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Damage Assessment Method for Light Steel Roof Frames: Case Study of Government Buildings

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Abstract
The tornado disaster in Ciamis Regency damaged 55 buildings, including the Panawangan District Office. The aim of this research was to identify the condition and level of damage to the Light Steel Roof Frame Structures that were damaged and determine the ranking or percentage of damage. By making direct observations at the location of the incident. The result is that: The roof covering element uses zincalum metal with the batten frame partially damaged on the left side of the building above the hall and the right corner of the front of the building. The battom chord, top chord and web elements are partially detached. The trim element made of GRC material is damaged. came loose, and the Gypsum ceiling elements with hollow frames fell on the outside and inside the hall. The percentage of damage obtained is 14.50% and the damage level ≤ 30% is categorized as Light Damage.

INTRODUCTION

The roof structure is the part of the building that holds or transmits loads from the roof. The roof structure is divided into roof trusses and roof truss supports. A roof can be said to be of quality if its structure is strong/sturdy and durable/long-lasting. The roof frame functions to support the load of the roof covering material. (Setiawan & Suryani, 2022), climate factors are an important consideration in designing the shape and construction of roofs/buildings. The existence of a roof is very important considering its function is like an umbrella that protects the building from weather disturbances (heat, rain, and wind). Therefore, a roof must be strong.

Changes in a building's roof frame in terms of function, shape and type of material used are a transformation of human needs for the goals to be achieved. The phenomenon that exists in Indonesia in meeting the needs that are often used in building roof frame materials begins with using wood material, as the need for wood is very large and it is not easy to get good wood (strong according to strength specifications) and the price is high to meet the specifications, so the engineers thought about replacing the roof frame of the building. The role of Science and Technology is needed to create other materials as a substitute for wood.

Light steel is a steel structural component made from steel sheets or plates made from zinc-alum which is processed in a cold state which is then designed and carried out by experts, then manufactured using machines. The use of light steel in roof truss structures has several advantages, including light weight, homogeneous material, termite resistant, coated with aluminum zinc, does not rot, has high tensile stress, and is easy to install. Apart from the advantages of light steel, it also has weaknesses, including: it is easily blown away by the wind, it can collapse, the manufacturing process is not environmentally friendly, and if you make a mistake in the calculation it will result in breakage so you need experts. (PUPR, 2018).

Light steel roof trusses have been used as roof truss coverings in various countries in the world, to protect the buildings underneath, especially for residential buildings (Reda et al., 2019) and (Almasri et al., 2023) office buildings (Pranoto & Jepriani, 2020), this means that light steel has become an important material that can be used for roof frames as a substitute for other materials such as wood.

But in several places we often hear news of building collapses due to the use of light steel roof trusses, including incidents of collapsing of light steel roof trusses in Ciamis Regency often occurring, such as. The roof of the SDN 1 Bojongmengger building, Cisaga District, collapsed. The collapse of two local classrooms, namely Class V and Class VI, occurred on Saturday evening, March 2, 2013. Currently, the building debris and light steel frame that collapsed have been removed, these items are stacked on one side of the wall of the classroom whose roof collapsed. According to Hendra, as a member of the Ciamis Regency DPRD who visited the school, he said that the school should not just accept the building before carrying out a thorough inspection. This action is to anticipate the possibility that there will be school rooms that are not in accordance with the plan. (Administrator, 2013). Pikiran Rakyat.com.

The roof of the classroom at SDN 3 Muktisari, Cipaku District, Ciamis Regency collapsed. It is suspected that the elementary school roof collapsed due to the light steel frame being unable to support the load, after several days of heavy rain, the part that collapsed was the roof of the Class III classroom on Monday 5 February 2018 at around 23.00 WIB. (Nurhandoko, 2018). Pikiran Rakyat.com.

The roofs of two emergency rooms at the Ciamis District Hospital, West Java, collapsed on Monday (19/10/2020) evening. For the time being, the cause of the collapse of the buildings is thought to be because the roof frames made of light steel were not strong enough to support the weight of the earthen roof tiles which were wet after being poured by rain all day. (Hasanudin, 2020). Tribunnews.com.

