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The Unit Price Implication of Reinforcement Usage in Tie Beam Reinforced Concrete Construction

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Abstract – The construction cost as one of the most important project resources should be planned and used efficiently. Cost estimation can be analyzed using standard of unit price analysis according to Indonesian National Standard (SNI 7394:2008). Related to unit price analysis for tie beam reinforced concrete, the standard mentioned a specific analysis that combine all materials requirement include reinforcement (unit price analysis No. 6.29). In such analysis, reinforcement requirement is stated as much as 200 kg/m^3 of concrete. Considering the diversity of dimension design of building structure caused by geographical location and building function, a further study required to response these problems. This research is aimed to provide information to what extent the unit price analysis related to tie beam reinforced concrete can be applied in cost estimating. Research process initiated with secondary data collection to building construction located in zone 10 and 15 based on earthquake zone map (SNI 1726:2012) in Province of Aceh. The results of analysis informed that the ratio of reinforcement requirement of tie beam in zone 10 is 198.03 kg/m^3 to 217.26 kg/m^3 of concrete with average ratio 209.83 kg/m^3. For zone 15, reinforcement requirement ratio is 203.76 kg/m^3 to 233.83 kg/m^3 of concrete with average ratio 215.17 kg/m^3. The potential inaccurate of cost estimation appears in the two review zones. Such inaccuracies may have an impact on the insufficient costs for the work. Thus, the use of the standard unit price analysis needs further assessment for proper application.

Keywords: unit price, construction, building, tie beam, reinforcement usage.

Introduction

The structure components of the building have a very significant portion in a construction cost. According to the Regulation on Ministry of Public Work No. 45/PRT/M/2007, the structural components of the building have a proportion of 25%-35% of total cost. Tie beam as a component in structural components has the important function to transmit vertical loads due to gravitational forces received from the columns and the walls and then spread out evenly to a foundation underneath. In addition, tie beam also received the lateral force in horizontal direction due to the earthquake. The design of those components must consider the zoning of earthquake as regulated in SNI 1726:2012 (Procedures on Earthquake Resistance Planning for Building and Non-Building).

The cost estimation of the building analyzed by several methods. Cost estimation can be analyzed using standard of unit price analysis according to SNI 7394:2008 (Procedures on Unit Price Analysis of Concrete Work for Building Construction and Housing). Specifically, for tie beam of reinforced concrete, there is an analysis that combine all materials requirement include reinforcement. In such analysis, reinforcement requirement is stated as much as 200 kg/m^3 of concrete. The configuration raises some problems such as how much reinforcement need for tie beam in a building based on the function of building and zoning of earthquake.

A number of studies have been conducted by examining issues related to unit price analysis of building (Tas & Yaman, 2005; Mubarak, 2010; Mubarak & Tripoli, 2011; Stoy, Pollalis, &Dursun, 2012; Fachrurrazi *et al.*, 2017). The studies are focused on building unit price modeling using a number of variables. Studies aimed at analyzing reinforcement requirements have also been made, such as for reinforced concrete beam (Tripoli *et al.*, 2017) and reinforced concrete slabs (Tripoli, Nurisra, & Mubarak, 2017). Especially for the components of reinforced concrete tie beams, there are no particular studies

focused on effects of the standard of unit price implementation to the various locations or building functions. Therefore, the research aims to identify the use of reinforcement in tie beam reinforced concrete and the applicable of standard of unit price analysis due to variety of building functions and earthquake zones in Aceh. The scope of the research limited to building projects that have been built since the year 2012 to 2016 in zone 10 and 15 according to the map of earthquake zone.

Materials and Methods

Object and data

The research focus on reinforcement requirement of tie beam in building construction. The secondary data obtained from detail engineering design drawings for building classified as office, residential, and educational building. The objects consist of two and three stories building. The locations of objects studied are located in some districts in Province of Aceh that positioned in zone 10 and 15 according to the map of Indonesian earthquake zone (Figure 1). The distributions of district according to the zone are:

1. Zone 10, covering districts or cities of Lhokseumawe, Aceh Utara, and Langsa;
2. Zone 15, covering districts or cities of Aceh Barat, Aceh Barat Daya, Aceh Besar, Aceh Jaya, Aceh Selatan, Nagan Raya, Banda Aceh, and Subulussalam.

