BEHAVIOR OF BUILT-UP PRECAST CONCRETE SLAB REINFORCED BY EXTERNAL BARS IN PARABOLA CURVE

INTRODUCTION

The built up section and composite section occasionally have been used instead of the standard section or the conventional designed section such as truss is used instead of the standard section of steel section (wide flange, angle, channel, etc.) when it takes long span. Metal deck system is used instead of conventional concrete slab for shortening the construction time. It is interesting to determine a new design of built up section using the conventional compressive strength of concrete and the conventional tensile strength of steel because it induces some benefits such as

1. It is able to be fabricated at anywhere without any special equipment.

2. This conceptual design is able to be applied for any span.

3. According to the calculation it is expected to obtain high strength of built up section compared with precast slab in the market as shown.

This research proposes an alternative design of precast slab which is composed of 10 cm. thick concrete slab on the checker plate (2.30 mm. thick) with the external reinforcing bars in parabola curve. This idea applies to the cable carrying uniform distributed load such as the cable suspension bridge. On account of the convenience of the testing, the specimens will be designed for the span length of 3 m.using the conventional strength of concrete and steel which are generally used in construction. The 210 ksc. and 2400 ksc. will be used for the strength of concrete and the strength of rebar respectively for this research.

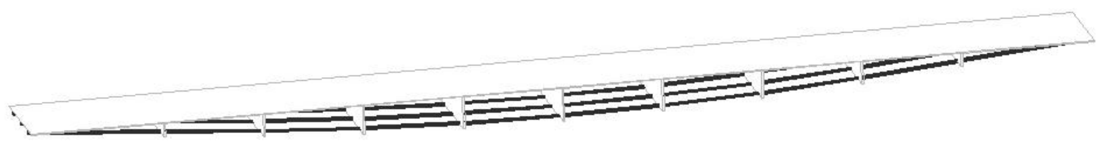

Figure 1 Specimen in drawing

The specimens will be tested for the bending moment capacity and deflection due to specified uniform loads and then those uniform loads from the testing will be compared with those from the calculation. Also the deflection and internal forces in those rebars will be compared with the results from theoretical results by Finite Element Analysis Program.

Objectives

1. Overall Objectives

Study the behavior and determine and compare the ultimate load capacity of the built-up section between that from calculation and that from the experiment.

2. Specific Objectives

2.1 Determine the ultimate uniform load capacity of the built-up section from the experiment and compare this value from the calculation.

2.2 Determine load-deflection relationship from the experiment.

2.3 Compare deflection and internal tensile force in the rebars from the experiment with those from FEM analysis program.

Scope of Research

1. The models of the built up sections will be calculated for their ultimate load capacities.

2. The specimens will be built up and will be tested for their ultimate load capacities.

3. Three models with varied sag of the parabolic rebars of different three values (0.15m.,0.20m. and 0.25 m.) will be investigated for this research.

4. Three specimens will be tested for each model.

5. The results from the experiment will be compared to those from the calculation.

LITERATURE REVIEW

Theorectical Computation

Analysis of forces in cable

Taksin (1998) Consider cable as shown in Figure 2 if this cable deflects in the parabolic curve that will lead to

$$H = wL^2/8h \quad (1)$$

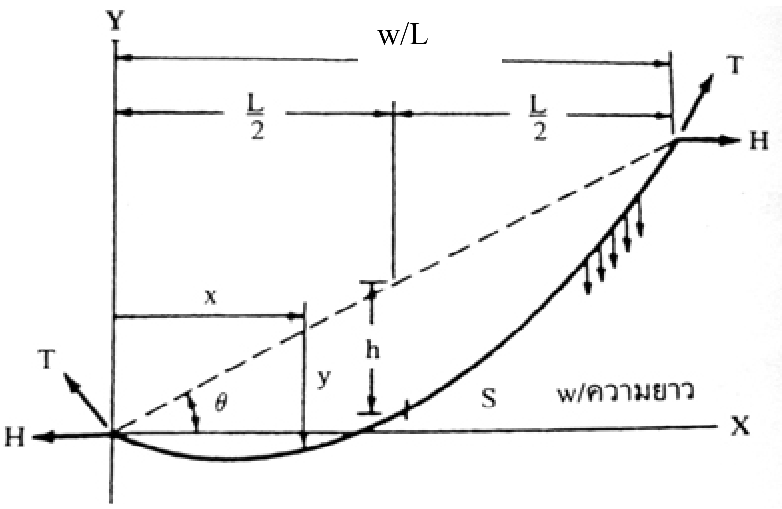

Figure 2 Force and Geometry of Cable in the analysis

Generally its sag at any point along the cable “y” follows to

$$y = 4hx(x-L)/L^2 + x\tan\theta \quad (2)$$

$$dy/dx = 8hx/L^2 - 4hL/L + \tan\theta \quad (3)$$

$$ds = [1+(dy/dx)^2]^{1/2} \quad (4)$$

$$T_x = H/\cos\theta = H(ds/dx) \quad (5)$$

where T_x = tensile force in the cable at x

Substitute ds/dx lead to

$$T_x = H[1+64h^2x^2/L^4 +16(h/L)^2+ \tan^2\theta- 64h^2x/L^3+(16hx/L)(\tan\theta/L) -(8h/L) \tan\theta]^{1/2} \quad (6)$$

The approximated cable's length is

$$S = L[1+8/3(h/L)^2-32/5(h/L)^5] \quad (7)$$

Hypothesis for simplified analysis

When an external uniform load subjects to the built-up model as below

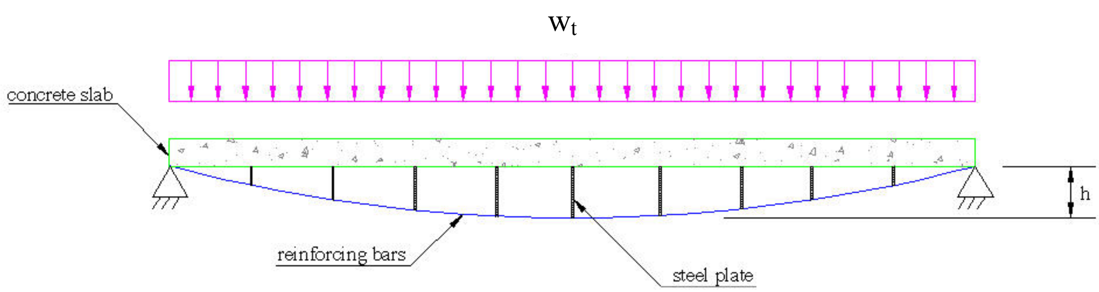

Figure 3 Theoretical model of built up slab with external reinforcing bars

By superposition method a partial uniform load is resisted by slab and the remaining uniform load is transferred to the rebars by steel plates with equal spacing along the span. Those rebars will be designed as parabolic cable.

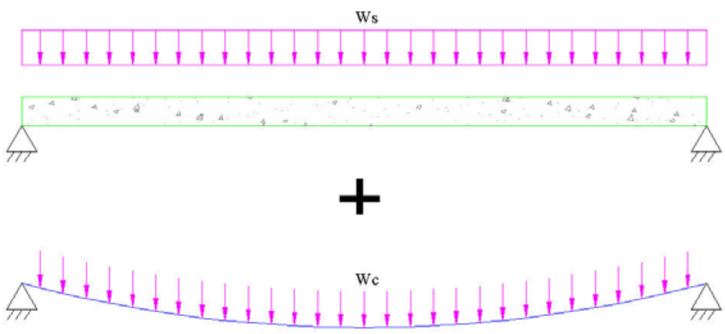

Figure 4 Superposition of applied uniform load

Assumption $w_t = w_s + w_c$

where w_t = total ultimate uniform load

w_s = uniform load resisted by slab

w_c = uniform load resisted by cable (rebar)

Consider parabolic curve cable (θ=0 degree)

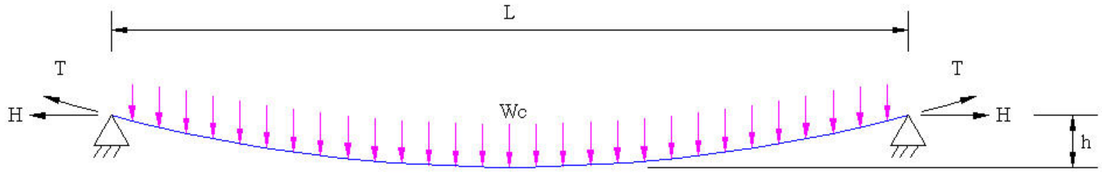

Figure 5 Theoretical model of parabolic cable applied with uniform load

From Equation (1)

$$w_c = 8Hh/ L^2 \quad (9)$$

From Equation (6)

Substitute **θ = 0** and x = L/2 then

$$T_{L/2} = H \quad (10)$$

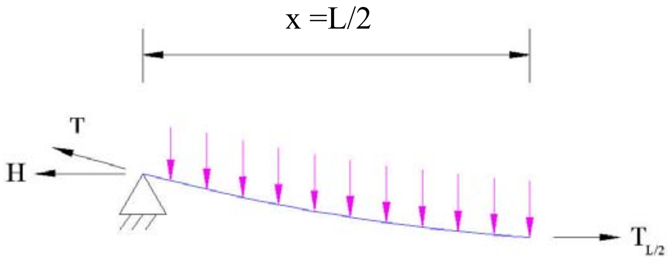

Figure 6 Free body diagram of parabolic cable applied with uniform load

Given $T_{L/2} = H = As.fs$ (11)

Substitute $H = As.fs$ into Equation (9)

$$w_c = 8(As.fs)h/ L^2 \quad (12)$$

Model for built up slab with external rebars

A built-up model of 10 cm. thick concrete slab installed by 3 RB9 of rebars in parabola curve which is designed follow simplified analysis.

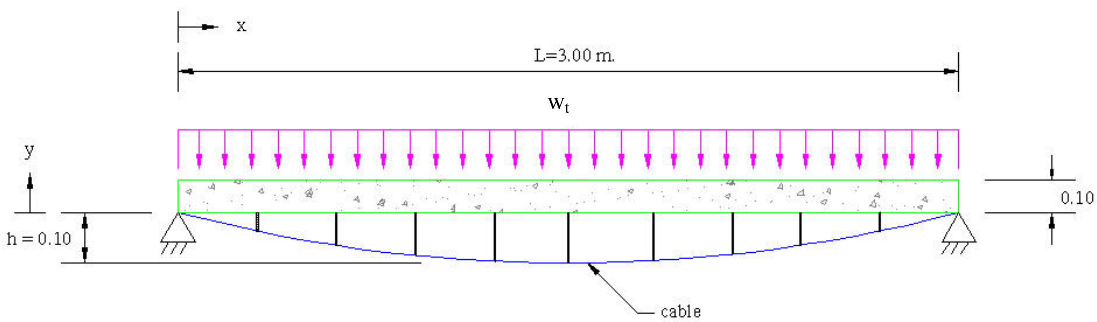

Figure 7 Analysis model in case of simple span with uniform load

Data for calculation of testing model

Concrete, fc' = 210 ksc.

SR24, fy = 2400 ksc

b = slab's width = 0.30 m.

L = span length of slab =3.00 m.

As = 1.908 cm^2. (= 3 RB9 cables)

h = 0.10 m.

<u>Rebars' profile</u>

From Equation (2) and $\theta = 0$

$y = 4hx(x-L)/L^2$

Let the sag at distance x be equal to y, the sag of cable shown in Table 1.

<u>Table 1</u> Profile of rebar (y)

Axis	Profile of rebar (y)								
x (m.)	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70
y (m.)	-0.036	-0.064	-0.084	-0.096	-0.10	-0.096	-0.084	-0.064	-0.036

By FEM program, w_t is applied to this model and gradually is increased until the maximum tensile forces in the rebars which are close at the support reach yield strength of the rebars (the tensile force at yield strength of the rebar is As.fy = 4,579 kg.).If the value of w_t is varied, Give Equations for Tx max. and Tx min., the maximum tensile force of the rebars (T_x max.) and the minimum tensile force of the rebars (T_x min.) (at the lowest sag position) are shown in Table 2.

Table 2 Maximum and minimum tension in cable

Load/Force	Maximum and minimum tension in cable					
w_t (kg./m.)	1000	1100	1200	1300	1400	1500
T_x max .(kg.)	3123	3435	3748	4060	4372	4684
T_x min.(kg.)	3100	3411	3721	4031	4341	4651

From Table 2 if T_x max. is equal to 4,579 kg. ,w_t will be 1,466 kg./m. by the interpolation. Apply w_t = 1,466 kg./m. back to the model and determine T_x min., Ms (Resisting moment in the slab) by FEM program that results 4,546 kg., 1,172 kg.-m. respectively

From Equation 9 $w_c = 8(As.fs)h/ L^2$

substituting T_x min. = 4,546 kg. into As.fs, h = 0.10 m. and L = 3.00 m.

then w_c = 404 kg./m.

From $w_s = 8Ms/ L^2$ = 1,042 kg./m.

From the assumption, $w_t = w_s + w_c$

w_t = 1,446 kg./m.

Compare to the exact applied load w_t = 1,466 kg./m.------1.36% diff.)

Check slab's moment capacity

Given data: slab's thickness 0.10 m., fc' = 210 ksc

element's width 0.30 m., assume Fy (checkered plate) = 2,500 ksc.

Calculate ρ_b = $0.85 \beta_1 fc' * 6117/Fy/(6117+Fy)$ where $\beta_1 = 0.85$

= 0.043

$0.75\rho_b$ = 0.032

ρ = As/b/d = (30*0.23)/30/10 = 0.023 < 0.032 O.K.

ΦMc = 0.90*As*Fy(d-a/2) where a = As*Fy/(0.85*fc'*b)

Substitute the given data lead to

ΦMc = 1,302 kg.-m.

From maximum allowable moment capacity, ΦMc = 1,302 kg.-m.

The ultimate moment, Mu = Ms = 1,172 kg.-m. (<ΦMc)

Therefore this slab is able to resist Mu

Design steel plate

Check b/t ratio to prevent local buckling $b/t <= 16.2 (k_e)^{1/2}$

where

b = width =25 cm.
t = thickness
k_e = 1.0

then

t = b/16.2 = 25/16.2 = 1.54 cm.

where

b = width =20 cm.

t = thickness

k_e = 1.0

then

t = b/16.2 = 20/16.2 = 1.23 cm.

where

b = width =15 cm.

t = thickness

k_e = 1.0

then

t = b/16.2 = 15/16.2 = 0.93 cm.

where

b = width =10 cm.

t = thickness

k_e = 1.0

then

t = b/16.2 = 10/16.2 = 0.62 cm.

Repeat design's steps for the example to determine the ultimate load capacity and rebars' profile for the first model, second model and the third model.

First model

fc' = 210 ksc.

SR24, fy = 2400 ksc

b = 0.30 m. (slab's width)

L = 3.00 m.

As = 1.908 cm^2. (3 RB9)

h = 0.15 m.

Table 3 Rebar profile when h = 0.15m.

Axis	Rebar profile when h = 0.15m.								
x (m.)	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70
y (m.)	-0.054	-0.096	-0.126	-0.144	-0.150	-0.144	-0.126	-0.096	-0.054

Table 4 Maximum and minimum tension in cable

Load/Force	Maximum and minimum tension in cable					
w_t (kg./m.)	1000	1100	1200	1300	1400	1500
T_x max .(kg.)	3501	3852	4202	4552	4902	5252
T_x min.(kg.)	3447	3791	4136	4480	4825	5170

From table 4 when T_x max is equal to 4,579 kg. ,w_t will be 1,308 kg./m. by the interpolation. Apply w_t = 1,308 kg./m. back to the model and determine T_x min., Ms (Resisting moment in the slab) by FEM program that results 4,508 kg., 780 kg.-m. respectively

From Equation (9) $w_c = 8(As.fs)h/ L^2$

Substituting T_x min. = 4,508 kg. into As.fs, h = 0.15 m. and L = 3.00 m.

When w_c = 601 kg./m.

From $w_s = 8Ms/ L^2$ = 693 kg./m.

From the assumption, $w_t = w_s + w_c$

w_t = 1,294 kg./m.

Compare to the exact applied load w_t = 1,308 kg./m.------1.07% diff.)

<u>Check slab's moment capacity</u>

From maximum allowable moment capacity, ΦMc = 1,302 kg.-m.

The ultimate moment, Mu = Ms = 780 kg.-m. (<ΦMc)

Therefore this slab is able to resist Mu

Second model

	fc'	=	210 ksc.
SR24,	fy	=	2400 ksc
	b	=	0.30 m. (slab's width)
	L	=	3.00 m.
	As	=	1.908 cm^2. (3 RB9)
	h	=	0.20 m.

Table 5 Rebar profile when h = 0.20m.

Axis	Rebar profile when h = 0.20m.								
x (m.)	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70
y (m.)	-0.072	-0.128	-0.168	-0.192	-0.20	-0.192	-0.168	-0.128	-0.072

Table 6 Maximum and minimum tension in cable

Load/Force	Maximum and minimum tension in cable					
w_t (kg./m.)	1000	1100	1200	1300	1400	1500
T_x max .(kg.)	3467	3814	4160	4508	4854	5201
T_x min.(kg.)	3373	3710	4047	4385	4722	5059

From table 6 when T_x max is equal to 4,579 kg. ,w_t will be 1,321 kg./m. by the interpolation. Apply w_t = 1,321 kg./m. back to the model and determine T_x min., Ms (Resisting moment in the slab) by FEM program that results 4,455 kg., 584 kg.-m. respectively

From Equation (9) $w_c = 8(As.fs)h/ L^2$

substituting T_x min. = 4,455 kg. into As.fs, h = 0.20 m. and L = 3.00 m.

then w_c = 792 kg./m.

From $w_s = 8Ms/ L^2$ = 519 kg./m.

From the assumption, $w_t = w_s + w_c$

w_t = 1,311 kg./m.

(Compare to the exact applied load w_t = 1,321 kg./m.------0.75% diff.)

Check slab's moment capacity

From maximum allowable moment capacity, ΦMc = 1,302 kg.-m.

The ultimate moment, Mu = Ms = 584 kg.-m. (<ΦMc)

Therefore this slab is able to resist Mu

Third model

	fc'	=	210 ksc.
SR24,	fy	=	2400 ksc
	b	=	0.30 m. (slab's width)
	L	=	3.00 m.
	As	=	1.908 cm^2. (3 RB9)
	h	=	0.25 m.

Table 7 Rebar profile when h = 0.25m

Axis	Rebar profile when h = 0.25m								
x (m.)	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70
y (m.)	-0.09	-0.16	-0.21	-0.24	-0.25	-0.24	-0.21	-0.16	-0.09

Table 8 Maximum and minimum tension in cable

Load/Force	Maximum and minimum tension in cable					
w_t (kg./m.)	1000	1100	1200	1300	1400	1500
T_x max .(kg.)	3278	3606	3934	4261	4589	4917
T_x min.(kg.)	3414	3456	3770	4084	4398	4712

From table 8 when T_x max is equal to 4,579 kg. ,w_t will be 1,397 kg./m. by the interpolation. Apply w_t = 1,397 kg./m. back to the model and determine T_x min., Ms (Resisting moment in the slab) by FEM program that results 4,389 kg., 466 kg.-m. respectively

From Equation (9) $w_c = 8(As.fs)h/ L^2$

substituting T_x min. = 4,389 kg. into As.fs, h = 0.25 m. and L = 3.00 m.

then w_c = 975 kg./m.

From $w_s = 8Ms/ L^2$ = 414 kg./m.

From the assumption, $w_t = w_s + w_c$

w_t = 1,389 kg./m.

(Compare to the exact applied load w_t = 1,397 kg./m.-------0.57% diff.)

Check slab's moment capacity

From maximum allowable moment capacity, ΦMc = 1,302 kg.-m.

The ultimate moment, Mu = Ms = 466 kg.-m. (<ΦMc)

Therefore this slab is able to resist Mu

Comparison of the results between FEM analysis and the simplified method

1. From FEM program, T_x min.(at the lowest sag) which is equal to H is decrease while the lowest sag h is increase that is according to the parabolic cable's equilibrium equation

$$T_x = H[1+64h^2x^2/L^4 +16(h/L)^2+ \tan^2\theta- 64h^2x/L^3+(16hx/L)(\tan\theta/L) -(8h/L)\tan\theta]^{1/2}$$

substituting $\theta = 0$, $x = 0.00$ m., $L = 3.00$ m. and T_x max.= As.fy = 4579 kg. lead to

$$T_x \text{ max.}= H[1+16(h/L)^2]^{½}$$

$$H = T_x \text{ min.}= T_x \text{ max.} / [1+16(h/L)^2]^{½} \quad (13)$$

Table 9 Comparison of tension in the cable between FEM and simplified method

Title	Comparison of tension in the cable between FEM and simplified method		
h (m.)	0.15	0.20	0.25
T_x min. (kg.) by FEM	4508	4455	4389
T_x min. (kg.) by Equation (13)	4490	4424	4344
% difference	0.40%	0.70%	1.02%

2. When h is increase, the uniform load resisted by cable, w_c, is increase that is following the equation $w_c = 8H.h/L^2$ but the uniform load resisted by slab, w_s, is decrease that is following the equation $w_s = 8Ms/ L^2$

Table 10 Load resistance components, w_c and w_s, following those equations by simplified method

Title	simplified method		
h (m.)	0.15	0.20	0.25
w_c (kg./m.)	610	792	975
w_s (kg./m.)	693	519	414

3. The assumption that the uniform load is resisted by one way slab system and parabolic cable, $w_t = w_s + w_c$, is available when compared to FEM program.