The roof of three rooms at SDN 1 Sukadana, Sukadana District, Ciamis Regency, which was made of lightweight steel roof trusses, collapsed when it was pouring rain. It is suspected that part of the roof collapsed on Friday, January 1 2021 evening, unable to withstand the load caused by the rain. (Nurhandoko, 2021). Pikiran-rakyat.com.

The collapse of the Light Steel Roof Frame occurred at SD Muhammadiyah Bogor, Playen District, Gunung Kidul Regency, Special Region of Yogyakarta, which occurred on Monday 8 November 2022. (Yuwono, 2022). Kompas.com.

The roof of the shophouse terrace using light steel roof frames from Pekalongan Regency, collapsed. As a result, several motorbikes and a car were crushed under rubble. This incident happened at 10.00 WIB, Saturday (17/9/2022. "There was no rain or strong wind, I thought there was "earthquake. Bruk, really loud. It turned out that one side had collapsed," said Sri. According to her, the roof of the shophouse terrace that collapsed had been tilting since about a month ago. (Robby, 2022). Detik.com.

The tornado disaster occurred in Ciamis Regency, West Java, located in Panawangan District on Wednesday, January 4, 2023, at 15:43, strong winds accompanied by heavy rain destroyed the buildings in its path, damaged 55 houses, the Panawangan District office, schools, and mosque. Apart from that, a number of fallen trees blocked roads and hit houses. (M Dani, 2023) are seen in Figure 1.

Figure 1. Impact conditions after a tornado in Panawangan District

Problems and Aim

Based on the problems of several incidents, it is very necessary to review the level of damage to each building by making direct observations at the location of the incident.

The Panawangan District Office is a government building to serve the community in terms of public services, this requires a proper and reliable building. With the disaster that occurred on Wednesday, January 4, 2023, at 15:43, strong winds accompanied by heavy rain destroyed the building, with this incident the service was moved to another building temporarily. In this case, so that the building can be repaired quickly, it is necessary to calculate the damage experienced by the office building, and to immediately report it to the Regency Government.

The aim of this research is to identify the condition and level of damage to the Light Steel Roof Truss Structure which is damaged and determine the ranking or percentage of damage to the Light Steel Roof Frame Structure elements.

Previous research discussed identifying overall building damage (Kempa, 2018). Meanwhile, in this research we are focusing on the roof frame of the building that was damaged.

Literature review

The use of light steel has now become a trend. There are many light steel producers, but sometimes because there are so many light steel producers, competition in the market becomes unbalanced. For example, some producers offer light steel at lower prices, but the quality of the steel decreases. Deviations that occur in the light steel industry cause the failure of projects that use light steel. Error This happen Because error connection, element errors, and production errors. That failure is wrong the only one due to the lack of standards or special process for light steel in Indonesia. (Sari & Arsyad, 2020).

From the results of research conducted at the Queensland University of Technology that lightweight steel roof battens fail prematurely at their screw connections to rafters or trusses, due to extreme wind events such as tropical cyclones, tornadoes and thunderstorms which often significantly affect coastal areas of Australia. Because such localized pull-through failures occur at lower roof joint levels, they often lead to loss of the entire

roof system during extreme wind events . Detailed probabilistic analyzes and Monte Carlo simulations were performed for this purpose. Fragility curves were also used to evaluate the influence of roof batten span and spacing and, the degree of improvement that can be achieved with the proposed strengthening method for roof battens. (Sivapathasundaram & Mahendran, 2016).

Another research carried out an investigation into the collapse of a steel roof truss in an industrial factory some after extraordinary snowfall. This light roof structure with a low slope is supported the steel column is 16.3 m high and covers a covered area of 26,080 m2 according to the plan built as a Mero type double layer steel space frame system which has a height of 2 m. In addition, a 90 cm high boundary wall was placed around the building and siphonics system is used for roof drainage. To find out the main cause of partial collapse roof structure, site investigations were carried out and findings were collected, then the suitability of the structural frame was checked with respect to current Turkish steel buildings design code. The nature of the roof frame material that carries the main load is checked by carrying out a tensile test. Finally, it was understood that there were two unexpected things Catastrophic collapse was experienced as a result of ice pools occurring in roof edge areas due to the roof sections being heated intermittently by radiant heating installed on the roof structure and freezing siphonic system. (Piroglu & Ozakgul, 2016).

