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Damages and Repairs of Voided Concrete Precast Slab Bridge Girder

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Abstrak

Tulisan ini mencakup analisis kerusakan retakan pada slab gelagar jembatan. Kerusakan diperkirakan terjadi pada sewaktu penanganan di transportasi, yaitu dengan menggunakan angkutan laut (kapal), dan/atau darat (trailer). Kerusakan tersebut berupa retakan pada bagian tengah bentang mulai dari serat-serat di atasnya. Seperti diketahui, komponen pada beton prategang menggunakan sistem di mana area komponen yang ditarik disusun berdasarkan dengan memberikan tegangan tekan kepada kawat atau tendon, kemudian ditarik kembali ke bentuk semula. Artinya, tegangan tekan yang disebabkan oleh kawat atau tendon adalah gaya tekan yang aktif, berlawanan dengan beton bertulang. Tulangan bekerja secara pasif, karena hanya bekerja setelah beton ditarik dan retak. Desain beton prategang didasarkan pada kondisi elastis, dimana tegangan akibat gaya prategang, beban mati dan beban hidup dapat dijumlahkan secara matematis/aljabar. Artinya, kondisi tegangan dapat dipantau dengan pasti berdasarkan prinsip elastisitas. Hanya di beberapa area kritis kapasitas penampang perlu diperiksa; misalnya kapasitas momen pada pusat bentang dan kapasitas geser pada tumupuan/penempatan. Dengan demikian, komponen balok beton prategang merupakan komponen yang "hidup", dalam arti distribusi tegangan sangat bergantung pada urutan pembebanan. Termasuk pada saat mengangkat, memindahkan dan membawanya dengan transportasi. Dari analisis yang diperoleh hasil total momen kawatnya pada saat transfer = 723,23 kN-m. Dengan demikian tegangan pada serat bagian atas adalah f_{tt} = -1,94 MPa, Tegangan tarik ijin pada saat transfer $(f)_{tt}$= -1,37 MPa , tegangan tarik pada serat bagian atas lebih kecil dari tegangan tarik yang diijinkan, keretakan terjadi dari serat bagian atas ke bawah secara vertikal. Perbaikan girder ini dapat dilakukan dengan material atau component utama setelah di lakukan perhitungan analisa beban. Menggunakan epoxy Sikadur – 752 yang memiliki kualitas dan kekuatan prima, retakan yang terjadi kurang dari 2,0 mm dapat di epoksi dengan material ini. Dengan meggunakan perbaikan girder seperti ini, kekuatan kabel pratekan tidak berkurang secara signifikan.

Keywords *: The voided slab girder, prestressed concrete, Sikadur bridge*

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A. INTRODUCTION

As we known, prestressed components use a system in which the component's tensile area is annulled by applying compressive stress by a wire or tendon that is attracted and which wants to return to its original shape. This means that the compressive stress caused by a wire or tendon is an active compressive action, which is different from concrete reinforcement reinforced passively working, because it only works after the concrete is pulled and cracked.

The prestressed concrete design is based on elastic conditions, where the stresses due to the prestressing force, dead load and live load can be added algebraically. This means that the stress conditions can be monitored with certainty based on elastical principles. Only in some critical areas the cross-sectional capacity is checked; for example, the moment capacity at the center of the span and the shear capacity at placement.

Thus, the prestressed beam component is a "live" component, in the sense that the stress distribution is very dependent on the loading sequence and the conditions of lifting and transportation.

There are several stages of loading that need to be checked in a prestressed system, among others, the transfer stage, the working dead load stage and the working live load stage. All these steps need to be checked against their respective loading conditions. The transfer stage examines the initial pre-stress force before the loss of pre-stress occurs, and this stage occurs not for a long time because after that, there will be camber which invites dead load activity.

The working dead load stage is reviewed in the semi-final pre-stress condition with short-term loss of pre-stress and working dead load due to camber, the component is free from the ground and only rests on both ends. The live load stage is viewed in conditions where long-term loss of pre-stress, shrinkage and creep and elastic shortening have occurred.