Table 11 Comparison of total load resistance, w_t , between FEM and simplified method

Title		Simplified method	
h (m.)	0.15	0.20	0.25
w_t (kg./m.)/by FEM program	1308	1321	1397
w_t (kg./m.)/by equ. ($w_t = w_s + w_c$)	1293	1311	1389
% difference	1.07%	0.75%	0.57%

MATERIALS AND METHODS

Material

1. Concrete with compressive strength fc' = 210 ksc.
2. Rebar RB9 (SR24)
3. Steel plate 12 mm. thick (A36)
4. Checkered plate 2.3 mm.
5. Angle section , L 100x100x10
6. Bolt M9 and nut

Equipment

1. Computer with Finite Element Software
2. Hydraulic jack (capacity 100 tons)
3. Transferred beam
4. Data locker
5. Sand bags
6. Dial guage and strain gauge
7. Welding machine

Methodology

1. Sample preparation and measurement

The 10 cm. thickness of precast concrete slabs will be prepared and include the installation of the angle members L 100x100x10 and checkered plates 2.3 mm. thick as shown.

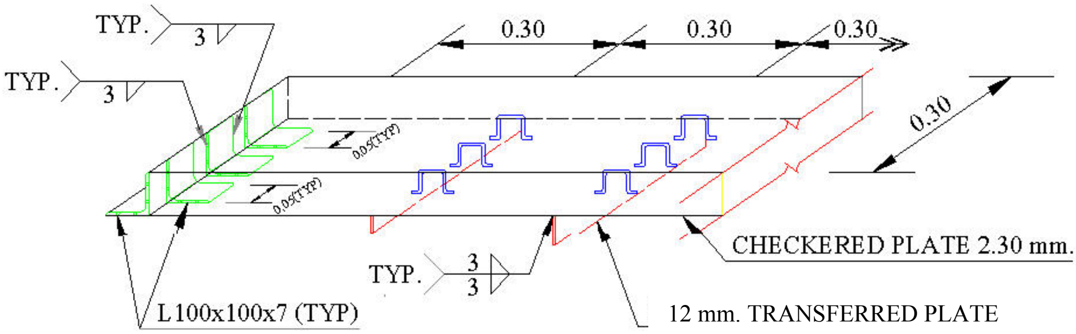

Figure 8 Typical details of steel checkered plate and transferred plates

2. Cure these precast slabs until their strength up to 210 ksc.

3. Weld transferred plates 12 mm. thick to the checkered plate at the bottom of the slab and then install the rebars (3-RB9) by welding both ends to the cherkered plate beneath the angle as shown.

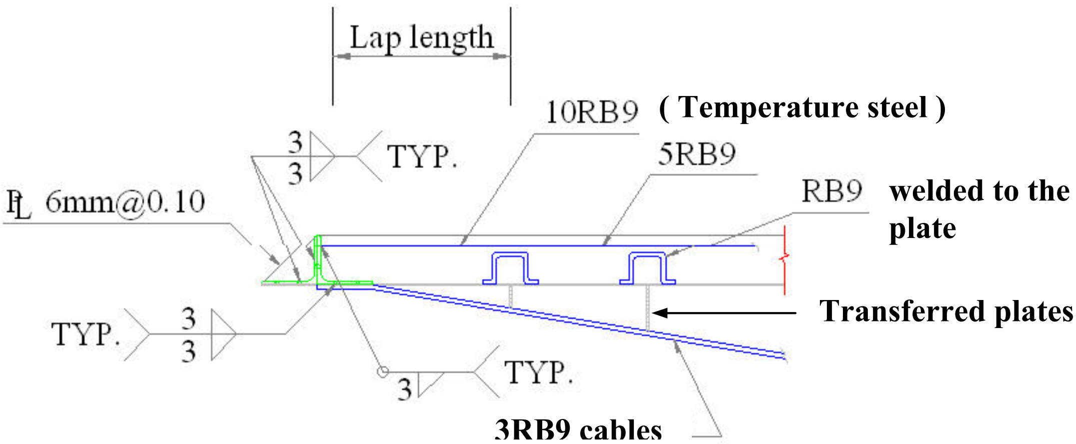

Figure 9 Typical details of steel cables

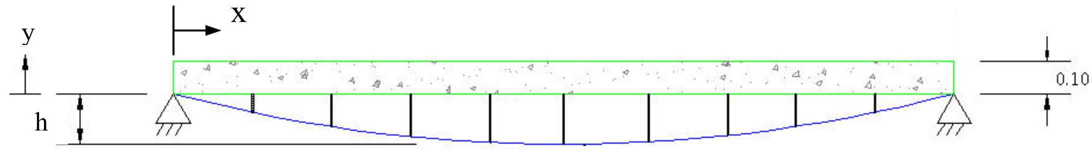

Figure 10 Test Models

Table 12 Details of Test Models

Model no.	h (m)	y (m)								
		0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70
1	0.15	-0.054	-0.096	-0.126	-0.144	-0.150	-0.144	-0.126	-0.096	-0.054
2	0.20	-0.072	-0.128	-0.168	-0.192	-0.20	-0.192	-0.168	-0.128	-0.072
3	0.25	-0.09	-0.16	-0.21	-0.24	-0.25	-0.24	-0.21	-0.16	-0.09

Note: Three samples will be tested for each model.

4. The dial guage with accuracy 0.01 mm. will be installed to measure the deflection.

5. Apply the third point load on a transferred beam which is on a layer of sand bags in order to transfer load as uniform load over the surface of the test models.

6. Measure the strain of the rebars at the end of span and the middle of span via the strain gauges.

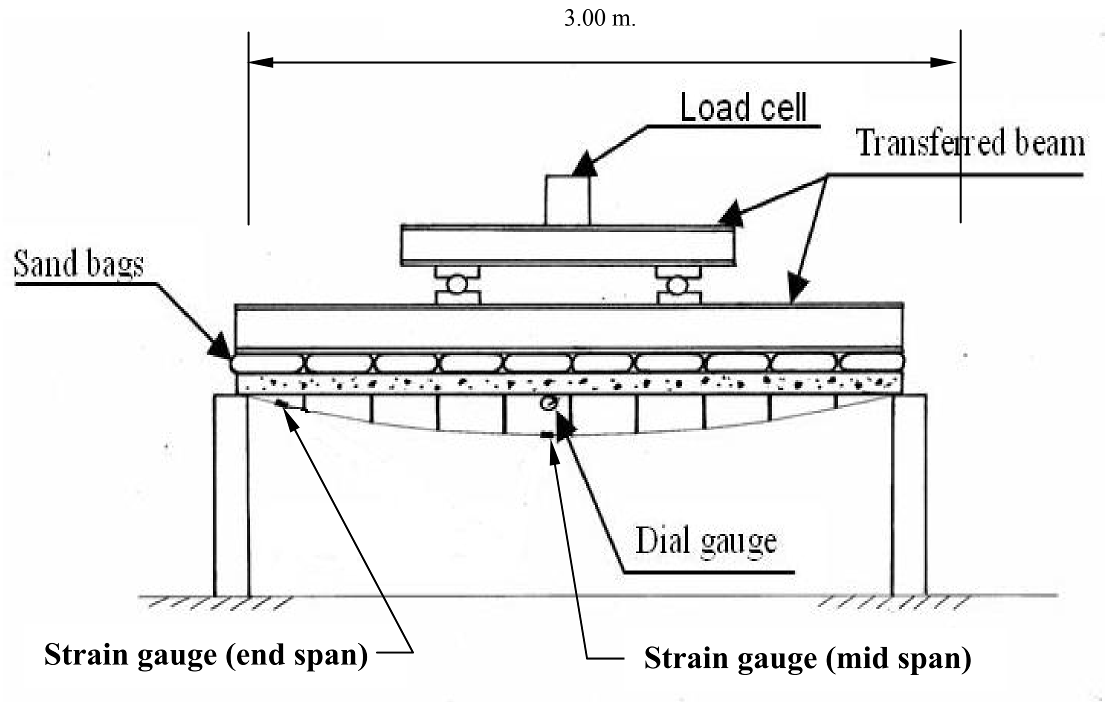

Figure 11 Test set-up in drawing

Figure 12 Actual test set-up

TEST RESULTS

Average yield stress of checkered plate and rebar, RB9, from test as shown in Table 13 and Table 14 are 3,376 ksc. and 2,911 ksc. respectively thus the yield stress of the checkered plate and of the rebar of 3,300 ksc. and 2,900 ksc. will be used in FEM analysis respectively. Meanwhile the average compressive strength of concrete at 28 days as shown in Table 15 is 261 ksc. thus the 260 ksc. of the compressive strength of concrete will be used in FEM analysis.

The load strain relationship, the load stress relationship and the load deflection relationship of each sample from testing are plotted and compared to those by FEM as shown in Figure 15 to Figure 35 and Table 16

Table 13 Tensile strength of checkered plate

Sample	**Width**	**Depth**	**Length**	**Yield Load**	**Yield Stress**	**Average Yield Stress**
(No.)	(mm.)	(mm.)	(cm.)	(kg.)	(ksc.)	(ksc.)
1	25.12	1.98	60	1,700	3,418	
2	25.22	1.99	60	1,650	3,288	3,376
3	24.87	1.98	60	1,685	3,422	

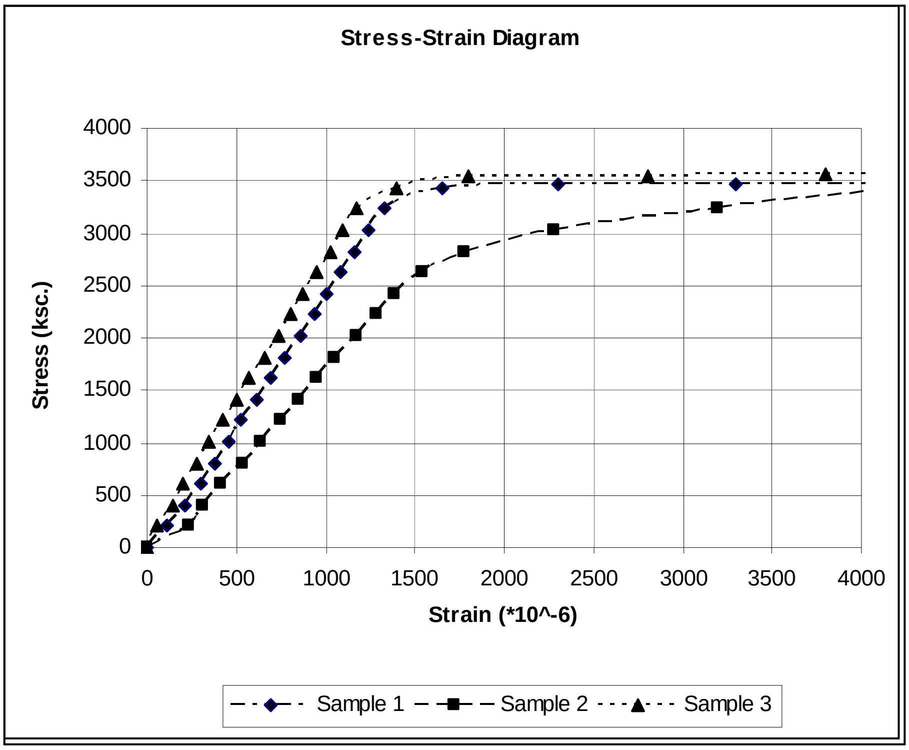

Figure 13 Stress-Strain curve for checkered plate

Table 14 Tensile strength of RB9

Sample (No.)	Diameter (mm.)	Length (cm.)	Yield Load (kg.)	Yield Stress (ksc.)	Average Yield Stress (ksc.)
1	8.98	50.0	1,800	2,842	
2	8.95	50.0	1,850	2,941	2,911
3	8.97	50.0	1,865	2,951	

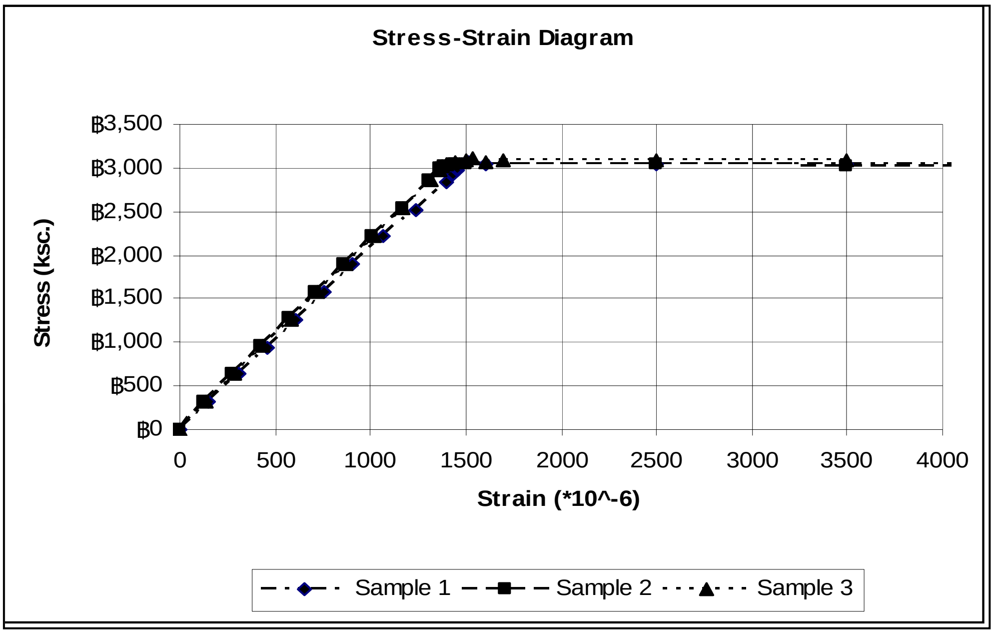

Figure 14 Stress-Strain curve for RB9

Table 15 Compressive strength of 15 x 30 cm. concrete cylinders.

Age (Days)	Sample No.	Compressive Strength (ksc)	Average (ksc)
7	1	192	186
	2	179	
	3	187	
14	1	215	211
	2	200	
	3	219	
28	1	253	261
	2	274	
	3	257	