Previous research stated that the results of load analysis of the rod forces at the time of collapse showed that both types of frames had the same load capacity at the same theoretical span. This is because the collapse analysis focuses on the manual results of the roof truss rod forces by assuming that the roof truss will experience failure at the compression rods. From the manual results, it is known that the roof truss with a theoretical span of 12 meters experiences flexural buckling failure in the compression members when the total load reaches 2797 N, whereas with a theoretical span of 24 meters the roof truss will experience flexural buckling failure when the total load reaches 703.7 N. As for the results There is a difference in maximum load in manual analysis and program analysis. This is because in manual analysis, the failure of frame construction focuses on the results of the force of the roof frame members by assuming that the roof frame will experience failure at the compression members. Meanwhile, in the analysis carried out by the program, construction collapse is analyzed using the finite element method where the entire frame member is divided into small parts whose size can still be measured. (Sucipta et al., 2013).

Terms in Light Steel

In the training material book for installing Light Steel Roof Trusses, there are several names or terms for Light Steel Roof Frame structures (CBM, 2022).

Building Damage Level

Building damage is the non-functioning of a building or building component due to depreciation/end of the life of the building, or due to human activity, or natural behavior such as excessive functional load, fire. earthquake, or other similar causes. (Peraturan Menteri Pekerjaan Umum No.24/PRT/M/2008, 2008). The intensity of building damage can be classified into three levels of damage:

1. Light Damage (LD), Light damage is damage, especially to non-structural components, such as roof coverings, ceilings, floor coverings and infill walls.
2. Moderate Damage (MD), Moderate damage is damage to some non-structural components and/or structural components such as roof structures, floors, etc.
3. Severe Damage (SD), Severe damage is damage to the majority of building components, both structural and non-structural, which, after repair, can still function properly as it should.

According to the Ministry of PUPR in the Guidebook for Procedures for Identifying and Verifying Damage (Kemendikbud, 2021), to find out the categories of levels of damage to buildings are listed in Table 1.

Table 1. Classification of the level of roof damage according to the description of the damage

Classification	Damage Description	Mark
Not broken	The roof frame is in good condition	0,00
Very Light Damage	• (light steel) The sagging in the frame is starting to appear, the curtains are sagging • The roof tile came loose from its holder	0,20
Light Damage	• (light steel) The bends in the frame expand, the construction vibrates due to the wind • Broken battens, damaged rafters. • The roof tiles are cracked and there are limited leaks	0,35
Moderately Damaged	• The roof structure sags • (mild steel) cracks/tears in mild steel at bolt or screw connections • The curtains/ceiling frame sag. Widespread leaks	0,50
Heavy Damaged	• (mild steel) cracks/tears in mild steel at bolt or screw connections are widespread, deflections in the mild steel frame occur in many places • The roof covering sags greatly with the possibility of major collapse	0,70
Very Heavy Damaged	• The roof truss collapsed • Bending of structural components • Joints break, profiles bend, construction collapses	0,85
Incompatible Components	• The material, dimensions and construction of the roof frame are indicated as not complying with technical requirements (refer to the Technical Plan if any, Technical Instructions and/or SNI)	1,00

RESEARCH METHODS

In this research, the author collected data by making direct observations at the location of the incident, documenting the events that occurred, and recording some of the data needed to be used as field data.

The assessment flow is carried out by carrying out visual observations indicating the impact of damage on the safety aspects of building components and continuing with calculating the volume of component damage which is carried out sequentially, then if the level of damage has reached severe damage, then the calculation does not need to proceed to the assessment of the next component. The resulting percentage figure is not related to the financing required.