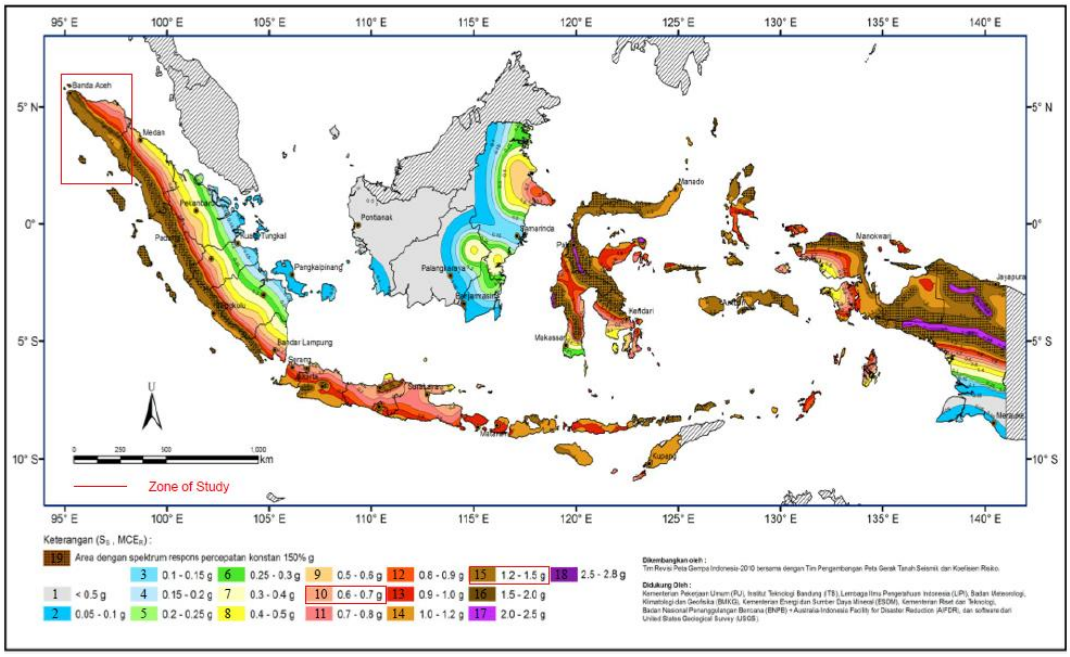

Figure 1. The map of Indonesian earthquake zone

Analysis

The analysis in this research conducted in the stage below:

1. Data Grouping
   The collected data is grouped by the earthquake zone 10 and zone 15. Then data from each the earthquake zone reclassified by function of educational buildings (EDC), residential buildings (RES), and office buildings (OFC).
2. The use of reinforcement
   The use of reinforcement calculated based on detail engineering drawings by identifying the diameter (in cm) and length (in cm) of steel bars from all tie beams in a building. The total length information was then converted to the weight of steel uses (in kg). A dimension sheet form uses to analyze the use of reinforcement.
3. The volume of concrete

The quantity of concrete for tie beams measured as volume in cubic meter. The volume calculated based on detail engineering drawings by identifying the cross-section area and length of all tie beam in a building. The total volume calculated by using a quantity take-off form.

4. The ratio of reinforcement uses for each cubic meter of concrete volume
   The ratio analyzed by divided the reinforcement use and the concrete volume, as stated in the Eq.1 below.

$$Ratio\ of\ reinforcement\ = \frac{reinforcement\ weight}{concrete\ volume} \quad (1)$$

5. Statistical analyses
   Statistical analyses use to provide descriptive information from groups of data in form of average ($\bar{x}$) and standard deviation (σ). The minimum and maximum value are also provided to overview the critical value from sets of data.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (2)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} \quad (3)$$

where, x is all values of data, and i is number of data from 1 to *n*.

