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Analysis of Strength, Stiffness, and Stability The Formwork Construction in LRT Jabodebek Project

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Abstrak

The Upper Longitudinal Beam casting on the Jabodebek LRT Project requires a shoring to be able to withstand the workloads. To avoid the failure of formwork construction, formwork must meet the strength, stiffness, and stability requirements for each formwork component material. The analysis is carried out on the value of bending stress, deflection, and shear that occur in each component of formwork. From the analysis carried out each obtained as follows. Strength requirements with flexural stress values that occur in Plywood, Girder GT 24, and Steel Waller SRZ materials, each of which is smaller than σ permit = 100 kg / cm2, 70000 kg / cm2, and 1200 kg / cm2. Stiffness requirements with deflection values that occur on Plywood and Girder GT 24 material are Δ permit = l / 400. Whereas the SRZ Steel Waller fulfills Δ permit = l / 240. Stability requirements with shear stress values that occur in Plywood, Girder GT 24, and Steel Waller SRZ materials, each of which is smaller than τ permit = 12 kg / cm2, 1400 kg / cm2, and 696 kg / cm2. Peri Up Shoring can support all formwork loads. So it can be said that the construction of the Upper Longitudinal Beam formwork is in a safe condition.
Keywords: Formwork, Bending Stress, Deflection, Shear Stress

1. Introduction

In the construction of concrete work, there area three main components that must be completed carefully and will succeed in the structural work. The three components are concrete mixture, concrete reinforcement and formwork.

Formwork is a temporary mold that is used to hold concrete as long as the concrete is poured and shaped in accordance with the desired shape. Because it functions as a temporary mold, formwork will be removed or dismantled if the concrete that has been poured has reached sufficient strength. To avoid formwork failures due to working loads and other factors, a formwork construction must meet the strength, stiffness and stability requirements. Formwork is said to be strong if when receiving loads - the workloads formwork material is not broken. The strength of formwork becomes a major component in producing quality structural dimensions that are in accordance with the plan. Formwork is said to be rigid, when when receiving loads - loads that work formwork material does not change shape. Formwork must also be stable, so that when receiving the formwork load does not collapse. This requirement must be met considering that formwork is work that is carried out repeatedly in high rise buildings and requires a large fee for rental costs and make it.

The construction of Light Rail Tansit Infrastructure Project is implemented by PT. Adhi Karya (Persero) Tbk. Formwork construction that is used for casting Transversal Beam and Lower Longitudinal Beam at Cawang Station is a steel profile structure fabricated by PT. Adhi Karya subcontractor's according to the needs of construction in the field. The construction process of the steel scaffolding construction requires lifting equipment such as a crawler / mobile crane. The steel formwork construction cannot be used for the construction of the Upper Longitudinal Beam because there is no wiggle room for the crane when assembling the steel scaffolding construction if the floor plate on the Concourse Level has been casted. Longitudinal Beam elevation is ± 4,588 to the Concourse Level floor plate. So we need a formwork scaffolding system to withstand the forces that emerge when the Longitudinal Beam casting takes place. So this research aims to analyze the strength of the formwork structure against the flexural stress, deflection and shear stress of the material permits used so that it can be ensured that the formwork construction is safe.

2. Literatur Review

According to Amien Sajekti (2009) quoted by Doloksaribu (2018), that formwork is a temporary mold for fresh concrete and as a support is used scaffolding (shore). [3]

According to Asiyanto (2010) quoted by Fitriansyah (2018), Formwork is a tool of concrete structures, for molding concrete into the desired shape, size, and controlling its position and alignment. [5]

Reference and scaffolding or formwork or formwork is a temporary construction in the form of a mall / mold on both the upper and lower sides of the desired concrete shape. Formwork functions as desired construction, while Scaffolding serves as a helper strengthening the form of construction.

According to Wigbout (1997), formwork construction works perform 5 functions, namely: [4]

1. Formwork determines the shape of the concrete construction to be made. The simple form of a concrete construction requires a simple formwork.
2. Formwork must be able to safely absorb the load caused by concrete species and various external loads and vibrations. In this case the change in shape that arises and the friction can be allowed as long as it does not exceed these tolerances.
3. Formwork must be able to be simply installed, removed and moved.
4. Preventing loss of wetness from new concrete.
5. Provides thermal insulation.

In planning a formwork, the following data are needed:

1. Concrete Self Weight (q) = Volume x Concrete Specific Gravity
   Reinforcement Concrete Self Weight q = 2400 Kg/m^3 = 24 kN/m^3
   Wet concrete specific gravity q = 2500 Kg/m^3 =25 kN/m^3
2. Live Load
   q = 250 Kg/m^2 = 2500 N/m^2
   Live load consist of the weight of workers, tools and belisting materials, vibrators, buckets, cast pipes and wheelbarrows.
3. Shock Load
   q = 100 Kg/m^2 = 1000 N/m^2
   Shock load is the load that occurs due to concrete work that is jerking at the time of pouring and vibration by the vibrator during compaction.

