Odua Weston Jambi Hotel's Structural Building Design with Prestressed Concrete Slab System Approach

R Bayuaji [1], M S Darmawan[1], M A Rofiq[1], S E Santoso[1] and E Hardiyanto[1]

[1]Department of Civil Infrastructure Engineering Institut Teknologi Sepuluh Nopember Indonesia

E-mail: bayuaji@ce.its.ac.id

Abstract. Odua Weston Jambi Hotel is an eight-floor hotel and located in a prone to earth-quake area. This building used conventional concrete to its structural beam and column. This research's purpose was to maximize the second-floor's function by modifing its architectural design. *Special Moment Resisting Frame System (SMRFS) approach* was used in the structural design, referred to SNI 03-2847-2013 dan SNI 1726-2012 and to compensate the needs of a spacious hall without any column in the centre of the hall, so therefore, prestressed concrete plate is used to solve this problem.

1. Introduction

Odua Weston Jambi Hotel is an eight floor building with conventional and structural concrete building with the height of 35.3 meter tall excluded the basement. Based on a review, this building used reinforced concrete applied to its beam and column. In order to maximize its space function, a modification was planned by designing a non-column hall at the second floor, which is used for meeting room. To compensate that design, prestressed concrete slab is applied because it can resist a bigger deflection.

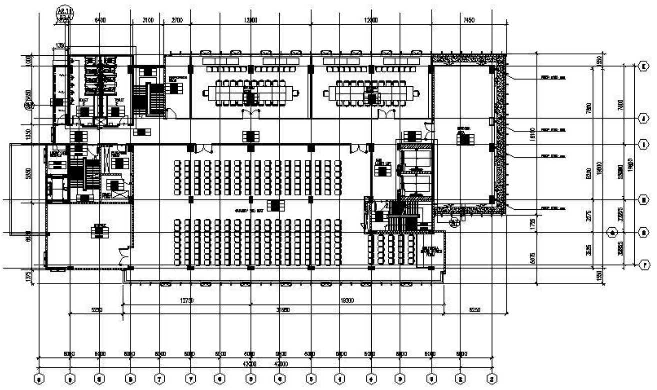

Figure 1. Odua Weston Jambi Hotel's second floor.

Figure 1 shows column segments at Odua Weston Jambi Hotel's Second Floor. To maximize its floor space function, H5, H6, H7 column would be eliminated. This structural building modification

IOP Conf. Series: Materials Science and Engineering **267** (2017) 012021 doi:10.1088/1757-899X/267/1/012021

are being planned to use conventional and structural concrete and prestressed concrete plate with the area of 24 meter × 12 meter landscape constructed at third floor and 5,2 meter x 24 meter plate constructed from fourth floor to eight floor.

2. Methodology

The installation of prestressed concrete plate are as follows:

2.1 Section Design

Post-tensioned prestressed concrete was choosen in this design because, if prestressed concrete construction is too wide and the structural component is long and heavy, it must be best casted locally or casted part-by-part, and it should be prestressed with postension system, otherwise pre-tensioned concrete is unecconomical (Lin and Burns, 1996). For prestressed concrete design, groating is choosed to be created because of its steel-concrete mixture and to increase prestressed loss. This design used partial prestressed component which allow tensile stress towards its working load, and in the pre-tensioned areas, additional reinforcement is used to be added to non prestressed reinforcement (Lin and Burns, 1996).

2.2 Wire Layout Arrangement

Wire type area stipulation limitation should meet design criteria and permitted requirements. Wire type and quantity stipulation determines wire setting and its limited and permitted requirement.

2.3 Prestressed Loss

Prestressed loss occur because of continous transfer according to time function. This calculation is used to determine prestressed effective force. Prestressed loss effects can lead to concrete elasticity abbreviation, friction, wooble effect, holder armature, creep, shrinkage and steel relaxation.

2.4 Stress Control

Controlling stress in the beam at jacking and service step is a critical step in the design. Control function is to measure wether dimension of the plate can receive given amount of stress and wether the amount of received stress is fit the stress design.

2.5 Deflection Control

Occured deflections are calculated and controled so it would not exceed the stipulated constraint. Deflection is calculated according to loading models which was affected by its own load and external load.