LOAD STRAIN RELATIONSHIP

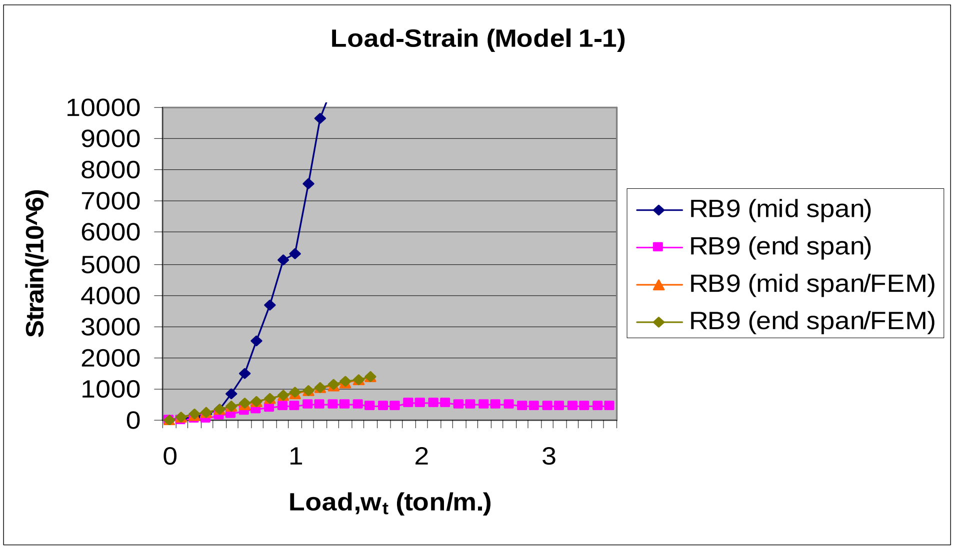

Figure 15 Load-Strain curve for Model 1-1

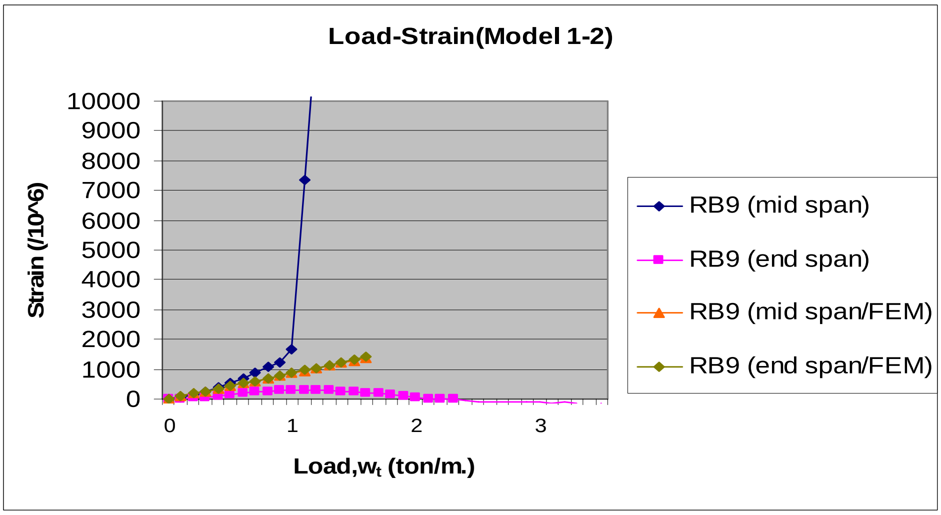

Figure 16 Load-Strain curve for Model 1-2

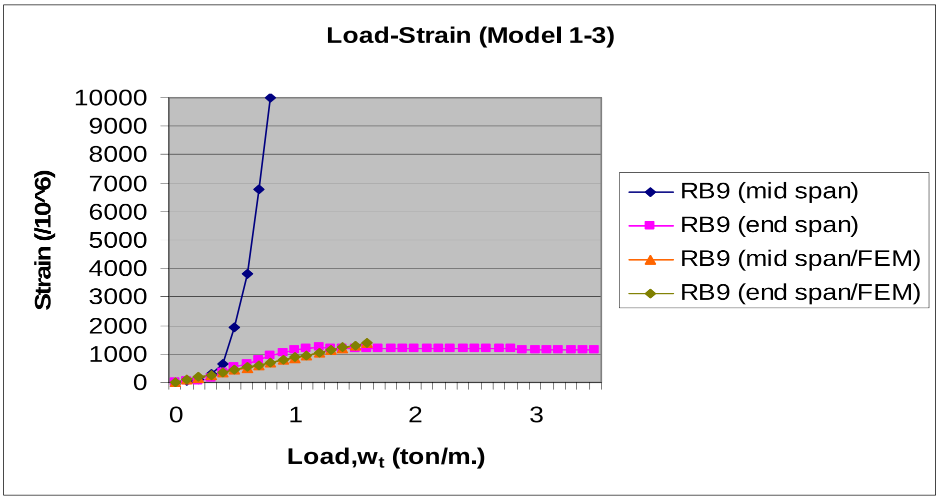

Figure 17 Load-Strain curve for Model 1-3

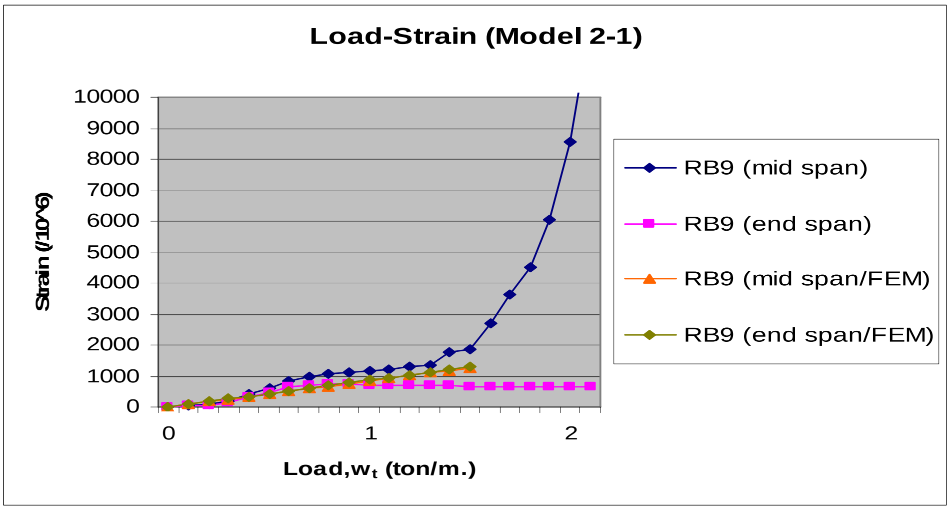

Figure 18 Load-Strain curve for Model 2-1

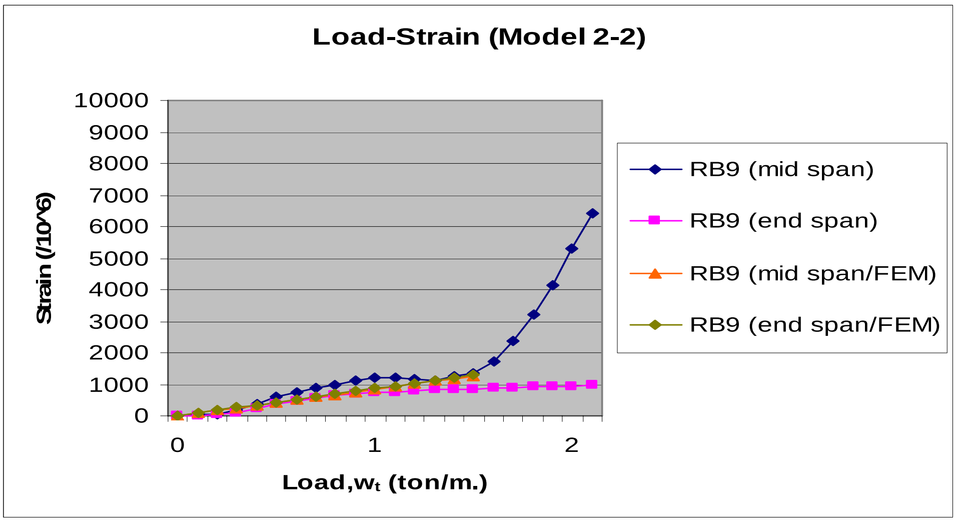

Figure 19 Load-Strain curve for Model 2-2

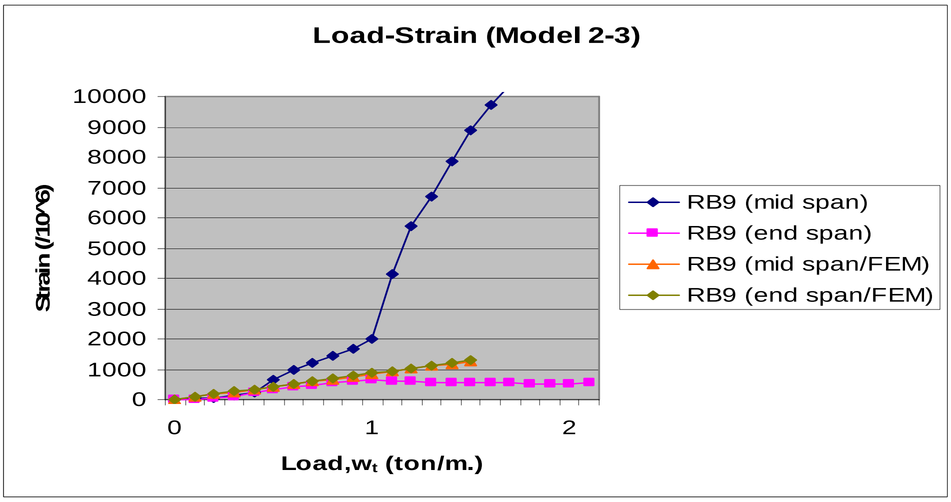

Figure 20 Load-Strain curve for Model 2-3

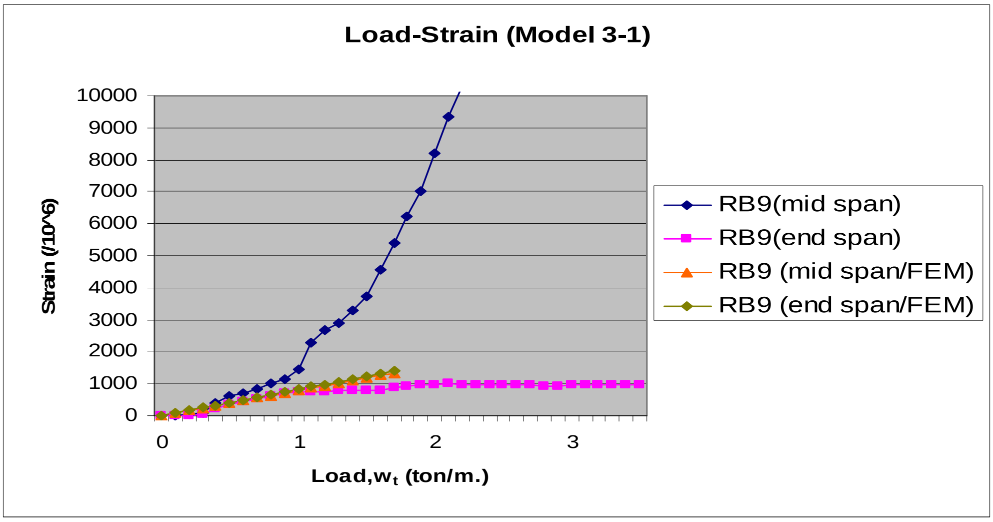

Figure 21 Load-Strain curve for Model 3-1

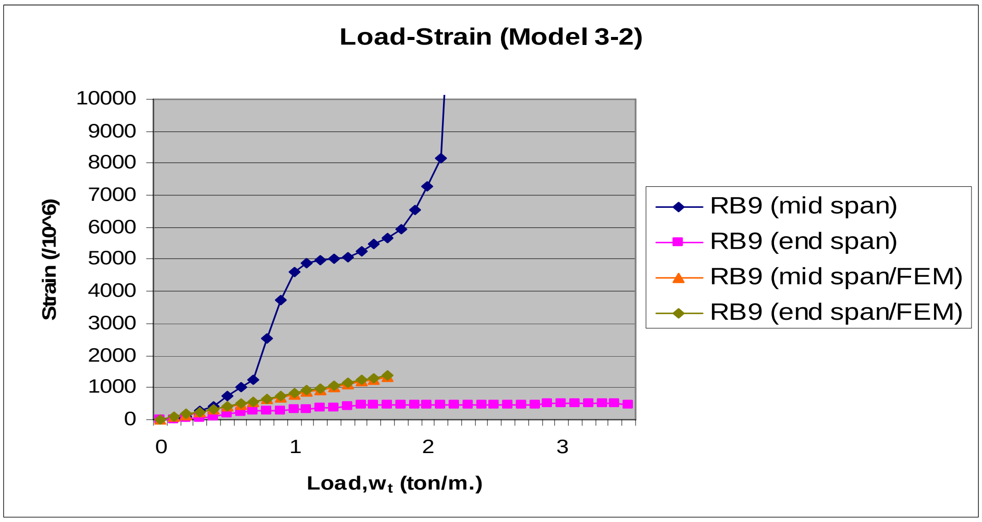

Figure 22 Load-Strain curve for Model 3-2

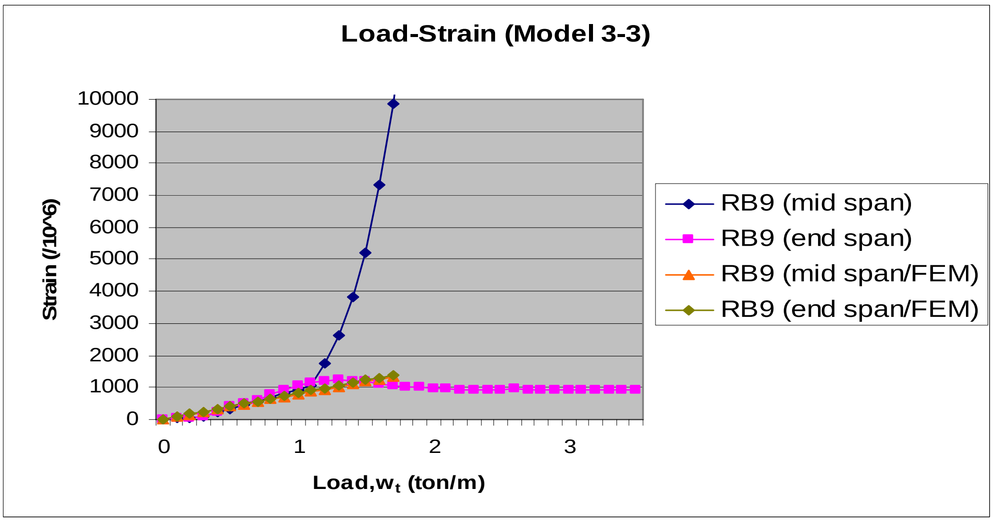

Figure 23 Load-Strain curve for Model 3-3

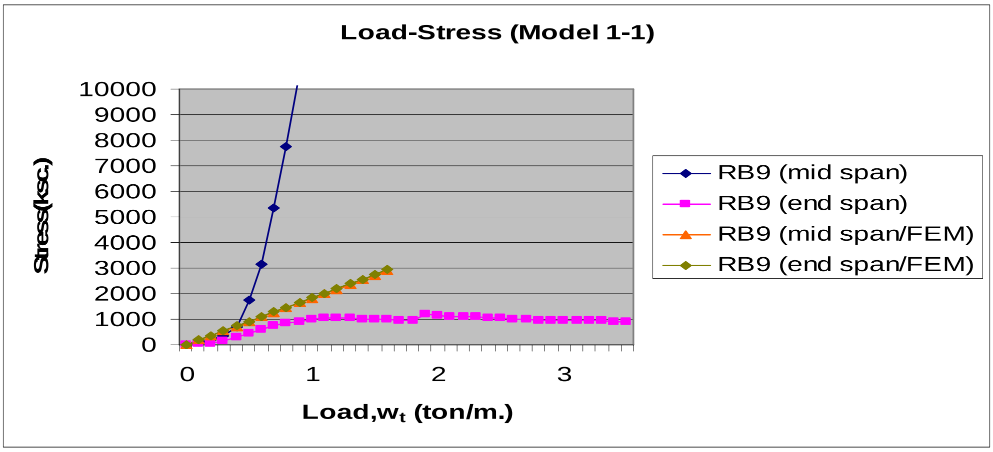

Figure 24 Load-Stress curve for Model 1-1

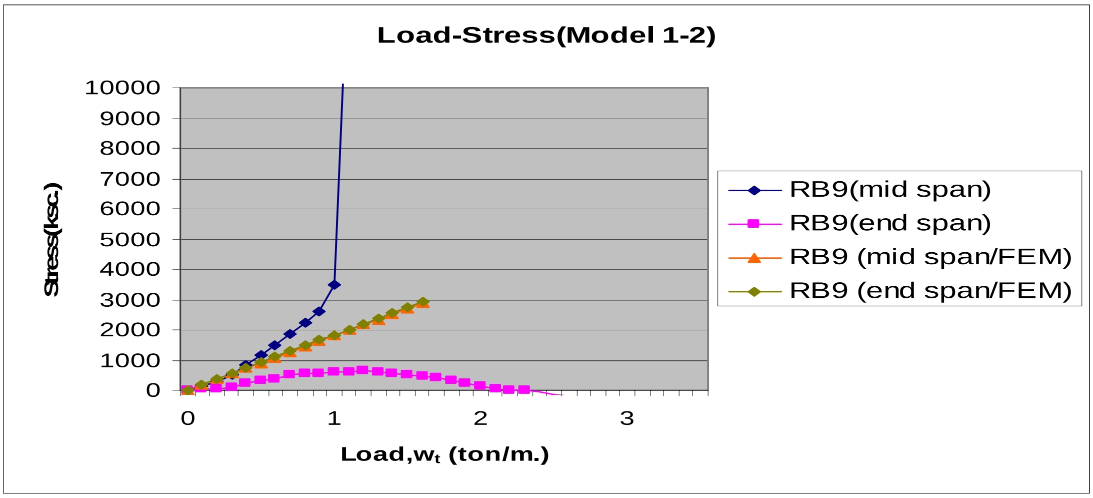

Figure 25 Load-Stress curve for Model 1-2

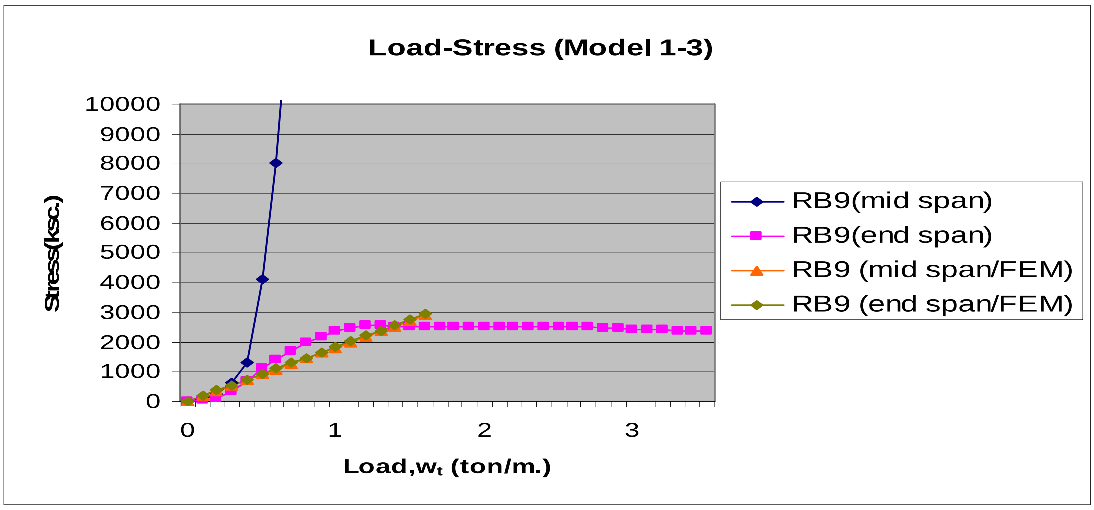

Figure 26 Load-Stress curve for Model 1-3

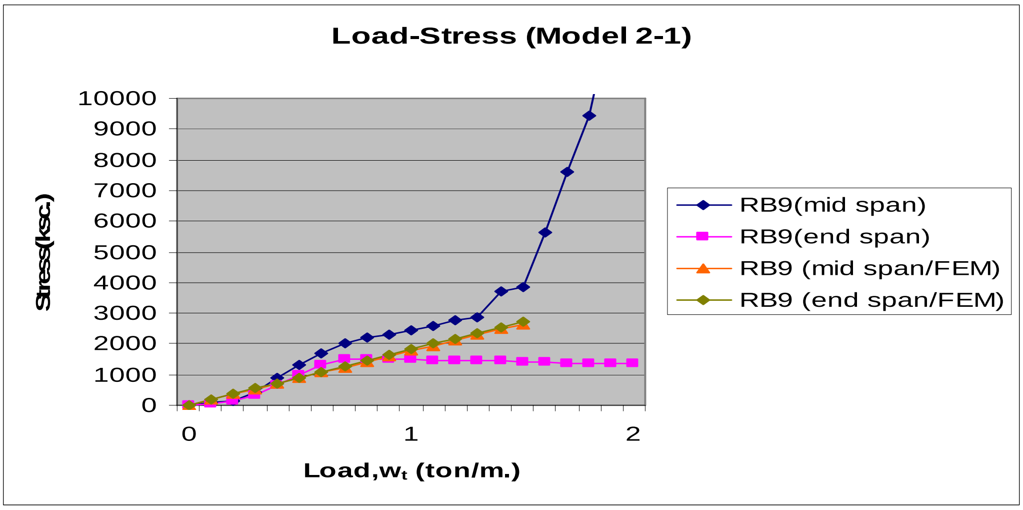

Figure 27 Load-Stress curve for Model 2-1

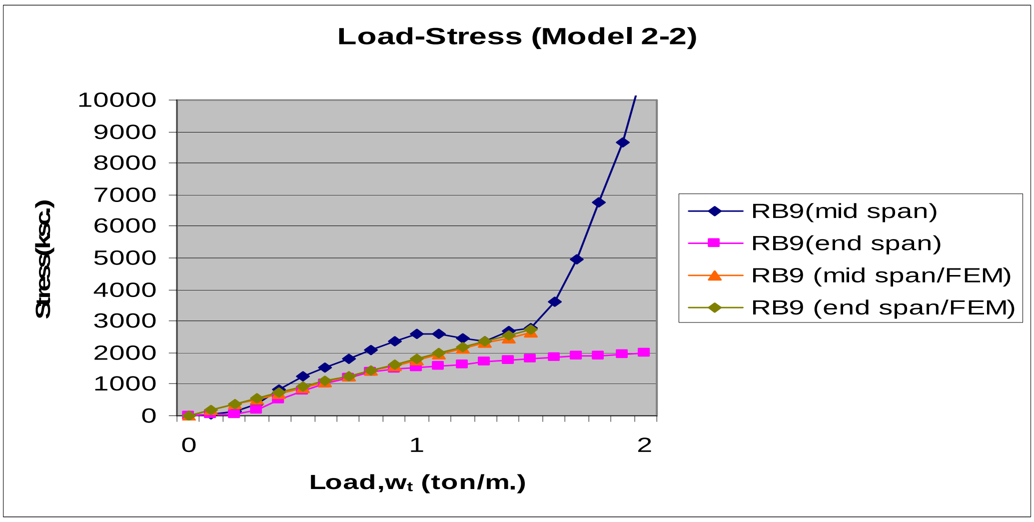

Figure 28 Load-Stress curve for Model 2-2

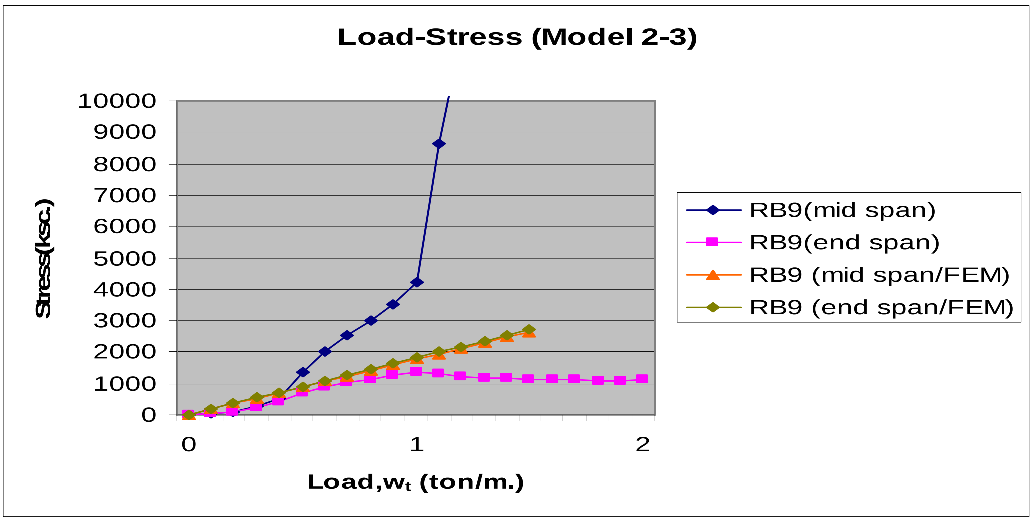

Figure 29 Load-Stress curve for Model 2-3

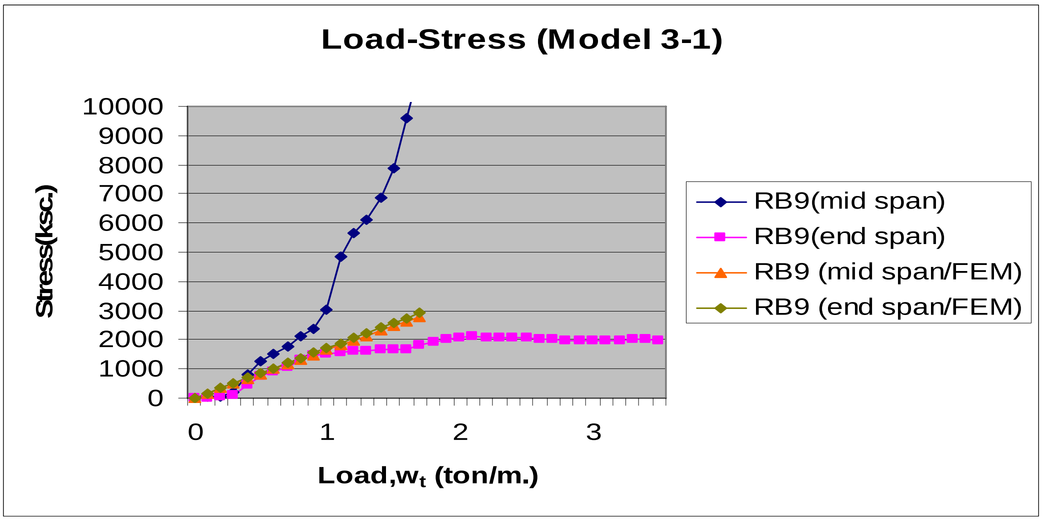

Figure 30 Load-Stress curve for Model 3-1

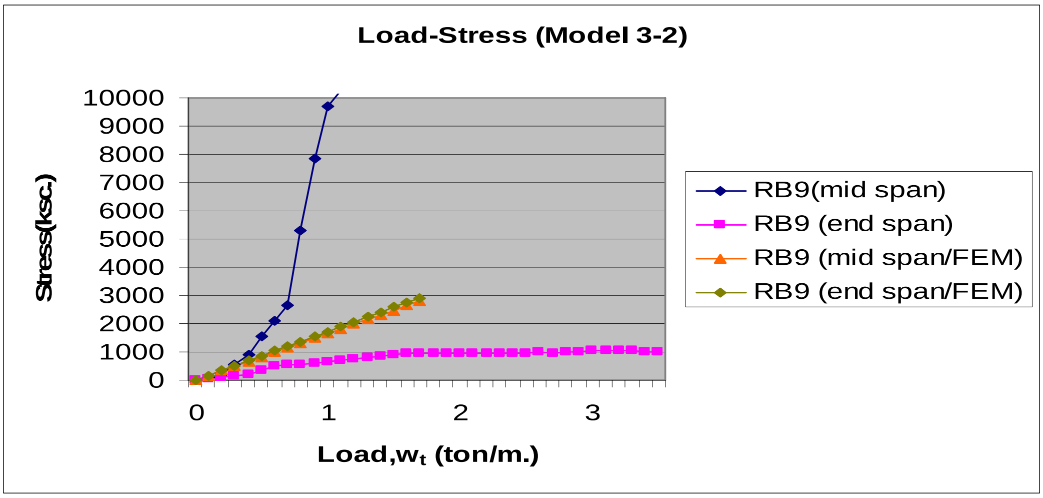

Figure 31 Load-Stress curve for Model 3-2

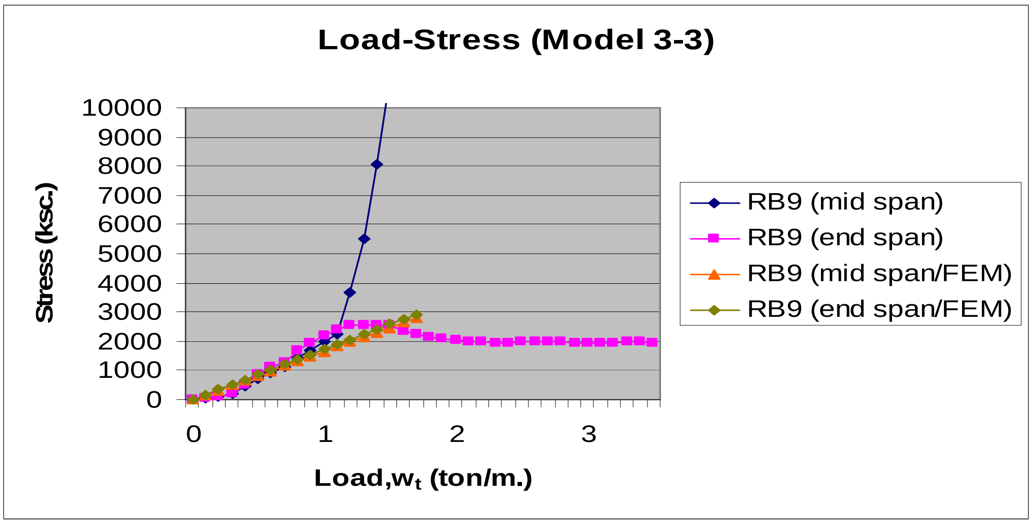

Figure 32 Load-Stress curve for Model 3-3

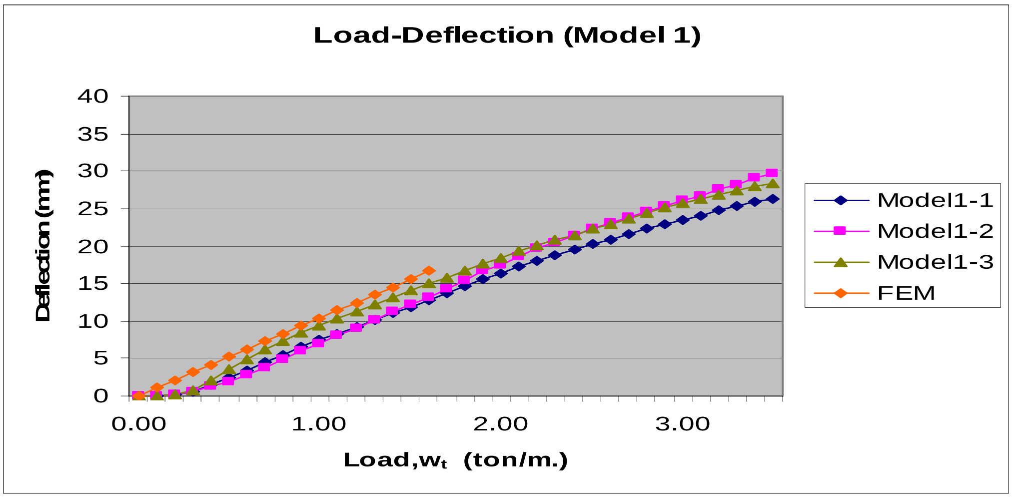

Figure 33 Load-Deflection curve for Model 1

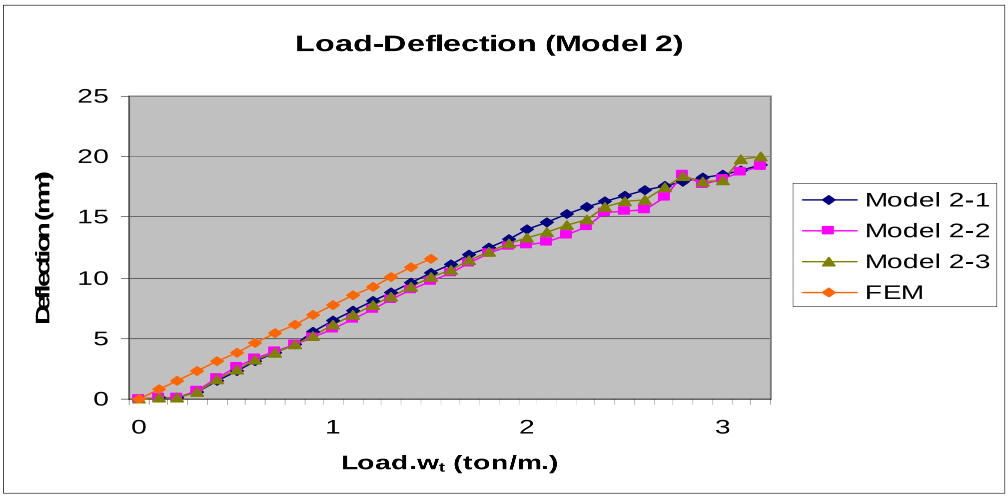

Figure 34 Load-Deflection curve for Model 2

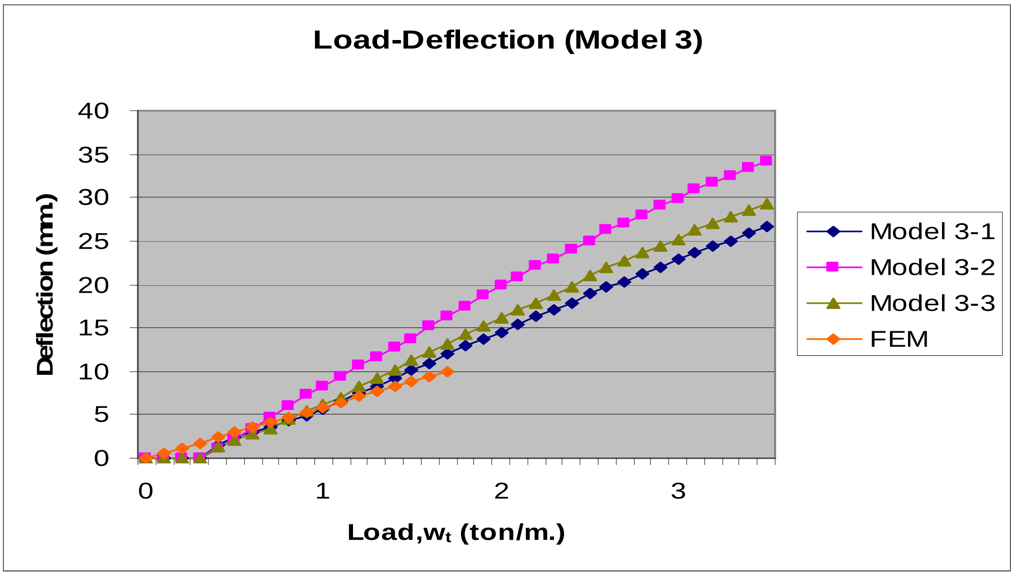

Figure 35 Load-Deflection curve for Model 2

DISCUSSION

According to the results from Table 16, it was found that the rebars (RB9) installed in parabolic curve have their first yield strains at the middle span of the specimen while having less strains at the end of span as shown in appendix B (Testing Results)

On the other hand, according to the theory and also FEM analysis, those rebars have their first yield strains at both ends while having minimum strains at the middle span. Thus, in order to investigate the cause which leads to these above opposing results, a review of the analysis was made.

Table 16 Comparison of Load, w_t (ton/m) from Test with FEM at yield strength of rebar

Model	Load w_t (ton/m)		Mid span deflection (mm)	
	Test	FEM	Test	FEM
1-1	0.57		3.15	
1-2	0.92	1.52	6.15	15.80
1-3	0.45		2.78	
2-1	1.26		8.41	
2-2	1.50	1.54	9.77	11.91
2-3	0.75		4.17	
3-1	0.96		5.3	
3-2	0.70	1.63	4.76	9.58
3-3	1.04		6.54	

The investigation via FEM program by assume uniform load 1 ton/m. on the sample model 2, with two different specified joints at the checkered plate to the transferred plate of hinge joint and rigid joint was made. The comparison of the internal forces in the row of the transferred plate are shown below.

Table 17 Comparison of the internal forces of the transferred plates by FEM program

Type of joint	Internal forces of the transferred plate (kg.) at								
	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L
Hinge	180	180	180	180	180	180	180	180	180
Rigid	64	126	173	189	194	189	173	126	64

