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HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
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THEORETICAL EFFECTS OF GEOMETRICAL PARAMETERS ON REINFORCED CONCRETE BOX CULVERTS

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MESUT KUŞ

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Theoretical Effects of Geometrical Parameters on Reinforced Concrete Box Culverts

M.Sc. Thesis

In

Civil Engineering

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ABSTRACT

THEORETICAL EFFECTS OF GEOMETRICAL PARAMETERS ON REINFORCED CONCRETE BOX CULVERTS

KUŞ, Mesut

M.Sc. in Civil Engineering

Supervisor(s): Asst. Prof. Şafak Hengirmen TERCAN,

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In this thesis, a parametric study that investigated geometrical parameters of reinforced concrete box culverts (RCBC) is presented. Dead and live loads, which act on RCBC, and derivation of vehicle load formulas were explained. These formulas were summarized in a table. Span width, culvert height and fill depth effects on RCBC design were investigated by creating a number of 88 2D finite element culvert models. An Excel sheet was developed by using VBA and CSI API to establish SAP2000 models and to generate analysis results. Analysis results revealed that while vehicle load was predominant for fills that did not have a depth value greater than 1 m, vertical earth load was predominant after 1 m fill depth. Minimum values of internal forces and base soil pressures occurred at 0.7 – 1.0 m fill depth range. It is concluded that while span width and fill depth parameters have an important effect on internal forces of RCBC models, effect of culvert height is insignificant. This research also reveals that using multiple cell RCBC instead of single cell RCBC is more economical and reliable due to much lower internal forces and base soil stress.

Keywords: reinforced concrete box culvert, multiple cell, vehicle, span width, fill depth

ÖZET

GEOMETRİK PARAMETRELERİN BETONARME KUTU MENFEZLER ÜZERİNDEKİ TEORİK ETKİLERİ

KUŞ, Mesut

Yüksek Lisans Tezi İnşaat Mühendisliği

Tez Yöneticisi(leri): Yrd. Doç. Dr. Şafak Hengirmen TERCAN,

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Mart 2017, 74 sayfa

Bu tezde, betonarme kutu menfezlerin (RCBC) geometrik parametrelerini inceleyen parametrik bir çalışma sunulmuştur. RCBC üzerinde etkili olan ölü ve canlı yükler ile taşıt yükü formüllerinin türetilmesi açıklanmıştır. Bu formüller bir tabloda özetlenmiştir. Menfez genişliği, yüksekliği ve dolgu derinliğinin RCBC tasarımı üzerindeki etkileri SAP2000 programında 88 adet iki boyutlu sonlu elamanlar modeli oluşturularak incelenmiştir. SAP2000 modellerini oluşturmak ve analiz sonuçları elde etmek için VBA ve CSI API kullanılarak bir Excel programı geliştirilmiştir. Analiz sonuçları taşıt yükünün dolgu derinliğinin 1 m' den az olduğu değerlerde hakim yük konumunda iken, dolgu derinliğinin 1 m' den fazla olduğu değerlerde ise toprak yükünün hakim yük konumuna geçtiğini ortaya çıkarmıştır. Minimum iç kuvvetler ve taban zemin gerilmeleri, 0.7 - 1.0 m dolgu derinliği aralığında meydana gelmiştir. Açıklık genişliği ve dolgu derinliği parametreleri RCBC modellerinin iç kuvvetleri üzerinde önemli bir etkiye sahip iken, menfez yüksekliğinin etkisinin kayda değer olmadığı sonucuna varılmıştır. Bu araştırma ayrıca tek hücreli RCBC yerine çok hücreli RCBC tasarımlarının kullanılmasının düşük iç kuvvetler ve zemin gerilmeleri nedeniyle daha ekonomik ve güvenilir olduğunu ortaya koymaktadır.