Calculation Formula

According to F.Wigbout Ing. (1997), for each situation in casting, the flexure in a field can be calculated using the following formula: Simplified formula by oleh F.Wigbout (1997) In his book entitled "*Bekisting (Kotak Cetak) Hal.133*" published by Erlangga. [4]

Correction of M.Max, D.Max & Deflection

$$\sigma Max = \frac{M.Max}{W}$$

$$\tau Max = \frac{D.Max \times S}{I \times b}$$

$$\Delta Max = \frac{5 \times w \times l^4}{384 \times E \times I}$$

Explanation :

- M.Max = Moment Maximum (kg.cm)
- D.Max = Displacement Makximum (kg)
- σ.Max = Bending Stress Maximum (kg/cm2)
- τ.Max = Shear Stress Maximum (kg/cm2)
- Δ.Max = Deflection Maximum (mm)
- W = Momen Resistance (cm3)
- S = Axis Distance (cm)
- I = Moment Inersia (cm4)
- A = Cross-sectional Area (cm2)
- b = Width (cm)
- h = Height (cm)

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- w = Weight (kg/m)
- E = Modulus Elasticity (kg/cm2)
- l = Cross Section Length (cm)

3. Research Methodology

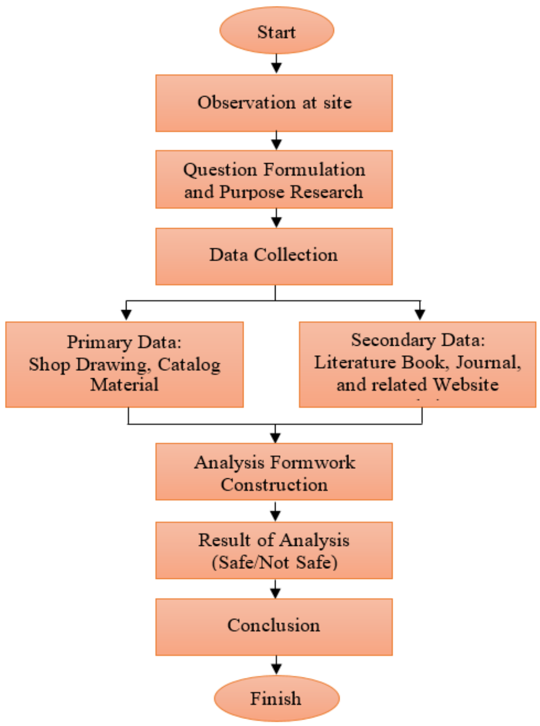

Figure 1. Flow Chart Research Method
(Source: Author, 2020)

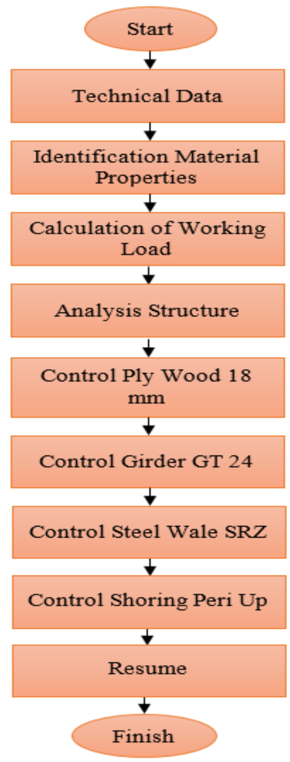

Figure 2. Flow Chart Analysis
(Source: Author, 2020)

Planning of a formwork shoring on the beam must of course take into account its strength, stiffness, and stability. In order to guarantee the achievement of strength, rigidity, and stability of formwork construction, it must be designed as a general structural design. Following is the flowchart methodology used in the completion of this Research.

4. Results and Discussion

IV.1. Data Dimention Upper Longitudinal Beam

Refer to Shop Drawing (LRT-CV-ST-DW-L2-TRLV-01 sd 47) getting form PT. Adhi Karya as a main contractor on Light Rail Transit JABODEBEK that is known the Upper Longitudinal Beam beam dimension data shown in Figure 3 and Table 1 below.

From the dimensional data in Figure 3 and Table 1, the calculation of shoring can be grouped because it has the same dimensions.

1. Block sizes 900x1000, namely: B1, B1R, B2, B3, B3L, B4, B4L, B5, B5L, B6, B6A, and B8L
2. Block Size 600 x1200, namely: B10
3. Block Size 800 x 1300, namely: B11

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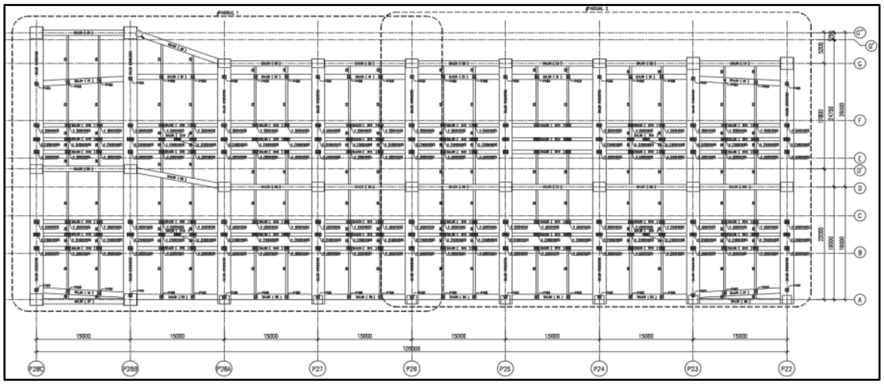

