CHAPTER 8

NUMERICAL RESULTS

8.1 Influence of Concrete Barriers

The results by the finite element analysis (FEA) by Models 1 and 2 are shown in Table 8.1 and Figure 8.1 together with the loading-test results and the design values.

It is observed that the design analysis tends to overestimate both of the stress and the vertical displacement measured in the loading test. The differences at the mid-span of Girder G4 are as much as 20.5 N/mm^2 or 58% in the stress and 6 mm or 25% in the vertical displacement.

FEA by Model 1 also overestimates the stress measured in the loading test, but the difference is smaller than that due to the design analysis.

The inclusion of the concrete barriers in the analysis, i.e. FEA by Model 2, improves stress significantly, yielding the stress values close to the stress measured in the loading test. On the other hand, the displacements obtained by Model 1 are better than those by Model 2. The loading test has shown large difference in the vertical displacement between Girders G4 and G1. Girder G1 moved even upward in the test. However, Model 2 predicts much smaller difference in the vertical displacement between Girders G4 and G1, and the movement of Girder G1 is downward, which does not agree with the loading-test result.

The trends in the present FEA are inconsistent: Model 2 gives better stress while Model 1 gives better vertical displacement. Because stress is closely related to deformation, it may be stated that Model 2 has simulated the deformation of the superstructure better. Considering that the girders of this bridge are statically determinate, the displacements at the bearings due to the deformations of the piers, if any, might change the deflection of the superstructure in the way of rigid-body movement, i.e. without much influencing the deformation of the superstructure, which may account for the inconsistency observed herein.

In any case, the results by Models 1 and 2 suggest the importance of the contribution of the concrete barriers to the actual structural behavior of this steel-composite bridge, as the two models yield quite different results.

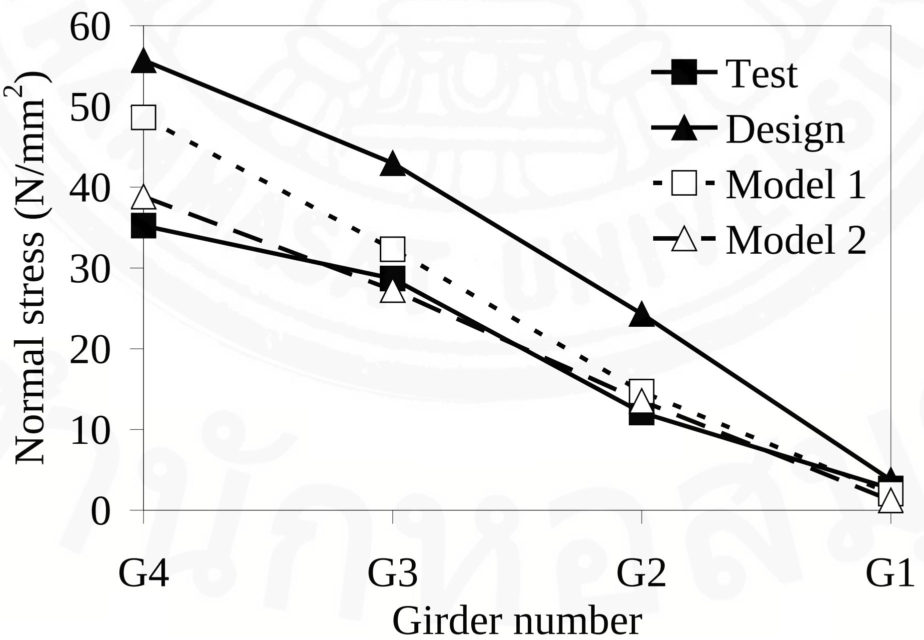
Table 8.1 Stress and displacement at the mid-span

(a) Normal stress (N/mm^2)