What needs to be considered at each stage of loading is that the load component must work and not be eliminated by any conditions at a certain time; for example, at the time of stacking or at the time of transportation.

B. Literature Review

This report covers the design of voided concrete precast and prestressed slab for bridge girder. The report contains specification of materials used, geometry of girder, design procedure, loading combination and the design.

The design is carried out conforming to the following codes.

1. Bridge Management System (BMS) 1992 part BDC (Bridge Design Code) with revisions to:
   a. Part 6 with Concrete Structural Planning for Bridges (SK.SNI T-12-2004), in accordance with the Minister of Public Works Decision No. 26O / KPTSIM / 2004.
   b. Section 7 with the design of steel structures for bridges (SK.SNI T-03-2005). Decision
   c. Minister of Public Works Decision No. 498 / KPTS / M / 2005.
   d. The loading of bridges is in accordance with the Loading Standards for SNI Bridges 1725: 2016
2. Earthquake Resistance Planning Standards for Bridges, SNI 2833: 2008.
3. AASHTO LFRD Bridge Design Specifications, 2012.
4. CEB –FIP (1990) for shrinkage and creep calculations
5. SNI 7833: 2012 - Procedure for Designing Precast Loads and Structural Concrete for Buildings

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1. **Concrete**
   Concrete materials used are of high compression strength with the following data.
   a. Weight: 24 kN/m3
   b. Characteristic compression strength, f'c = 70 Mpa (at service) = 30 Mpa (at transfer)
   c. Allowable compression, $\bar{f}cs$ = 0.45 f'c (at service)
   d. $\bar{f}ct$ = 0.60 f'c (at transfer)
   e. Allowable tension,$\bar{f}ts$ = 0.50 √(f'c) (at service)
   f. $\bar{f}tt$ = 0.25 √(f'c) (at transfer)
   g. Modulus of Elasticity: Es = 200000 Mpa
   h. Poisson's Ratio: ν = 0.30

2. **Prestressing Materials**
   a. Strand: PC dia. 15.2 mm, A = 140 mm2
   b. Rupture strength: 1862 Mpa
   c. Yield strength: -
   d. Modulus Elasticity: Ep = 193.053 Mpa

3. **Girder Dimension**
   a. Clear interior span: 14.95 m
   b. Stepping plate: 0.30 m
   c. Cross section:
      1) Total height, d = 660 mm
      2) Top width, bt = 950 mm
      3) Bottom width, bb = 970 mm
      4) Void dia. = 300 mm
      5) Top height, dt = 327.8 mm
      6) Bottom height, db = 332.2 mm
      7) Cross section area, A = 492,228 mm^2
      8) Inertia moment, Izz = 21.4068 x 109 mm4
      9) Top Kern area limit, kt = 132.67 mm
      10) Bottom Kern area limit, kb = 130.91 mm

   d) Weight = 11.808 kN/m

As usually carried out, the design of concrete precast prestressed girder is based on elastic method, or working stress or load method. In addition, ultimate capacity is checked at critical sections, such as moment capacity at mid span and shear capacity at supports.
The design of girder cross section is governed by allowable stresses, i.e., allowable compression stress at compression face and allowable tension stress at tensile face. At transfer, the stresses must satisfy the following conditions.

$$f_{tt} = \frac{F_0}{A} + \frac{F_o.e.dt}{I_{zz}} + \frac{Md.dt}{I_{zz}} \geq \bar{f}_{tt} \quad (1)$$

$$f_{bt} = \frac{F_0}{A} + \frac{F_o.e.db}{I_{zz}} + \frac{Md.db}{I_{zz}} \leq \bar{f}_{ct}$$

At service stage, the following inequalities govern,

$$f_{ts} = \frac{F_e}{A} + \frac{F_e.e.dt}{I_{zz}} + \frac{Md.dt}{I_{zz}} \leq \bar{f}_{cs} \quad (2)$$

$$f_{bs} = \frac{F_0}{A} + \frac{F_e.e.db}{I_{zz}} + \frac{Md.db}{I_{zz}} \geq \bar{f}_{ct}$$

C. Methodology

This report includes a crack damage analysis of the voided slab girder of the bridge. Damage is estimated to occur during handling, in the form of sea transportation (ships).and /or land (trailers). The damage is in the form of cracks in the middle of the span starting from the fibers above. As is well known, the pre-stressed component uses a system in which the area is tensile the component is threaded by exerting a compressive stress by the pulled wire or tendon and who want to get back into shape.

