THE NEW DESIGN CRITERIA FOR STEEL CONSTRUCTION WITH RESPECT TO OCCUPATIONAL HEALTH AND SAFETY

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THE NEW DESIGN CRITERIA FOR STEEL CONSTRUCTION WITH RESPECT TO OCCUPATIONAL HEALTH AND SAFETY

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ABSTRACT : Occupational Health and Safety (OHS) is one of the main purpose of construction project that must be fulfilled. To reduce the work risk, a safe design since the pre-construction stage which is often called prevention through design, should be considered. In this research, the risk is reduced by using engineering control. In the implementation, there were still not sufficient OHS consideration in the steel construction design. The objectives of this research is to determine the OHS based design criteria compile from literature studies and field investigation and to implement this criteria since the design stage. The design criteria covers the structural elements, such as column, beam, and rafter as well as structural connection using end plate and angle plate. The criteria itself is divided into 3 categories, unsuitable, allowed and suitable. The most common criteria including the availability of lifting hole, guardrail and dummy hole. The purpose of these criteria is mainly to reduce the risk of falling which is the most frequent accident occurred.

KEY WORD: steel structure, design criteria, occupational health and safety, design recommendation

1. INTRODUCTION

Every year the number of construction project increased in Indonesia. It is because Indonesia is a developing country so an enhancement in quality and quantity of infrastructure is needed. The increasing of construction project mean the chance of work accident would be increased too. In 2015, the number of work accident in Indonesia in construction sector reached 110.285 cases, respectively in 2016 the number of work accident reduce to 101.367 cases and reduce around 20.975 cases to 80.393 cases in 2017[1]. The decreasing of work accident every year means the developing of OHS implementation in Indonesia are in a good pace. But the number still showing a pretty high number.

To reduce the number of work accident in Indonesia, an OHS instrument is needed. This instrument hopefully could reduce the work accident risk in construction sector in Indonesia. The instrument created in the form of a list of design criteria which considering OHS in the design phase[2][3][4]. The criteria used to help the designer in designing a steel structure with a lower work accident risk.

2. LITERATURE STUDY

2.1. Prevention Through Design

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Prevention through Design (PtD), was more known as Design for Safety (DfS) in some European country. PtD is a consideration about the safety of construction process in the design phase. The main purpose of PtD is to reduce the risk that attached to the worker[5]. PtD itself is a program or method to prevent the work accident which initiated by the National Institute of Occupational Safety and Health (NIOSH).

In the relation with hazard control, this research use engineering controls which is one of risk controlling in hierarchy of controls (**Figure 1**)[6]. Engineering controls is a hazard control which modify or change the design existed, so the risk of work accident occurrence would be lower. The using of engineering controls in this research is to modify a design with a higher risk of work accident into a lower risk work accident design. This modification is based on the assessment using the criteria created. Through the design phase, several PtD applications can be implemented, such as identifying anchorage points, allocating guard rail holes in vertical steel elements, avoiding hanging connections and eliminating sharp corners[4][7][8].

There are 5 barriers in implementing PtD, first is the designer's fear of liability toward worker safety and the exposure to third party lawsuits. Second is the increase in design fees due to the extra time that designers spend to incorporate safety measures in the design. Third is the lack of the designers' safety expertise that is articulated in identifying and installing safety measures and alternatives during the design phase[9][10][11][12]. Fourth is the lack of regulatory requirements in the U.S, which differ from other countries such as UK, Australia, and Singapore. Finally, yet most importantly, is the lack of education and training among the AEC industry professionals and AEC academic curriculum regarding the PtD concept and implementation[13][14].

2.2. Constructability

Constructability is a project management technique to review the construction progress from the beginning to the end in the pre-construction phase. The purpose is to identify the obstacles that could happen before the project held to reduce and prevent error in project, delay and extra cost[15].

2.3. Lifting Equipment, Bolt Fasteners and Weld In Steel Construction

According to NIOSH, the maximum load lifted by a worker without any lifting equipment is 23 kg. Based on this statement, the material removal with pretty big load and dimension required a lifting equipment such as chain block, mobile crane and tower crane. There are some things to be considered in the usage of lifting equipment such as the load lifted by the equipment should not passing the load limit capacity or often called Safe Working Load (SWL).

In the implementation of steel construction, connection is one of the things should be considered. The connection in steel construction according to the work method divided to 2 types, which is weld and bolt. In the erection process, there should be enough space and access for the worker hand and the equipment. There should be a consideration for choosing the right equipment would be used based on the dimension since the design process so there would be enough space for the worker. Other than that, there are somethings to considered such as the awkward or dangerous working position for the worker.