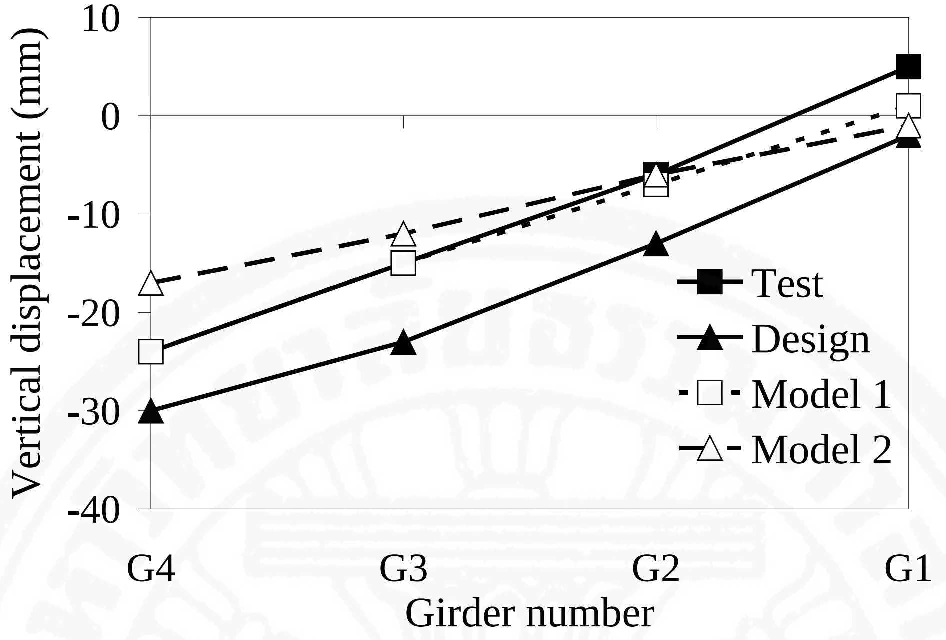
	G4	G3	G2	G1
Test	35.2	28.7	12.1	2.7
Design	55.7	43.0	24.3	3.7
Model 1	48.6	32.3	14.7	2.1
Model 2	38.8	27.3	13.5	1.2
Model 3	39.4	26.5	12.8	1.8
Model 4	40.3	26.9	13.0	1.7
Model 5	39.7	26.5	12.7	1.6
Model 6	38.0	25.7	12.5	2.0
Model 7	38.8	26.4	13.0	2.1

(b) Vertical displacement (mm)

	G4	G3	G2	G1
Test	-24	-15	-6	5
Design	-30	-23	-13	-2
Model 1	-24	-15	-7	1
Model 2	-17	-12	-6	-1
Model 3	-26	-16	-6	4
Model 4	-26	-16	-6	4
Model 5	-26	-16	-6	4
Model 6	-25	-15	-6	4
Model 7	-25	-15	-6	4



(a) Normal stress at the mid-span



(b) Vertical displacement at the mid-span

Figure 8.1 Influence of concrete barriers

8.2 Interaction between Superstructure and Bridge Pier

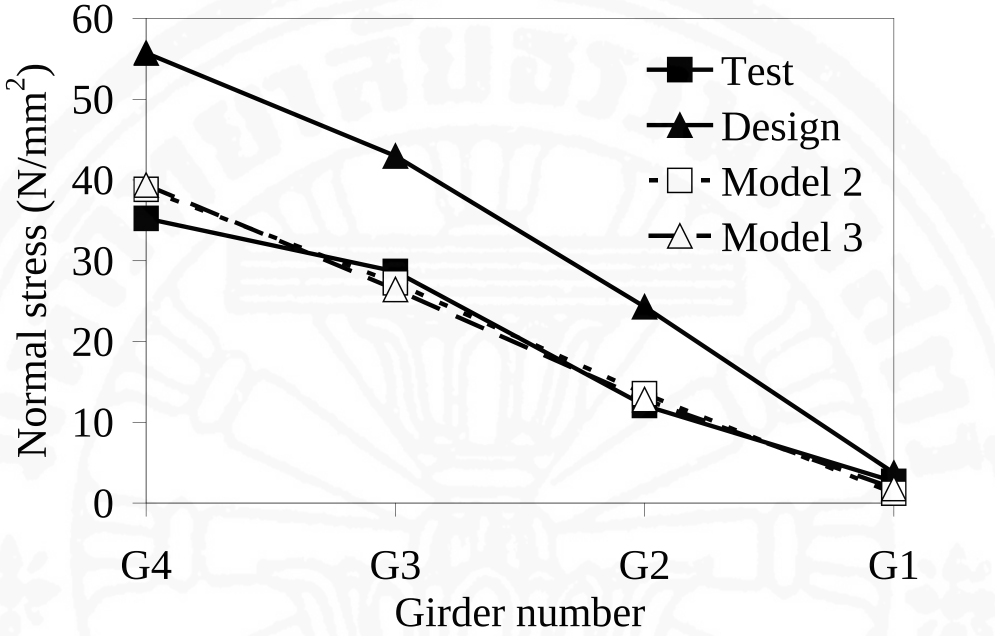
The results of FEA by Model 3 are presented in Table 8.1 and Figure 8.2. The stress values are not much different from those by Model 2, and they remain in good agreement with the test results. On the other hand, the vertical displacements are noticeably improved by Model 3. In fact, the vertical displacements due to Model 3 compare very well with those measured in the loading test.