Prestressed concrete designs are based on elastic conditions, in which the stresses are due prestress force, dead load and live load can be added algebraically. It means that stress conditions can be monitored with certainty based on elastical principles. Only in some critical areas the cross-sectional capacity is checked; for example, the moment capacity at the center of the span and the shear capacity at placement.Thus, the component of the prestressed beam is a component that is "alive", deep meaning that the stress distribution is very dependent on the sequence of loading and conditions lifting and transportation.

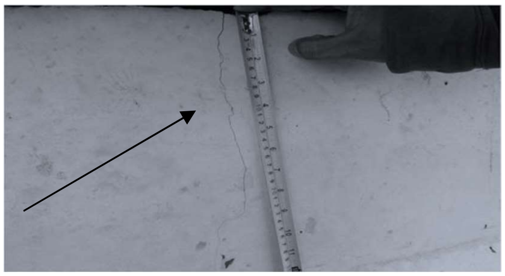

Figure 1. Craked at Girder

Figure 2. End BlockDamage

In The Form Of Chipping On The Girder

1. **Crack Damage in Upper Middle Span Fibers**

From visual observations, it can be concluded that the cracks in the upper middle span fibers are due to the tensile occurrence due to bending moments based on the vertical direction of the cracks in the girder. This could be due to uneven placement during sea or land transportation. As is known, before the live load works, what acts on the girder is the prestress force and the girder's own weight. The girder's own weight creates a positive moment against the negative moment due to the strand cable. However, if the transport time, the girders are positioned so that their own weight does not work, there will be a greater drag in the upper fiber region of the girder.

2. **Chipped Damage to End Block**

Chipping is thought to occur as a result of impact on the slab during transportation. This is based on the observation that chipping occurs at the corners of the slab and seeing its condition, while it is considered that the concrete is in good quality.

D. RESULTS AND DIUSSSCION

1. Design Procedur

The four inequality equations are used, prestressing losses are computed so as to find effective prestressing force Fe. All quantities then are inserted in Equation (1) and (2) to check stresses.

2. Loading

Loading combination that should be subjected upon the beam are, own weight of girder, superimposed dead load consisting of asphaltic pavement, join grout, and diapraghm, and live load.

1. Girder Own Weight
   Girder own weight load, Wd = 0.492 x 24 kN/m = 11.808 kN/m
2. Superimposed Dead Load

Ashpaltic	=	Ac Asphaltic x Asphaltic Weight
	=	0.0485 m2 x 2.2 t/m3
	=	0.1067 t/m'
	=	1.0464069 KN/m'
Joint Grout	=	A grouting x Grouting Weight
	=	0.020 m2 x 2.5 t/m3
	=	0.051 t/m'
	=	0.500157 KN/m'
Diaphragm	=	Vol. Diaphragm x Conc. Weight
	=	0.04 m3 x 2.5 t/m3
	=	0.10603 t/pcs.
	=	1.03982 KN/pcs

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Tabel 1. N diaphragm = 4 pcs

Diaphragm	Unit	1	2	3	4
Location	M	0.00	4.98	9.97	14.95
Support Va	kN	1.04	0.69	0.35	0.00
Mid Moment	kN.m	0.00	2.59	2.59	0.00

Total Moment at Middle Span 5.1818 KN.m = q x L^2 /8, eqivalen load q diaphragm = 0.19 KN/m.