Anahtar Kelimeler: betonarme kutu menfez, çok hücreli, taşıt, tabliye genişliği, dolgu yüksekliği

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SYMBOLS AND ABBREVIATIONS

A	Wheel load area
a	Equivalent rectangle compression block depth of cocnrete section
AASHTO	American Association of State Highway and Transportation Officials
A_C	Concrete section area
As	Required rebar area for bending design
ASTM	American Society for Testing and Materials
B_C	Top slab width of box culvert
b_w	Concrete section width
d	Effective depth of concrete section
DL	Distributed vertical earth load
E	Wheel load distribution width
EP_1	Lateral earth pressure at the center of top slab
EP_2	Lateral earth pressure at the center of bottom slab
f_{cd}	Design compressive strength of concrete
f_{ck}	Characteristic compressive strength of concrete
f_{ctd}	Design tensile strength of concrete
f_{ctk}	Characteristic tensile strength of concrete
f_{yk}	Characteristic minimum yield stress of rebar
F_e	Soil-interaction factor
f_{yd}	Minimum design yield stress of rebar
f_{yd}	Minimum design yield stress of rebar
ϕ	Friction angle
γ	Unit weight
γ_{mc}	Material coefficient for concrete
γ_{ms}	Material coefficient for rebar
Hc	Effective height
I	Impact factor

K_0	At rest earth coefficient
k_1	Equivalent rectangle compression block depth coefficient
L	Design length
L_D	Distribution length of dual wheels
L_S	Distribution length of single wheels
LS	Lateral surcharge load
LL_{max}	Maximum uniformly distributed vehicle load
LL_{min}	Minimum uniformly distributed vehicle load
M_d	Design moment
Mt	Maximum moment result of top slab
Mw	Maximum moment result of walls
Mb	Maximum moment result of base slab
N_d	Design axial force
P_{max}	Maximum wheel load
P_{min}	Minimum wheel load
qs	Maximum base soil stress
RCBC	Reinforced concrete box culvert
S	Effective span width
SSHB	Standard Specifications for Highway Bridges
t	Section thickness
VBA	Visual basic programming language
V_d	Design shear force
V_{cr}	Critical shear force
Vt	Maximum shear force result of top slab
Vw	Maximum shear force result of walls
Vb	Maximum shear force result of base slab
W_E	Total overburden pressure
Z	Fill depth

CHAPTER 1

INTRODUCTION

Reinforced concrete box culverts (RCBC) are often used under roads for the conveyance of water and used at road-pipeline crossings to ensure safety of pipelines. A typical culvert is embedded in soil and subjected to earth and vehicle loads. RCBC can have either single cell or multiple cells and can be categorized by the construction type as cast-in-place or precast (Connecticut Department of Transportation, 2000).

Figure 1.1 Picture of a typical reinforced concrete box culvert.

Box culverts were known to builders as earlier as first few years of twentieth century in Maryland. In the 1900-01 Geological Survey Report, the author mentioned that "after a number of attempts the contractor abandoned the construction of a box culvert at this point and substituted 30-inch pipe". State Roads Commission of Maryland included designs for both box culverts and box bridges in the first Standard Plans for roadway structures in 1912. There were four designs for steel-concrete (reinforced concrete) culverts and one design for a box bridge. The dimensions of culverts were changed from 18 inches x 18 inches (46 cm x 46 cm) to 6 ft x 6 ft. (1.83 m x 1.83 m). While concrete sections at the bottom and the walls were plain concrete, reinforced concrete were used at the top slab of box culverts (Maryland Department of Transportation, 1997).