Table 8.2 shows the vertical displacements of the beams of the bridge pier at the bearings obtained in the analysis by Model 3. This table confirms that the bridge piers indeed deform and the beams of the bridge piers displace, which is not considered in the design analysis, though.

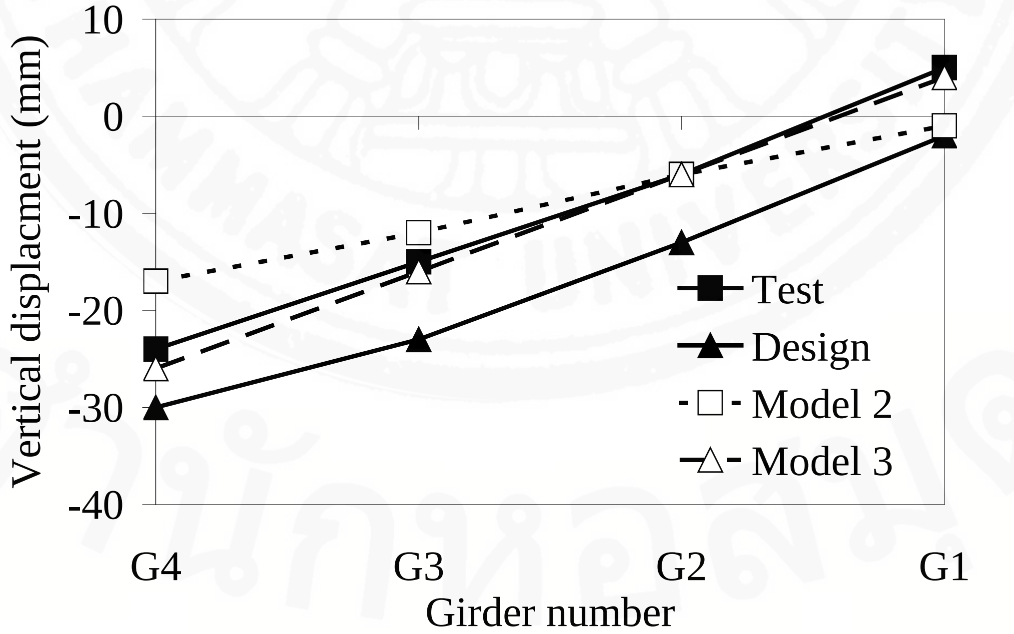
The amounts of the vertical displacements at Pier S6 and Pier S7 are similar to each other. The vertical displacements at the bearings are close to the differences in the mid-span vertical displacement between Models 2 and 3. As discussed previously, the displacements at the bearings may not change the stress states, even though they change the vertical displacements. This is exactly what seems to happen when the bridge piers are included in the finite element analysis, suggesting the importance of the inclusion of the bridge piers in the analysis to capture the actual structural behavior of an overpass. It should be noted that the deformations of the bridge piers are even more important if a bridge is continuous, i.e. statically indeterminate, since the stress states of the girders could be affected also by the vertical displacements of the beams of the bridge piers.