3. Two-Way Direction Tendon Prestressed Plate Design

Noted that prestressed plate size with L_x= 12 m and L_y= 24 m with concrete tension is equal to 30 Mpa and concrete elasticity, E_c= 27691 MPa. Plate with width of 250 mm with 4 strands tendon type strand-7 Ply and strand type A.S.T.M A 416/80 grade 270 kpsi 1.7 mm is designed. Tendon with 4 × 183,7 kN which is equal 729 KN forces is used with several specifications; three tendons per meter, number of tendon in short side is 12 meter × 3 tendons per meter = 36 pieces and for the higher side is 24 meter × 3 tendons per meter = 72 pieces.

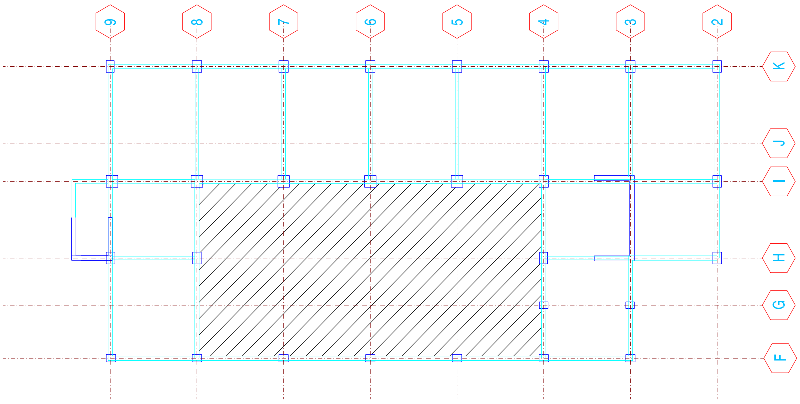

Figure 2. Odua Weston Jambi Hotel's Third Floor.

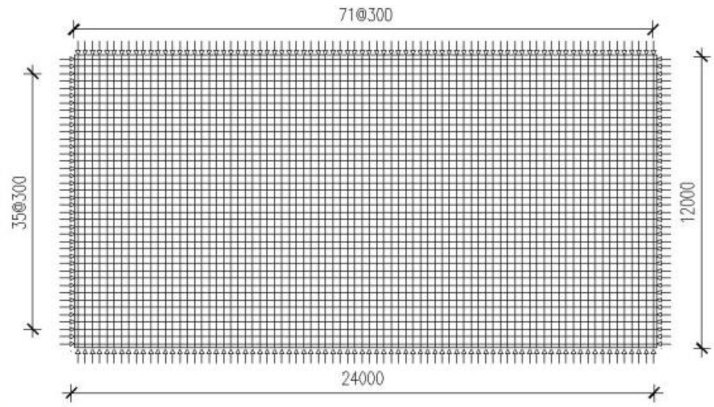

Figure 3. Prestressed concrete slab tendons layout 24 meter x 12 meter.

4. One-Way Direction Tendon Prestressed Plate Design

Noted that prestressed plate size is L_x= 12 m and L_y= 24 m with concrete tension = 30 Mpa and concrete elasticity, E_c= 27691 MPa. Plate with the width of 250 mm with 4 strand(s) tendon(s) type strand-7 Ply and strand type A.S.T.M A 416/80 grade 270 kpsi 12.7 mm is designed. Tendon with 4 × 183,7 kN = 729 KN forces is used with several specification; three tendons per meter, number of tendon in short side is 5.2 meter × 3 tendons per meter = 16 pieces.

IOP Conf. Series: Materials Science and Engineering **267** (2017) 012021 doi:10.1088/1757-899X/267/1/012021

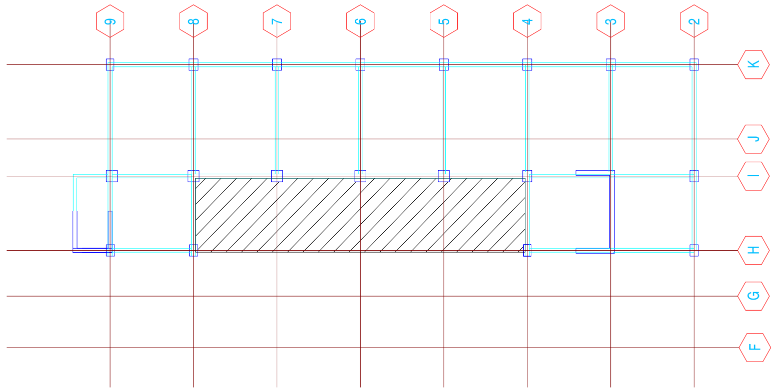

Figure 4. Odua Weston Jambi Hotel's Fourth-Eight Floor.