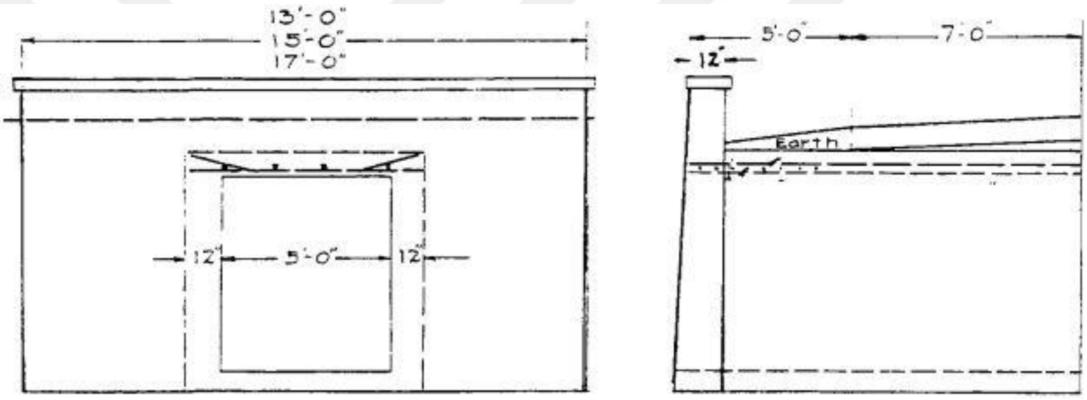


Figure 1.2 "Steel-concrete" box culvert, 1912 Standard Plans (Maryland Department of Transportation, 1997).

There are three types of culvert installation methods which are negative projection, positive projection and induced trench embankment installation as shown in Figure 1.3. In the case of negative projection, a culvert is installed under the natural ground surface and an embankment is filled on it. If the culvert is on the natural ground and embankment is above the culvert, it is called positive projection. The induced trench method is similar to the positive projection except in this installation method, there is a compressible material (e.g., hay, sawdust, peat, shredded rubber tire, etc.) above the culvert. The induced trench method was developed for rigid pipes under high embankment load. Since soil above the culvert settles more than the adjacent soils, upward forces occur at the surface of the adjacent soils layers and thus total vertical earth pressure on the culvert is reduced (Oshati et al., 2012).

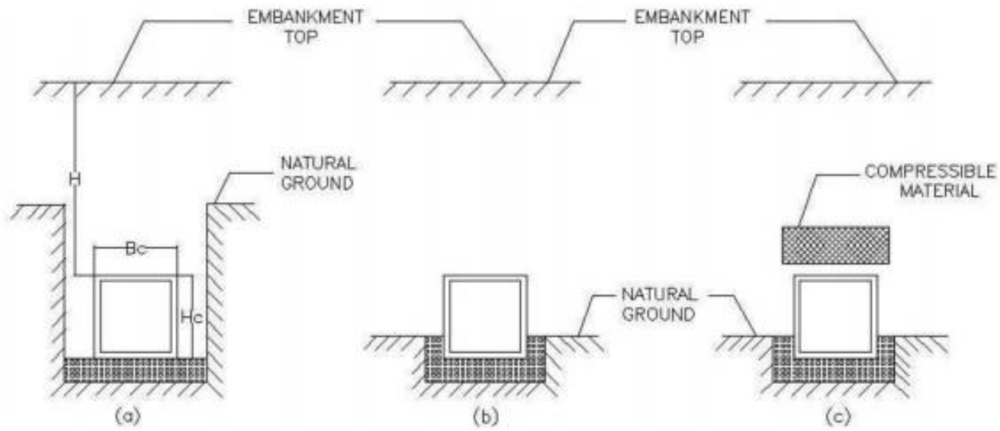


Figure 1.3 Culvert embankment installation types: (a) negative projection, (b) positive projection, and (c) induced trench (Oshati et al., 2012).

The current American Association of State Highway and Transportation Officials Standard Specifications for Highway Bridges (AASHTO SSHB) is mainly used for analysis of RCBC (AASHTO, 2002). Although there is a great deal of experimental study that investigates effects of loads on RCBC, there are a few studies that investigate theoretical effects of geometrical parameters on RCBC. Understanding the effects of these parameters is important for more economical and reliable designing.

1.1 Purpose of Thesis

The main objective of this study is to investigate the theoretical effects of geometrical parameters such as span width, culvert height and fill depth on RCBC design. An extensive parametric analysis will be carried out to understand effects of geometrical parameters on RCBC

The other aim of this study is to achieve the following goals:

- To explain and define material properties and geometrical parameters of reinforced concrete box culverts in detail.
- To explain live and dead loads that act on RCBC and the derivation of vehicle load distribution formulas in detail.
- To explain analysis and design procedures of RCBC in detail with example analysis and design report. Flexure and shear design formulas are also explained in chapter 6.

1.2 Literature Review

1.2.1 Experimental Studies

Previous studies showed that results of experimental studies on culverts have been in a good agreement with results of AASHTO SSHB methods. Some of essential experimental studies are referred here.