Table 8.2 Vertical displacement at the bearings (mm)

	G4	G3	G2	G1
S6	-8.3	-5.1	-0.4	5.3
S7	-8.2	-4.8	-0.2	5.1



(a) Normal stress at the mid-span

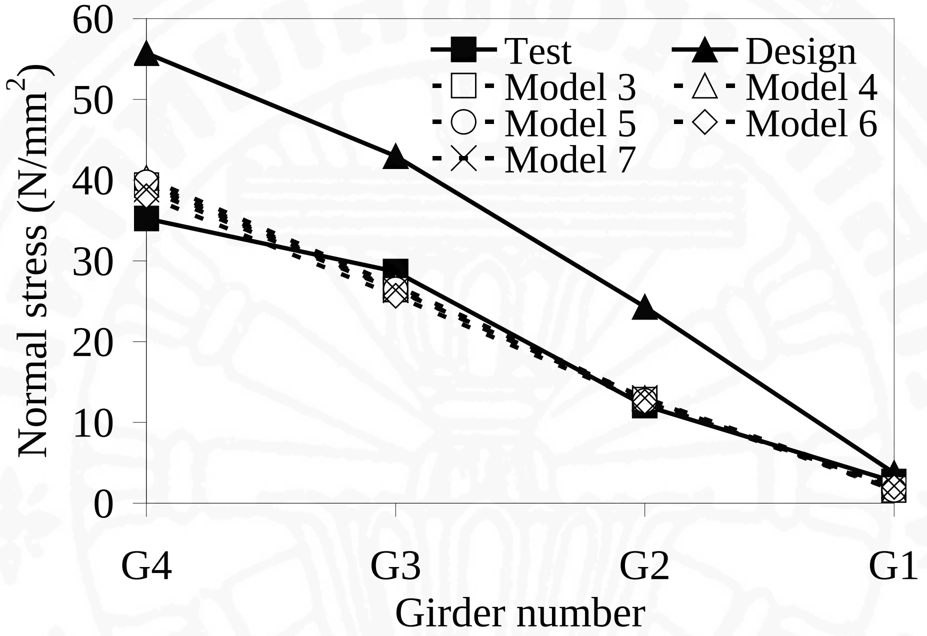


(b) Vertical displacement at the mid-span

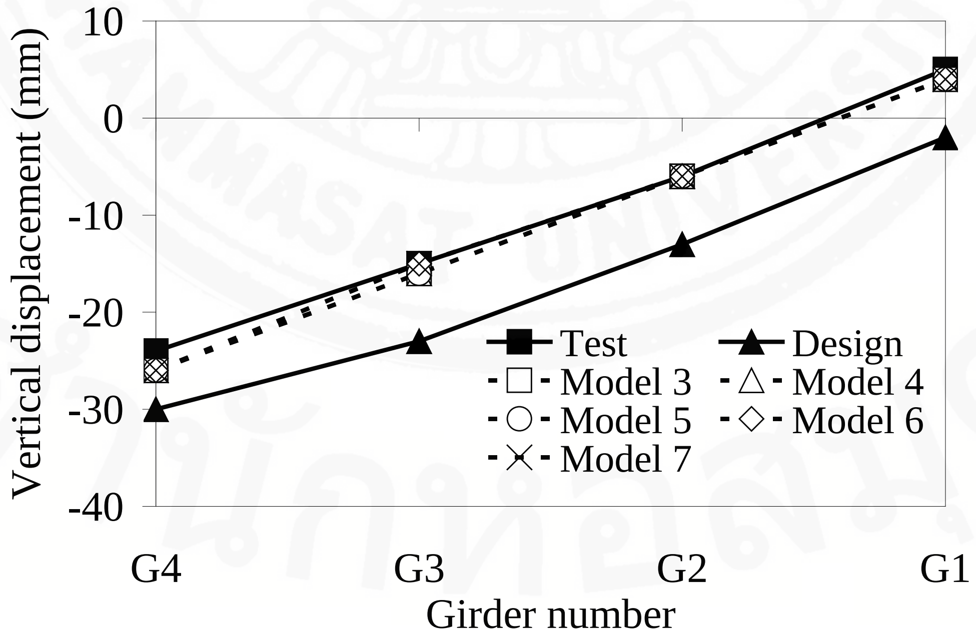
Figure 8.2 Influence of interaction between superstructure and bridge Pier

8.3 Influence of Young's Modulus of Concrete

The influence of the variation of Young's modulus of concrete is studied by conducting FEA by Models 4 to 7. The results are presented in Table 8.1 and in Figure 8.3 together with those by Model 3. Young's modulus of concrete is sure to influence the structural behavior of the bridge, but the differences in both the stress and the vertical displacement turn out to be very small. Therefore, it may be stated that the variation of Young's modulus of concrete is negligible for evaluating the structural behavior of a steel-concrete composite bridge.