Figure 3. Site Plan Beam at *Platform Level*
(Source. : Data LRT Cawang BNN Station,2019)

Table 1. Dimention Upper Longitudinal Beam

Name of Beam	Dimention (mm)	Length (mm)		Name of Beam	Dimention (mm)	Length (mm)
B1	900 x 1000	12850		B5L	900 x 1000	12800
B1R	900 x 1000	12850		B6	900 x 1000	12850
B2	900 x 1000	13856		B6A	900 x 1000	12850
B3	900 x 1000	12850		B8L	900 x 1000	12850
B3L	900 x 1000	12850		B10	600 x 1200	12850
B4	900 x 1000	12850		B11	800 x 1300	12850
B4L	900 x 1000	12850				
B5	900 x 1000	12850				

(Sorce : Author, 2020)

*IV.2 Shoring Calculation for Beam 900*1000 mm*

IV.2.1 Section Drawing

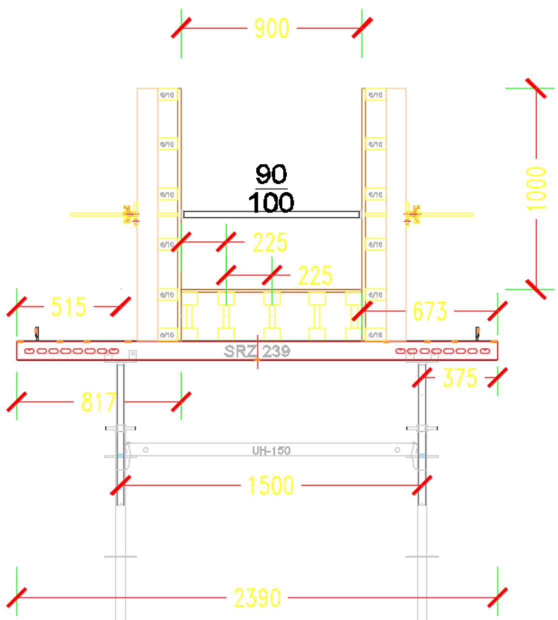

Figure 4. *Upper Longitudinal Beam 900x1000 mm*
(Source : Author, 2020)

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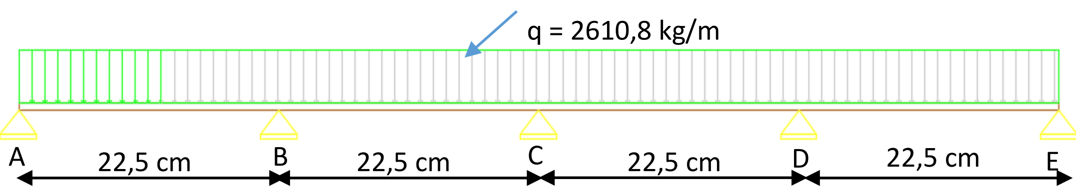
IV.2.2 Structural Analysis

IV.2.2.1 Control Ply Wood 18 mm

Load to be used :

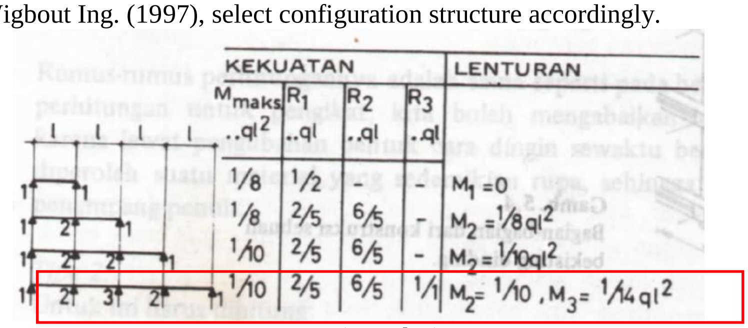
Concrete Load = 2500 kg/m^2 x 1 m x 0,9 m = 2250 kg/m
Live Load = 250 kg/m^2 x 1 m = 250 kg/m
Shock Load = 100 kg/m2 x 1 = 100 kg/m
Selfweight of Plywood = 600 kg/m^3 x 0,018 x 1 m = 10,8 kg/m
Total = 2610,8 kg/m

➢ Modeling Load



➢ M.Max

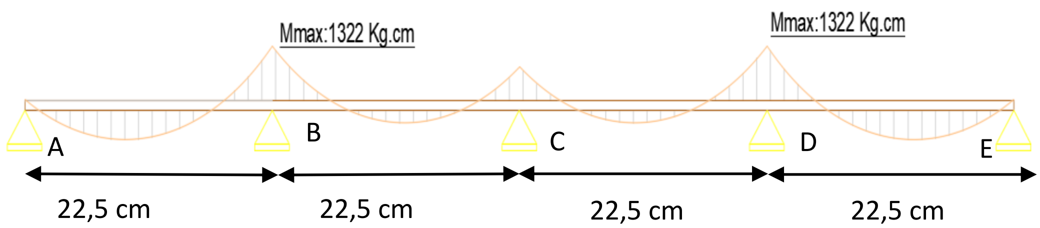
According to F.Wigbout Ing. (1997), select configuration structure accordingly.



