Study of M-N Interaction Curve on a Pier of "PLS flyover Bridge Project"

Waseda University　Student Member　〇LAM HEANG, Haijie GE
Member　Weiwei LIN, Hideyuki KASANO
Fellow　Teruhiko YODA

1. Introduction

This paper mainly focuses on the use of interaction curve to verify the safety of the pier of the bridge. The selected pier is the pier M6 as shown in Figure 1. For the sake of simplicity, the loading conditions are summarized in Table 1 with all possible combinations of critical loading cases. Due to the limitation of the space, only brief description of interaction curve is provided. The following specifications are used in this study:

- « AASHTO LRFD Bridge design specification 2005 » for loading condition and safety factor
- « ACI 318M-08 » for the construction of interaction curve

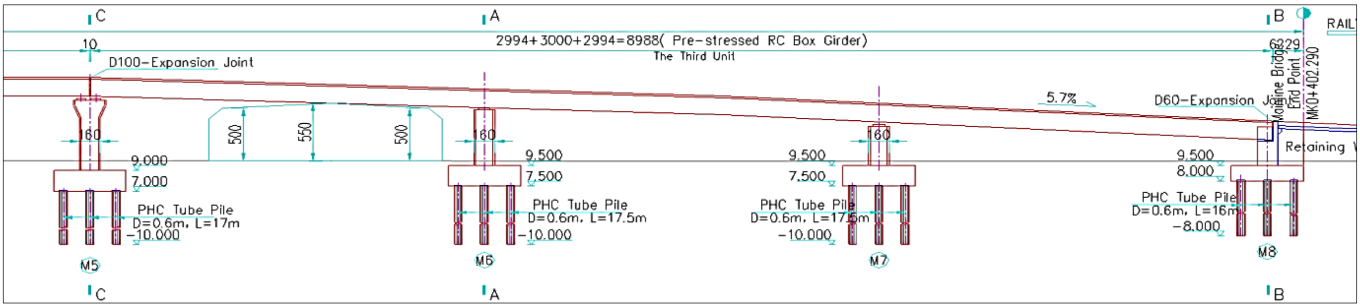
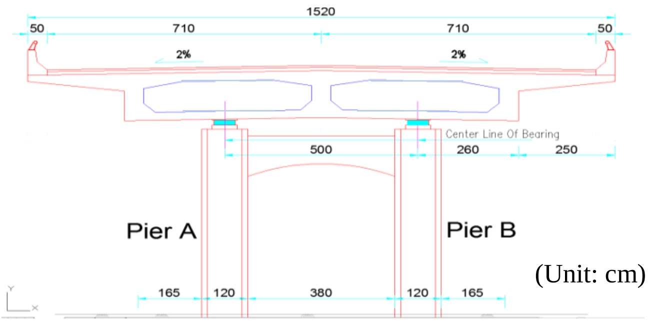


Figure 1: General view of the bridge

2. Loading Condition

Following the design specification provided by AASHTO, there are 5 types of load apply to this bridge including the dead load, live load, wind load, friction load (braking force) and other load (temperature, shrinkage…). For the limit state verification, the study is limited to only the strength limit state and need to verify the strength limit state I, the strength limit state III and the strength limit state V. For live load conditions, the truck type HL-93 is used and the bridge is designed as 4 lanes traffic.



(Unit: cm)