(a) Normal stress at the mid-span



(b) Vertical displacement at the mid-span

Figure 8.3 Influence of Young's modulus of concrete

8.4 Reactions at Bearings

The internal forces acting at the bearings between the superstructure and the bridge piers are called reactions herein. Those acting on the superstructure in Models 1 to 3 are summarized in Table 8.3 and Figure 8.4. Very different results are obtained between the models.

Firstly, it is noted that the reactions in the y-direction at the bearings of Girder G1 in Models 1 and 2 are negative while the reaction in Model 3 is positive. The phenomenon can be accounted for as follows:

The loading condition in the present study is eccentric since all the truck loads are applied near Girder G4. This loading condition tends to move Girder G4 downward while Girder G1 tends to move upward. This causes the negative vertical reaction at the bearings of Girder G1 in Models 1 and 2, since the girders cannot move upward at the bearings. On the other hand, in Model 3 where the deformation of the bridge piers are also taken into account, the beams of the bridge piers displace, pushing up Girder G1, resulting in the positive vertical reactions at the bearings of Girder G1 in this model.

The differences in the other reactions between the three models are also noticeable. The inclusion of the concrete barriers and the bridge piers in the analysis is thus important for evaluating the reactions as well. To be noted, the negligence of these factors can yield smaller reactions at some bearings. The observation herein therefore implies that the design of the bearings can be not only wrong but also unsafe if the whole bridge is not modeled appropriately.

The present bridge is simply-supported. Therefore, no horizontal reactions need be computed in the design. This is because each girder is assumed to deform independently in the design, once external loads are distributed to the girders. However, the assumption of the independent behavior of the girders is not true since the girders do interact through concrete deck and cross frames. The present results confirm the point, showing the existence of the horizontal reactions. The negligence of the horizontal loads in the design of the bearings therefore can be completely wrong. Caution must be used for the design of the bearings.

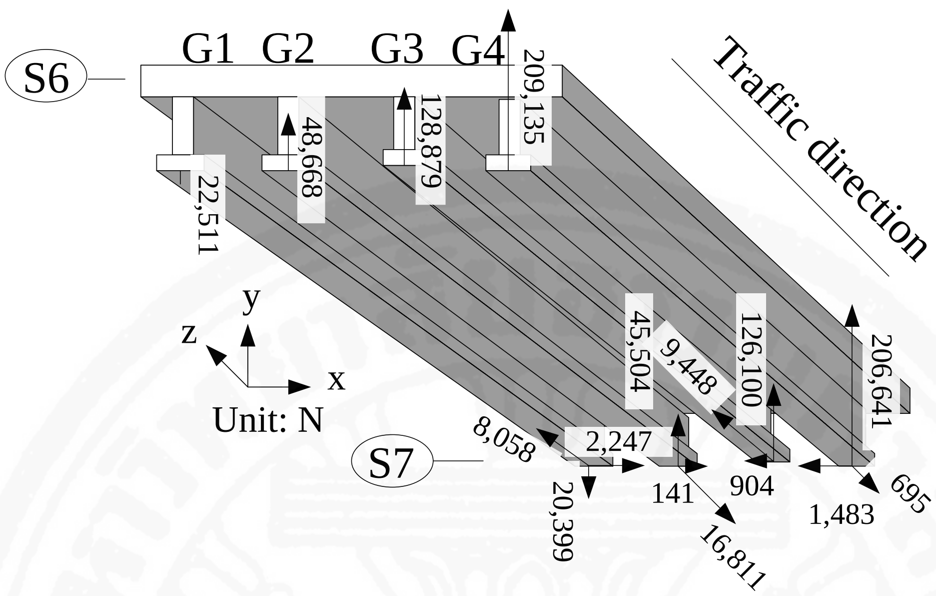
Table 8.3 Reactions (kN)

(a) S6 (y-direction)

