Original Research Article

Comparative Study of Light Steel Roof Frame Construction Methods With Conventional Methods And Prefabricated Methods

Abstract : :

Technology of house construction method have been experiencing development from time to time. In general, there are two construction methods that can be applied to lightweight steel roof truss which are the conventional method and the prefabricated method. The assembly of the lightweight steel roof truss using the conventional method is assembled directly on site, but the prefabricated method was done off site and then carried to the house unit using heavy equipment. With heavy equipment, the prefabricated method is considered to be more cost friendly and time efficient. This research is intended to compare the working methods, costs and time of lightweight steel roof truss using conventional methods and prefabricated methods. The research method used is Qualitative Method where the conventional method's data were collected from site observation on Cluster Type A. The results show that the lightweight steel roof truss using prefabricated method has a faster working time by 67% or three times faster than using conventional method. Meanwhile, the cost of using conventional methods is cheaper by 25% on average than using prefabricated methods.

Keywords:Roof Frame, Prefabricated, Conventional, Time, Cost

1. INTRODUCTION

The population in Indonesia has increased every year. According to the Central Bureau of Statistics (BPS) in the 2010-2020 period Indonesia had an increase in population of 1.25%, recorded in 2010 the total population in Indonesia was 237.63 million people and in 2020 the population has increased to 270.20 million soul. The increase in population in Indonesia has an impact on the increasing need for housing. In residential construction work, one of the elements of the building is the roof frame(Silitonga, 2021).

The roof frame is the uppermost part of a house building, which functions as a load bearer from the roof covering material, generally in the form of beams arranged vertically and horizontally. The shape and type of roof is influenced by the climate of the local area, the appearance desired by the architect, the available costs, and the ease of obtaining materials, the more complicated the shape of the roof, the longer it will take. To get efficient costs and time, it is necessary to do good planning regarding construction methods for roof truss work(Sejati et al., 2023).

The construction method is divided into two (2), namely the conventional method and the prefabricated method(Shinde & Darade, 2018). The conventional method for roof truss work is a method in which the assembly of the truss components is carried out in the fabrication and the installation is carried out directly in the field. Conventional methods have the risk of increasing construction costs caused by high wages and long duration of work(Delgado Camacho et al., 2018).

The conventional method has a high level of difficulty and risk because the work is done from a height. This causes the productivity of roof truss work with conventional methods to be low. The second construction method that can be applied to roofing work is the prefabrication method. In the world of construction, assembly in the prefabrication method is carried out off-site or the assembly is in a workshop that is outside the project site(Beheshti Aval et al., 2017).

After the assembly process, the roof trusses are transported and attached to each housing unit with the help of heavy equipment. Because the assembly is done in bulk and the installation is assisted by heavy equipment, the prefabrication method is considered to be able to control costs and time to be more effective and efficient. To prove this, it is necessary to carry out a comparative analysis study between the conventional method and the prefabricated method which will be reviewed in terms of time and cost.(Parfitt et al., 2022). This research takes a case study of the Type A Cluster Project which is carrying out conventional roof truss work. As for the prefabrication method, it will take data from the Cluster Type B and Cluster Type C projects. The prefabrication method data in this study is secondary data needed to make simulation calculations of budget plans and estimated time in m2 units. The simulation calculation of the budget plan and estimated time for the prefabrication method can be used as a reference to apply to Type A Clusters.

2. LITERATURE REVIEWS

2.1 Light Steel Roof Construction Management

Construction Management is an effort of a project organization that aims to achieve a satisfactory result in accordance with the desired goals. To achieve satisfactory results, it is necessary to have an effective and efficient process of planning, implementing project activities, and managing resources(Kemmer, 2018). In implementing construction projects, it is necessary to have good management in order to produce effective and efficient resources, meaning that resources must be planned as well as possible so that construction projects are carried out on time without incurring excessive costs.