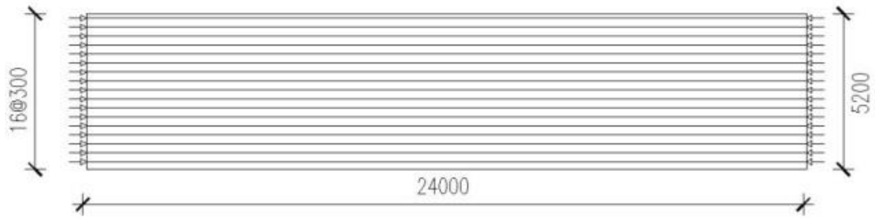

Figure 5. Prestressed concrete slab tendons layout 24 meter x 5,2 meter.

5. Tendon Anchor Design

According to the calculation result, three dashes is required to be assembled within 0,2 H – 1 H range, or with assumption that 1 H = 250 mm then 0,8 H = 200 mm, so dash space is 200 mm/3 which is equal with 66,667 mm. So that dash (Ø) which is 10 mm and dash range which is 60 mm can be used (Freyssinet Spesification).

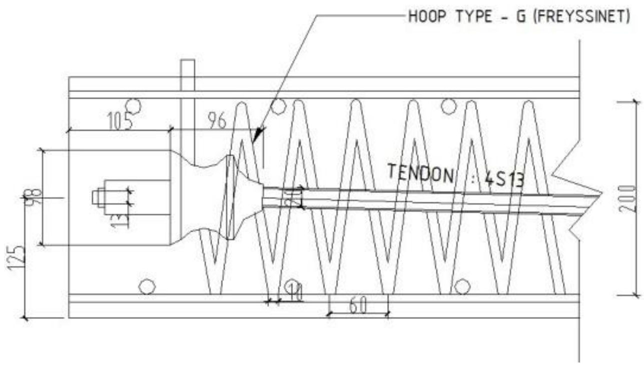

Figure 6. Detail of active anchor.

6. Prestressed Plate Details

Prestressed plate is designed to unmonolithycal concentrate towards its beam by installing a pegs at one side and rubber sheets at both side. According to calculation result, D13 peg is used with the distance of 1.200 mm. Figure 6 shows 12 m landscape of prestressed plate's section. Raised floor is used to overcome floor elevation difference. Parabolical prestressed plate tendon design is shown in Figure 7.

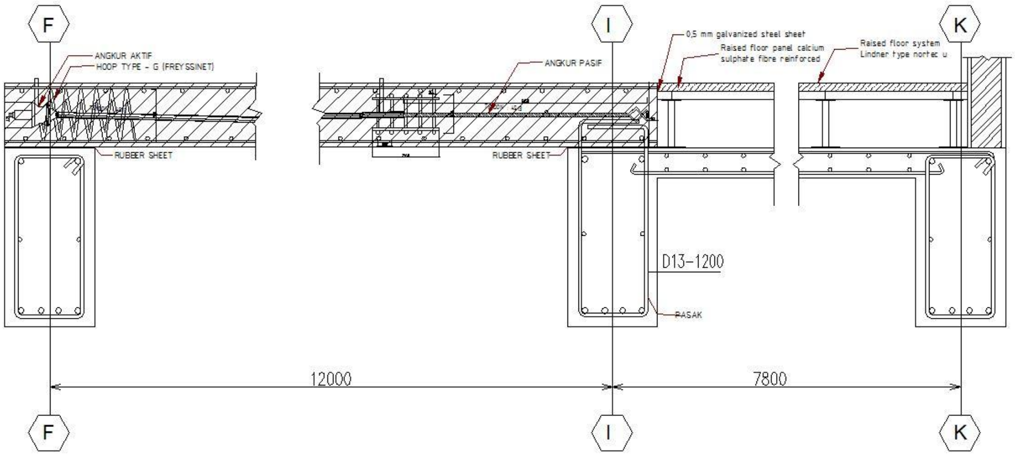

Figure 7. Prestressed concrete slab piece.

