. The weight of structural elements will be calculated and analysed automatically through the SAP200 V.22 software.

Roof load calculation:
Portal distance (a) = 5 m
Gording distance (b) = 1.37 m
Area (axb) = 6.85 m
Burden roof (d) = 0.05 Kn/m2
Person load (Lr) = 1 Kn/m2

Results load on curtains:
Roof dxc/a = 0.0685 Kn/m
Person load (L) = 1 Kn/m2
R fxc/a = 0.2685 Kn/m

b. Earthquake load

Structural analysis of earthquake loads refers to SNI 1726-2019 Procedures for Planning Earthquake Resistance for Building an Non-Building Structures. Structural analysis of earthquake loads on buildngs is carried out using the Static Analysis Method.

1) Location of the building = ASMI Kalimantan Tengah
2) Site Class = SC (Hard)

Qp = C X N X Ap (Meyerhof 1976)
Qp = Pile end bearing capacity = 40t
N = Standard penetration value
Ap = Piler base value = 0,14m2
C = Soil coefficient = 6,7 ton/m2 (uji Lab)

N = QP / C x Ap = 42,64

Table 3.1 Site Classification

Site Class	V_s (m/second)	N or N_{ch}	S_u (kPa)
SA (hard rock)	>1500	N/A	N/A
SB (rock)	750 to1500	N/A	N/A
SC (hard soil, very dense, and soft rock)	350 to 750	>50	≥100
SD (medium soil)	175 to 350	15 to 50	50 to 100
SE (soft soil)	<175	<15	<50
	Or any soil profile containing more than 3 m of soil with the following characteristics: 1. Plasticity index, PI > 20 2. Water levels, w ≥ 40% 3. Shear strength is not strong S_u < 25 kPa		
SF (special soil, which require specific geotechnical investigations and site-specific response analysis following 0)	Any subsoil profile that has one or more of the following characteristics: - Prone and potentially fail or collapse due to earthquake loads such as easy liquefaction, very sensitive clay, weak cemented soil - Highly organic clay and/or peat (H thickness > 3 m)		

Source: SNI 1726-2019

3) Type of building = workshop
4) Risk category = II (two) table 3 SNI 1729-2019
5) Priority factor = I (one) table 4 SNI 1729-2019
6) Ss (g) = 0,0899 Web rsa ciptakarya
7) S1 (g) = 0,0486 Web rsa ciptakarya

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8) TL	= 12 second (picture 20 SNI 1729-2019)
9) Site Coefficient Fa	= 1,2 SAP 2000
10) Site Coefficient Fv	= 1,7 SAP 2000
11) SMS (Ss x Fa)	= 0,107
12) SM1 (S1 x Fv)	= 0,0826
13) SDS	= 0,0719 Web rsa ciptakarya
14) SD1	= 0,0551 Web rsa ciptakarya
15) R (Earthquake reduction factor)	= 8 table 12 SNI 1729-2019
16) More powerful factor	= 3 table 12 SNI 1729-2019
17) Deflectin magnification factor	= 5,5 table 12 SNI 1729-2019

c. Wind load

The wind load used in the SPGAU (Main Wind Force Resistant System) design for enclosed or partially enclosed buildings should not be less than 16 lb/ft2 (0,77 kN/M2) multiplied by the building wall area and 8 lb/ft2 (0,38 kN/m2) multiplied by the roof area of the building projected onto a vertical plane perpendicular to the wind direction which is assumed to refer to SNI 1727-2020.

Minimum wind load = 0,77 Kn/m2
= 78,52 Kg/m2

1. Average wind speed = 2,572 m/s
   = 5,753 mph
   Conversion from 5 knots (BMKG wind map for Central Kalimantan)

2. Speed of wind = $\sqrt{(\text{wind load x 16})}$
   = 35,444 m/s
   = 79,285
   (minimum standard of SNI 1727-20200
3. Kd = 0,85 table 26.6-1 SNI 1727-2020
4. Exposure Category = B article 26.7.3 Exposure Category SNI 1727-2020

d. Loading Combination

1 1,4 D
2 1,2 D + 1,6 L + 0,5 R
3 1,2 D + 1,6 R + 0,5 W
4 1,2 D + 1,0 W + 1 L + 0,5 R
5 1,2 D + 1 E + 1 L
6 0,9 D + 1 W
7 0,9 D + 1 E

3.2 Cross-sectional Analysis of Steel Structures

The design dimensions of this steel column use steel profile:

- K1 = HB 400X400
- K2 = WF 350X175
- K3/K4 = WF 300X150
- Regel = WF 250x125
- Rafter = WF 300x150
- BO = WF 300x150
- RO = WF 248x124
- CNP = 150x50
- Wind bond = iron with diameter 16

The cross section of the structure is designed according to the existing load and the working forces. Then, after completion of the profile modelling on the structure it is runned using SAP2000 V.22 program and checked for the strength of the steel structure.