Construction projects are unique, because the resources in each construction project have different needs depending on the location, scale and designation of the construction. However, the calculation of resources can be done mathematically to obtain optimal results. Aspects of the resources used in construction projects consist of 5M, namely Material, Machine, Man, Money, and Method.(Afif Salim et al., 2019).

Lightweight steel roof truss construction is roof truss construction made from lightweight steel. According to SNI No. 8399 of 2017, mild steel profiles are steel bars that have compact and uniform profile cross-sectional forms along the length of the rod and on the surface can be given an indentation or not, mild steel profiles are commonly used for roof trusses, mild steel profiles have a thickness between 0.4 mm to 1.10 mm. Mild steel profile is a type of steel made from a metal mixture consisting of several metal elements in the form of steel plates formed in a certain model through a press-breaking or roll forming process. The forming material used is high quality steel (high tension steel) G-550(Syamsuddin & Susanti, 2023).

According to SNI No. 8399 of 2017, mild steel weighing around 6-7 kg/m2 is the lightest material compared to wood which weighs around 20 kg/m2 and concrete which weighs around 30 kg/m2. Besides having a relatively lighter specific gravity,

mild steel is also resistant to corrosion/rust. Resistant to termites, better structural strength, stiffer than wood, and the process is relatively faster, so contractors and owners prefer to use lightweight steel roof trusses. Mild steel is high tensile steel G-550 (Minimum yield strength 0.55 kg/cm2) with standard materials JIS G3302, ASTM A792 and SGC 570. For roof trusses the standard quality of mild steel used is G550, which means mild steel has strong The minimum tensile is 550 Mpa(Zhao et al., 2019).

The roof truss is a structural system that functions as a support for the roof covering, the roof truss consists of several main elements such as the truss, rafters and battens. Various forms of roofs are used based on the size and style adopted from the house, this research only focuses on residential houses whose roofs have a gable shape. The shape of the gable roof is fairly simple because it is only composed of two sides of the roof plane that are connected to one ridge. Generally, a gable roof in a residential house has a slope angle of 30-45 degrees(Zheng et al., 2017).

Assembling the light steel roof truss structure needs to pay attention to the provisions on the distance between the installation of the truss. The heavier the load being supported, the shorter the distance between the horses. In addition to the distance between the trusses, another thing that must be considered is the installation of a connecting device so that the structural system is stable, strong and does not damage the anti-rust coating. The connecting tools commonly used in the installation of lightweight steel roof trusses are screws(Syamsudin et al., 2023).

2.2 Prefabrication Method

According to the Minister of Public Works and Public Housing of the Republic of Indonesia Number 1 of 2022, the prefabrication method is a construction method that is carried out by making roof components in advance, which are carried out in fabrications that are outside the project site. These components are then transported and installed to the location using a crane. Along with its development, the use of conventional methods on roof trusses has begun to be replaced with prefabricated methods because the implementation is faster and the number of workers required is less so that costs incurred can be streamlined.(Fauzi Rachman Yusuf & Deddy Effendy., 2022).

The prefabrication method has several advantages compared to the conventional method, including faster construction schedules, more efficient implementation costs, and increased quality of work.(Bertram et al., 2019).

2.3 Budget

The budget plan is an estimate of the calculation of the costs required for each work component in a construction project so that the total cost required for the completion stage of the construction project is obtained.(Paikun et al., 2018). The RAB includes the calculation of the cost of resource requirements in the form of materials, tools, labor wages and other necessary costs. There are five (5) things that underlie the preparation of the RAB, namely, general regulations, construction drawings, list of wages and material prices, list of analyzes, and volume of work(Rizqi et al., 2022).

The cost of implementing a construction project consists of two parts, namely direct costs and indirect costs. Direct costs are costs related to carrying out work in the field such as costs for using materials, costs for using tools, and costs for labor wages. Meanwhile, indirect costs are costs that are not directly related to the final result of construction, but include costs derived from the construction process. Indirect costs consist of overhead costs, profits, incidental costs, and taxes(Wijaya & Anondho, 2022).