CABLE 12	4S ASTMA416	X	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000
		Y	125	112.778	102.778	95	89.444	86.111	85	86.111	89.444	95	102.778	112.778	125
		Z	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Figure 8. Tendon coordinate.

7. Prestressed Plate Beam Support Reinforcement 70/35

Torque value that was obtained from auxiliary program is used to calculate the required number of the reinforcement. After that, beam reinforcement should be designed according to SNI 2847-2013. This picture below shows field reinforcement support requirement and its friction from the calculation results.

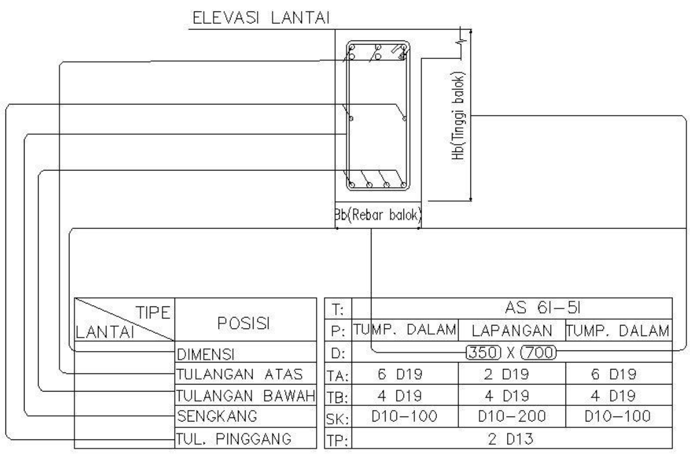

Figure 9. Beam reinforcement.

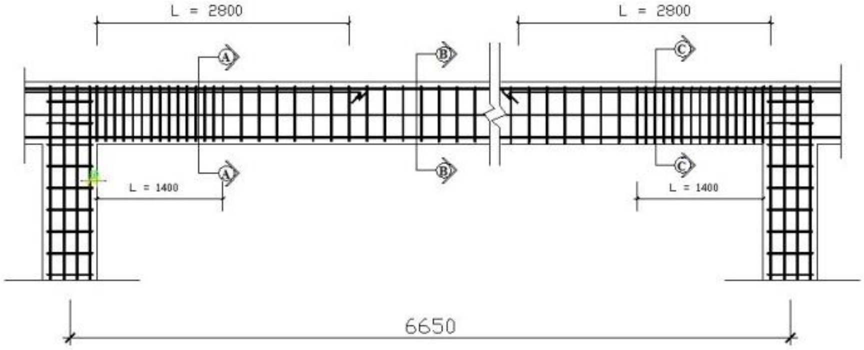

Figure 10. Cross section of beam.

8. Column Reinforcement

Column dimension is 550 mm x 880 mm. Rebar area that was obtained from auxiliary program is used to calculate required number of reinforcement. After that, column reinforcement should be designed according to SNI 2847-2013. This Figure 11 and Figure 12 below show required number of reinforcement according to the calculation result.

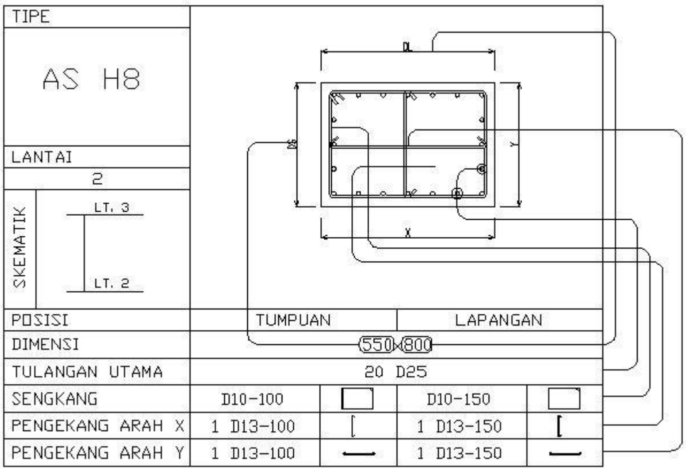

Figure 11. Column reinforcement.