	KEKUATAN				LENTURAN
	M_{maks} ..ql^2	R_1 ..ql	R_2 ..ql	R_3 ..ql	
1 1	1/8	1/2	-	-	$M_1 = 0$
1 2 1	1/8	2/5	6/5	-	$M_2 = 1/8\,ql^2$
1 2 2 1	1/10	2/5	6/5	-	$M_2 = 1/10\,ql^2$
1 2 3 2 1	1/10	2/5	6/5	1/1	$M_2 = 1/10$, $M_3 = 1/14\,ql^2$

The moment maximum occurs in joint area no. 2 (B and C)

M Max = 1/10 x q x l^2
= 1/10 x 2610,8 x 0,225^2
= 12,711 kg.m ~ 1271,1 kg.cm



➢ D.Max

D Max occurs in joint B and D :

D Max = 6/5 x q x l
= 6/5 x 2610,8 x 0,225
= 704,916 kg

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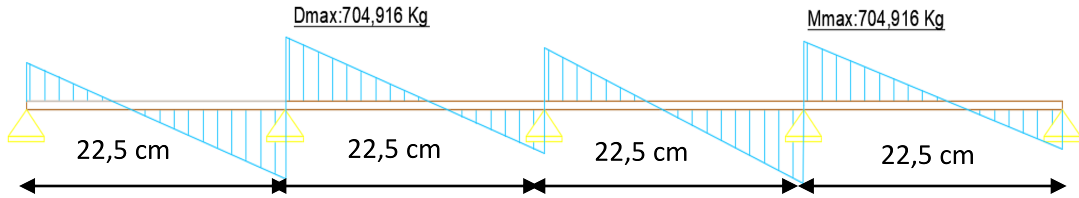
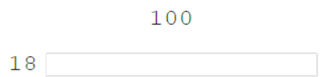


- Correction of M.Max, D.Max & Deflection
  Properties Plywood 18 mm



b	=	100	cm
Ax	=	180	cm^2
Ix	=	48.6	cm^4
Wx	=	54	cm^3
Sx	=	40.5	cm^3
Δ max	=	L/400	
E	=	100,000	kg/cm^2
σ ijin	=	100	kg/cm^2
τ ijin	=	12	kg/cm^2

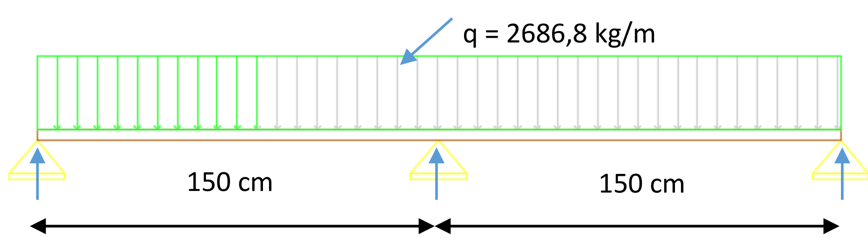
1) $\sigma Max = \frac{M.Max}{W} = \frac{1271}{54} = 23{,}537\ kg/\ cm^2$
   : 23,537 kg/cm^2 < σ_{ijin} =100 kg/cm^2 ......(OK)
2) $\tau Max = \frac{D.Max \times S}{I \times b} = \frac{704{,}916 \times 40{,}5}{48{,}6 \times 100} = 5{,}874\ kg/\ cm^2$
   : 5,874 kg/cm^2 < τ_{ijin} 12 kg/cm^2 ......(OK)
3) $\Delta Max = \frac{5 \times w \times l^4}{384 \times E \times I} = \frac{5 \times 26{,}022 \times 22{,}5^4}{384 \times 100000 \times 48{,}6} = 0{,}018\ cm$
   : 0,018 cm < Δ_{ijin} = l/400 = 0,0562 cm ....(OK)

IV.2.2.2 *Control Girder GT 24*

Load to be used :

Concrete Load = 2500 kg/m^2 x 1 m x 0,9 m	= 2250 kg/m
Live Load = 250 kg/m^2 x 1 m	= 250 kg/m
Shock Load = 100 kg/m2 x 1	= 100 kg/m
Selfweight of Plywood = 600 kg/m^3 x 0,018 x 1 m	= 10,8 kg/m
Bekisting Samping 70 kg/m2	= 70 kg/m
Selfweight of Girder GT 24	= 6 kg/m
Total	= 2686,8 kg/m