Analysis of the Unit Price of Work (AHSP) is influenced by the value of the coefficient which shows the unit cost of materials, the unit cost of workers' wages, and the unit cost of equipment. In addition, the calculation of unit prices must adjust to field conditions, worker productivity, equipment productivity, and implementation methods. So, to determine the unit price of work, it must be known in advance the unit price of materials, the unit price of wages, and the unit price of tools. Then the results of these calculations are multiplied by a predetermined coefficient by adjusting the conditions in the field(Acemoglu & Restrepo, 2018).

2.4 Time Analysis

The use of resources and the duration of a construction project can determine time performance standards. From resources and performance, scheduling can be carried out so that it will produce output in the form of report formats regarding time progress indicators Time or schedule is one of the main targets for determining the success of a project. Scheduling is needed to determine the activities that need to be carried out to complete a project based on a certain sequence or time frame. Bad scheduling will result in project delays, which can then bring various forms of losses, such as increased costs, failed products to enter the market, and others.(Acemoglu & Restrepo, 2018).

2.5 Productivity

Productivity is the ratio between the volume of output to the amount of input used. The output or outcome is the result of the required value in the form of units, while the input or input is in the form of resources used in a process, the

resource in question is 5M (Man, Material, Machine, Money, Method). There are several references in determining the productivity coefficient, which are based on the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia (PUPR) number 1 of 2022 concerning Guidelines for Preparing Estimated Costs for Construction Work in the Field of Public Works, and based on the results of work in the field. The value of calculating the coefficient of worker productivity is needed to analyze time and analyze costs in conventional and prefabricated light steel roof truss work.(Key, 2019).

3. METHODOLOGY

This research was conducted in three (3) locations for residential development projects, namely Cluster Type B, Cluster Type C which had carried out light steel roof truss work using the prefabricated method and Cluster Type A which was carrying out light steel roof truss work using conventional methods. The discussion of this research is a comparison of conventional roof truss work and the prefabricated method that will be carried out in the Type A Cluster project. There are three (3) types of house types in Type A Cluster based on their size, namely:

a. Type of house 5 x 11 meters (deluxe and premium)
b. Type of house 6 x 11 meters (deluxe and premium)
c. Type of house 7 x 11 meters (deluxe and premium)

There are several differences in the houses reviewed, starting from the type, roof area, and roof shape. Therefore it is necessary to calculate the volume which is useful for processing time and costs in the Cluster Type A project. The method used in this study is the Qualitative Method, where the resulting data output is in the form of a description of the phenomenon that is happening and is presented factually and systematically(Creswell. J., 2018). This research method does not focus on the amount or quantity of data collected, but rather the results of an in-depth analysis of the data that has been obtained. The results of this study are in the form of a Cost Budget Plan (RAB) and work duration which are represented using Gantt Charts for each construction method, then the two methods are compared to determine the most efficient construction method in terms of time and cost.

The data needed in this study is divided into 2 types of data, namely primary data and secondary data. The primary data in this study are the data needed for conventional construction methods in the form of work implementation methods, labor productivity, and tool productivity(Creswell. J., 2018). The secondary data referred to in this study are Roof Construction Drawings on Type A, B and C Clusters.

After collecting primary data and secondary data, data processing is carried out. Data processing is carried out to analyze existing problems. There are two (2) types of data processing used in this study, namely data processing in the conventional method and data processing in the prefabricated method.(Creswell. J., 2018).

The results obtained from conventional method data processing are the stages of implementation, time and cost(Creswell. J., 2018). Data on implementation stages were obtained from SOPs and field observations of Type A Cluster projects and then the stages of implementation were described.

Data on the prefabrication method were obtained from secondary data, namely project archives for Cluster Type B and Cluster Type C. The data includes project implementation stages, SOPs for prefabrication methods, worker and tool productivity. The data is needed to calculate time, cost, and describe the stages of implementing the prefabrication method. Cost and time calculations are obtained by calculating the average of the three clusters regarding the time and cost required in m2 units.