Results and Discussion

Actual use of reinforcement

The ratios of reinforcement requirement of tie beam provide information of actual usage of reinforcement for each m^3 of concrete. The analysis conducted to the 21 buildings which are from zone 10 (6 buildings) and zone 15 (15 buildings). The results of calculation of the ratio of reinforcement requirement of tie beam can be seen in Table 1 and Table 2.

Table 1 The ratio of reinforcement usage of tie beam for Zone 10

No	Project Name	Building Function	Concrete Volume (m^3)	Reinforcement Volume (kg)	Reinforcement Use Ratio (kg/ m^3)
1	OFC-1	Office	22.80	4,953.50	217.26
2	OFC-2	Office	18.51	3,665.47	198.03
3	EDC-1	Education	42.94	9,009.32	209.80
4	EDC-2	Education	46.40	9,993.10	215.37
5	RES-1	Residential	24.60	5,099.72	207.31
6	RES-2	Residential	5.69	1,201.34	211.22
				Average ratio	209.83
				Max ratio	217.26
				Min ratio	198.03
				Standard Deviation (STDEV)	6.83

Referring to Table 1 and 2, the reinforcements use for tie beam range in 198.03 to 217.26 kg/m^3 of concrete and 203.76 to 233.83 kg/m^3 of concrete, respectively for Zone 10 and 15. The standard deviations specify the value of 6.83 kg/m^3 of concrete for zone 10 and 10.51 kg/m^3 of concrete for zone 15. This indicates that the higher seismic response spectrums acceleration (Zone 10 = 0.6-0.7*g*; Zone 15 = 1.2-1.5*g*) lead to the greater the amount of reinforcement used in reinforced concrete components. This confirms that the material requirements planning must be based on a zoning where the buildings built, and cannot be based on a certain standard value.

Table 2 The ratio of reinforcement usage of tie beam for Zone 15

No	Project Name	Building Function	Concrete Volume (m^3)	Reinforcement Volume (kg)	Reinforcement Use Ratio (kg/ m^3)
1	EDC-3	Education	15.00	3,110.64	207.38
2	EDC-4	Education	14.86	3,474.71	233.83
3	RES-3	Residential	3.46	796.36	230.16
4	RES-4	Residential	12.04	2,508.81	208.37
5	OFC-3	Office	18.95	4,034.45	212.90
6	EDC-5	Education	8.52	1,858.76	218.16
7	EDC-6	Education	12.40	2,893.49	233.35
8	EDC-7	Education	4.98	1,067.56	214.37
9	OFC-4	Office	10.97	2,234.24	203.76
10	RES-5	Residential	12.50	2,554.88	204.39
11	OFC-5	Office	12.65	2,617.59	206.97
12	OFC-6	Office	55.99	12,332.23	220.27
13	RES-6	Residential	29.63	6,538.98	220.69
14	RES-7	Residential	5.60	1,152.14	205.74
15	RES-8	Residential	21.02	4,356.75	207.24
				Average ratio	215.17
				Max ratio	233.83
				Min ratio	203.76
				Standard Deviation (STDEV)	10.51

The ratio of reinforcement use based on the earthquake zones

According to unit price analysis on SNI 7394:2008 (unit price analysis No. 6.29) for tie beam of reinforce concrete, the standard set reinforcement requirement of 200 kg/m^3 of concrete. The comparison of the projects analysis and the ratio of reinforcement requirement standard for the two earthquake zones provided in Table 3 and Table 4.

Table 3 Comparison of tie beam reinforcement usage for Zone 10

Building No.	Reinforcement Ratio (kg/m^3)	SNI 7394:2008 (kg/m^3)	Deviation (kg/m^3)	Deviation (%)
1	217.26	200	17.26	8.63
2	198.03	200	-1.97	-0.99
3	209.80	200	9.797	4.90
4	215.37	200	15.37	7.68
5	207.31	200	7.306	3.65
6	211.22	200	11.22	5.61
Average	209.83	200	9.83	4.92

Reviewing the information in Table 3 and Table 4, the results of the data analysis for earthquake zones indicates that the average reinforcement ratio of 209.83 kg/m^3 of concrete (Zone 10) and 215.17 kg/m^3 of concrete (zone 15) are above the requirement value stated on standard of unit price analysis (200 kg/m^3). The consequences of using the standard analysis were the non-fulfillment of the actual amount of reinforcement needs. On the other words, the estimation will not accurate for applied in the estimation for both earthquake zones. Potential inaccurate of estimation could be defined by considering the percentage of deviations. For Zone 10 and Zone 15, the potential of additional reinforcements are 4.92% and 7.59% in average respectively. It denotes insufficient opportunities of reinforcement volume if the unit price

analysis used. A further consequence is the emergence of a potential increase in the cost to cover the shortfall that emerged in the analysis of the reinforced concrete tie beam.