It was found that the internal forces in the row of the transferred plate for specified rigid joint are not uniform over the span but those for specified hinge joint are uniform over the span like the design assumption. Those internal forces in the row of the transferred plates will be transferred to the rebar therefore the uniformity of these forces should influence the characteristic of the tensile forces in the rebar at any position along the span.

Comparison load-strain relationship of specimen model 2 computed by FEM analysis between that from the first test and that from the re-test.

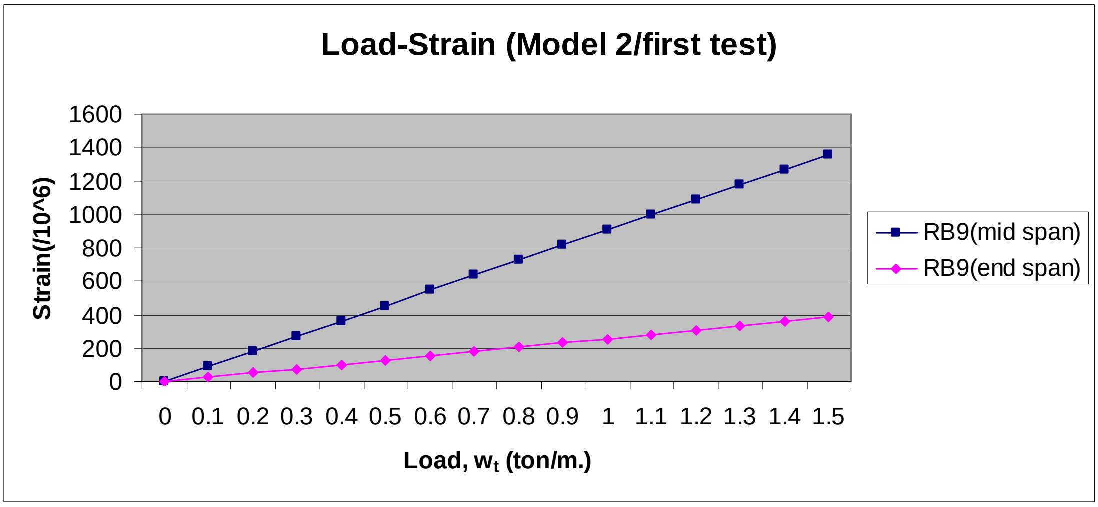

Figure 36 Load-Strain curve for Model 2(rigid joint) by FEM

In the first test, the row of joints at the transferred plate to the checkered plate are specified as ***rigid joint***, strain of the rebar at the middle of span is higher than strain at the end of span and induce 1.47 tons/m. of load capacity, the load that makes the first yield in the rebar.

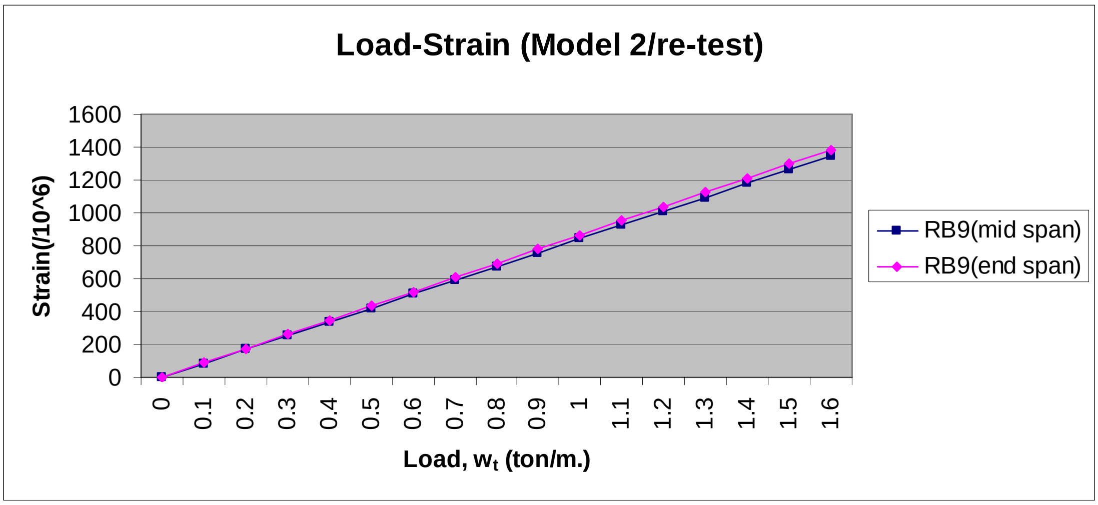

Figure 37 Load-Strain curve for Model 2(hinge joint) by FEM

In the re-test, the row of joints at the transferred plate to the checkered plate are specified as ***hinge joint***, strain of the rebar at the end of span is higher than strain at the middle of span and induce 1.54 tons/m. of load capacity.

It was found that the load capacity of the specimen, which makes the row of joints at the transferred plate to the checkered plate specified as hinge joint, is higher than that of another one specified as rigid joint.

After re-analysis by FEM program, it was found that the different specification of the joint at the checkered plate to the transferred plate lead to the significantly different result as follows:

1. When specified "hinge" at those joints, consequently the first yield strain of the rebars occurs at both ends of span while the minimum strain occurs at the middle span, as done for the first analysis.

2. When specified "rigid" at those joints, consequently the first yield strain of the rebars occurs at the middle span while the minimum strain occurs at both ends of span similar to the results from the test.

Therefore in order to prove the above results, that the different joint specification causes the different results, the specimens model 2 were selected to be modified by changing their connection details at checkered plate to transfer plate by welding joint which results in the rigid joint as Figures 38 and 39 becoming the new detail which is as hinge joint as Figures 40 and 41. The new results from the re-test will be further discussed.

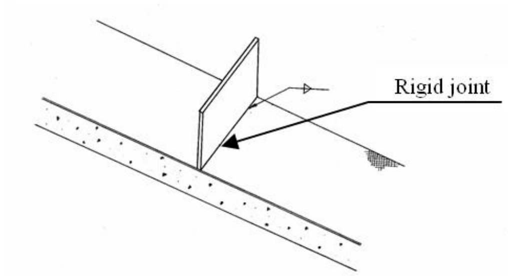

Figure 38 The joint at transferred plate to checkered plate welded for the first test in drawing.

Figure 39 The joint at transferred plate to checkered plate welded for the first test in actual test.

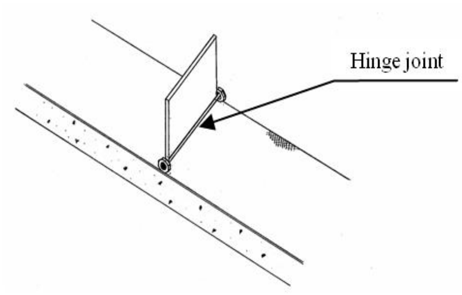

Figure 40 The joint at transferred plate to checkered plate changed as hinge joint for the re-test in drawing.

Figure 41 The joint at transferred plate to checkered plate changed as hinge joint for the re-test in actual test.

After re-test for the modified specimens, model 2,as previously mentioned and refering to the load-strain relationship results, it was found that the higher strain of the rebars occur at the end of span while the less strain occurs at the middle span which conforms to the results from the theory and FEM analysis as shown.

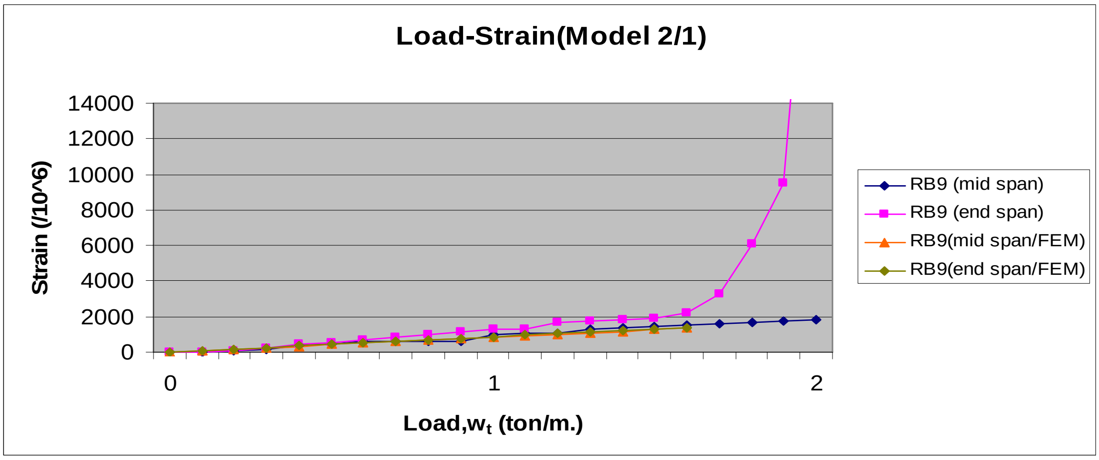

Figure 42 Load-Strain curve for Model 2/1(re-test)

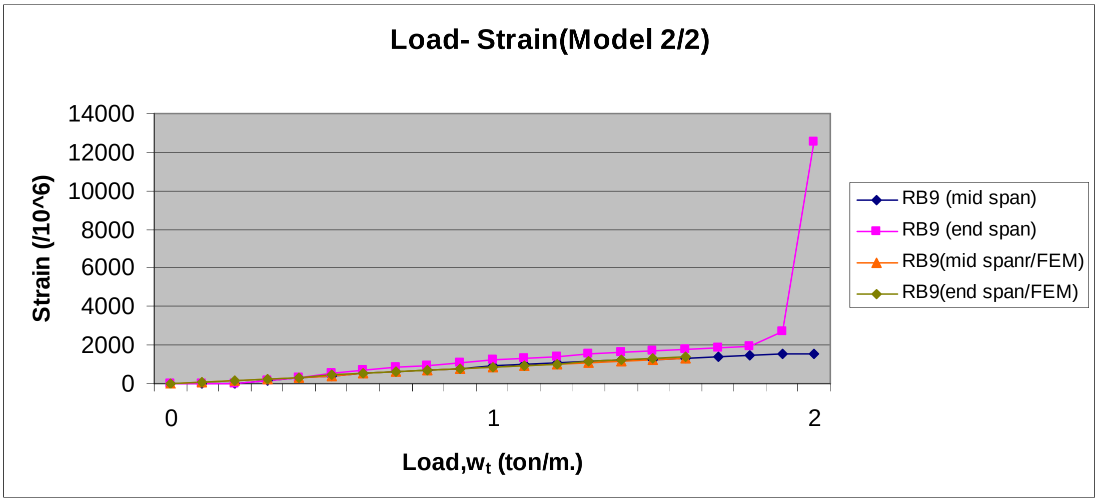

Figure 43 Load-Strain curve for Model 2/2(re-test)

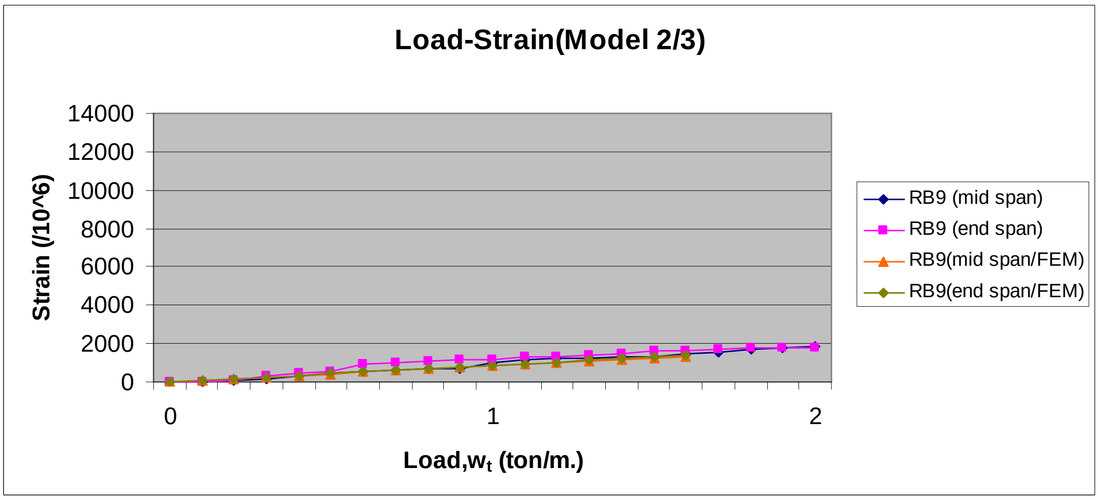

Figure 44 Load-Strain curve for Model 2/3(re-test)