4. RESULTS AND DISCUSSION

4.1. Research result

This study focuses on the comparison between two (2) light steel roof truss work methods, namely the conventional method and the prefabricated method. This study uses case studies in three (3) different clusters, namely Cluster Type B, Cluster Type C and Cluster Type A. Cluster Type B has one type of unit, namely the standard type, Cluster Type C has two types of units, namely Type Basic and Premium. . Cluster Type A has two types of units, namely deluxe and premium types, each cluster has a different roof truss area.

Cluster Area Type A, B and C

The type of roof in the Type A Cluster is differentiated based on the size of the housing units built, the housing units have the same length, namely eleven (11) meters, but the width has three (3) variations, namely 5 meters, 6 meters and 7 meters. To make it easier to write for each housing unit, a code is given, namely 5 x 11 Deluxe (5D), 5 x 11 Premium (5P), 6 x 11 Deluxe (6D), 6 x 11 Premium (6P), 7 x 11 Deluxe (7D).), and 7 x 11 Premium (7P). Based on the different types of houses, the roof truss area can be calculated in units of area for each housing unit. The calculation of the roof truss area in Cluster Type A can be seen in Table 1 below.

Table 1. Work Area per m2 Light Steel Cluster Type A roof truss

No	Kode Unit	Dimensi		Sudut	Luasan	Total Unit	Total Luasan
		Panjang (m)	Lebar (m)	(°)	(m^2)		(m^2)
1	5D	3,33	3,94	30	21	5	105,03
		1,65	3,08	30			
	5P	5,03	3,94	30	23	9	205,70
2	6D	4,35	3,94	30	25	8	200,77
		1,65	2,80	30			
	6P	6,00	3,94	30	27	18	490,72
3	7D	5,40	3,94	30	30	10	302,25
		1,61	3,08	30			
	7P	7,00	3,94	30	32	11	349,87

There are three types of housing units in Cluster Type B and Cluster Type C, namely Type Basic, premium and standard. There are different types of each unit, so the roof frame also has a different area.

Table 2. Work Area per m2 Light Steel Cluster Roof Frame Type B and C

No	*Cluster*	Tipe Unit	Dimensi		Sudut (°)	Luasan (m^2)
			Panjang (m)	Lebar (m)		
1	*Type* B	*Basic*	6,17	4,84	35	36
		Premium	6,17	5,84	35	44
2	*Type C*	*Standar*	7,07	4,91	45	49

Time Analysis

To find out the duration of time needed by workers, field observations are needed related to work productivity. Data on worker productivity can be seen in Table 3 below:

Table 3. Productivity of Cluster Roof Frame Type A Conventional Method

Hari	Kelompok 1 (m^2/hari)	Kelompok 2 (m^2/hari)	Total (m^2/hari)
1	10,5	12,5	23
2	13,5	12,5	26
3	16	12	28
4	16	13	29
5	12,5	15	27,5
6	12,5	15	27,5
7	14	15	29
Total (m^2/7 hari)			190
Rata-rata (m^2/hari)			27
Total Luasan Seluruh Unit (m^2)			1654,34
Durasi Pekerjaan (hari)			61

Based onobservations made for seven (7) days, it is known that the total area produced by the two groups of workers is 27 m2/day.

Time Analysis of Roof Trusses Cluster Type A, B and C Prefabrication Methods

The standard type housing units in the Type B Cluster have an area of 49.07 m2, while the Type Basic housing units in the Type C Cluster have an area of 36.39 m2, and for the premium type it is 43.91 m2. The average area of Cluster Type B and Cluster Type C is 43.12 m2. Calculation of the daily productivity of roof truss fabrication using the prefabrication method shows that the daily productivity of workers in one day is 81.07 m2/day.

It takes 41 minutes for one housing unit to complete mobilization and attaching the roof truss to the housing unit. Based on Table 3. and Table 3. the average roof truss installation for Cluster Type B and Cluster Type C is (12 + 6)/2 = 9 units/day. This data will be simulated in Cluster Type A to get the duration of the prefabricated roof truss work.