- Modeling Load



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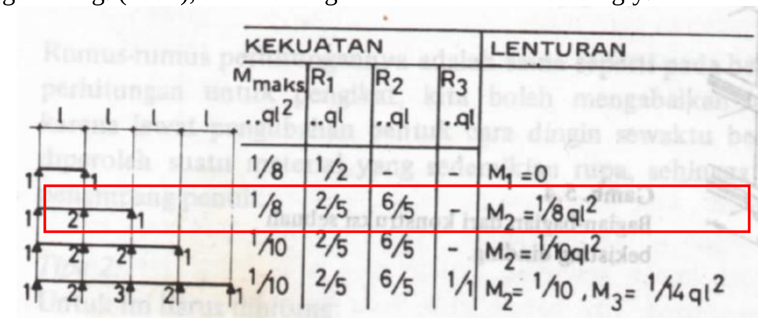
- M.Max

According to F.Wigbout Ing. (1997), select configuration structure accordingly.



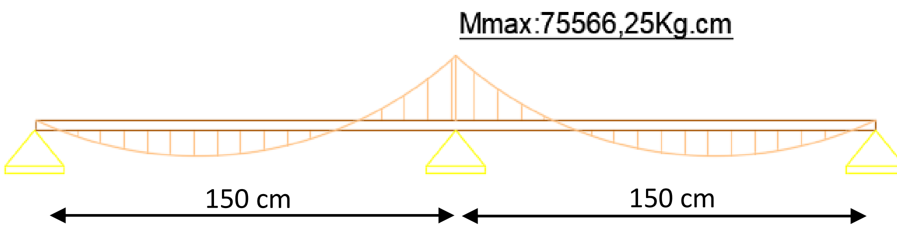
	KEKUATAN				LENTURAN
	M_{maks} ..ql^2	R_1 ..ql	R_2 ..ql	R_3 ..ql	
1 – 1	1/8	1/2	-	-	$M_1 = 0$
1 – 2 – 1	1/8	2/5	6/5	-	$M_2 = 1/8\,ql^2$
1 – 2 – 2 – 1	1/10	2/5	6/5	-	$M_2 = 1/10\,ql^2$
1 – 2 – 3 – 2 – 1	1/10	2/5	6/5	1/1	$M_2 = 1/10$, $M_3 = 1/14\,ql^2$

The moment maximum occurs in joint area no. 2 (Middle Joint)

M Max $= 1/8 \times q \times l^2$

$= 1/8 \times 2686{,}8 \times 1{,}5^2$

$= 755{,}662$ kg.m ~ 75566,25 kg.cm

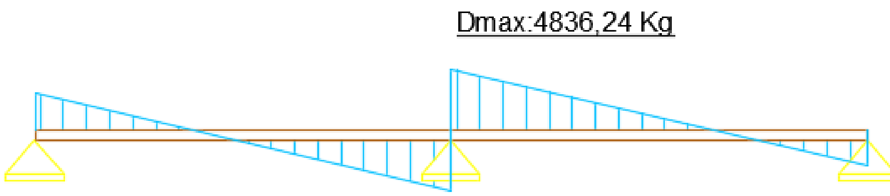


- D.Max

D Max $= 6/5 \times q \times l$

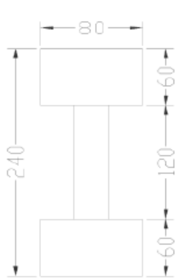
$= 6/5 \times 2686{,}8 \times 1{,}5$

$= 4836{,}24$ kg



- Correction of M.Max, D.Max & Deflection

Properties Girder GT 24



b	=	8	cm
Ax	=	96	cm^2
Ix	=	8000	cm^4
Wx	=	700	cm^3
Sx	=	525	cm^3
Δ max	=	L/400	
E	=	100,000	kg/cm^2
Mmax	=	70000	kg.cm
Dmax	=	1400	kg

1) $\sigma Max = \frac{M.Max}{W} = \frac{75566,25}{700} = 107,951\ kg/\ cm^2$
: 107,951 kg/cm^2 < σ ijin 70000 kg/cm^2 ....(OK)

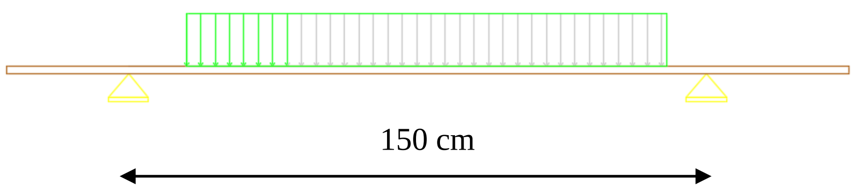
2) $\tau Max = \frac{D.Max\ x\ S}{I\ x\ b} = \frac{4836,24\ x\ 525}{8000\ x\ 8} = 39,672\ kg/\ cm^2$
: 39,672 kg/cm^2 < τ ijin 1400 kg/cm^2 ....(OK)