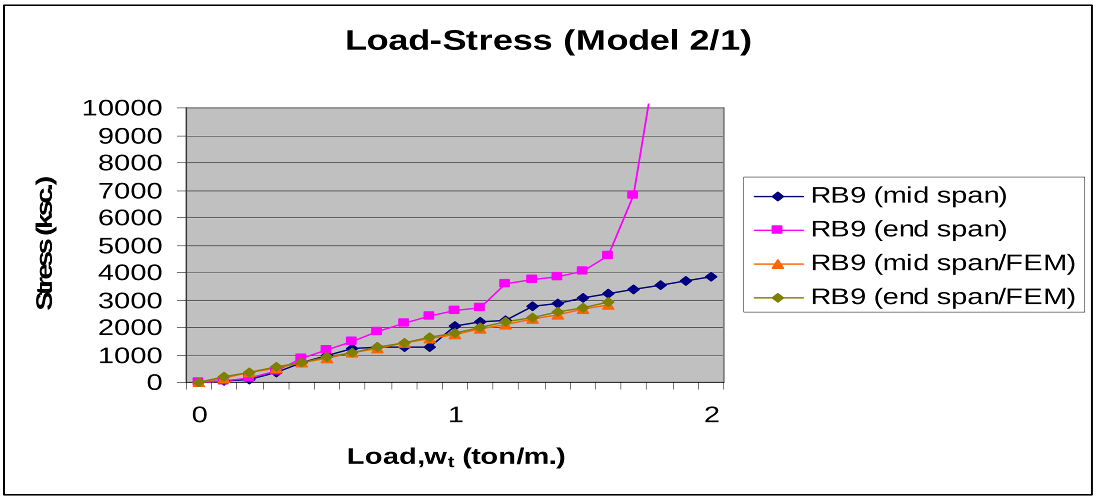

Figure 45 Load-Stress curve for Model 2/1(re-test)

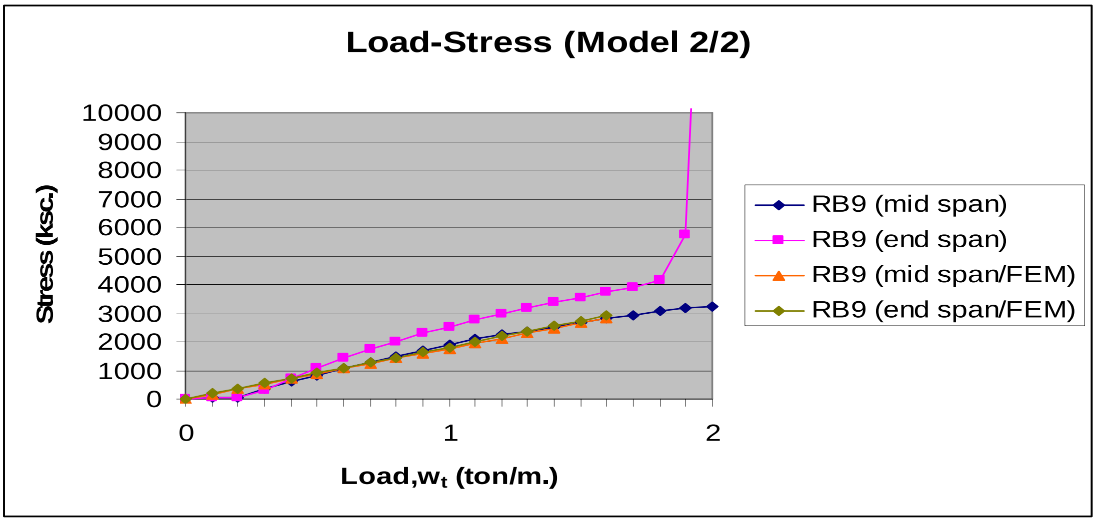

Figure 46 Load-Stress curve for Model 2/2(re-test)

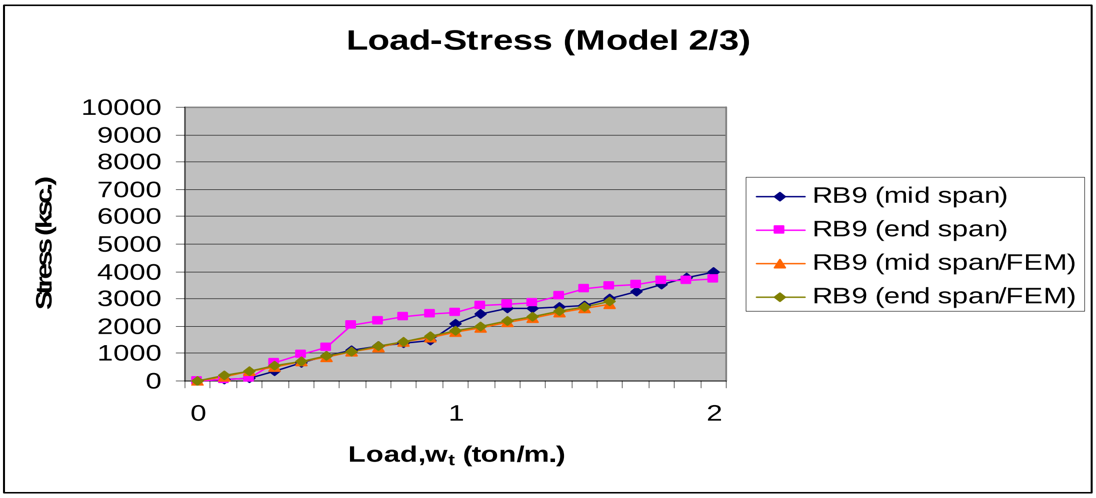

Figure 47 Load-Stress curve for Model 2/3(re-test)

From the load-strain relationship results above, the results from testing of model 2/3 obviously deviate from the results of FEM analysis but those of model 2/1 and model 2/2 are very close to the results from the theory and FEM analysis.

The results from testing which deviated from those of the theory might occur because

1. The load which is transferred via the transferred beam subject on the specimen, is not actually uniform load as defined in the theory.

2. There are deviation of the strain values due to some mistakes from the installation of strain gauge such as too little the curing time of glue before testing that might induce slipping of the strain gauge during the test and might lead to the results happening of the model 2/3. The contact surface between the strain gauge and rebar is not clean which might induce some spots of void between the strain gauge and rebar.

3. Some joints of the transferred plates with rebar do not contact each other during the test that induce incomplete load-transferring to the rebar.

4. The connection details, between the row of the transferred plates and the checkered plate, which are made as hinge joints as shown in Figure 3 result the spacing of gap between each of the transferred plate and the checkered plate that might lead to non-uniformly transferred load through those transferred plates.

Comparison of load-displacement relationship of the sample model 2 (re-testing) between that from FEM analysis and that from the re-test.

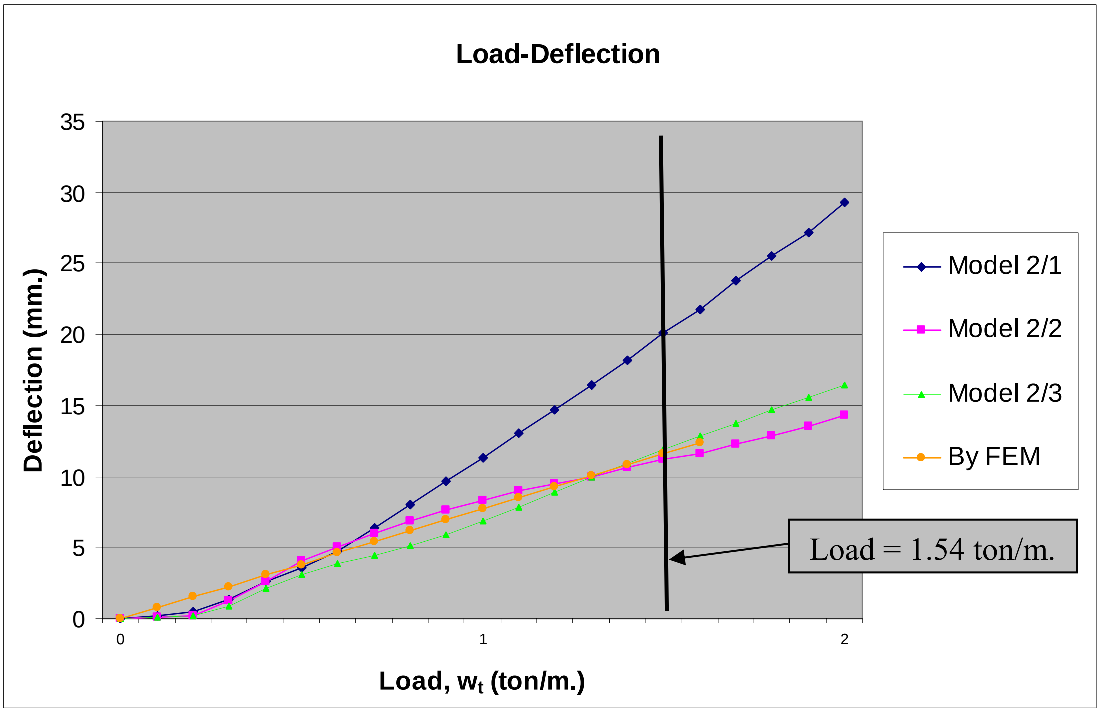

Figure 48 Load-Deflection curve for Model 2(re-test)

It was found that two curves from model 2/2 and model 2/3 are close to the curve from FEM analysis until load up to 1.54 ton/m., the load at the first yield occurs in the rebar at the end of span which is defined as load capacity of the sample.

Table 18 Comparison of Load w_t (ton/m) from test, re-test and FEM analysis at yield strength of rebar

Model	Load w_t (ton/m)			Mid span deflection (mm)		
	Test	Re-test	FEM	Test	Re-test	FEM
2-1	1.26	1.11		8.41	13.02	
2-2	1.50	1.12	1.54	9.77	9.02	11.91
2-3	0.75	1.22		4.17	9.11	

Conclusion of data from the results of the sample model 2 (first test)

Use the yield stress of the rebar, f_y, is 2,900 ksc.

Use the modulus of elasticity of the rebar, E_s, is 2,100,000 ksc.

The yield strain of the rebar $= f_y / E_s = 1.38$ e-03

Dead load of sand bags and transfer beams = 0.394 ton

Self weight of sample = 0.28 ton

The ultimate load in case of the first yield of the rebar occurs at mid span of the sample in first test, as shown.

	Model 2-1	Model 2-2	Model 2-3	FEM
Load, w_t (ton/m.)	1.258	1.501	0.752	1.48

Average load = (1.258+1.501+0.752)/3 =1.17 ton/m.

Superimposed load = (Average load) - (Self weight of sample)
= 1.17 - 0.093 = 1.077 ton/m. or 1.077/0.3 =3.59 ton/ m^2

Superimposed load by FEM = 1.48 – 0.093 = 1.387 ton/m.or 1.387/0.3
= 4.623 ton/ m^2

Let allowable service load = Superimpose load / Safety factor,2.00 therefore

Allowable service load from testing = 3.59/2 = 1.795 ton/ m^2

Allowable service load by FEM = 4.623/2 = 2.312 ton/ m^2

The service load in case of the deflection at mid span reached the allowable deflection, L/250 = 3,000 /250 = 12 mm., as show.

	Model 2-1	Model 2-2	Model 2-3	FEM
Load, w_t (ton/m.)	1.725	1.798	1.771	1.66

Average load = (1.725+1.798+1.771)/3 =1.765 ton/m.

Superimposed load = (Average load) - (Self weight of sample)
= 1.765 - 0.093 = 1.672 ton/m. or 1.672/0.3 =5.573 ton/ m^2

Service load by FEM = 1.66 -.093 =1.567 ton/m. or 1.567/0.3 =5.223 ton/ m^2

Conclusion of data from the results of the sample model 2(re-test)

Use the yield stress of the rebar, f_y, is 2,900 ksc.

Use the modulus of elasticity of the rebar, E_s, is 2,100,000 ksc.

The yield strain of the rebar =f_y/ E_s= 1.38 e-03

Dead load of sand bags and transfer beams = 0.394 ton

Self weight of sample = 0.28 ton

The ultimate load in case of the first yield of the rebar occurs near the support of the sample, re-test, as shown.

	Model 2/1	Model 2/2	Model 2/3	FEM
Load, w_t (ton/m.)	1.110	1.118	1.222	1.54

Average load = (1.11+1.118+1.222)/3 =1.15 ton/m.

Superimposed load = (Average load) - (Self weight of sample)
= 1.15 - 0.093 = 1.057 ton/m. or 1.057/0.3 =3.52 ton/ m^2

Superimposed load by FEM = 1.54 – 0.093 = 1.447 ton/m.or 1.447/0.3
= 4.823 ton/ m^2

Let allowable service load = Superimpose load / Safety factor,2.00 therefore

Allowable service load from testing = 3.52/2 = 1.76 ton/ m^2

Allowable service load by FEM = 4.823/2 = 2.412 ton/ m^2

The service load in case of the deflection at mid span reached the allowable deflection, L/250 = 3,000 /250 = 12 mm., as show.

	Model 2-1	Model 2-2	Model 2-3	FEM
Load, w_t (ton/m.)	1.041	1.658	1.525	1.56

Average load = (1.041+10658+1.525)/3 =1.765 ton/m.

Superimposed load = (Average load) - (Self weight of sample)
= 1.765 - 0.093 = 1.672 ton/m. or 1.672/0.3 =5.573 ton/ m^2

Service load by FEM = 1.56 -.093 =1.467 ton/m. or 1.467/0.3 =4.89 ton/ m^2

Comparison between allowable safe load of samples model 2

Assumptions : Safe load capacity is the lower of two load's conditions below

1. Safe load capacity of the specimen is equal to the superimposed load divided by safety factor, 2.00.

2. The load which induces the maximum deflection of the specimen, L/250 that is 12 mm.

Table 19 Comparison of allowable service load between samples model 2 from testing and from FEM on page 35 and page 36

Type of slab with span 3.00 m.	Self weight (kg/m^2)	Allowable service load (kg/m^2)
Specimen Model 2(rigid joint)* from testing	280	3,590/2 =1,795
Specimen Model 2(hinge joint)** from testing	280	3,520/2 =1,760
Specimen Model 2(hinge joint)** from FEM	280	4,823/2 =2,412

Note: * rigid joint = the row of joints at the transferred plate to the checkered plate are specified as ***rigid joint***

** hinge joint = the row of joints at the transferred plate to the checkered plate are specified as ***hinge joint***

The ultimate load capacity from testing is less than that from the theory, which may be caused from the lists of reasons below:

1. The connection details between the row of transferred plates and the checkered plate are welded which induce those joints as rigid joints so that consequently the internal forces in the rebars at any position along the span of specimen do not conform to those from the theory in which joints are indicated as hinge joints.

2. The connection details between the row of the transferred plates and the checkered plate might lead to non-uniformly transferred load through those transferred plates.

3. Incomplete load-transferring to the rebar during the test.

4. There are deviations of the strain values due to some mistakes from the installation of strain gauge.

5. The load applied from load cell is not uniformly distributed to the specimen.

CONCLUSION

1. The behavior of the built-up section subjected load conform to that from the simplified analysis and FEM analysis.

2. It was found that the service load capacity of the built-up section with 3 m. span is controlled more by the strength of the rebars than the deflection, the strength of the built-up section is controlled by the yield strength of the rebars not by the allowable deflection. However the control condition depends on the area of rebars (cable), span length and yield strength of the rebar. It means that the service load capacity may be controlled by the deflection for longer span nevertheless the area of rebar and yield strength of rebar should be considered simultaneously.

3. The built-up section, model 2 which has the hinge joint between the row of the transferred plates to the bottom of slab, is able to serve the service load as much as 1,700 kg/ m^2 approximately which is increase service load from cast in place of one way slab with 0.30 m width x 0.10 m. thick with $\rho = 0.75\ \rho_b = 0.033$ (design $f_c' = 260$ ksc. and $f_y = 2{,}900$ ksc. which the same as material test results), 550 kg/ m^2.

4. This built-up section is recommended for the occurrence which needs low technology for fabrication or needs particular design instead of the standard section of pre-cast slab which is available in the market.

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APPENDICES

Appendix A

Equipments' data

Weight of transferred beams = 231 kg.

Weight of sand bags = 163 kg.

Load cell 100 tons

Strain gauge 5 mm. of gauge length

Self weight of specimens as shown.

Appendix Table A1 Self weight

SPECIMEN	SELF WEIGHT
Model 1-1	253 kg
Model 1-2	255 kg.
Model 2-1	280 kg.
Model 2-2	281 kg.
Model 2-3	281 kg.
Model 3-1	308 kg.
Model 3-2	298 kg.
Model 3-3	317 kg.

Appendix B

Test Results

<u>Appendix Table B1</u> Load-Strain data of specimen, Model 1-1

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	32.955	107.786	-41.724	10.295
0.2	54.598	141.212	-64.984	16.721
0.3	82.285	208.089	-92.875	24.729
0.4	119.297	286.036	-127.010	31.817
0.5	126.214	306.185	-138.337	36.187
0.6	155.603	367.069	-165.822	44.739
0.7	184.145	476.566	-197.863	52.748
0.8	212.784	592.146	-224.599	60.189
0.9	231.601	1047.359	-243.200	63.899
1	251.174	1232.659	-274.587	70.349
1.1	274.220	1411.127	-301.464	77.838
1.2	294.009	1584.124	-322.482	83.579
1.3	316.465	1892.194	-355.138	89.674
1.4	340.175	2377.575	-385.128	96.999
1.5	359.634	2709.040	-409.864	102.740
1.6	381.834	3140.353	-436.566	109.615
1.7	393.313	3468.410	-460.219	118.641
1.8	407.463	3896.322	-485.071	123.768
1.9	412.873	4553.413	-517.166	130.668
2	428.203	4989.751	-540.433	139.198
2.1	441.361	5202.261	-557.510	145.317
2.2	452.229	5222.635	-579.744	151.413
2.3	465.834	5233.026	-603.129	162.566
2.4	476.205	5365.950	-619.389	166.772
2.5	480.647	6455.996	-642.460	173.672
2.6	490.381	7173.733	-660.878	182.344
2.7	497.729	7941.859	-676.969	188.417

Appendix Table B1 (continued)

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	502.360	8849.879	-697.975	196.262
2.9	508.716	9409.254	-718.047	204.415
3	508.810	9845.480	-732.146	211.552
3.1	514.480	10182.800	-750.345	219.373
3.2	506.449	10552.669	-766.865	226.581
3.3	496.290	10952.939	-776.792	234.663
3.4	494.166	10748.674	-789.234	243.170
3.5	489.254	11057.289	-806.114	250.993
3.6	486.893	11238.354	-816.877	255.979
3.7	481.391	11291.104	-833.061	262.785
3.8	477.588	11474.611	-842.770	261.699
3.9	475.584	11932.994	-859.862	268.222
4	471.262	12116.615	-871.009	274.768
4.1	469.114	12252.313	-883.115	281.101
4.2	469.069	12293.144	-895.197	284.505
4.3	465.127	12508.208	-910.872	294.879
4.4	463.758	12626.433	-926.261	298.591
4.5	459.838	12481.891	-935.945	298.449
4.6	459.109	11426.808	-951.644	306.531
4.7	451.764	14636.997	-962.551	321.421
4.8	449.147	14512.091	-973.911	326.172
4.9	444.165	14287.806	-986.639	331.986
5	571.496	14098.437	-1002.481	342.291
5.1	565.519	13970.993	-1010.200	345.316
5.2	554.808	13879.923	-1021.344	352.455
5.3	552.473	13812.511	-1028.893	358.766
5.4	548.068	13761.198	-1037.090	364.746

Appendix Table B1 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	539.476	13693.131	-1053.867	373.350
5.6	535.815	13617.270	-1063.548	379.401
5.7	528.086	13544.068	-1075.244	425.992
5.8	529.782	13492.799	-1084.975	438.640
5.9	523.963	13372.387	-1095.494	446.039
6	525.288	13321.578	-1104.577	453.391
6.1	518.636	13274.368	-1112.389	459.396
6.2	520.176	13249.296	-1117.853	467.789
6.3	518.174	13216.014	-1126.623	477.907
6.4	515.280	13193.202	-1134.435	485.378
6.5	513.557	13157.379	-1140.234	482.257
6.6	505.127	13162.354	-1147.686	492.778
6.7	498.442	13158.940	-1152.957	495.733
6.8	490.655	12606.671	-1161.489	507.602
6.9	488.348	12585.569	-1165.706	513.655
7	482.094	12591.414	-1168.892	514.412
7.1	484.866	12600.890	-1175.889	520.275
7.2	478.150	12591.344	-1180.824	528.243
7.3	475.071	12573.648	-1187.389	532.617
7.4	477.472	12576.771	-1195.777	538.978
7.5	474.364	11896.176	-1201.048	541.602
7.6	470.174	11676.367	-1206.774	544.369
7.7	465.769	11610.681	-1208.906	550.021
7.8	460.686	11562.811	-1214.657	549.311
7.9	459.485	11544.607	-1220.097	544.653
8	456.836	11521.936	-1226.758	544.510
8.1	457.514	11498.001	-1229.825	546.189

Appendix Table B1 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	456.837	11474.786	-1234.976	550.161
8.3	452.000	11455.077	-1239.480	549.546
8.4	450.398	11431.742	-1241.972	559.169
8.5	445.930	11403.204	-1245.926	570.068
8.6	447.997	11387.919	-1250.358	577.161
8.7	447.505	11383.527	-1253.066	582.197
8.8	446.949	11365.359	-1260.133	588.297
8.9	445.439	11364.100	-1264.493	591.371
9	443.251	11357.590	-1266.146	589.314
9.1	441.744	11351.953	-1268.112	594.540
9.2	442.666	11357.710	-1271.610	594.729
9.3	438.753	11346.153	-1274.364	596.669
9.4	435.059	11251.416	-1275.680	596.834
9.5	436.076	11055.779	-1285.385	602.604
9.6	430.347	11052.679	-1285.600	604.495
9.7	430.898	11039.160	-1289.265	610.691
9.8	431.454	11020.980	-1293.242	612.724