Loading Resume :

a. Total non composite DL = diaphragm + joint grouting = 0.69 kN/m
b. Total composite DL = asphaltic = 1.05 kN/m

Live Load

"T" Loading (SNI 1725:2016)

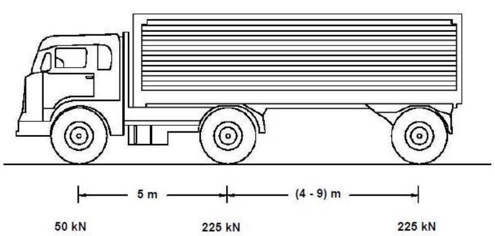

Figure 3. Truck Load

"D" Loading (SNI 1725:2016)

1) Dynamic load factor = 1+0.4 = 1.4 (L = 14.95 m < 50 m)

   = 1.4 (L = 14.95 m < 50 m)
2) Concentrated line load (BGT) = 49 kN/m
3) Distribution factor (DF) = 1,0

   = 1.0
4) Distribution load = 9.0 kN/m2 (L ≤ 30 m)

   = 9.0 kN/m2 (L ≤ 30 m)

Girder Design

Computation of Forces

Forces Due To Girder Own Weight

Moment at midspan M_{DG} = 1/8 x 11.808 x 14.952 = 329.89 kN.m

Shear at support VA = ½ x 11.808 x 14.95 = 88.26 kN

Forces Due Superimposed Dead Load

5) Non Composite DL = diaphragm + joint grouting
   Moment at midspan M_{DG} = 1/8 x 0.69 x14.952 = 19.27 kN.m
   Shear at support VA = ½ x 0.69 x 14.95 = 5.16 kN
6) Composite DL = Asphaltic
   Moment at midspan M_{DG} = 1/8 x 1.05 x14.952 = 29.33 kN.m
   Shear at support VA = ½ x 1.05 x 14.95 = 7.85 kN

Forces Due Live Load

Considering that the live load that governs the desigm is the "T" loading, then the moment and shear forces are computed below.

Table 1: Computation of live load

Item	Unit	P1	P2	P3
Load	kN	25	112,5	112,5
Impact		1,3	1,3	1,3
LL + I	kN	32,5	146,25	146,25
Distance	M	12,475	7,475	3,475
Va	kN	5,38	73,13	112,26
Va	**kN**		**190,76**	
Mmax	**kN.m**		**840,94**	

Total Forces Due All Loads

Table 2: Computation of all loads

Load Type	Shear (kN)	Moment (kN.m)
Girder Own Weight	88.26	329.89
Non Composite Dead Load	5.16	19.27
Composite Dead Load	7.85	29.33
Live Load	190.76	840.94
Total	**471.688**	**1993.271**

Design of Cross Section

The cross section at mid span is shown in Figure 4. Computed cross section properties are tabulated in Table 3.

Table 3: Mid section properties

Properties	Cross Section
H	670 mm
B	1000 mm
D	300 mm
A	492228 mm2
I	2.14E+10 mm4
yb	327.8 mm
yt	-332.2 mm

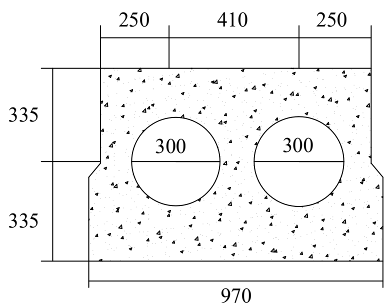

Figure 4. Mid Span Cross Section

Design of Cable Prestressing

The use of Magnel diagram results in the determination of cable prestressing stress and force. In this case, curved post tension tendon or debonded pretension cable may be used. For this, 23 strands of diameter 15.2 are used. The force is 195.5 kN per strand. Three layers of cable are used, 3 cables on top layer, 10 cables on upper bottom layer and 10 cables on lower bottom layer, as shown in Figure 4. Computation of moments generated by prestressing force, is shown in Table 4.