Table 4. Comparison of tie beam reinforcement usage for Zone 15

Building No.	Reinforcement Ratio (kg/m³)	SNI 7394:2008 (kg/m³)	Deviation (kg/m³)	Deviation (%)
1	207.38	200	7.38	3.69
2	233.83	200	33.83	16.91
3	230.16	200	30.16	15.08
4	208.37	200	8.37	4.19
5	212.90	200	12.90	6.45
6	218.16	200	18.16	9.08
7	233.35	200	33.35	16.67
8	214.37	200	14.37	7.18
9	203.76	200	3.76	1.88
10	204.39	200	4.39	2.20
11	206.97	200	6.96	3.48
12	220.27	200	20.27	10.14
13	220.69	200	20.69	10.34
14	205.74	200	5.74	2.87
15	207.24	200	7.24	3.62
Average	215.17	200	15.17	7.59

The ratio of reinforcement use based on the building function

Related to the data collected, the functional utilization of buildings classified into 3 (three) types of buildings, namely education, office, and residential. The classification refers to the SNI 1727:2013 about the minimum load for the design of buildings and other structures (Fig. 2 and Table 5).

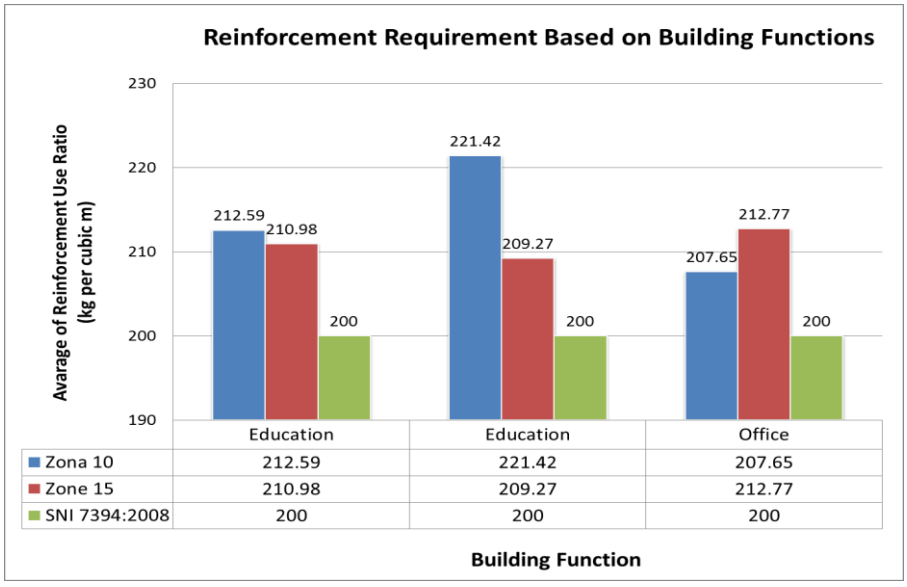

Figure 2. Reinforcement based on the function of the building

Figure 2 illustrates the use of reinforcement has a similar trend at 3 classifications of the building functions. The values of reinforcement use ratio are above 200 kg/m^3 for both buildings in Zone 10 and Zone 15. The highest value usage ratio arises in educational buildings, followed by residential buildings and offices. The deviation characteristics for those functions provide in Table 5.