Appendix Table B2 Load-Strain data of specimen, Model 1-2

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	31.614	177.7742	-74.3176	19.7943
0.2	40.0405	186.0819	-112.547	29.2199
0.3	65.3193	276.8382	-156.3905	40.6317
0.4	78.9855	329.2509	-180.7942	45.7343
0.5	95.2035	369.2369	-209.5895	57.0737
0.6	105.5411	411.4963	-222.4035	63.7365
0.7	134.5752	498.1547	-254.5079	73.8718
0.8	138.1861	517.2624	-273.2952	77.6274
0.9	156.1729	573.5958	-279.6293	81.8806
1	169.416	630.7841	-319.5062	92.0875
1.1	181.8793	671.3505	-347.0019	98.9624
1.2	190.5901	727.2671	-378.238	106.8999
1.3	210.6314	786.525	-425.3079	116.1146
1.4	226.5661	852.1111	-469.0647	124.8331
1.5	250.4337	918.413	-502.8888	136.0318
1.6	261.3402	978.4655	-535.6327	142.1274
1.7	265.3059	1036.1757	-581.471	155.8077
1.8	265.9433	1089.9095	-614.0672	166.4403
1.9	264.6685	1146.205	-670.9836	179.1998
2	271.2551	1211.9579	-698.5404	192.8806
2.1	277.2758	1260.298	-728.2553	200.8202
2.2	275.9296	1459.8708	-760.199	210.6023
2.3	288.9615	1613.1167	-796.9626	227.5435
2.4	292.1484	1687.6501	-822.2861	238.3899
2.5	291.4397	4431.8792	-864.154	249.6614
2.6	295.6898	6288.197	-893.2888	264.9739
2.7	296.54	8302.5883	-919.9771	272.3463

Appendix Table B2 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	297.6733	10695.4276	-957.8842	286.1701
2.9	299.1597	11939.307	-981.2616	298.7896
3	302.631	12951.8988	-1006.5803	311.4794
3.1	304.5431	14267.8168	-1042.9021	328.6355
3.2	294.698	15167.8832	-1078.504	338.5605
3.3	289.8118	16071.2471	-1091.0192	354.5124
3.4	277.133	17041.2989	-1116.981	365.7853
3.5	268.7757	18361.8219	-1148.9131	387.41
3.6	261.5518	18982.3159	-1177.1035	393.9322
3.7	252.4872	19140.9973	-1201.6263	400.4557
3.8	246.8925	19685.752	-1218.5974	411.0196
3.9	233.6483	21000.6898	-1258.0032	425.9799
4	226.9906	21484.1993	-1282.74	434.3464
4.1	219.1297	21837.6385	-1303.2326	436.1892
4.2	211.1273	21932.505	-1327.6085	435.7643
4.3	198.4508	22559.8109	-1371.3243	445.6904
4.4	195.3343	22866.0186	-1397.351	460.2977
4.5	186.9077	22590.4854	-1412.7374	458.312
4.6	177.2052	20466.8695	-1447.1029	473.273
4.7	166.5826	20004.6766	-1464.5731	484.5473
4.8	149.0212	19735.6135	-1498.7245	495.6085
4.9	139.8864	19688.94	-1516.7682	502.0612
5	116.8004	18880.3562	-1547.9678	517.1647
5.1	113.0481	18633.4693	-1555.947	515.6752
5.2	79.7643	18412.9175	-1577.1531	526.1714
5.3	64.1149	18251.3174	-1590.5234	540.3537
5.4	58.7341	18132.5053	-1602.4562	550.3524

Appendix Table B2 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	44.2181	17961.9812	-1631.209	555.4578
5.6	30.481	17768.6327	-1651.4781	564.2517
5.7	17.1698	17599.9783	-1665.0635	570.9168
5.8	15.0453	17486.8857	-1678.0018	577.0153
5.9	3.4343	17213.6817	-1702.5105	583.8949
6	3.7886	17121.5959	-1713.9386	587.4394
6.1	-6.6906	17025.0377	-1727.1635	590.1351
6.2	-4.0718	16969.3175	-1736.5797	599.6378
6.3	-6.2662	16907.1703	-1753.1094	609.7788
6.4	-12.568	16852.9032	-1766.4773	618.5005
6.5	-17.8069	16763.8859	-1778.6239	614.1748
6.6	-46.2693	16716.9245	-1790.1947	620.9832
6.7	-53.7036	16693.011	-1801.1898	624.3159
6.8	-71.8981	16658.7673	-1811.4668	629.28
6.9	-80.8894	16645.6188	-1816.9293	631.7626
7	-83.9336	16660.8621	-1826.9901	635.8051
7.1	-83.085	16677.1887	-1839.136	636.8684
7.2	-87.1906	16705.22	-1851.9271	648.0029
7.3	-91.7219	16690.1204	-1862.7067	651.5489
7.4	-86.2706	16720.6085	-1873.6298	658.9243
7.5	-95.7575	15172.4998	-1881.4628	659.209
7.6	-99.6516	14676.2162	-1890.5891	656.7977
7.7	-102.483	14533.408	-1896.1223	659.4923
7.8	-106.0942	14439.5587	-1905.9676	662.4704
7.9	-108.0756	14401.2868	-1911.5731	660.0591
8	-109.987	14365.5395	-1921.5606	664.7399
8.1	-110.7655	14315.0192	-1925.7291	666.938

Appendix Table B2 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	-111.3326	14263.8529	-1934.9986	672.8252
8.3	-115.6509	14216.4365	-1942.3279	672.7537
8.4	-117.6336	14169.4542	-1949.2266	698.4281
8.5	-117.7751	14105.6152	-1948.7946	721.8323
8.6	-122.3062	14072.6877	-1957.3461	736.7975
8.7	-123.2963	14054.9633	-1959.7167	747.0829
8.8	-121.1734	14013.321	-1975.0941	758.1472
8.9	-120.9606	14002.8747	-1983.7165	763.3251
9	-121.2435	13995.5263	-1987.8847	755.0974
9.1	-126.4117	13983.7109	-1986.3755	753.5361
9.2	-122.6592	13988.3219	-1989.3927	757.154
9.3	-125.6332	13963.8279	-1997.8713	756.8706
9.4	-132.0756	13747.5857	-2008.9365	754.3876
9.5	-132.3585	13307.3277	-2015.3315	762.3319
9.6	-137.031	13296.8891	-2018.6371	762.8987
9.7	-131.1556	13271.4772	-2024.026	771.198
9.8	-132.6413	13239.1549	-2030.5645	772.5448

Appendix Table B3 Load-Strain data of specimen, Model 1-3

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	67.2523	145.5848	-50.8556	11.091
0.2	123.7535	237.5539	-82.4047	20.9421
0.3	181.5363	347.4299	-122.2354	33.5561
0.4	278.9054	528.8561	-200.2365	49.7152
0.5	283.438	549.3166	-205.4216	51.487
0.6	361.2693	689.7121	-275.0621	70.4808
0.7	417.8593	931.5426	-339.0805	84.3712
0.8	500.165	1259.1749	-400.5026	102.9409
0.9	538.629	2568.4802	-449.9697	109.8154
1	584.1073	3067.1927	-504.2562	118.9582
1.1	640.7807	3562.029	-557.389	134.5511
1.2	691.436	4025.106	-589.2092	143.837
1.3	738.7643	4890.0568	-640.1062	152.9087
1.4	793.9586	6280.6148	-686.3207	166.1636
1.5	828.4668	7208.7061	-726.7017	172.1878
1.6	884.1625	8442.5946	-774.0651	186.7187
1.7	914.6345	9369.0547	-799.1845	200.1158
1.8	956.4457	10599.0573	-841.145	204.8643
1.9	973.9501	12514.0325	-880.513	212.8036
2	1013.3543	13757.295	-922.7576	224.7122
2.1	1046.8066	14346.4836	-944.2749	235.1319
2.2	1080.7563	14208.0341	-979.0329	243.638
2.3	1108.5403	14085.9626	-1012.4232	260.154
2.4	1136.468	14410.2007	-1035.8812	261.9262
2.5	1150.5016	14936.1079	-1063.2253	271.355
2.6	1175.4528	15233.0022	-1089.3447	282.0585
2.7	1196.6471	15522.9887	-1110.9308	292.9051

Appendix Table B3 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	1209.4071	15854.2101	-1136.0415	302.6161
2.9	1226.9875	16288.4556	-1172.8787	314.4556
3	1223.7978	16584.5418	-1189.8582	323.1755
3.1	1238.8969	16280.5833	-1208.1322	329.4838
3.2	1224.6475	16490.123	-1222.09	341.182
3.3	1199.0585	16787.5707	-1239.356	349.4759
3.4	1205.3664	15204.7229	-1250.7224	363.7251
3.5	1198.987	14810.0462	-1269.4277	365.5689
3.6	1199.1286	14732.7469	-1273.5285	374.006
3.7	1191.6853	14732.3134	-1297.5563	387.9007
3.8	1185.8725	14738.0822	-1309.7131	374.0761
3.9	1193.104	14798.2924	-1321.5823	378.6852
4	1186.795	14865.6453	-1330.2869	389.9564
4.1	1188.2124	14919.3017	-1346.1126	407.1144
4.2	1196.0806	14946.9262	-1357.9813	417.7492
4.3	1196.9316	14964.8116	-1361.2906	438.9478
4.4	1195.939	15013.2795	-1381.4322	435.4742
4.5	1192.6077	14855.1887	-1395.0988	437.0336
4.6	1200.1213	13813.554	-1407.8305	446.3212
4.7	1188.7087	13660.417	-1423.08	479.7167
4.8	1198.4193	13642.1955	-1423.0075	482.9072
4.9	1192.6077	13601.647	-1443.1478	493.8963
5	1197.6397	13546.0485	-1459.4752	509.7085
5.1	1187.6447	13499.8152	-1474.6515	520.273
5.2	1196.2937	13510.9051	-1486.8785	531.1937
5.3	1206.5721	13517.4585	-1496.1564	535.9439
5.4	1201.822	13518.2504	-1508.8143	543.886

Appendix Table B3 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	1196.5769	13532.2206	-1530.391	564.5922
5.6	1201.8934	13551.0894	-1539.1649	573.9525
5.7	1197.4279	13551.3772	-1560.6685	707.0603
5.8	1203.4526	13546.5527	-1576.9227	738.9038
5.9	1201.6804	13542.8079	-1583.9708	754.2234
6	1204.3737	13518.034	-1599.7923	772.7346
6.1	1199.5535	13506.0082	-1610.0036	788.0535
6.2	1200.476	13504.064	-1616.979	803.7288
6.3	1198.0659	13489.6612	-1626.7592	823.9428
6.4	1197.7112	13491.4616	-1636.828	837.6322
6.5	1198.987	13498.0861	-1642.0778	832.5971
6.6	1208.061	13556.4908	-1652.8647	857.3515
6.7	1200.1213	13572.5511	-1657.6822	862.8834
6.8	1200.4045	12336.5766	-1672.9989	893.5268
6.9	1204.0905	12301.1888	-1680.19	909.2038
7	1192.7494	12299.3907	-1679.6865	907.4304
7.1	1198.2776	12304.8575	-1688.5316	923.958
7.2	1186.9366	12254.8718	-1690.5455	936.727
7.3	1184.3849	12229.2689	-1699.4617	946.3029
7.4	1184.4551	12205.9643	-1713.6997	958.0087
7.5	1186.795	12188.705	-1721.6812	965.5981
7.6	1181.0524	12179.4282	-1729.7339	976.3107
7.7	1173.7521	12171.1573	-1730.5971	990.5692
7.8	1165.671	12154.9056	-1738.0039	985.4618
7.9	1164.8915	12151.3099	-1748.7173	973.8987
8	1160.7094	12134.9136	-1758.7123	968.7914
8.1	1163.0479	12130.3835	-1763.7453	971.6285

<u>Appendix Table B3</u> (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	1162.0566	12128.1548	-1769.9288	977.6577
8.3	1155.2514	12130.2399	-1776.1123	975.8842
8.4	1153.5495	12123.5523	-1776.6882	979.0776
8.5	1143.4133	12121.7545	-1788.9826	988.3704
8.6	1152.6998	12119.5258	-1793.7282	994.6845
8.7	1152.5582	12127.1478	-1799.4806	999.5085
8.8	1149.1557	12127.0041	-1805.3041	1006.7445
8.9	1145.4699	12134.5551	-1809.7623	1010.7884
9	1140.7201	12126.9317	-1810.553	1012.8454
9.1	1142.422	12125.781	-1817.9592	1030.0848
9.2	1140.7916	12134.4101	-1825.4364	1027.0343
9.3	1134.7661	12132.325	-1825.2203	1033.1354
9.4	1132.7108	12130.6709	-1818.1028	1036.1144
9.5	1135.3338	12120.9637	-1840.823	1045.4793
9.6	1126.8282	12124.2719	-1838.1624	1050.5871
9.7	1122.2202	12118.59	-1843.7696	1060.8754
9.8	1124.9847	12109.0991	-1849.162	1065.6282

Appendix Table B4 Load-Displacement data of specimen Model 1

Load (ton)	Displacement (mm.)		
	Model 1-1	Model 1-2	Model 1-3
0.1	0.19	0.22	0.19
0.2	0.46	0.44	0.58
0.3	0.75	0.67	0.99
0.4	1.18	0.92	1.67
0.5	1.34	1.22	1.73
0.6	1.66	1.36	2.29
0.7	2.05	1.71	2.79
0.8	2.36	1.87	3.33
0.9	2.56	1.93	3.71
1	2.95	2.32	4.16
1.1	3.27	2.58	4.61
1.2	3.59	2.88	5.01
1.3	3.95	3.24	5.46
1.4	4.33	3.63	5.9
1.5	4.65	3.94	6.3
1.6	4.99	4.22	6.76
1.7	5.31	4.65	7.04
1.8	5.65	4.98	7.45
1.9	6.04	5.46	7.82
2	6.37	5.79	8.22
2.1	6.64	6.09	8.51
2.2	6.93	6.39	8.85
2.3	7.29	6.83	9.21
2.4	7.54	7.1	9.49
2.5	7.88	7.53	9.81
2.6	8.17	7.88	10.09
2.7	8.45	8.19	10.41
2.8	8.78	8.59	10.72

Appendix Table B4 (continued)

Load	Displacement (mm.)		
(ton)	Model 1-1	Model 1-2	Model 1-3
2.9	9.08	8.87	11.1
3	9.35	9.19	11.38
3.1	9.68	9.6	11.69
3.2	9.96	9.94	11.98
3.3	10.26	10.26	12.32
3.4	10.57	10.59	12.66
3.5	10.88	10.99	12.95
3.6	11.20	11.35	13.28
3.7	11.45	11.62	13.56
3.8	11.70	11.88	13.85
3.9	12.08	12.41	14.17
4	12.35	12.73	14.43
4.1	12.65	13.01	14.81
4.2	12.90	13.28	15.1
4.3	13.30	13.84	15.43
4.4	13.61	14.27	15.68
4.5	13.81	14.39	15.99
4.6	14.18	14.92	16.28
4.7	14.47	15.2	16.64
4.8	14.82	15.71	16.9
4.9	15.12	16	17.26
5	15.48	16.54	17.51
5.1	15.72	16.77	17.82
5.2	15.99	17.1	18.08
5.3	16.21	17.38	18.29
5.4	16.44	17.64	18.53
5.5	16.82	18.08	18.92
5.6	17.05	18.44	19.07

Appendix Table B4 (continued)

Load (ton)	Displacement (mm.)		
	Model 1-1	Model 1-2	Model 1-3
5.7	17.35	18.73	19.43
5.8	17.60	18.99	19.73
5.9	17.95	19.53	19.95
6	18.19	19.78	20.24
6.1	18.42	20.06	20.47
6.2	18.65	20.32	20.71
6.3	18.89	20.59	20.97
6.4	19.09	20.85	21.14
6.5	19.35	21.3	21.28
6.6	19.67	21.63	21.65
6.7	19.85	21.88	21.79
6.8	20.18	22.15	22.24
6.9	20.41	22.41	22.5
7	20.56	22.67	22.57
7.1	20.78	22.92	22.79
7.2	21.00	23.17	23.04
7.3	21.24	23.43	23.3
7.4	21.48	23.69	23.56
7.5	21.70	23.93	23.81
7.6	21.92	24.2	24.02
7.7	22.15	24.44	24.3
7.8	22.38	24.69	24.55
7.9	22.59	24.93	24.76
8	22.83	25.19	25.03
8.1	23.05	25.44	25.26
8.2	23.23	25.69	25.41
8.3	23.38	25.92	25.52
8.4	23.59	26.14	25.75

Appendix Table B4 (continued)

Load (ton)	Displacement (mm.)		
	Model 1-1	Model 1-2	Model 1-3
8.5	23.81	26.38	26.01
8.6	24.00	26.62	26.18
8.7	24.23	26.88	26.42
8.8	24.52	27.28	26.66
8.9	24.69	27.52	26.8
9	24.88	27.79	26.94
9.1	25.00	27.87	27.14
9.2	25.18	28.07	27.32
9.3	25.37	28.32	27.49
9.4	25.53	28.57	27.59
9.5	25.90	29.09	27.88
9.6	25.98	29.18	27.98
9.7	26.14	29.39	28.12
9.8	26.30	29.59	28.28

Appendix Table B5 Load-Strain data of specimen, Model 2-1

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	74.1233	98.6993	-49.8579	4.1653
0.2	140.9136	193.3344	-96.3409	18.6853
0.3	178.1009	248.6432	-121.9227	24.5652
0.4	238.0275	329.517	-156.5128	32.2148
0.5	288.7494	397.4756	-188.9397	39.7944
0.6	358.531	477.2257	-235.4873	49.8525
0.7	421.6571	552.6502	-260.9941	62.9579
0.8	465.7979	609.6136	-286.5716	67.1373
0.9	517.2398	669.2078	-314.3114	76.5582
1	561.1032	732.0022	-334.9883	85.9091
1.1	620.0617	803.6823	-364.2387	102.9816
1.2	659.3225	849.505	-384.4841	109.5697
1.3	672.5744	880.9792	-400.6212	111.4122
1.4	700.5686	954.8011	-430.9497	127.6347
1.5	726.58	1008.5912	-463.8717	138.6143
1.6	721.9022	1047.5311	-487.4277	143.999
1.7	720.1303	1050.63	-502.483	150.516
1.8	728.7052	1081.365	-523.2999	157.6005
1.9	732.8166	1084.35	-556.4352	176.9415
2	725.5161	1095.66	-582.5091	185.2299
2.1	726.2253	1120.58	-600.0119	193.3781
2.2	731.0447	1145.35	-634.5123	209.7435
2.3	726.0837	1165.365	-654.4629	222.7083
2.4	705.9555	1185.452	-678.8063	230.6439
2.5	696.7417	1195.35	-720.577	245.9477
2.6	703.0496	1214.38	-739.2296	255.7249
2.7	703.4744	1268.65	-761.9869	268.0527

Appendix Table B5 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	696.0338	1288.54	-786.2549	277.1223
2.9	702.9081	1311.245	-824.7821	289.0258
3	701.4194	1320.35	-852.7929	301.2124
3.1	695.1115	1335.46	-889.0118	316.8719
3.2	698.2304	1330.24	-915.3657	324.1693
3.3	700.0022	1452.02	-935.0228	330.546
3.4	687.8125	1440.578	-972.103	345.5683
3.5	685.0483	1551.23	-992.4782	355.4881
3.6	682.4257	1624.58	-1020.269	363.2118
3.7	676.6856	1735.28	-1057.7787	384.3999
3.8	667.8981	1786.59	-1084.9184	394.1071
3.9	669.8115	1998.245	-1104.4282	417.704
4	675.3386	2265.47	-1147.6213	456.1839
4.1	670.874	2653.28	-1165.5453	474.8218
4.2	658.3301	2789.32	-1176.0541	479.0744
4.3	656.3454	3245.24	-1218.3799	514.2965
4.4	649.6844	3564.12	-1245.9491	522.3046
4.5	654.6451	3785.24	-1261.8555	531.5183
4.6	661.2359	3954.24	-1284.8168	542.5026
4.7	649.826	4358.14	-1307.7762	552.0711
4.8	644.3693	4892.35	-1333.686	566.1746
4.9	647.1334	5240.32	-1358.3724	579.0741
5	642.1014	5847.1	-1378.2368	586.658
5.1	649.4013	6547.87	-1398.7471	595.8723
5.2	635.7237	7542.36	-1450.5625	606.7157
5.3	636.7148	8452.47	-1469.4886	613.1657
5.4	649.9676	8894.55	-1485.5363	624.7901

Appendix Table B5 (continued)

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	636.5732	9872.35	-1512.5202	633.7917
5.6	641.109	11425.35	-1530.5825	637.6904
5.7	638.2033	15547.25	-1554.1837	640.8083
5.8	639.0541	18457.35	-1573.3952	644.707
5.9	656.4168	21475.25	-1604.6231	665.6169