With the following steps:

The first step is to document several damaged parts of the roof frame structure, the second step is to check whether the condition of the building meets the criteria for roof damage which is indicated to have an impact on safety aspects, and the third step calculates the volume of component damage based on the damage classification.
Calculation of roof damage is the sum of damage to the roof covering and roof frame structure including curtains (Kemendikbud, 2021). By calculating the following formula:

Percentage of Roof Damage = % Area of Damage = ((Area of Damage)/($Total$ Area)) x 100%

The level of damage can be classified into four categories, namely:
- Light Damage (LD) : ≤ 30 %
- Moderate Damage (MD) : > 30 % - 45 %
- Severe Damage (SD) : > 45 % - 65 %
- Total Damage (TD) : ≥ 65 %

RESULTS AND DISCUSSION

Data was taken from the location used as an observation site, namely the Panawangan District Office building, Ciamis Regency, West Java, which had its roof made of light steel damaged due to a tornado.

Figure 2. The roof frame of the side of the building was damaged.

It can be seen in Figure 2 that the Panawangan District building with a building size of 15 x 21 m, one floor is used for the District Office, on the side of the building below which is intended for hall space, the roof of the building which is made of light steel frame is damaged, with the roof covering elements using multi-roof lifted and separated from the Batten section.

And on the right side of the Panawangan District Office building, there is a detachment of the roof covering element, and part of the ceiling which was installed from Gypsum material is detached from the frame, as seen in Figure 3.

Figure 3. The right roof and ceiling cover came off.

In this research, there are several steps taken by researchers to obtain data to assess the level of damage to roof trusses using light steel material due to the natural disaster of a tornado in Ciamis, West Java.

The research first step was to document several damaged parts of the roof frame structure as in Figure 4.

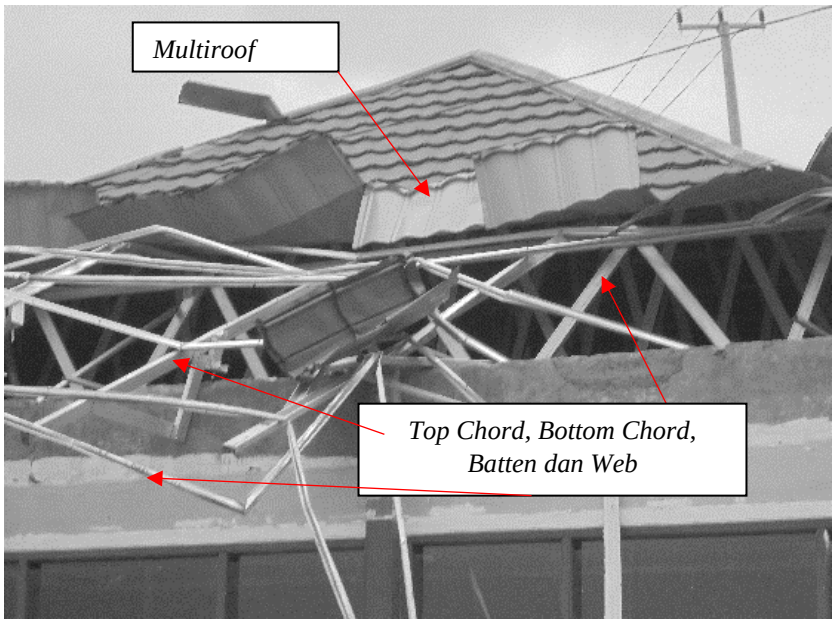

Figure 4. damaged of parts of the frame and roof.

Parts of the light steel frame structure, namely Top Chord, Bottom Chord, Web , and Batten which can be seen in Figure 4, were partially damaged and parts of the roof covering made of multiroof material came off, and other parts of the building roof were damaged, especially the reinforcing parts of the lightweight steel roof frame that connects the building and the roof frame is the L Bracket because this element strengthens the roof frame and the building to be stable. In fact, the L Bracket which should be strong enough to hold the roof frame from the building base is separated from its base, as seen in Figure 5.