3) $\Delta Max = \frac{5\ x\ w\ x\ l^4}{384\ x\ E\ x\ I} = \frac{5\ x\ 26,082\ x\ 1,5^4}{384\ x\ 100000\ x\ 8000} = 0,0001\ cm$
: 0,0001 cm < Δ ijin = l/400 = 0,375 cm ....(OK)

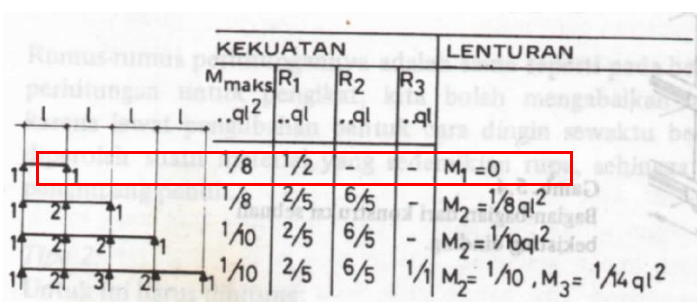
IV.2.2.3 Control Steel Wale SRZ

Load to be used :
Concrete Load = 2500 kg/m^2 x 1 m x 0,9 m = 2250 kg/m
Live Load = 250 kg/m^2 x 1 m = 250 kg/m
Shock Load = 100 kg/m2 x 1 = 100 kg/m
Selfweight of Plywood = 600 kg/m^3 x 0,018 x 1 m = 10,8 kg/m
Side Formwork 70 kg/m2 = 70 kg/m
Selfweight of Girder GT 24 = 6 kg/m
Selfweight of Steel Wale = 19,08 kg/m
Total = 2705,88 kg/m

➢ Modelling Load

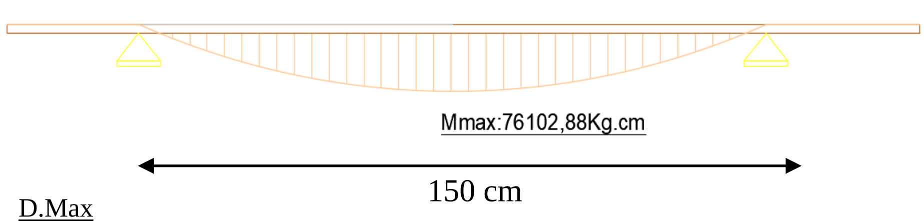


➢ M.Max



KEKUATAN				LENTURAN
M_{maks} ..ql^2	R_1 ..ql	R_2 ..ql	R_3 ..ql	
1/8	1/2	-	-	$M_1 = 0$
1/8	2/5	6/5	-	$M_2 = 1/8\ ql^2$
1/10	2/5	6/5	-	$M_2 = 1/10\ ql^2$
1/10	2/5	6/5	1/1	$M_2 = 1/10$, $M_3 = 1/14\ ql^2$

The moment maximum occurs in 1/8 x q x l^2
M Max = 1/8 x q x l^2
= 1/8 x 2705,88 x 1,5^2
= 761,029 kg.m ~ 76102,88 kg.cm



➢ D.Max
D Max = 1/2 x q x l
= 1/2 x 2705,88 x 1,5
= 2029,41 kg

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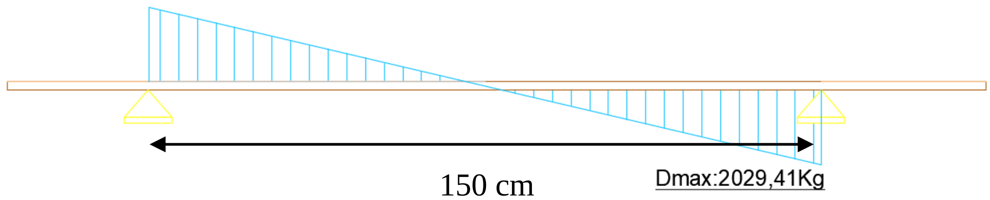
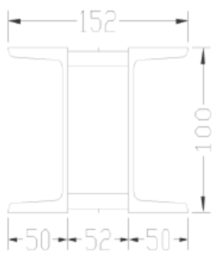


- Correction of M.Max, D.Max & Deflection
  Properties Steel Waller



b	=	1	cm
Ax	=	23	cm^2
Ix	=	372	cm^4
Wx	=	74.38	cm^3
Sx	=	43.38	cm^3
Δ max	=	L/240	
E	=	2,100,000	kg/cm^2
σ ijin	=	1200	kg/cm^2
τ ijin	=	696	kg/cm^2

1) $\sigma Max = \frac{M.Max}{W} = \frac{76102,88}{74,38} = 1023,163\ kg/\ cm^2$

: $1023,163\ kg/cm^2 < \sigma_{ijin}\ 1200\ kg/cm^2$ ....(OK)

2) $\tau Max = \frac{D.Max\ x\ S}{I\ x\ b} = \frac{2029,41\ x\ 43,38}{372\ x\ 1} = 236,607\ kg/\ cm^2$