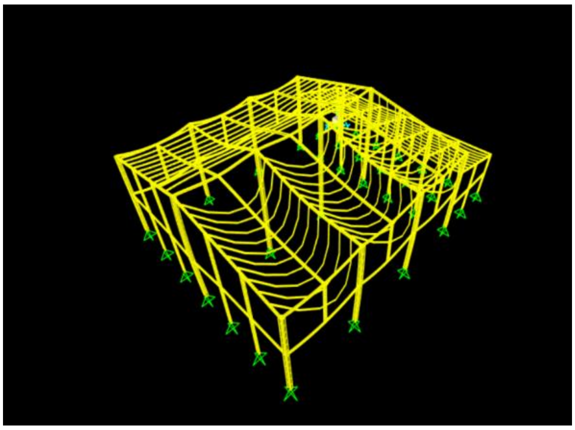

Figure 3.1 Structure Deformed due to Dead Load
Source: Designed for this Research, 2022

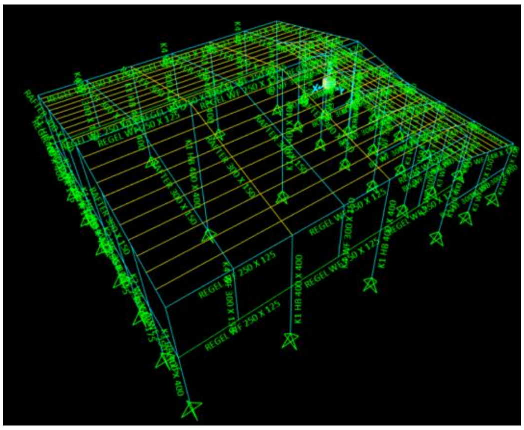

Figure 3.2 Checking 3-Dimensional Structure
Source: Designed for this Research, 2022

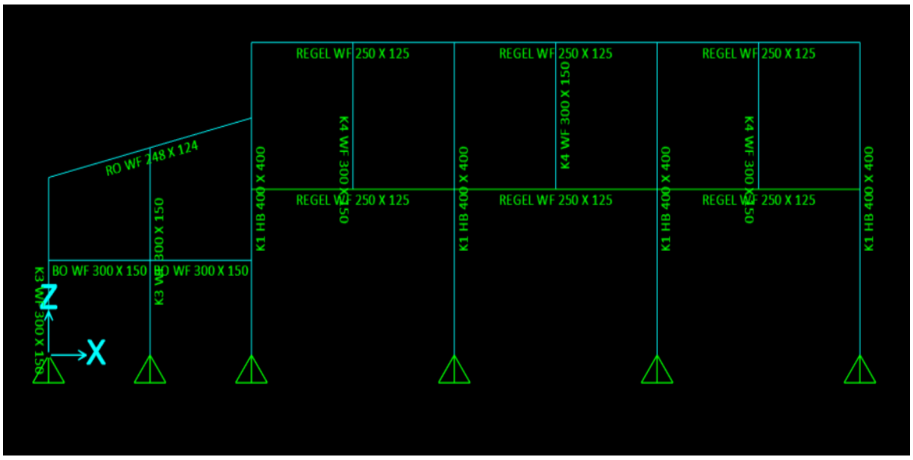

Figure 3.3 Portal Steel Structure Check
Source: Designed for this Research, 2022

3.3 Result of Steel Structure Analysis

From the result of running the steel structures analysis using SAP2000 V.22 software, all cross sections are safe which can be seen from the figure of portal steel structure check which there was no red colour and the result of the Verify Analysis VS Design Section on the SAP2000 V.22 software showed that nothing was failed.

4. CONCLUSION

According to the result of structure analysis using SAP2000 V.22, there were no failed frames in workshop facility structure making. Below are the summary of the structure types and materials used:

Table 4.1 Structure Types and Materials

Structure Types	Material	Status
K1	HB 400X400	OK
K2	WF 350X175	OK
K3/K4	WF 300X150	OK
Regel	WF 250x125	OK
Rafter	WF 300x150	OK
BO	WF 300x150	OK
RO	WF 248x124	OK
CNP	150x50	OK
Wind Ties	Steel dia 16	OK

Source: Designed for this Research, 2022

In addition, it is also necessary to consider the deflection and slenderness of the structural material. Where, for the Rafter deflection of 29.35 mm ≤ 31 mm (permitted deflection) and the column slenderness of 7 m (L) ≥ (Lr) 5.74 m. The result of structure analysis using SAP2000 V.22, indicates that there are no failed frames/structures with structural susceptibility > 1.0 (red) meaning that they are unable to carry the load that will occur. Meanwhile, frames/structures < 1.0 (grey, blue, green, yellow, orange) mean that they are capable of bear the brunt of what is to come. Furthermore, the recommendation to other research among others, structural analysis using SAP2000 program is better use the original program and must be done by expert who understand the function and how to use the program correctly so there are no errors in analyzing the structure that can trigger the structure failure. It is better if the program calculation also equipped with manual control. Preferably in designing building structure, it must be planned well and consider any risks that may occurs on the building. If the structure is not well planned, will be fatal to the building and human.

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