Analysis of Roof Truss Time between Conventional Method and Type A, B and C Cluster Prefabrication Method

Table 4. Comparison of Roof Truss Implementation Time in Type A Clusters

Unit Tipe	Luasan (m^2)	Durasi (hari)		Selisih Waktu (%)
		Konvensional	Prefabrikasi	
5D	21	0,778	0,259	67
5P	23	0,852	0,284	67
6D	25	0,926	0,308	67
6P	27	1,000	0,333	67
7D	30	1,111	0,370	67
7P	32	1,185	0,395	67

Table 5. Worker Coefficient of Conventional Method Roof Frame

Hari	Produktivitas (m^2/hari)	Koefisien Tenaga Kerja (OH)			
		Pekerja	Tukang	Kepala Tukang	Mandor
1	11,5	0,087	0,087	0,043	0,029
2	13	0,077	0,077	0,038	0,026
3	14	0,071	0,071	0,036	0,024
4	14,5	0,069	0,069	0,034	0,023
5	13,75	0,073	0,073	0,036	0,024
6	13,75	0,073	0,073	0,036	0,024
7	14,5	0,069	0,069	0,034	0,023
Rata-Rata (OH)		0,074	0,074	0,037	0,025

Table 6. Unit Price Analysis of Conventional Methods Using the Matrix

Lebar/Panjang	*Premium*	*Deluxe*
	11	11
5	Rp 145.672	Rp 148.369
6	Rp 147.262	Rp 147.521
7	Rp 144.973	**Rp 146.739**

Table 7. Analysis of Work Unit Prices Prefabricated Method Using a Matrix

Lebar/Panjang	*Premium*	*Deluxe*
	11	11
5	Rp 182.226	Rp 184.923
6	Rp 183.816	Rp 184.075
7	Rp 181.527	**Rp 183.293**

Table 8. Comparison of the Budget Plan for the Cost of Conventional Roof Frame Work and the Prefabricated Method

Tipe unit	Luas Unit (m^2)	Harga Satuan (Rp)		Total Harga (Rp)		Selisih Harga (Rp)	Persentase (%)
		Konv.	Prefab.	Konv.	Prefab.		
5D	21	148.369	184.923	3.115.759	3.883.392	767.633	24,64
5P	23	145.672	182.226	3.350.460	4.191.201	840.740	25,09
6D	25	147.521	184.075	3.688.014	4.601.863	913.848	24,78
6P	27	147.262	183.816	3.976.074	4.963.030	986.956	24,82
7D	30	146.739	183.293	4.402.157	5.498.775	1.096.618	24,91
7P	32	144.973	181.527	4.639.146	5.808.871	1.169.726	25,21

Based on the prices obtained from the calculation results in Table 4. there are differences in unit prices for the conventional method and the prefabricated method. The price difference between the conventional method and the prefabricated method for roof truss unit types 5D, 5P, 6D, 6P, 7D, and 7P respectively Rp. .

5. CONCLUSION

The difference in the method of carrying out light steel roof truss work with the conventional method and the prefabrication method lies in the assembly process, adding reinforcement rods, and the mobilization process. Assembling lightweight steel roof truss components using conventional methods is carried out in the construction area, does not require additional reinforcement rods, and the mobilization process is done manually. Meanwhile, the prefabricated assembly method was carried out off-site, using additional reinforcement rods, and mobilized using heavy equipment.

Based on time analysis, the total duration required for lightweight steel roof truss work using the conventional method is 61 days, while the duration required for light steel roof truss work using the prefabricated method is 21 days. It can be concluded that the roof truss work with the prefabricated method is 40 days faster than the roof truss work with the conventional method. If calculated in units of area per unit, the prefabrication method has a duration acceleration of 67% or three times faster than the conventional method. Based on the cost analysis that has been done, roof truss work with the Conventional Method is cheaper with an average percentage of 25% compared to the prefabricated method.

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