Table 4. List of cable

Cable No.	**Eccentricity (m)**	**Fo (kN)**	**Fe (kN)**	**Mid Span Moment (kN/m)**	
				At Transfer	**At Service**
1	-0.2522	195.5	158.6678	-49.31	-40.02
2	-0.2522	195.5	158.6678	-49.31	-40.02
3	-0.2522	195.5	158.6678	-49.31	-40.02
4	0.1978	195.5	158.6678	38.67	31.38
5	0.1978	195.5	158.6678	38.67	31.38
6	0.1978	195.5	158.6678	38.67	31.38
7	0.1978	195.5	158.6678	38.67	31.38
8	0.1978	195.5	158.6678	38.67	31.38
9	0.1978	195.5	158.6678	38.67	31.38
10	0.1978	195.5	158.6678	38.67	31.38
11	0.1978	195.5	158.6678	38.67	31.38
12	0.1978	195.5	158.6678	38.67	31.38
13	0.1978	195.5	158.6678	38.67	31.38
14	0.2478	195.5	158.6678	48.44	39.32
15	0.2478	195.5	158.6678	48.44	39.32
16	0.2478	195.5	158.6678	48.44	39.32
17	0.2478	195.5	158.6678	48.44	39.32
18	0.2478	195.5	158.6678	48.44	39.32
19	0.2478	195.5	158.6678	48.44	39.32
20	0.2478	195.5	158.6678	48.44	39.32
21	0.2478	195.5	158.6678	48.44	39.32
22	0.2478	195.5	158.6678	48.44	39.32
23	0.2478	195.5	158.6678	48.44	39.32
				723.23	**586.98**

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Total Moment

Computation of Stresses

The stresses at top and bottom surface of cross section are computed for transfer and service stages. First, the forces at mid span cross section are given in Table 5. Stresses exerted on the top and bottom surface are given in Table 6.

Table 5. Forces at Mid Span Cross Section

Force	Moment	Dead Load	ADL	Live Load
Fo = 4496.50 kN	Mo =723.23 kN/m	329.89	48.60	840.94
Fe = 3649.36 kN	Me = 586.98 kN/m			

Table 6. Stresses at mid span cross section

	At Transfer (MPa)	At Service (MPa)
Top	3.031 ≥ -2.96 (OK)	17.229 ≤ 31.5 (OK)
Bottom	15.158 ≤ 21 (OK)	-2.271 ≥ -4.18 (OK)

Design of Shear Reinforcement

Shear forces exerted on certain locations are shown in Table 7

Table 7. Share forces

Station	Share (kN)			
	Dead Load	AD	Live Load	Ultimate
1 (x = 7.475 m)	0	0	0	0
2 (x = 3.738 m)	0	0	0	0
3 (x = 1.869 m)	0	0	0	0
4 (x = 0.000 m)	0	X	-	-

Shear ultimate strength is computed $0.17\sqrt{f_c'} = 0.17\sqrt{70} = 1.422$ MPa. The ultimate shear stress is shown in Table 8. The shear stresses taken by shear reinforcement is also shown in the table. If for shear reinforcement, two-leg closed stirrups are used of D10, then the space of stirrup is given in the table.

Table 8. Share reinforcement

Span	Vc (kPa)	Vu (kPa)	Vs (kPa)	Stirrup
1-2	1422.32	479.136	-	D10-300
2-3	1422.32	718.704	-	D10-200
3-4	1422.32	958.271	-	D10-100

Cable Layout

The bending moment diagram due to dead and live load are of parabolic shape. However, the cables are design as straight pretensioned cables. To cover bending moment due to dead and live load by straight pretensioned cables, cables are debonded at certain locations. The cables with respected debonde location are given in Table 9.

Table 9. Pattern of debonding of cables

Cable	Station			
	1	2	3	4
	7,475 m	3,738 m	1,869 m	0,0 m
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	X	-	-
5	0	0	X	-
6	0	X	-	-
7	0	0	X	-
8	0	X	-	-
9	0	X	-	-
10	0	0	X	-
11	0	X	-	-
12	0	0	X	-
13	0	X	-	-
14	0	0	0	0
15	0	X	-	-
16	0	X	-	-
17	0	0	0	0
18	0	0	X	-
19	0	0	X	-
20	0	0	0	0
21	0	X	-	-
22	0	X	-	-
23	0	0	0	0

Note : 0= Continuous, x = Debonded

The design of voided slab concrete precast prestresses system is compiled in detailed drawing is shown in figure 5