3. RESEARCH METHOD

In this research, there would be a literature study to collect theory and data from some source such as journal, thesis and website. After that, the research continued to field observation to collect references to help formulate the design criteria. The design criteria used in the design assessment made based on the literature study and field observation. This criteria include some condition that should be considered to rate the implementation of OHS. After the criteria finished, the next things is analysing

the construction drawing to see and rate the safety level of the steel structure design. In analysing the drawing, the design criteria that has been made used to rate the safety level of the design.

4. RESULTS

Regarding to the literature study and field observation, there are some criteria related to steel construction design which consider the OHS. This design criteria made to help the steel structure designer in implementing OHS since the design phase. The criteria divided to 4 part of structural element, which is column, beam, rafter and connection (end plate and angle plate). The criteria main purpose is to increasing the worker safety since the construction phase. The criteria divided into 3 categories, unsuitable, allowed and suitable. The category is to help getting the final score of OHS implementation in the related project. In the assessment phase, every category has a score each 0, 1 and 2. 0 Point given to the criteria that categorized as unsuitable, 1 point for the allowed criteria and 2 point for the suitable criteria. The criteria of column, beam and rafter could be seen in the **Table 1.** And the criteria for the end plate connection and angle connection could be seen in the **Table 2.**

Lifting hole in column is to provide a spot to hook or tie lifting rope. This is meant to reduce the falling risk of the column because of the lifting rope not tied properly or slipped. Guardrail availability is to provide a guardrail in the edge of the building in a relatively high elevation, to reduce the falling risk of the worker. Guardrail at least provide in 1 spot in 1000 mm elevation, but more recommended to provide in 2 spot, in 500 mm and 1000 mm elevation. Harness hole is to provide a spot to hook up the harness or rope. For the column, this hole at least should be provided in 1 spot at the *flange* section of the column and provide the hole at least above the worker head (±200 cm). To prevent the worker tripped, pedestal column should be design at least 300 mm high. But if the pedestal column has 150 – 300 mm height, there should be a tripping hazard or barricade around the pedestal column. The number of anchor for the column recommended are 4 point in the 4 different quadrant, so the column could withstand 2 way force equally. But if the usage of least than 4 anchor desired, there should be at least 2-3 anchor with the position and number calculated carefully to withstand 2 way force. The position of column splices recommended is in the 1000 – 1400 mm elevation or at worker chest height to prevent an awkward or difficult work position. If not possible, the minimum height allowed is around 600 – 1000 mm or 1400 – 1600 mm. The reason for this elevation is because the worker could have a difficult work position to do the work.

The recommended member weight to be lifted is < 60% from the Safe Working Load (SWL) with lifting machine and for the manpower or manual, the recommended member weight to be lifted or pulled by pulley is $\leq$ 20 kg/person. But if not possible, the allowed load to be lifted by the lifting machine is 60-80% SWL and for the manpower or manual is 20-30 kg/person. Lifting hole for beam should be provided at least located in 2 spots and each has 1 hole in the *flange section*. But its more recommended the lifting hole provided at least located in 2 spots and each has 1 hole in the web section or 2 spots each has 2 or 4 hole for the *flange section*. The minimum width of beam flange is 150 – 200 mm to provide the beam as a footing for the worker if necessary. But more recommended if the flange width wider than 200 mm. Harness hole for beam at least provide 1 hole in the bottom flange section with the distance between the hole around 1000 mm to 2000 mm each hole. But more recommended if there is 1 hole in the bottom flange section each 1000 mm distance. The position of beam splices at least provided in the 0.00 – 0.20 span, 0.30 – 0.35 span, 0.65 – 0.70 span or 0.80 – 1.00 span. But more recommended to provide in the 0.20 – 0.30 span or 0.70 to 0.80 span.