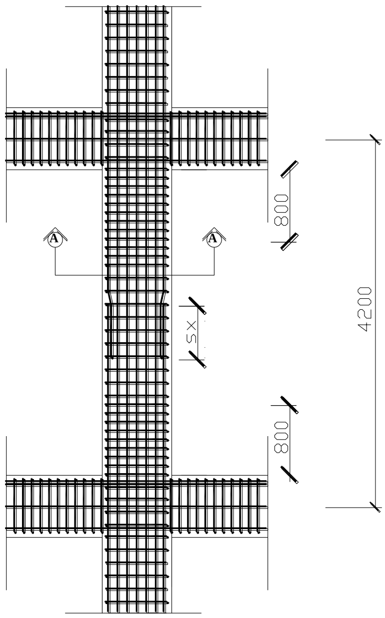

Figure 12. Cross section of column.

9. Story Drift Control

Elasticity of movement value and δ_{xe} from structural analysis should be determined to obtain interstage deviation value. Then, δ_{xe} value is multiplied by magnifying factor C_{d}/I_{e}. After that, interstage deviation value can be obtained by calculating the difference between magnified elasticity movement towards one of level up-value with magnified elasticity movement on one level-down value. Then, this deviation value is controlled with deviation limit of 0,02 h_{sx}. Table 1 shows deviation values that is resulted from seismic forces x.

Table 1. Deviation values.

Lantai	Elevasi (m)	Tinggi antar tingkat (m)	δe (mm)	δxe (mm)	δx (mm)	δa (mm)	Ket
	1	2	3 (Output SAP)	4 (Δtiap Lantai)	5 = Cd x 4 / I	6 = 0,02 x 1	
lt. LG-G	-2.60	4.20	0	0	0	0	OK
lt. G-1	1.60	4.80	0.3	0.3	1.65	84	OK
lt. 1-2	6.40	3.60	2.3	2	11	180	OK
lt. 2-3	10.00	4.20	4.2	2.2	12.1	252	OK
lt. 3-4	14.20	3.40	6.6	4.4	24.2	336	OK
lt. 4-5	17.60	3.40	8.7	4.3	23.65	404	OK
lt. 5-6	21.00	3.40	10.8	6.5	35.75	472	OK
lt. 6-7	24.40	3.40	12.9	6.4	35.2	540	OK
lt. 7-8	27.80	3.40	14.9	8.5	46.75	608	OK
lt. 8-9	31.20	3.40	16.9	8.4	46.2	676	OK

IOP Conf. Series: Materials Science and Engineering **267** (2017) 012021 doi:10.1088/1757-899X/267/1/012021

10. Two-Way Prestressed Plate Deflection Control

10.1. Condition 1
Condition after 25% stressed with load combination of 1 DL + 0,25 Prestress. Deflection occured downwards in amount of 11 mm (SAP2000 output < 100 mm).

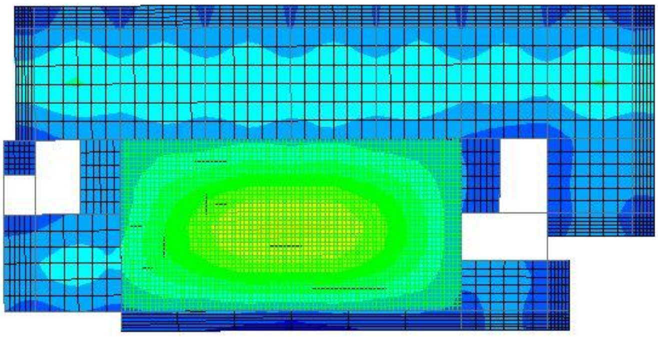

Figure 13. First condition of slab deflection.

10.2. Condition 2 (Service)
Condition after 100% stressed with load combination of 1,4 DL + 1,6 LL + 1 Prestress. Deflection occured downwards in amount of 6 mm (SAP2000 output < 100 mm).

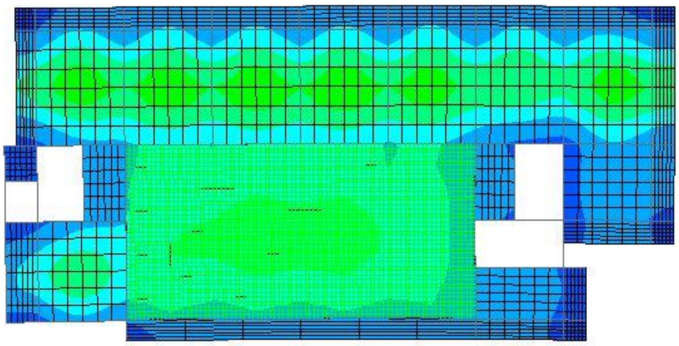

Figure 14. Second condition of slab deflection.