Abdel-Karim et al. (1990) conducted a full-scale experiment of a double cell reinforced concrete box culvert and investigated live load distribution through soil. Experimental live load tests indicated that live load distribution in longitudinal and transverse direction is nearly same and they recommended that usage of live load distribution over a square area can be continued. They also found that after 8 ft. (2.44 m) of fill depth live load effect was decreased considerably and thus AASHTO's distinction between single and multiple RCBC is inessential for live load distribution. In the tests, AASHTO's 1.75 vehicle load distribution factor was validated regardless of fill depth (Abdel-Karim et al., 1990).

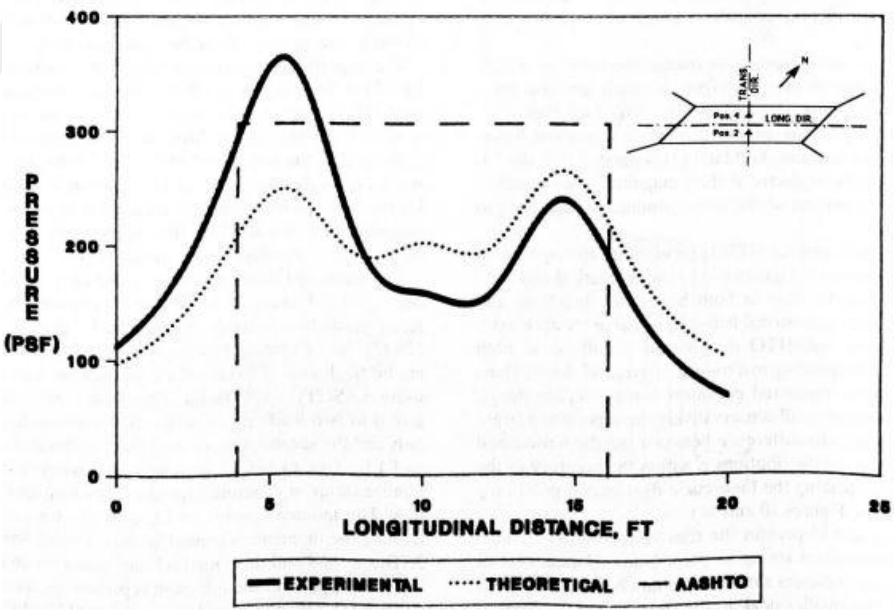


Figure 1.4 Longitudinal pressure distribution at 3.5 ft (1.07 m) of fill owing to axle load, position 2 (Abdel-Karim et al., 1990).

Kim and Yoo (2005) used finite element modelling to analyze different geometric configurations and backfill material properties for a concrete box culvert installed using the ITI method. The study reports that the width and the height of the compressible material should not be greater than 1.5 times of box culvert width and box culvert height, respectively. This is due to fact that there is no earth load reduction is observed beyond these dimensions. The study also revealed that placing compressible material directly above the box culvert is most efficient way for reduction of earth load and soil-interaction factor (Kim and Yoo, 2005).

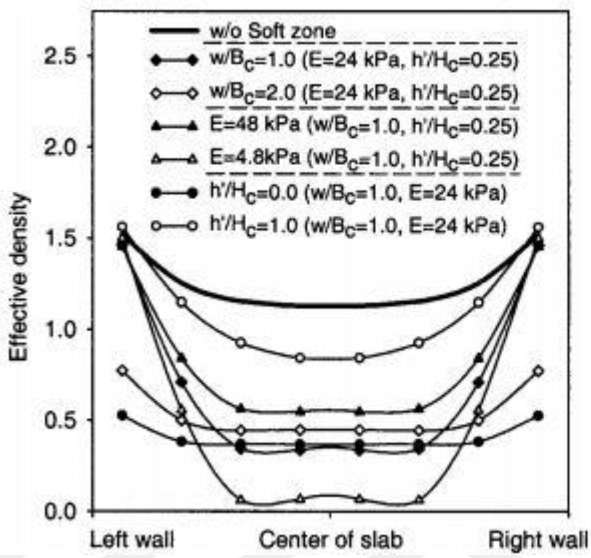


Figure 1.5 Effective density affected by imperfect trench installations (Kim and Yoo, 2005).