Table 1. Design Criteria for Column, Beam and Rafter

No.	Item	Criteria			Source
		Unsuitable	Allowed	Suitable	
1.	Column				
	Lifting hole	None	1 point with 1-3 hole(s) (flange)	1 point 1 hole (web) / 1 point with 4 holes (flange)	
	Guradrail availability	None	1 point	2 points	NIOSH
	Harness hole	None	1 point	1 point overhead	NIOSH
	Pedestal column height	< 150 mm	150 mm ≤ x ≤ 300 mm	> 300 mm	
	Number of anchorage	< 2 anchorages	2 - 3 anchorages	≥ 4 anchorages	NIOSH
	Splices Location	< 600 mm or > 1600 mm	600 - 1000 mm or 1400 - 1600 mm	1000 - 1400 mm	NIOSH
	Member Weight	≥ SWL (machine) or > 30 kg/manpower	90 - 99% SWL (machine) or 20 - 30 kg/manpower	< 90% SWL (machine) or ≤ 20 kg/manpower	
2.	Beam				
	Lifting hole	None	2 points with 1 hole each	2 points with 1 hole each (web) / 2 points with 2 or 4 holes each (flange)	
	Flange width	< 150 mm	150 - 200 mm	> 200 mm	NIOSH
	Harness hole	None	1 hole for every >1000 mm	1 hole for every 1000 mm	NIOSH
	Splices Location	0.35 - 0.65 L	0.00 - 0.20 L, 0.30 - 0.35 L, 0.65 - 0.70 L, or 0.80 - 1.00 L	0.20 - 0.30 L or 0.70 - 0.80 L	
	Member Weight	≥ SWL (machine) or > 30 kg/manpower	90 - 99% SWL (machine) or 20 - 30 kg/manpower	< 90% SWL (machine) or ≤ 20 kg/manpower	
3.	Rafter				
	Lifting hole	None	1 point with 4 holes (flange)	3 points with 1 hole each (web) / 3 points with 2 holes each (flange)	
	Harness hole	None	1 hole for every 1000 mm - 2000 mm	1 hole for every1000 mm	
	Splices Location	0.35 - 0.65 L	0.00 - 0.20 L, 0.30 - 0.35 L, 0.65 - 0.70 L, or 0.80 - 1.00 L	0.20 - 0.30 L or 0.70 - 0.80 L	
	Member Weight	≥ SWL (machine) or > 30 kg/manpower	90 - 99% SWL (machine) or 20 - 30 kg/manpower	< 90% SWL (machine) or ≤ 20 kg/manpower	

Tabel 2. Design Criteria for Connection

No.	Criteria	Criteria			Source
		Unsuitable	Allowed	Suitable	
4.	Connection				
	End Plate Connection				
	Dummy hole / seats	None	1 dummy hole	1 seat / 2 dummy holes	NIOSH
	Number of bolts each connection (Moment)	1 - 2 bolt(s)	3 bolts in 2 rows or > 4 bolts in 2 rows	4 bolts in 2 rows	
	Number of bolts each connection (shear)	1 bolt	> 2 bolts	2 bolts	
	Double connection	Without Support	1 support (dummy hole or angle plate)	2 supports (dummy hole or angle plate)	NIOSH
	Angle plate connection				
	Dummy hole / seats	None	1 dummy hole	1 seat / 2 dummy holes	NIOSH
	Number of bolts each connection (Moment)	1 - 2 bolt(s)	3 bolts in 2 rows or > 4 bolts in 2 rows	4 bolts in 2 rows	
	Number of bolts each connection (shear)	1 bolt	> 2 bolts	2 bolts	
	Double connection	Without Support	1 support (dummy hole or angle plate)	2 supports (dummy hole or angle plate)	NIOSH
	Hanging connection	Exist	N/A	Not exist	NIOSH

Lifting hole for rafter should be provided at least located on 1 spot with 4 holes each at flange section. But more recommended the lifting hole provided at least at 3 spot with 1 hole each for the web section or 3 spot with 2 or 4 hole each for flange section. The end plate connection or angle connection at least should have 1 dummy hole. But more recommended to provided 1 seats or 2 dummy holes. The purpose of providing dummy hole or seats is to provide a temporary seat for the member while being connected. The end plate connection or angle connection at least have 3 bolts or more than 4 bolt that located in 2 different rows for the moment connection. But more recommended to provide 4 bolt in 2 different rows. The decision of the number bolt is to optimize the number of bolt used so the work duration for the worker in the high elevation could be reduce. The end plate connection or angle connection should have at least more than 2 bolts for the shear connection. But more recommended to provide 2 bolts to optimize the number of bolt used so the work duration for the worker in the high elevation could be reduce. For the double connection, there should be at least a support (dummy hole) for one side of the connection. But more recommended to provide support for both side of the connection in the form of dummy hole or seats. This support is to reduce the falling risk of the member while the member being connected in the state of the bolts has not fastened. The usage of the hanging connection should be avoided because the connection does not have a support that could hold the member if the connection failed.

5. CONCLUSION

The conlclusion of the research are :

1. The prevention step for the work accident should be done earlier in the project, which is in the design phase. By doing a prevention, such as using the design criteria with OHS consideration or the prevention through design, could reduce the work accident risk that could occurred in steel construction project.

2. The design criteria discussing about 5 elements in steel structure including column, beam, rafter, end plate connection and angle plate connection. Each elements has some criteria that should be considered regarding the OHS.

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