: $236,607\ kg/cm^2 < \tau_{ijin}\ 696\ kg/cm^2$ ....(OK)

3) $\Delta Max = \frac{5\ x\ w\ x\ l^4}{384\ x\ E\ x\ I} = \frac{5\ x\ 26,142\ x\ 1,5^4}{384\ x\ 2100000\ x\ 372} = 0,0001\ cm$

: $0,0001\ cm < \Delta_{ijin} = l/240 = 0,625\ cm$ ....(OK)

IV.2.2.4 Control Shoring

Load to be used :

Concrete Load = 2500 kg/m^2 x 1 m x 0,9 m	= 2250 kg/m
Live Load = 250 kg/m^2 x 1 m	= 250 kg/m
Shock Load = 100 kg/m2 x 1	= 100 kg/m
Selfweight of Plywood = 600 kg/m^3 x 0,018 x 1 m	= 10,8 kg/m
Side Formwork 70 kg/m2	= 70 kg/m
Selfweight of Girder GT 24	= 6 kg/m
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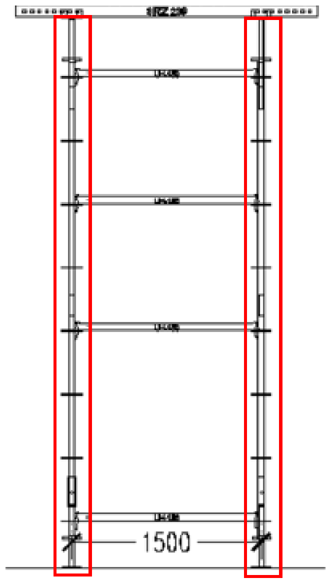

Calculation formula for 1 span :

D Max = 1/2 x q x l
= 1/2 x 2705,88 x 1,5
= 2029,41 kg < P_{ijin} = 4000 kg ....(OK)

IV.2.3 Resume Control Stress, Strain, and Deflection

The static calculation of the formwork shoring structure above, it can be concluded in Table 2 :

Table 2. Resume Control Stress, Strain, and Deflection Shoring for Beam 90*100 cm

Item	Control Value					Unit	Status
Plywood 18 mm	σ_{maks} =	23,537	<	σ_{ijin} =	100	kg/cm^2	OK
	τ_{maks} =	5,874	<	τ_{ijin} =	12	kg/cm^2	OK
	Δ_{maks} =	0,018	<	Δ_{ijin} =	0,0562	cm	OK
Girder GT 24	σ_{maks} =	107,951	<	σ_{ijin} =	70000	kg/cm^2	OK
	τ_{maks} =	39,672	<	τ_{ijin} =	1400	kg/cm^2	OK
	Δ_{maks} =	0,0001	<	Δ_{ijin} =	0,375	cm	OK
Steel Wale SRZ	σ_{maks} =	1023,163	<	σ_{ijin} =	1200	kg/cm^2	OK
	τ_{maks} =	236,607	<	τ_{ijin} =	696	kg/cm^2	OK
	Δ_{maks} =	0,0001	<	Δ_{ijin} =	0,625	cm	OK
Shoring	P_{maks} =	2029,41	<	P_{ijin} =	4000	kg	OK

(Source :Author, 2020)

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IV.3 *Shoring Calculation for Beam 600*1200 mm*

IV.3.1 Section Drawing

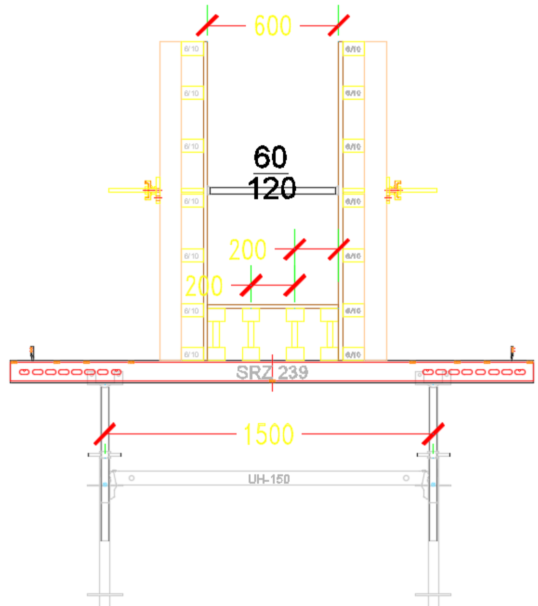

Figure 5. *Upper Longitudinal Beam 600x1200 mm*
(Source : Author, 2020)

IV.3.2 Resume Control Stress, Strain, and Deflection

The static calculation of the formwork shoring structure above, it can be concluded in Table 3 :

Table 3. Resume Control of Stress, Strain, and Deflection Shoring for Beam 60*120 cm