Table 5 The deviation of reinforcement usage based on building functions

Building Function	Earthquake Zone	Average Deviation (kg/m^3)	Average Deviation (%)
Education	Zone 10	12.59	6.29
	Zone 15	21.42	10.71
Residential	Zone 10	7.64	3.82
	Zone 15	10.98	5.49
Office	Zone 10	9.26	4.63
	Zone 15	12.77	6.38

The building for educational function has the highest average deviation comparing to the standard of unit price analysis of tie beam reinforced concrete. The value reaches 6.29% for zone 10 and 10.71% for Zone 15. By focused to the conditions, in terms of cost analysis of tie beam reinforced concrete work on educational buildings, the estimation has the highest potential risks of inaccurate when compared to buildings with two other functions.

The Implication of Additional Cost

Implies of additional cost to be consequences while reinforcement use increases and otherwise. Referring to the zones or building functions analyzed, all confirmed the tendency of the reinforcement use above of the requirement standard value. The amount of increase based on zoning and building functions are presented in Table 6 and 7.

Table 6. Potential of additional cost based on zones

	Reinforcement (kg/m^3)	Unit Price per m^3 of Tie Beam Reinforced Concrete (IDR)	Deviation to SNI 7394:2008	
			(IDR)	(%)
SNI 7394:2008	200.00	5,591,751	-	-
Zone 10	209.83	5,748,638	156,887	2.81
Zone 15	215.17	5,833,864	242,113	4.33

Table 7 Potential of additional cost based on building functions

Zone	Building Function	Reinforcement (kg/m^3)	Unit Price per m^3 of Tie Beam Reinforced Concrete (IDR)	Deviation to SNI 7394:2008	
				(IDR)	(%)
10	Education	212.59	5,792,687	200,936	3.59
	Residential	209.27	5,739,700	147,949	2.65
	Office	207.65	5,713,845	122,094	2.18
15	Education	221.42	5,933,614	341,863	6.11
	Residential	212.77	5,795,560	203,809	3.64
	Office	210.98	5,766,992	175,241	3.13

Based on the assessment zone, the results of the analysis show that the biggest potential cost addition occurred in the Zone 15, which is 4.33% when compared to the unit price of SNI 7394: 2008. The percentage means that for every m^3 tie beam reinforced concrete, the use of standard unit price will give the consequence of budget shortfall of IDR. 242,113 of the actual conditions. This condition is a

direct impact of the increasing use of reinforcement to accommodate the earthquake load in those zones. When assessed by building function, the biggest potential cost addition occurred in educational buildings. The condition has the same tendency in Zone 10 (3.59%) and Zone 15 (6.11%). The deviation for the function is seen to be almost double when compared to the other two building functions. Thus, the reinforcing requirement pattern established in the standard is not feasible to be used in the estimated cost of buildings constructed in areas with 0.6-0.7*g* (Zone 10) of seismic response spectrums acceleration as shown in Fig. 1 and zones with larger response values. Standard applications in zones with seismic response spectrums acceleration below those values still require further review to ensure proper use of the standard.

Conclusions

1. The actual use of reinforcement of tie beam reinforced concrete earthquake range in 198.03 to 217.26 kg/m^3 of concrete for Zone 10 and 203.76 to 233.83 kg/m^3 of concrete for Zone 15. This indicates that the higher seismic response spectrums acceleration lead to the greater the amount of reinforcement used in reinforced concrete components. This confirms that the material requirements planning must be based on a zoning where the buildings built, and cannot be based on a certain standard value.
2. The average of reinforcement ratios are 209.83 kg/m^3 of concrete for Zone 10 and 215.17 kg/m^3 of concrete for Zone 15. Those ratios are both above the requirement value mentioned on standard of unit price analysis (200 kg/m^3). Potential inaccurate of estimation could be defined as 4.92% for Zone 10 and 7.59% for Zone 15.
3. The reinforcement uses for three building function (educational, residential, and office) observed indicated the similar tendency. The reinforcement ratios for the three functions are above 200 kg/m^3 for both zones. The highest value usage ratio arises in educational buildings (EDC), followed by residential buildings (RES) and offices (OFC).
4. The reinforcing requirement pattern established in the standard is not feasible to be used in the estimated cost of buildings constructed in area of Zone 10 and above. The application of standard will result the shortfall of budget for the work. It need further evaluation and review while the standard planned to apply in zones with seismic response spectrums acceleration below the previous values observed.

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