Figure 2: Cross-sectional view of Pier M6

Table 1: The loading case on the piers

Cases			Pier A		Pier B	
			N (kN)	My (kN•m)	N (kN)	My (kN•m)
Strength I	2lane		11180.01	4503.83	6313.16	4503.83
	3lane		10874.00	4718.07	6921.86	4718.07
	4lane		9519.74	4737.64	8915.24	4737.64
	2lane(min)		9034.47	4503.83	5167.62	4503.83
	3lane(min)		8728.70	4718.07	5776.33	4718.07
	4lane(min)		7374.20	4737.64	6769.70	4737.64
Strength III	W0		5000.72	3724.65	5061.96	3724.65
	W60		5020.85	3788.32	5041.82	3788.32
Strength V	2lane	W0	10212.53	4325.73	6563.06	4325.73
		W60	10245.97	4516.90	6529.61	4516.90
	3lane	W0	9976.66	4491.01	7032.63	4491.01
		W60	10010.10	4682.17	6999.18	4682.17
	4lane	W0	8931.75	4506.10	8570.38	4506.10
		W60	8965.20	4697.27	8536.93	4697.27
	2lane(min)	W0	8067.00	4325.73	5417.52	4325.73
		W60	8086.05	4471.42	5398.45	4398.45
	3lane(min)	W0	7831.12	4491.01	5887.09	4491.01
		W60	7864.56	4682.17	5853.64	4682.17
	4lane(min)	W0	6786.21	4506.10	7424.84	4506.10
		W60	6819.66	4697.27	5697.27	4697.27

Note: N, M_y are the values of the bottom section, W0: Wind load 0^o, W60: Wind load 60^0.

3. Construction of Interaction Curve

Material Properties:

Concrete: $f_c^{'} = 25MPa$, $E_c = 26{,}87GPa$

Rebar: $f_y = 400MPa$, $E_s = 200GPa$

Before tracing the interaction curve, firstly the buckling behavior of the pier should be checked by calculating the slenderness ratio. Next, by applying the loading case that has maximum compression (N=11180.01kN, My=4503.83kN•m), the pre-design rebar section is calculated by using the equation provided by Whitney. The minimum section recommended by AASHTO is used since the pre-design rebar section was found negative:

$$\frac{A_s \cdot f_y}{A_g \cdot f_c^{'}} \geq 0.135 \quad A_{s,\min} = 161.28cm^2$$