E. CONCLUSION GIRDER BEAM REPAIR

Data: span (L) = 14.95 m
cross section:
height = 660 mm
top width = 950 mm
bottom width = 970 mm
void diameter = 300 mm
top height = 327.8 mm
bottom height = 332.2 mm
area = 492,228 mm2
moment of inertia = 21.4068 x 109 mm4
upper limit of Kern = 132.67 mm
lower limit of Kern = 130.91 mm
pre-stressed force: initial = 4,496.50 kN
final = 3,649.36 kN

Number of wires = 23 strands
As a result, the total cable moment at the time of transfer = 723.23 kN-m
Thus, the tension on the upper fiber is

$$f_{tt} = \frac{F_0}{A} + \frac{F_o.e.dt}{I_{zz}} + \frac{Md.dt}{I_{zz}}$$

$$= \left(\frac{4496.50}{49228} x\ 10^3 - \frac{723.23x327.8}{21.4068\ x\ 10^3}\right)$$

$$= -1.94 \text{ MPa}$$

Permissible tensile stress at the time of transfer

$$\bar{f}_{tt} = -0.25\sqrt{f_c} = -0.25\sqrt{30} = -1.37\ MPa$$

Because the tensile stress on the upper fibers is smaller than the allowable tensile stresses, cracks occur from the upper fibers downward vertically.

1. Crack Repair

The girder repair can be carried out as follows. First, the girders that experience cracks are isolated and freed from the other gider units. Then, the girder is placed horizontally as perfectly as possible. After that, the cracked epoxy is carried out with a superior material.

There are several types of epoxy materials that are of prime quality and strength and are reliable to seal cracks. One of them is the Sikadur - 752 which has a strength of 640 kg/cm2 and a maximum crack limit of 5.0 mm

One of them is the Sikadur - 752 which has a strength of 640 kg/cm2 and a maximum crack limit of 5.0 mm.

The cracks that occurred were less than 2.0 mm so that it can be epoxy with this material. With
The cracks that occurred were less than 2.0 mm so that it can be epoxy with this material. With
this crack, the strength of the prestressed cable does not decrease significantly. Thus, the initial calculation of strength in planning is still valid and does not need to be recalculated.

It can be added that the authors have applied this epoxy material quite successfully several times in cases of structural damage. The most important thing in this connection is the accuracy in implementing the repair of the damage.

2. Chips Repair

Chipped repair can easily be done by patching the chunks with better quality concrete.

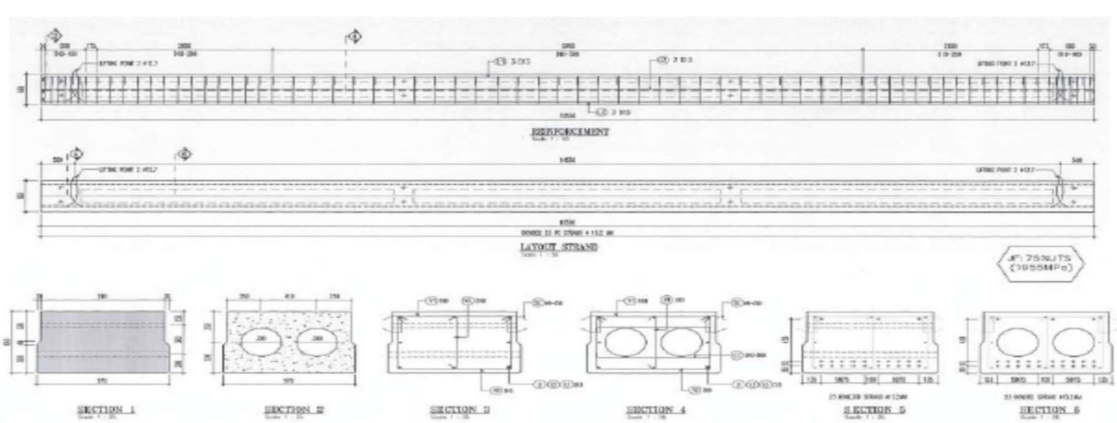

Figure 5. Detailing of girder

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