Item	Control Value					Unit	Status
Plywood 18 mm	σ_{maks} =	16	<	σ_{ijin} =	100	kg/cm^2	OK
	τ_{maks} =	4,322	<	τ_{ijin} =	12	kg/cm^2	OK
	Δ_{maks} =	0,011	<	Δ_{ijin} =	0,0562	cm	OK
Girder GT 24	σ_{maks} =	932	<	σ_{ijin} =	70000	kg/cm^2	OK
	τ_{maks} =	33,552	<	τ_{ijin} =	1400	kg/cm^2	OK
	Δ_{maks} =	0,021	<	Δ_{ijin} =	0,375	cm	OK
Steel Wale SRZ	σ_{maks} =	853	<	σ_{ijin} =	1200	kg/cm^2	OK
	τ_{maks} =	197,298	<	τ_{ijin} =	696	kg/cm^2	OK
	Δ_{maks} =	0,001	<	Δ_{ijin} =	0,625	cm	OK
Shoring	P_{maks} =	1691,91	<	P_{ijin} =	4000	kg	OK

(Source :Author, 2020)

*IV.4 Calculation Shoring for Beam 800*1300 mm*

IV.4.1 Section Drawing

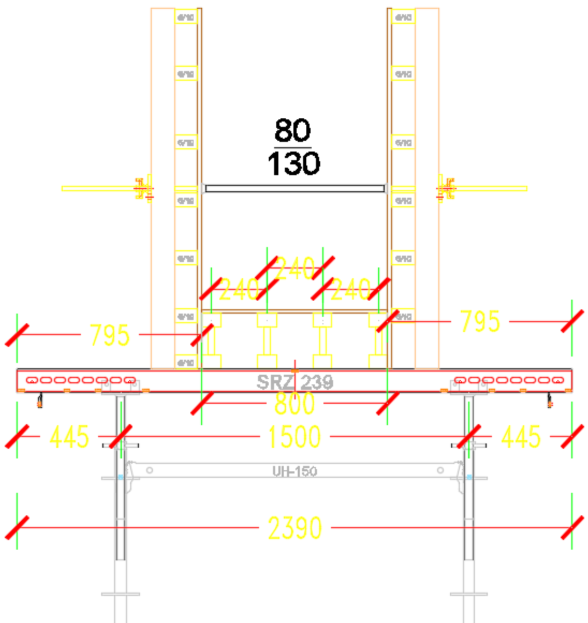

Figure 6. *Upper Longitudinal Beam 800x1300 mm*
(Source : Author, 2020)

IV.4.2 Resume Control Stress, Strain, and Deflection

The static calculation of the formwork shoring structure above, it can be concluded in Table 4. :

Table 4. Resume Control Stress, Strain, and Deflection Shoring for Casting Beam 80*130 cm

Item	Control Value					Unit	Status
Plywood 18 mm	σ_{maks} =	31,58	<	σ_{ijin} =	100	kg/cm^2	OK
	τ_{maks} =	7,106	<	τ_{ijin} =	12	kg/cm^2	OK
	Δ_{maks} =	0,023	<	Δ_{ijin} =	0,0562	cm	OK
Girder GT 24	σ_{maks} =	122	<	σ_{ijin} =	70000	kg/cm^2	OK
	τ_{maks} =	44,84	<	τ_{ijin} =	1400	kg/cm^2	OK
	Δ_{maks} =	0,021	<	Δ_{ijin} =	0,375	cm	OK
Steel Wale SRZ	σ_{maks} =	1155,507	<	σ_{ijin} =	1200	kg/cm^2	OK
	τ_{maks} =	267,266	<	τ_{ijin} =	696	kg/cm^2	OK
	Δ_{maks} =	0,001	<	Δ_{ijin} =	0,625	cm	OK
Shoring	P_{maks} =	2291,91	<	P_{ijin} =	4000	kg	OK

(Source :Author, 2020)

5. Conclusion

Based on the analysis and recapitulation of the value of bending stress, deflection and shear stress in the beam formwork components of the Upper Longitudinal Beam:

a) Upper Longitudinal Beam formwork fulfills strength requirements with flexural stress values that occur on Plywood, Girder GT 24, and Steel Waller SRZ materials, each of which is smaller than σ permit = 100 kg / cm^2, 70000 kg / cm^2, and 1200 kg / cm^2.

b) Upper Longitudinal Beam formwork meets the requirements of stiffness with deflection value occurring on Plywood and Girder GT 24 material is jin permit = l / 400. Whereas the SRZ Steel Waller fulfills Δ permit = l / 240.

c) Upper Longitudinal Beam formwork fulfills the stability requirements with shear stress values that occur in Plywood, Girder GT 24, and SRZ Steel Waller materials, each of which is smaller than τ permit = 12 kg / cm^2, 1400 kg / cm^2, and 696 kg / cm^2.

d) Peri Up Scaffolding / Shoring is able to support the entire formwork of Upper Longitudinal Beam Size 90x100 cm, 60x120, and 80x130 with the respective values P max = 2029.41 kg, P max = 1691.91 kg, and P max = 2291.91 kg. Where the 1 foot shoring capacity is able to withstand a permit load of P = 4000 kg.

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