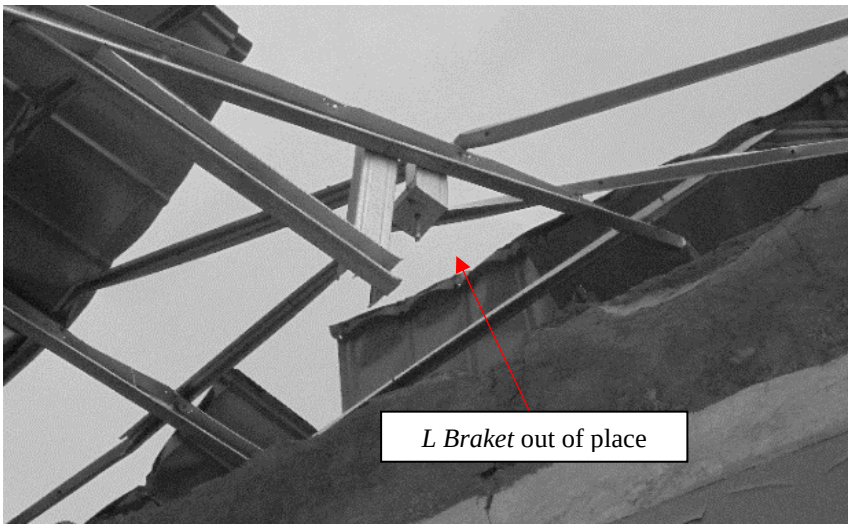

Figure 5. The *L Bracket* element is detached from its mount

The covering ceiling made of Gypsum was damaged on the outside and inside of the building, especially above the hall, as seen in Figure 6.

Figure 6. The gypsum ceiling cover fell

The second step is to check whether the condition of the building meets the criteria for roof damage which is indicated to have an impact on the Safety Aspect, from the documents obtained that parts of the roof truss elements in the existing Panawangan District Office building with the criteria for roof damage which is indicated to have an impact on the Safety Aspect, are presented in detail as follows:

- The roof and ridge covering elements made of zincalum metal with batten or batten frame were partially damaged at the left side of the building above the hall and the front right corner of the building.
- Some elements of the bottom chord and top chord are detached and some are still intact.
- The web element connecting the bottom chord and top chord on the damaged part is separated from the connection.
- The plank elements made of GRC material on the damaged parts came off.
- Gypsum ceiling elements with a hollow ceiling frame fall on the outside and inside the hall.

The third step is to calculate the percentage of roof damage. The building measures 15 m wide and 21 m long, forming a pyramid roof. To obtain a volume measure of the percentage level of damage to the Roof Frame of the Panawangan District Office building, use the following calculations:

Data on the roof area of the Panawangan District Office was taken from calculations of roof area segments coded with segment names on the roof, which are presented in Figure 7.

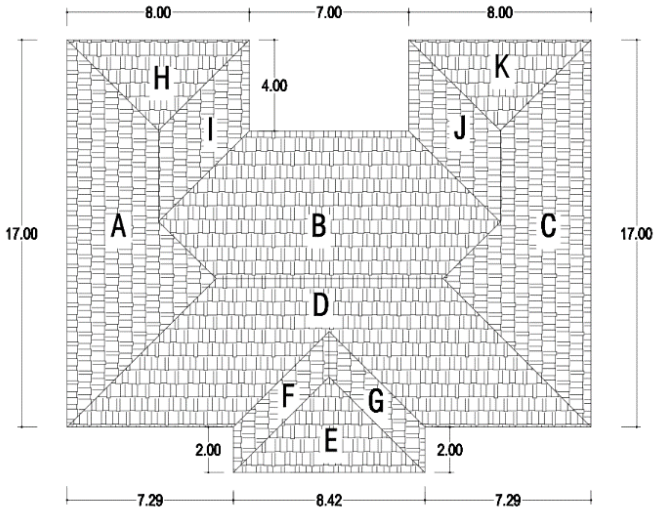

Figure 7. Sketch of the roof plan of the Panawangan District office

To find out the total area of the roof of a building in Panawangan District, it is calculated by multiplying the flat area of the roof shown on the plan multiplied by the slope of the roof, presented in Table 2.