Appendix Table B6 Load-Strain data of specimen, Model 2-2

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	41.4994	74.525	-14.3243	7.4058
0.2	83.6246	152.3862	-27.1552	24.344
0.3	141.1154	234.775	-40.8526	33.9108
0.4	174.7483	292.695	-48.2767	44.9664
0.5	221.2725	369.0675	-56.5674	57.7238
0.6	271.9732	440.9937	-62.7666	67.717
0.7	317.2237	509.0488	-69.8311	72.0401
0.8	370.7631	582.6382	-82.6613	84.16
0.9	388.8231	599.3665	-86.6262	90.0421
1	434.009	669.4438	-96.1413	101.7361
1.1	463.7564	711.1623	-104.0697	101.0983
1.2	503.3492	769.6863	-108.1785	108.7537
1.3	539.2617	812.4858	-116.684	120.0933
1.4	565.6822	853.5642	-121.5141	123.6372
1.5	597.9136	893.998	-134.1269	132.497
1.6	621.078	931.2729	-135.0649	137.1751
1.7	654.1604	977.671	-143.8582	142.8457
1.8	677.5392	1015.0214	-144.2902	153.3361
1.9	707.7889	1056.8274	-145.1556	157.7298
2	706.8683	1099.9992	-160.076	160.2111
2.1	705.027	1181.1764	-167.4992	169.9924
2.2	716.7162	1244.9016	-170.527	181.6173
2.3	721.2507	1229.5987	-178.2394	190.8323
2.4	735.845	1237.501	-184.9425	192.3913
2.5	740.5913	1222.1982	-187.105	200.8971
2.6	747.8178	1230.6047	-198.0604	214.2945
2.7	755.7534	1204.237	-212.5467	220.1072

Appendix Table B6 (continued)

Load (ton)	Strain(10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	766.6641	1187.7141	-221.6273	227.2659
2.9	774.5999	1181.607	-224.1504	237.3311
3	786.5731	1163.216	-231.2851	246.9715
3.1	803.5073	1150.931	-240.7988	258.3141
3.2	813.2849	1132.7565	-251.3216	264.1972
3.3	821.3625	1114.7247	-255.8618	276.8159
3.4	834.613	1105.6739	-272.7262	284.4012
3.5	837.2337	1115.1565	-275.2492	297.9414
3.6	839.2181	1140.371	-284.8338	301.8394
3.7	852.1844	1206.3215	-293.1938	311.6936
3.8	858.7741	1295.77	-298.5263	319.1375
3.9	865.2223	1433.6594	-304.5086	330.5511
4	874.0095	1620.8024	-313.517	341.0436
4.1	879.3941	1683.6228	-320.0025	346.5725
4.2	887.1892	1831.8482	-325.5514	357.633
4.3	881.3072	2099.3882	-334.9202	366.2819
4.4	896.0468	2282.4927	-345.4407	376.8449
4.5	896.8962	2569.296	-350.5576	384.431
4.6	900.1561	2886.5555	-362.5916	389.3936
4.7	914.6116	3122.9316	-367.9249	400.5962
4.8	910.3607	3450.2389	-382.6253	410.8049
4.9	927.6504	3623.8748	-389.2543	415.6974
5	934.3821	3999.7714	-391.7043	427.8919
5.1	936.6499	4496.4157	-404.0996	448.8076
5.2	950.1851	4848.9274	-414.6194	457.3157
5.3	952.5944	5216.8661	-421.3208	465.2572
5.4	955.4285	5597.7176	-428.8872	473.9773

Appendix Table B6 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	956.917	5708.2926	-431.9856	479.7214
5.6	961.4526	6214.8473	-438.255	486.6702
5.7	960.3187	6917.0012	-447.3335	488.7964
5.8	954.2946	8686.1808	-452.0893	490.6405
5.9	961.9488	12877.6811	-468.9503	499.2204

Appendix Table B7 Load-Strain data of specimen, Model 2-3

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	57.8365	62.4659	-36.7039	12.6122
0.2	93.5134	114.4302	-65.9046	20.9019
0.3	128.0588	149.7833	-86.7393	30.3969
0.4	159.2786	183.3641	-97.4802	43.2934
0.5	201.2604	217.7972	-133.6686	53.3562
0.6	242.5356	352.2765	-173.0265	61.5047
0.7	279.7766	501.9758	-220.2408	72.7002
0.8	315.1788	620.9405	-259.9559	80.9917
0.9	363.9642	760.0235	-319.8503	88.8573
1	386.9801	843.1428	-363.5253	95.5891
1.1	414.525	942.6808	-407.1257	96.7931
1.2	437.0437	998.3162	-430.0426	103.5963
1..3	451.4197	1084.0848	-459.9487	109.3359
1.4	483.5704	1169.7907	-488.8448	119.0448
1.5	497.5213	1277.893	-529.9183	130.3124
1.6	525.0693	1345.3465	-553.6247	135.2728
1.7	542.6334	1408.4699	-572.4309	148.8799
1.8	559.8433	1505.1532	-611.9875	153.2027
1.9	586.1197	1573.4059	-625.7493	162.1314
2	608.6413	1648.5603	-653.2723	170.4938
2.1	623.6572	1724.2902	-680.0736	182.7544
2.2	637.6816	1807.9903	-709.7553	190.3377
2.3	649.7224	1922.5658	-731.2244	198.5588
2.4	660.2056	2269.7187	-756.9421	207.0631
2.5	636.4768	2896.7652	-748.8745	217.5524
2.6	624.5776	3886.3594	-750.459	225.6309
2.7	607.6508	4773.0326	-748.3701	238.317

Appendix Table B7 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	605.9502	5321.9919	-760.9046	249.8705
2.9	593.131	5666.1702	-769.4053	258.8715
3	588.5979	5879.9115	-782.8044	269.9278
3.1	564.8722	6315.2473	-798.0769	275.5982
3.2	570.75	6582.0893	-810.5395	286.8677
3.3	550.9203	7028.8996	-822.2084	294.735
3.4	558.2142	7434.4284	-832.2929	310.4697
3.5	551.0618	7763.9117	-841.8016	318.8335
3.6	551.5576	8095.1538	-845.1881	329.4656
3.7	549.0069	8353.6141	-856.2809	340.8059
3.8	545.8201	8781.1935	-862.836	348.2488
3.9	532.7187	9127.91	-864.3477	364.977
4	531.9399	9419.4093	-872.5596	380.1464
4.1	541.0757	9659.8701	-881.491	393.6141
4.2	543.3421	9839.5083	-886.3177	402.8296
4.3	535.1968	10159.7759	-890.4236	416.794
4.4	539.801	10357.5849	-894.2403	428.6316
4.5	532.1515	10566.7741	-900.2908	438.9817
4.6	531.7984	10937.6867	-909.4397	451.5992
4.7	522.5914	11153.6102	-910.0153	461.7365
4.8	521.8826	11431.575	-920.9636	463.7218
4.9	521.954	11854.9968	-921.5392	488.0377
5	521.2453	12268.108	-926.7261	504.9815
5.1	536.8972	12987.3662	-935.657	515.4728
5.2	538.242	13443.1489	-943.5079	520.5781
5.3	534.4893	13721.3452	-952.5838	530.2899
5.4	531.3026	14099.3871	-961.9461	538.7972

Appendix Table B7 (continued)

Load	Strain(10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	542.3504	14523.6287	-970.1572	552.9065
5.6	545.6786	14737.8374	-969.8694	558.4356
5.7	536.4013	15222.5057	-980.1688	572.4737

Appendix Table B8 Load-Displacement data of specimen Model 2

Load	Displacement (mm.)		
(ton)	Model 2-1	Model 2-2	Model 2-3
0.1	0.15	0.2	0.155
0.2	0.53	0.59	0.54
0.3	0.73	0.97	0.83
0.4	1.06	1.33	1.175
0.5	1.36	1.65	1.485
0.6	1.7	1.97	1.815
0.7	2.01	2.27	2.12
0.8	2.26	2.63	2.395
0.9	2.53	2.79	2.61
1	2.8	3.06	2.88
1.1	3.11	3.26	3.135
1.2	3.31	3.54	3.375
1.3	3.44	3.74	3.54
1.4	3.77	3.92	3.795
1.5	4.02	4.12	4.02
1.6	4.34	4.24	4.24
1.7	4.5	4.47	4.435
1.8	4.76	4.66	4.66
1.9	5.14	4.85	4.945
2	5.43	5.04	5.185
2.1	5.72	5.27	5.445
2.2	6.1	5.5	5.75
2.3	6.39	5.77	6.03
2.4	6.64	5.99	6.265
2.5	7.04	6.25	6.595
2.6	7.26	6.56	6.86
2.7	7.47	6.88	7.125
2.8	7.71	7.11	7.36
2.9	8.05	7.36	7.655

Appendix Table B8 (continued)

Load	Displacement (mm.)		
(ton)	Model 2-1	Model 2-2	Model 2-3
3	8.31	7.62	7.915
3.1	8.59	7.87	8.18
3.2	8.8	8.16	8.43
3.3	9	8.4	8.65
3.4	9.35	8.67	8.94
3.5	9.56	8.9	9.16
3.6	9.74	9.18	9.39
3.7	10.15	9.46	9.735
3.8	10.37	9.7	9.965
3.9	10.58	9.97	10.205
4	10.94	10.26	10.53
4.1	11.04	10.38	10.64
4.2	11.21	10.64	10.855
4.3	11.63	10.95	11.22
4.4	11.85	11.16	11.435
4.5	12.06	11.43	11.675
4.6	12.24	11.73	11.915
4.7	12.49	11.94	12.145
4.8	12.7	12.22	12.39
4.9	12.92	12.37	12.575
5	13.12	12.58	12.78
5.1	13.34	12.67	12.935
5.2	13.76	12.68	13.15
5.3	13.97	12.72	13.275
5.4	14.14	12.77	13.385
5.5	14.39	12.78	13.515
5.6	14.58	12.94	13.69
5.7	14.78	13.11	
5.8	14.99	13.25	
5.9	15.22	13.46	

Appendix Table B9 Load-Strain data of specimen, Model 3-1

Load (ton)	Strain (10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	17.1506	32.9918	-9.1425	2.7437
0.2	56.8944	85.0901	-12.6034	22.8032
0.3	147.7227	254.9805	-18.731	53.1413
0.4	168.6244	303.9623	-28.4648	53.6377
0.5	215.1058	385.013	-33.7995	69.5873
0.6	264.7065	449.858	-34.5923	87.5927
0.7	325.5788	535.4712	-38.2699	100.2115
0.8	367.1774	599.4023	-38.2699	111.6949
0.9	370.0117	615.5458	-41.1532	110.9153
1	417.1407	672.0858	-43.4604	117.3664
1.1	430.0398	710.492	-58.2404	111.4116
1.2	459.6656	759.7814	-54.0582	120.911
1.3	492.9778	802.4595	-56.7975	126.0863
1.4	516.5802	836.3897	-62.494	128.0002
1.5	552.3044	892.7291	-62.9261	143.0286
1.6	596.6777	935.4835	-49.2284	163.1624
1.7	619.9292	1000.5798	-55.4998	166.7787
1.8	644.7391	1043.3391	-62.494	172.6624
1.9	665.0852	1073.4348	-65.3046	170.6067
2	699.1843	1128.2231	-70.9284	192.5136
2.1	714.7094	1160.386	-71.0725	192.0874
2.2	717.3329	1266.4161	-73.0915	202.5102
2.3	731.0157	1445.841	-74.6058	209.6
2.4	737.8923	1591.627	-69.7035	223.425
2.5	752.923	1917.8755	-77.493	237.8168
2.6	757.319	2299.945	-83.1881	249.2317
2.7	756.1132	2451.2044	-81.5298	251.5721

Appendix Table B9 (continued)

Load (ton)	Strain (10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	774.1927	2520.1095	-85.0631	261.7109
2.9	766.0385	2682.0945	-85.0631	270.7154
3	779.2971	2736.2619	-84.9904	282.6973
3.1	777.3115	2822.4371	-87.8737	291.9865
3.2	776.5318	2902.918	-93.3533	302.0543
3.3	781.2827	3048.2838	-95.0116	310.5628
3.4	786.8121	3169.6414	-99.7698	315.1711
3.5	793.6891	3282.671	-106.4743	324.2476
3.6	810.3515	3553.1392	-112.0966	348.0724
3.7	795.6747	3649.8047	-114.9083	356.0146
3.8	798.7234	3741.1992	-120.7486	362.6792
3.9	811.6991	3829.678	-124.0638	373.3885
4	813.2586	4199.1625	-124.7852	391.0448
4.1	797.164	4562.8671	-118.6569	397.9944
4.2	813.8967	4775.1265	-122.6222	404.6593
4.3	832.6154	5008.2223	-132.5703	415.9345
4.4	859.3452	5374.0178	-134.95	440.6831
4.5	892.956	5753.3231	-145.5467	450.967
4.6	907.2783	5981.654	-147.4203	460.1149
4.7	912.3846	6235.3604	-151.0974	468.3414
4.8	926.9931	6527.9899	-153.8364	478.9778
4.9	946.2105	6792.935	-158.5229	488.4809
5	960.18	7035.9739	-163.7842	501.3883
5.1	985.7085	7535.7039	-169.8395	513.3744
5.2	971.3838	7836.2543	-172.9392	515.0057
5.3	984.3606	8181.3411	-174.1653	530.9618
5.4	996.4876	8901.5907	-182.6714	550.6073

Appendix Table B9 (continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	1003.1542	9121.9888	-195.7911	550.0405
5.6	1014.287	9323.1324	-200.4048	559.5443
5.7	1015.4217	9719.2273	-205.8825	575.2178
5.8	1004.5723	9955.7573	-206.8192	581.1755
5.9	986.63	10285.2283	-213.5956	583.8716
6	982.9426	10611.2206	-218.7853	591.1762
6.1	980.9578	10955.4386	-223.1108	598.8369
6.2	977.9788	11271.5913	-237.094	604.1565
6.3	979.1135	11531.2381	-234.7873	610.0429
6.4	976.6309	11896.9433	-245.0949	619.4758
6.5	974.7878	12309.8695	-250.213	622.3137
6.6	986.63	12425.9984	-260.3765	648.2027
6.7	980.7447	12580.235	-266.5025	646.5009
6.8	983.3689	12697.693	-274.5045	656.0044
6.9	972.8018	12947.9974	-277.3871	663.5942
7	967.6964	13175.0195	-282.0718	671.0423
7.1	950.1097	13338.3125	-291.4422	691.8257
7.2	942.5934	13467.2523	-299.5153	700.4793
7.3	949.968	13443.1782	-308.813	712.4679
7.4	962.8029	13519.7991	-316.8133	723.8169
7.5	939.9693	13910.997	-322.2904	733.6773
7.6	952.8755	14096.1268	-325.3895	744.318
7.7	936.1403	14292.2563	-329.0659	754.1072
7.8	946.2807	14122.4541	-338.5073	766.1666
7.9	966.3486	14164.2884	-334.6156	779.4328
8	937.9846	14554.3059	-356.3092	790.0025
8.1	951.2443	14774.4903	-359.6249	794.8264

Appendix Table B9 (continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	962.6612	14850.5678	-360.7054	804.2611
8.3	944.2245	14952.2777	-367.2641	816.4642
8.4	758.5237	14925.5678	-379.3721	819.1597
8.5	942.3101	15032.8446	-383.3363	833.7738
8.6	944.5794	14853.1662	-400.1282	825.7574
8.7	960.3919	14732.1955	-391.048	840.1583
8.8	951.529	14172.7998	-397.5339	849.808
8.9	943.7995	14067.3494	-409.9295	861.5136
9	896.7133	14027.1783	-414.0375	890.3883

Appendix Table B10 Load-Strain data of specimen, Model 3-2

Load (ton)	Strain (10^{-6})			
	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	58.23	116.58	-25.68	12.66
0.2	68.02	268.48	-43.2	15.42
0.3	75.24	300.05	-65.53	28.66
0.4	86.96	385.35	-75.68	34.86
0.5	97.6963	423.8962	-87.5807	39.4453
0.6	140.9742	616.5047	-117.3687	56.4555
0.7	176.6031	723.955	-160.4264	68.5739
0.8	176.7459	749.3705	-165.6915	71.055
0.9	211.5971	872.9462	-196.631	79.9143
1	229.873	980.1405	-229.588	97.9164
1.1	238.1606	1010.5033	-237.1606	98.7673
1.2	240.3575	1039.578	-248.627	104.791
1.3	254.3842	1201.8684	-291.318	122.7234
1.4	260.6179	1260.2457	-313.6005	129.6684
1.5	258.6339	1595.7495	-335.3777	136.8277
1.6	271.5273	2033.9523	-357.5138	149.8695
1.7	264.3015	2514.3881	-387.9437	162.9816
1.8	276.2732	2828.8791	-415.415	176.4499
1.9	277.2652	3172.4695	-425.653	181.7661
2	289.8044	3749.8467	-445.5524	199.557
2.1	296.2513	4178.5455	-466.6063	208.7008
2.2	298.3055	4320.6018	-477.4212	216.4272
2.3	303.4072	4627.4199	-512.0996	228.0526
2.4	315.9467	4786.2211	-536.2547	246.3407
2.5	333.4455	4834.7517	-549.7366	257.5403
2.6	330.0446	4881.1986	-563.8658	260.6599
2.7	346.0555	4934.2638	-584.3397	272.1442

Appendix Table B10 (continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	347.1892	4934.2638	-606.3275	283.3442
2.9	363.0601	4973.5246	-628.4574	296.1047
3	367.735	4992.0781	-636.2435	308.4393
3.1	375.1745	5013.0031	-648.4979	315.1738
3.2	386.0852	5029.0399	-669.9795	333.2517
3.3	400.2556	5053.634	-681.3681	341.1208
3.4	408.9707	5056.2952	-709.7678	358.2767
3.5	416.056	5078.5924	-712.9398	366.8554
3.6	425.1245	5143.8237	-731.1753	387.2019
3.7	441.6343	5179.2807	-742.7085	394.2917
3.8	439.65	5235.5989	-756.9076	403.9337
3.9	456.3718	5374.3585	-786.9629	419.6743
4	445.3187	5445.2207	-811.6845	436.1221
4.1	452.4043	5489.2523	-821.6302	447.1836
4.2	444.9641	5576.8877	-845.4143	461.2213
4.3	449.3576	5620.4928	-858.3147	468.3116
4.4	452.5458	5678.3471	-872.8	477.033
4.5	451.129	5719.0787	-884.1875	495.3259
4.6	457.364	5781.9779	-892.6915	507.238
4.7	455.7341	5933.8447	-911.9327	502.1332
4.8	460.2692	6017.7775	-927.9309	507.8761
4.9	459.8445	6301.448	-951.6397	518.867
5	457.9302	6532.6215	-971.6735	511.2798
5.1	463.2445	6674.0906	-982.6981	517.8039
5.2	464.0951	6818.8938	-994.1557	520.3564
5.3	461.686	7296.8277	-1017.7915	521.4909
5.4	457.7887	7517.4985	-1027.2307	523.2636

Appendix Table B10 (continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	453.4666	7812.7943	-1032.7076	530.2128
5.6	458.4977	8153.0516	-1043.5148	536.3809
5.7	460.5523	8652.9442	-1050.7205	544.7481
5.8	464.9458	9384.093	-1059.5835	547.4423
5.9	458.8523	16224.517	-1087.9733	567.1571
6	456.1588	18756.5661	-1098.9252	570.9158
6.1	460.9068	20936.3775	-1111.6056	583.8921
6.2	460.9068	22179.6847	-1117.5139	587.721
6.3	471.6056	23877.1684	-1141.5059	601.194
6.4	464.5912	24182.6464	-1145.9007	610.2714
6.5	455.238	24469.2935	-1154.8355	617.0081
6.6	450.4199	24772.6846	-1162.2555	616.4414
6.7	457.7185	25009.1357	-1171.7659	624.0294
6.8	458.8523	25229.49	-1181.9245	628.9932
6.9	461.899	25466.0525	-1189.994	632.6092
7	473.377	26225.1195	-1221.3325	637.9994
7.1	464.9458	26338.8466	-1233.2917	640.339
7.2	455.5211	26430.1621	-1239.8476	653.3175
7.3	450.5614	26498.1028	-1251.6613	660.408
7.4	457.2224	26573.6959	-1258.4336	667.5713
7.5	462.8198	26655.5453	-1274.3534	669.8408
7.6	462.8198	26745.6396	-1284.367	678.2092
7.7	470.3302	26877.6709	-1293.2279	682.7483
7.8	476.2121	27143.5553	-1318.2243	702.1799
7.9	478.6914	27251.0617	-1326.0048	705.9391
8	488.0448	27384.5593	-1337.8174	715.5843
8.1	492.793	27528.0131	-1351.1442	724.2365

Appendix Table B10 (continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	490.8799	27670.8269	-1362.5975	728.4911
8.3	497.1152	27807.2541	-1367.7108	734.3784
8.4	497.3269	28085.7641	-1387.4482	740.3359
8.5	492.0125	28222.1038	-1403.4384	741.1159
8.6	498.8153	28327.0778	-1409.0559	747.7117
8.7	496.1931	28426.8316	-1420.1493	753.6694
8.8	496.123	28493.3685	-1430.304	756.5059
8.9	495.5554	28553.9378	-1441.4685	759.8402
9	492.8631	28618.6372	-1447.8064	763.9533