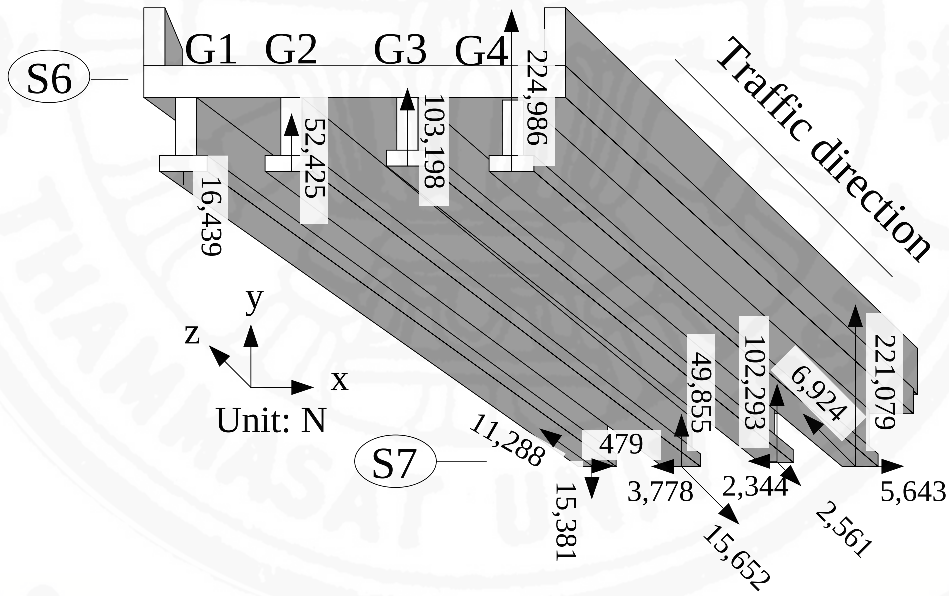
Model	G4	G3	G2	G1
1	209.1	128.9	48.7	-22.5
2	225.0	103.2	52.4	-16.4
3	274.7	40.5	29.1	19.9

(b) S7

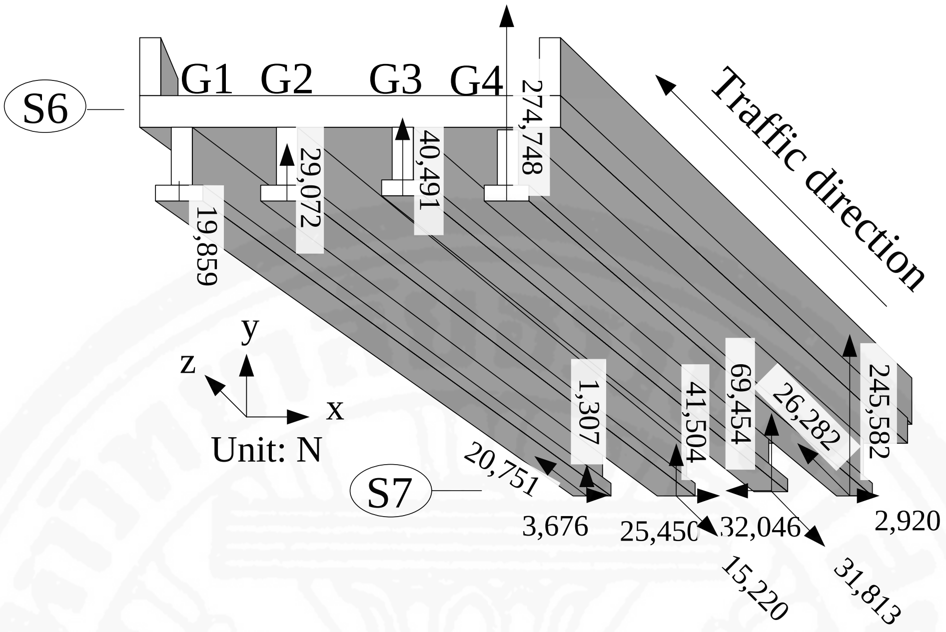
Model	G4			G3			G2			G1		
	x	y	z	x	y	z	x	y	z	x	y	z
1	-1.4	206.6	-0.7	-0.9	126.1	9.4	0.1	45.5	-16.8	2.2	-20.4	8.1
2	5.6	221.1	6.9	-2.3	102.3	-2.6	-3.8	49.9	-15.7	0.5	-15.4	11.3
3	2.9	245.6	26.3	-32.0	69.4	-31.8	25.5	41.5	-15.2	3.7	1.3	20.8



(a) Model 1 (no barrier)



(b) Model 2 (no settlement)



(c) Model 3

Figure 8.4 Reaction force