Table 2. The roof area of the Panawangan District office

Code	Flat area m^2		Slope 30^0		Roof Area m^2
A	58,5	x	1,16	=	67,86
B	75	x	1,16	=	87,00
C	58,5	x	1,16	=	67,86
D	90	x	1,16	=	104,40
E	17,6	x	1,16	=	20,42
F	8,4	x	1,16	=	9,74
G	8,4	x	1,16	=	9,74
H	15,9	x	1,16	=	18,44
I	16	x	1,16	=	18,56
J	16	x	1,16	=	18,56
K	15,9	x	1,16	=	18,44
			Total amount	=	**441,03**

Based on Table 2, it is found that the total roof area of the Panawangan District office is 441.03 m^2

To find out the extent of damage to the roofs of buildings in Panawangan District which were damaged by tornadoes and followed by rain, which is presented in Figure 8.

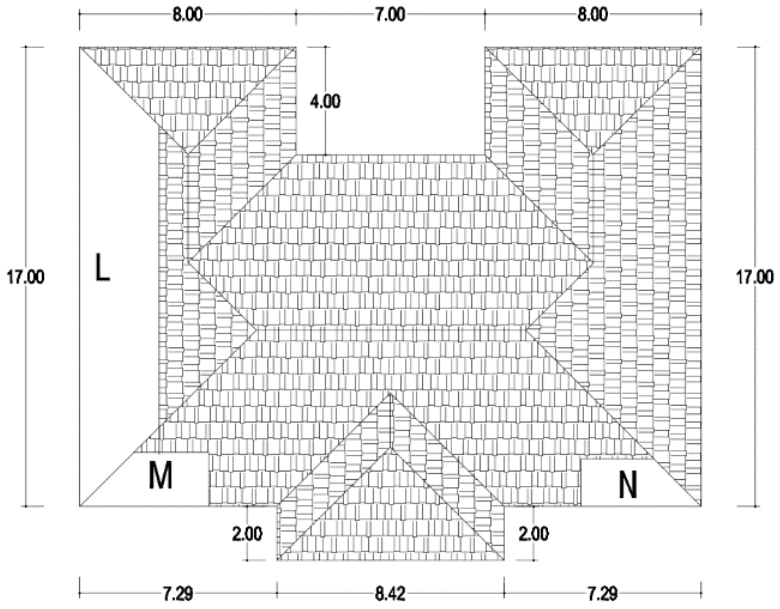

Figure 8. Sketch of the damaged roof plan with codes L,M and N

The data in Table 3 is the product of the flat area of the roof damaged, as shown in figure 8, times the slope of the damaged roof.

Table 3. The area of the damaged roof

Code	Flat area m^2		Slope 30^0		Roof area m^2
L	41,3	x	1,16	=	47,91
M	7,5	x	1,16	=	8,70
N	6,3	x	1,16	=	7,31
			Total amount	=	**63,92**

Based on Table 3, it is found that the roof area of the Panawangan District office that was damaged was a total of 63.92 m^2.

Roof Damage Percentage

- % Area of Damage = ((Area of Damage)/($Total$ Area)) x 100%
- Total damage area = 63,92 m^2
- Total area = 441,03 m^2
- % Area of Damage = (63,92 / 441,03) x 100%
  = 14,50 %

The percentage shows the damage value is 14.50%, which means that the Panawangan District office building as a result of a tornado accompanied by heavy rain is in the Lightly Damaged (LD) category, because according to the Ministry of PUPR, the determination of the level of damage to buildings is based on a quantitative measure of the magnitude of the damage that occurred. for each component, the results obtained from calculating the damage to the roofs of buildings in Panawangan District were at a damage level of ≤ 30%, categorized as Lightly Damaged.

CONCLUSION

From the results of the analysis of damage data from the Panawangan District Office, it can be concluded that the level of damage to the Lightweight Steel Roof Truss Structure elements is 14.50% categorized as Lightly Damaged (LD).

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