Appendix Table B11 Load-Strain data of specimen, Model 3-3

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
0.1	75.62	68.56	-18.64	8.33
0.2	98.67	95.63	-25.46	15.34
0.3	125.9524	116.7113	-29.8017	17.895
0.4	225.8298	177.852	-41.1871	29.8019
0.5	245.7357	207.5349	-41.9069	29.9435
0.6	317.2176	262.2866	-45.0777	37.244
0.7	364.3315	305.11	-51.9952	46.0321
0.8	409.7465	342.3964	-59.6324	54.0408
0.9	423.8473	352.2689	-60.4974	52.0571
1	461.0456	395.664	-66.0453	56.2388
1.1	523.5442	446.3789	-78.5818	69.7764
1.2	552.7391	459.6608	-82.4723	74.3116
1.3	618.2898	529.5587	-90.2545	84.0223
1.4	619.4951	534.9568	-88.164	83.1714
1.5	727.0798	621.4126	-106.5371	100.7497
1.6	739.8381	635.6918	-110.644	108.0508
1.7	797.1077	687.8402	-114.3904	118.8948
1.8	838.8587	730.0433	-117.5611	123.2898
1.9	873.2382	758.4645	-120.5151	131.7955
2	921.7972	812.1825	-120.7304	147.8144
2.1	952.8481	843.874	-122.1711	155.0444
2.2	984.8927	876.1357	-79.2302	161.9211
2.3	1047.4245	938.0325	-76.9971	174.5378
2.4	1074.9343	973.3533	-74.5474	181.6264
2.5	1116.0594	1033.3375	-73.1779	193.9614
2.6	1142.5067	1075.6979	-60.4974	202.3248
2.7	1171.7231	1205.494	-63.3064	220.9694

Appendix Table B11 (Continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
2.8	1194.9812	1458.3114	-58.6235	235.7139
2.9	1208.8089	1739.645	-54.5889	252.8688
3	1227.6019	1983.5687	-53.2194	267.8269
3.1	1222.7084	2415.7278	-46.8791	281.9354
3.2	1226.7506	2629.9228	-44.9338	287.5357
3.3	1210.7949	3118.8597	-49.6894	307.4567
3.4	1207.2493	3350.8101	-47.9594	316.3187
3.5	1204.4834	3828.6375	-47.023	336.5236
3.6	1200.2996	4058.6224	-48.5365	342.9052
3.7	1201.8606	4494.0034	-43.4929	360.9834
3.8	1207.7458	5205.3759	-28.8654	381.4739
3.9	1188.8128	5884.5642	-17.3372	388.989
4	1159.2411	6882.971	-9.771	409.6919
4.1	1123.7167	7343.3961	-9.6984	418.9811
4.2	1099.8222	7750.501	-9.05	426.3548
4.3	1085.5698	8198.6665	-7.8257	434.7917
4.4	1066.1428	9849.6729	-3.5743	448.6193
4.5	1045.5818	11120.751	-6.1682	464.8567
4.6	1040.7606	11725.3693	-6.3848	472.4426
4.7	1012.8256	13001.5338	-3.3578	492.5806
4.8	1015.1659	13572.342	-5.3031	501.6575
4.9	1004.6026	14114.4517	-5.5911	510.0963
5	1006.2322	15238.6909	-7.753	524.0667
5.1	1008.5725	16271.012	-7.2485	540.2339
5.2	998.1509	16773.3195	-7.2485	551.7222
5.3	978.6542	17311.3834	-7.8257	557.8908
5.4	968.5864	17870.0063	-6.6001	569.0246

Appendix Table B11 (Continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
5.5	960.7887	18471.3622	-9.915	567.678
5.6	951.3603	18998.1387	-6.0242	569.8044
5.7	946.1849	19453.0377	-13.8784	577.9605
5.8	942.214	19869.8796	-17.6965	576.0459
5.9	939.3073	20292.4112	-15.1027	576.3995
6	933.3524	21087.5181	-16.5435	580.7966
6.1	931.5099	21487.2061	-19.6431	585.4771
6.2	928.2485	21833.3103	-19.9311	592.4271
6.3	927.4689	22388.5304	-21.5885	593.4904
6.4	928.8163	22633.1833	-21.0114	598.1007
6.5	929.1697	22888.0762	-20.1463	603.8446
6.6	929.5959	23115.4011	-21.3719	600.0856
6.7	933.2822	23722.371	-26.5595	611.6448
6.8	937.1101	24302.1963	-25.3352	619.0915
6.9	936.897	24601.6753	-31.5318	621.9291
7	937.1816	25217.889	-30.8107	666.5367
7.1	952.1399	25534.9299	-33.6211	684.0542
7.2	945.6171	25849.8131	-33.3332	691.7147
7.3	949.0916	26107.2364	-38.6647	693.558
7.4	942.3569	26377.5725	-42.0508	703.9134
7.5	929.3126	26780.6247	-43.349	709.7293
7.6	932.4311	26973.0875	-43.2037	708.8779
7.7	935.621	27159.5983	-46.302	716.9636
7.8	938.9539	27343.5891	-47.7441	724.9078
7.9	925.2002	27514.7594	-49.2562	729.9426
8	920.9475	27662.8658	-49.1849	735.0502
8.1	931.3682	27809.1679	-49.8333	744.2699

Appendix Table B11 (Continued)

Load	Strain (10^{-6})			
(ton)	RB9 (end span)	RB9 (mid span)	Concrete (mid span)	Plate (mid span)
8.2	930.5172	27951.6913	-51.9226	757.179
8.3	929.7375	28100.6674	-55.4526	768.315
8.4	932.9275	28233.0703	-54.1558	773.9182
8.5	932.9275	28499.247	-64.0274	787.9627
8.6	932.5727	28631.486	-63.5956	794.2043
8.7	932.2193	28766.3014	-61.5777	806.9009
8.8	932.0062	28903.4046	-61.7943	811.3694
8.9	929.809	28801.3437	-67.4135	821.2293
9	928.1783	28764.4001	-71.6645	835.3447

Appendix Table B12 Load-Displacement data of specimen Model 3

Load	Displacement (mm.)		
(ton)	Model 3-1	Model 3-2	Model 3-3
0.1	0.03	0.04	0.05
0.2	0.09	0.08	0.075
0.3	0.85	0.75	0.69
0.4	1.15	1.1	0.99
0.5	1.53	1.2	1.26
0.6	1.83	1.52	1.54
0.7	2.23	2.26	1.85
0.8	2.52	2.34	2.1
0.9	2.59	2.77	2.18
1	2.84	3.32	2.41
1.1	3.06	3.46	2.75
1.2	3.27	3.6	2.84
1.3	3.5	4.28	3.22
1.4	3.63	4.76	3.35
1.5	3.9	5.1	3.93
1.6	4.03	5.45	4.07
1.7	4.34	6.03	4.45
1.8	4.54	6.49	4.78
1.9	4.68	6.81	4.92
2	4.91	7.25	5.39
2.1	5.06	7.58	5.59
2.2	5.34	7.82	5.81
2.3	5.59	8.34	6.22
2.4	5.86	8.86	6.44
2.5	6.29	9.02	6.81
2.6	6.65	9.34	7.03
2.7	6.98	9.76	7.46
2.8	7.18	10.13	7.85

Appendix Table B12 (Continued)

Load	Displacement (mm.)		
(ton)	Model 3-1	Model 3-2	Model 3-3
2.9	7.52	10.66	8.2
3	7.69	10.92	8.5
3.1	8.07	11.16	8.97
3.2	8.34	11.69	9.17
3.3	8.61	11.9	9.6
3.4	8.89	12.48	9.82
3.5	9.14	12.73	10.23
3.6	9.68	13.27	10.44
3.7	9.92	13.53	10.81
3.8	10.17	13.79	11.26
3.9	10.42	14.36	11.61
4	10.72	14.91	12.04
4.1	10.97	15.16	12.26
4.2	11.25	15.74	12.47
4.3	11.52	15.98	12.69
4.4	11.95	16.3	13.11
4.5	12.35	16.58	13.55
4.6	12.59	16.84	13.78
4.7	12.87	17.41	14.22
4.8	13.13	17.68	14.46
4.9	13.38	18.25	14.69
5	13.65	18.79	15.14
5.1	13.91	19.06	15.62
5.2	14.18	19.3	15.86
5.3	14.44	19.93	16.22
5.4	14.98	20.21	16.52
5.5	15.24	20.49	16.8
5.6	15.47	20.76	17.08

Appendix Table B12 (Continued)

Load	Displacement (mm.)		
(ton)	Model 3-1	Model 3-2	Model 3-3
5.7	15.82	21.04	17.31
5.8	16.06	21.3	17.58
5.9	16.29	22.16	17.82
6	16.59	22.42	18.33
6.1	16.78	22.69	18.56
6.2	17.09	22.95	18.77
6.3	17.34	23.55	19.22
6.4	17.62	23.82	19.44
6.5	17.81	24.1	19.69
6.6	18.4	24.37	19.93
6.7	18.66	24.63	20.47
6.8	18.98	24.9	20.97
6.9	19.25	25.17	21.2
7	19.45	26.06	21.65
7.1	19.76	26.31	21.92
7.2	20.03	26.59	22.2
7.3	20.2	26.86	22.43
7.4	20.35	27.12	22.73
7.5	20.75	27.39	23.16
7.6	21.11	27.64	23.4
7.7	21.25	27.9	23.62
7.8	21.64	28.52	23.89
7.9	21.7	28.79	24.15
8	22.04	29.06	24.36
8.1	22.27	29.33	24.63
8.2	22.42	29.62	24.89
8.3	22.85	29.88	25.16
8.4	22.9	30.42	25.42

Appendix Table B12 (Continued)

Load	Displacement (mm.)		
(ton)	Model 3-1	Model 3-2	Model 3-3
8.5	23.27	30.68	25.95
8.6	23.64	30.94	26.22
8.7	23.74	31.21	26.49
8.8	24.1	31.49	26.73
8.9	24.35	31.75	27.01
9	24.62	32.03	27.29

Appendix Table B13 Load-Strain data of specimen Model 2-1/re-test

Load	Strain (10^{-6})	
(ton)	RB9(end span)	RB9(mid span)
0.1	86.7611	70.0553
0.2	171.7939	147.4242
0.3	277.8693	231.3842
0.4	321.4206	273.4024
0.5	412.4248	342.0542
0.6	441.3209	367.3969
0.7	491.2539	411.9273
0.8	545.0155	451.3761
0.9	596.5119	503.2137
1	657.7182	554.1222
1.1	698.5938	568.1573
1.2	755.6265	603.6029
1.3	809.2602	615.2027
1.4	855.3865	591.3575
1.5	919.6551	619.715
1.6	962.0317	623.4386
1.7	1018.6542	620.7178
1.8	1051.2539	614.0581
1.9	1103.3454	637.4025
2	1149.9822	625.1567
2.1	1182.5877	614.3443
2.2	1218.6658	548.3227
2.3	1253.3993	887.755
2.4	1268.2147	996.938
2.5	1293.1675	1025.223
2.6	1288.4887	1060.862
2.7	1300.6814	1062.045
2.8	1249.217	1063.644
2.9	1209.1674	1065.243

Appendix Table B13 (Continued)

Load	Strain (10^{-6})	
(ton)	RB9(end span)	RB9(mid span)
3	1723.975047	1125.976
3.1	1747.69538	1207.48698
3.2	1771.415713	1288.997313
3.3	1791.66372	1325.156007
3.4	1810.69172	1345.38034
3.5	1829.71972	1365.604673
3.6	1856.841347	1391.61778
3.7	1886.80668	1419.66478
3.8	1916.772013	1447.71178
3.9	1992.20862	1473.166067
4	2083.62162	1497.7094
4.1	2175.03462	1522.252733
4.2	2458.89794	1546.977367
4.3	2810.37894	1571.7657
4.4	3161.85994	1596.554033
4.5	3947.907173	1622.661047
4.6	4886.63984	1649.23138
4.7	5825.372507	1675.801713
4.8	6910.580527	1702.66928
4.9	8047.25286	1729.64128
5	9183.925193	1756.61328
5.1	14812.9064	1780.96272
5.2	22020.2664	1804.39072
5.3	29227.6264	1827.81872
5.4	36434.9864	1851.268
5.5	43642.3464	1874.692

Appendix Table B14 Load-Strain data of specimen Model 2-2/re-test

Load (ton)	Strain (10^{-6})	
	RB9(end span)	RB9(mid span)
0.1	34.8167	38.8208
0.2	140.706	174.0223
0.3	197.5593	206.6827
0.4	252.1443	235.1263
0.5	316.5286	278.6526
0.6	376.0195	311.4594
0.7	451.2039	355.3456
0.8	482.8707	377.1472
0.9	575.4603	431.0437
1	626.2352	467.2152
1.1	675.1644	500.3862
1.2	720.8277	538.9191
1.3	777.0764	575.5953
1.4	818.9107	609.9848
1.5	864.7228	642.9459
1.6	908.4071	678.9826
1.7	955.8587	710.3012
1.8	974.3995	732.5395
1.9	1046.5763	785.0261
2	1082.5965	796.686
2.1	1117.6231	831.3692
2.2	1153.2188	861.9064
2.3	1197.0582	891.8717
2.4	1232.5853	920.4077
2.5	1271.7396	952.5929
2.6	1309.046	984.6363
2.7	1340.7412	1007.7384
2.8	1377.2688	1042.1435
2.9	1413.0878	1061.8146

Appendix Table B14 (Continued)

Load	Strain (10^{-6})	
(ton)	RB9(end span)	RB9(mid span)
3	1452.3199	1086.9219
3.1	1482.527	1111.3153
3.2	1504.2762	1127.7689
3.3	1526.1679	1142.2194
3.4	1560.9255	1170.4049
3.5	1593.4825	1193.5128
3.6	1626.537	1227.0657
3.7	1660.5165	1252.2495
3.8	1670.8243	1256.8995
3.9	1707.0805	1282.0132
4	1737.1536	1299.7563
4.1	1768.7197	1327.7327
4.2	1805.1229	1356.3539
4.3	1815.3607	1365.7992
4.4	1851.4802	1386.8357
4.5	1879.9223	1411.5227
4.6	1917.9641	1435.2082
4.7	1957.9286	1456.8916
4.8	2012.5428	1480.7212
4.9	2082.6657	1498.969
5	2440.3261	1519.5087
5.1	3530.9964	1538.3304
5.2	5863.3689	1536.7563
5.3	11213.8001	1537.5434
5.4	16391.6719	1535.682
5.5	19572.6995	1533.1058
5.6	21086.4523	1529.7426
5.7	21175.686	1523.3729

Appendix Table B14 (Continued)

Load	Strain (10^{-6})	
(ton)	RB9(end span)	RB9(mid span)
5.8	21138.9027	1529.5996
5.9	21018.9155	1515.7153
6	20696.243	1512.8531
6.1	20708.0628	1523.874
6.2	20714.3721	1530.7447
6.3	20725.7562	1534.3939
6.4	20729.2372	1528.8126
6.5	20732.7183	1532.7477
6.6	20761.7979	1532.8199
6.7	20770.0655	1527.9534
6.8	20777.6075	1533.035
6.9	20785.9483	1543.9131
7	20826.1251	1549.1377
7.1	20868.7707	1555.0773
7.2	20896.5503	1562.5202
7.3	20936.8048	1558.8709
7.4	20954.1408	1565.3825
7.5	20977.134	1573.8998
7.6	21015.0705	1597.2312
7.7	21035.309	1590.2892
7.8	21054.2423	1585.4224
7.9	21074.5547	1584.9213
8	21108.4328	1579.3397

Appendix Table B15 Load-Strain data of specimen Model 2-3/re-test

Load	Strain (10^{-6})	
(ton)	RB9(end span)	RB9(mid span)
0.1	58.9018	54.43805
0.2	263.5789841	160.72325
0.3	352.63542	219.03345
0.4	401.06842	254.26435
0.5	449.50142	310.3534
0.6	489.1197867	339.42815
0.7	525.64112	383.63645
0.8	562.1624533	414.26165
0.9	667.4130133	467.1287
1	796.81168	510.6687
1.1	926.2103467	534.27175
1.2	979.09178	571.261
1.3	1005.08878	595.399
1.4	1031.08578	600.67115
1.5	1057.457467	631.33045
1.6	1083.9608	651.2106
1.7	1110.464133	665.5095
1.8	1128.148393	673.2988
1.9	1142.73406	711.2143
2	1157.319727	710.92135
2.1	1165.748347	722.85675
2.2	1172.01368	705.11455
2.3	1178.279013	763.4150794
2.4	1209.52206	1034.048493
2.5	1249.54106	1096.74916
2.6	1289.56006	1159.449827
2.7	1306.700233	1198.260087
2.8	1315.8019	1228.67642
2.9	1324.903567	1259.092753

Appendix Table B15 (Continued)

Load (ton)	Strain (10^{-6})	
	RB9(end span)	RB9(mid span)
3	1333.98476	1267.952393
3.1	1343.05876	1269.23806
3.2	1352.13276	1270.523727
3.3	1385.01108	1274.728693
3.4	1426.25308	1279.95936
3.5	1467.49508	1285.190027
3.6	1511.69486	1292.140947
3.7	1556.93386	1299.69628
3.8	1602.17286	1307.251613
3.9	1622.191673	1339.47904
4	1633.34934	1380.37504
4.1	1644.507007	1421.27104
4.2	1653.107973	1460.113293
4.3	1660.81064	1498.23396
4.4	1668.513307	1536.354627
4.5	1688.292527	1577.50214
4.6	1712.31486	1619.71314
4.7	1736.337193	1661.92414
4.8	1745.690013	1702.774033
4.9	1749.88868	1743.1457
5	1754.087347	1783.517367
5.1	1757.254947	1816.576847
5.2	1760.06028	1847.06718
5.3	1762.865613	1877.557513
5.4	1765.67	1908.057
5.5	1768.492	1938.557

Appendix Table B16 Load-Displacement data of specimen Model 2/re-test

Load (ton)	Displacement (mm.)		
	Model 2-1	Model 2-2	Model 2-3
0.1	0.57	0.24	0.2
0.2	1.16	1.21	0.7
0.3	1.78	1.55	1.17
0.4	2.12	1.99	1.62
0.5	2.53	2.5	2.07
0.6	2.87	2.94	2.4
0.7	3.19	3.43	2.73
0.8	3.47	4.02	3.04
0.9	3.8	4.18	3.31
1	4.14	4.6	3.57
1.1	4.57	4.9	3.77
1.2	5.17	5.24	4.01
1.3	5.68	5.63	4.22
1.4	6.21	5.84	4.41
1.5	6.72	6.27	4.61
1.6	7.26	6.48	4.83
1.7	7.84	6.82	5.03
1.8	8.47	7.02	5.25
1.9	8.97	7.33	5.48
2	9.51	7.6	5.77
2.1	10.18	7.87	6.09
2.2	10.64	8.07	6.4
2.3	11.17	8.22	6.77
2.4	11.73	8.45	7.09
2.5	12.28	8.72	7.4
2.6	12.91	9.02	7.76
2.7	13.36	9.02	8.08
2.8	13.87	9.12	8.47
2.9	14.53	9.37	8.8

Appendix Table B16 (Continued)

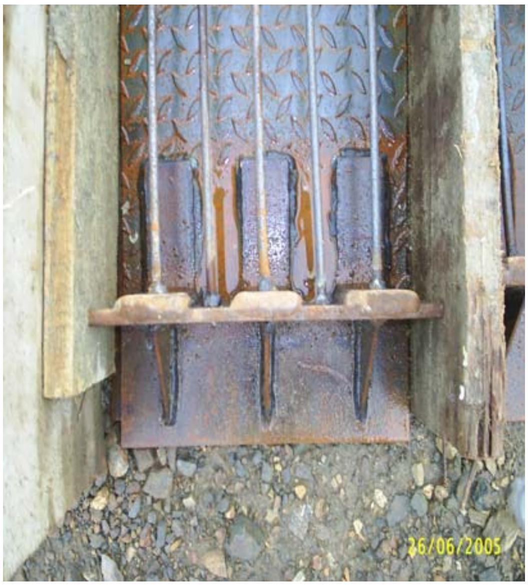
Load (ton)	Displacement (mm.)		
	Model 2-1	Model 2-2	Model 2-3
3	15.11	9.72	9.18
3.1	15.69	9.92	9.44
3.2	16.31	9.92	9.86
3.3	16.93	10.11	10.18
3.4	17.41	10.4	10.56
3.5	18	10.64	10.83
3.6	18.66	10.64	11.13
3.7	19.22	10.89	11.38
3.8	19.9	11.13	11.79
3.9	20.67	11.35	12.08
4	21.05	11.47	12.38
4.1	21.55	11.58	12.78
4.2	22.22	11.85	13.05
4.3	22.67	12.07	13.32
4.4	23.64	12.32	13.66
4.5	24.24	12.32	13.95
4.6	24.62	12.59	14.23
4.7	25.36	12.77	14.63
4.8	25.9	13.03	14.89
4.9	26.53	13.25	15.18
5	26.96	13.53	15.48
5.1	27.81	13.53	15.78
5.2	28.26	13.82	16.13
5.3	29.14	14.21	16.41
5.4	29.65	14.6	16.64
5.5	30.14	14.92	17.02

Appendix C

Figures

Appendix Figure C1 Reinforcement preparation

Appendix Figure C2 Shear key



Appendix Figure C3 Reinforcement at the end of specimen

Appendix Figure C4 Stiffeners provided at both ends

Appendix Figure C5 Concrete pouring

Appendix Figure C6 Specimens' preparation before curing

Testing

Appendix Figure C7 Transferred plates and rebars installed

Appendix Figure C8 Set-up specimen for testing

Appendix Figure C9 Strain and deflection read by the computer

Appendix Figure C10 Strain gauges installed to the rebars

Appendix Figure C11 Hinge and roller support