11. Tendon Prestressed Plate Stressing Excecution
According to calculation result, 12 m x 24 m plate with 250 mm width's casting duration is 6.5 hours. Stressing is done after the concrete aged 14 days (80% strength) with pre-tension of 0,7 $f_{pu.}$ Stressing is done step by step for every 45 MPa corresponding to its power pack stressing strength. Stressing used E.O.H.P power pack equipment, MK-I type, K-100 jack type with stressing strength 45 MPa. Strand extension should be watched during tendon stressing process to know the prestressed loss that was caused by anchor slip and tendon friction.

$$\Delta l = \frac{P}{E} \times l_x$$

$$P_{loss} \quad \frac{\Delta l \times E}{l_x}$$

Where:

Δ l = Strand elongation
P = Prestress force
E = Strand elasticity

Table 2.Strand elongation.

Pressure applied	Elongation	Elongation Observed	Pressure observed	Loss
Mpa	mm	Mm	Mpa	%
45	2.8272251	2.5	39.79166667	11.574
90	5.6544503	5.1	81.175	9.8056
135	8.4816754			
270	16.963351			
405	25.445026			

According to calculation result, 12 m tendon strand extension is 60,89 mm. Tendon stressing duration for 72 tendons with each length of 12 m are 13,2 hours meanwhile grouting duration are 15,4 hours per 72 tendons.

12. Conclusion

Refer to this research purpose, then the conclusions are as follows:

1. According to prestressed plate calculation, effective dimension to overcome architectural challenge is 250 mm with 12 m x 24 m landscape.
2. Odua Weston Jambi’s Second floor’s colum elimination is possible due to prestressed plate utilization.
3. According to control examination; double system control, mass participation value control, last spectrum respons value control, and drift control, designed structure met the reuqirement.
4. According to stressing excecution method, stressing duration time is 13,92 hours/ 72 tendons with tendon’s length 12 m (4 strand 7 wire tendon).
5. According to grouting excecution method, grouting duration time is 15,4 hours/ 72 tendons with tendon’s length 12 m (4 strand 7 wire tendon).

13. References

[1] Ministry of Public Works, 2013, *Indonesian National Standard:Structural Concrete Requirement for Building* (SNI 2847-2013*)*, Building Problem Investigation Directorate, Jendral Cipta Karya Directorate, Public Works and Electricity Departement, Bandung.

[2] Ministry of Public Works, 2013, *Indonesian National Standard:Minimum Load for Building Design and Another Structure* (SNI 1727-2013*)*, Building Problem Investigation Directorate, Jendral Cipta Karya Directorate, Public Works and Electricity Departement, Bandung.

[3] Ministry of Public Works, 2012, *Indonesian National Standard:Earthquake Resistance Design Procedur for Building and Another* (SNI 1726-2012*)*, Building Problem Investigation Directorate, Jendral Cipta Karya Directorate, Public Works and Electricity Departement, Bandung.

[4] Ministry of Public Works, 2012, *Indonesian National Standard:Precast and Prestressed Concrete Design for Building* (SNI 7833-2012),Building Problem Investigation Directorate, Jendral Cipta Karya Directorate, Public Works and Electricity Departement, Bandung.

[5] Ned, T.Y.Lin and Burns, H, 1996, *Prestressed Concrete Structure Design*, Yogyakarta: Erlangga.

[6] Nawy, Edward G, 2001, *Steel Construction Profil Table*, Jakarta: Erlangga.

[7] Iswandi Imran and Fajar Hendrik, 2009, *Earthquake Resistance Reinforcement Concrete Structure According to SNI 03-2847-2002*, Yogyakarta : Erlangga.

[8] Budiadi, Andri, 2008, *Prestressed Concrete Practical Design According to SNI 03-2847-2002*, Yogyakarta: ANDI.

[9] Raju, N Khrisna, 1988, *Prestressed Concrete Second Edition*, Yogyakarta: Erlangga.