$$We\ use\ 44@22 = 167.26cm^2$$

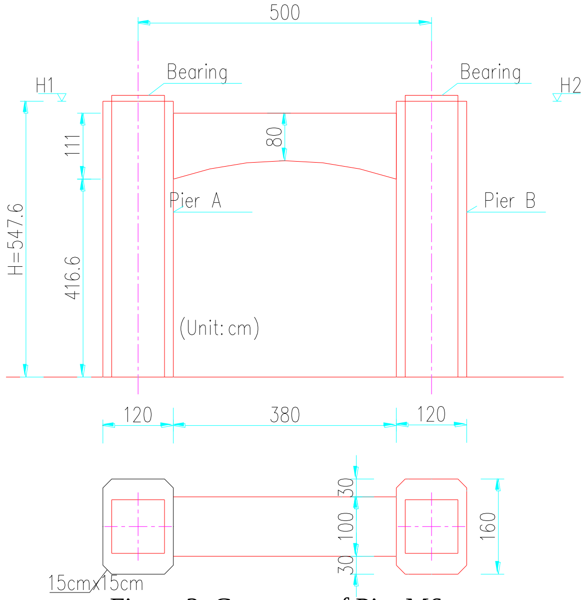


Figure 3: Geometry of Pier M6

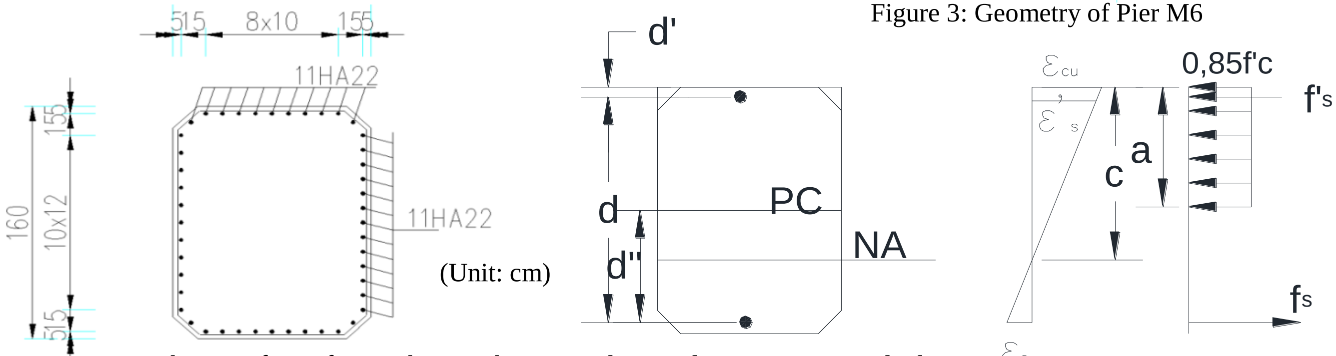


Figure 4: Distribution of Reinforcing bars in the Pier and general assumption in calculation

Now, after having the reinforcement details of the pre-design section, the finding of interaction curve can begin by clearly define 3 conditions below as shown in Figure 5:

- Balance means concrete crash when the steel begins to yield where ε_c=0.3% and ε_s=0.2%, $f_s=f_y$=400MPa
- Compression control means concrete crash before steel yield where ε_c=0.3% and ε_s<0.2%, $f_s<f_y$
- Transition and Tension control means steel begins to yield before the concrete crashes where ε_c=0.3% and ε_s>0.2%, $f_s=f_y$=400MPa

By applying the above strain relation and equilibrium equations, the interaction curve can be obtained by varying the eccentricity of the applied load. After constructing the M-N interaction curve, every loading case is inside the curve (safety zone) as shown in Figure 6. For each loading case, a safety factor of 1/ϕ (with ϕ=0.75) is applied.

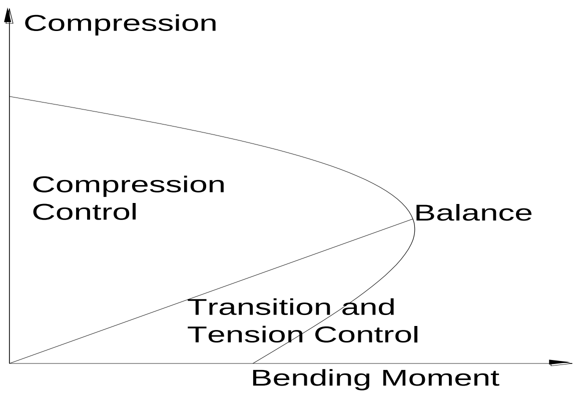


Figure 5: General Interaction Curve for column

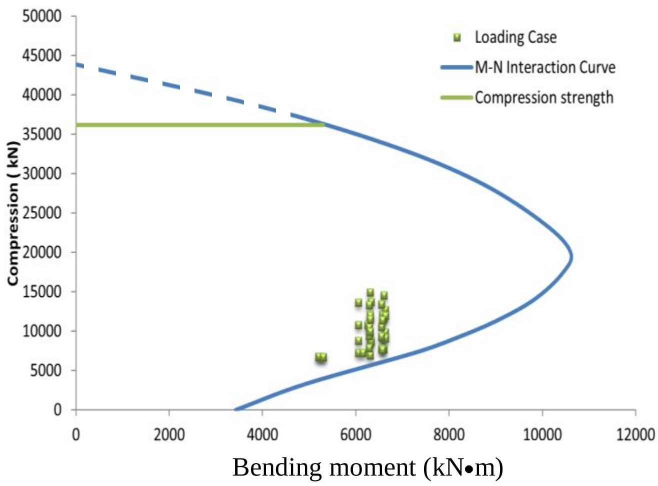


Figure 6: M-N interaction curve for pier M6

4. Conclusion

By using the M-N interaction curve, a structure such as bridge that has many loading cases can be verified easily. Furthermore, it is found that the bending moment is not changing so much in most of the loading case. Moreover, it is suggested that the case with maximum compression is not likely the most dangerous case for the pier of this bridge. In fact, the critical loading case can be somehow the loading case that has very small value of compression.