Pimentel et al. (2009) conducted an experiment of a reinforced concrete box culvert with 9.5 m embankment depth. A nonlinear finite element model was also used to investigate nonlinear and elastic behaviour of concrete box culvert. After finding experimental results and finite element analysis results were close, a parametric study was done to evaluate soil-structure interaction and failure mechanism of concrete box culverts. Soil interaction analysis results showed that soil-interaction factor varies between AASHTO compacted side fill and uncompacted side fill interaction factors. This study also indicated that overburden pressure caused by fill depth is greater than the normal weight of embankment above the culvert (Pimentel et al., 2009).

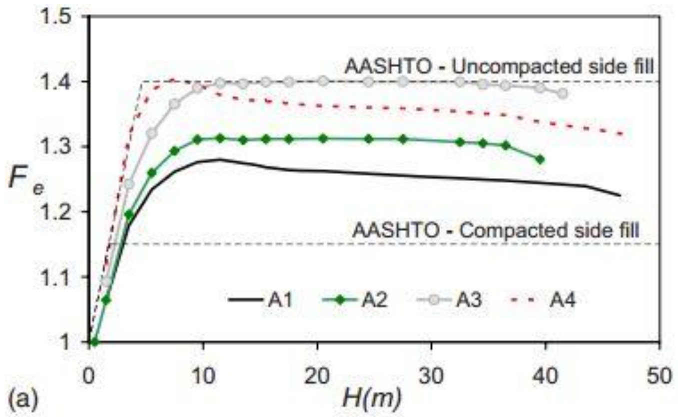


Figure 1.6 Evolution of global interaction factor (Pimentel et al., 2009).

Chen et al. (2010) also conducted a full-scale experiment to address the issue of vertical earth pressures not being accurately estimated. They also conducted a finite element model for comparison. The study concluded that overburden pressure calculated by the AASHTO SSHB method is accurate and in a good agreement with the test results. They also found that height of the backfill, width of the trench, slope angle of the trench, stiffness and dimensions of the culvert, and the material properties of the backfill and the foundation soil affect the vertical earth pressure on the culvert (Chen et al., 2010).

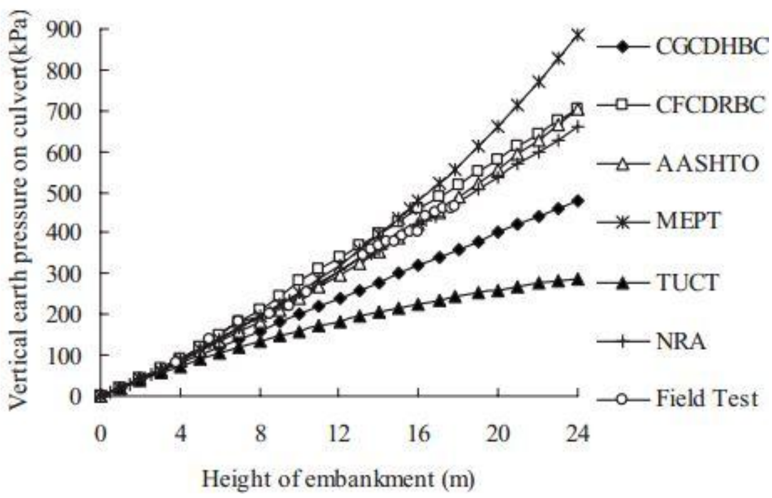


Figure 1.7 Comparison of theoretical results with field data on vertical earth pressure (Chen et al., 2010).

Maximos et al. (2010) conducted an experimental program to evaluate the fatigue effects on reinforced concrete (RC) box culverts. The study covered testing of two fullscale RC box culvert sections designed and manufactured according to ASTM C1577. The first specimen was 12 ft x 4 ft x 12 in. (3657.6 x 1219.2 x 304.8 mm), and the second was 7 ft x 4 ft x 8 in. (2133.6 x 1219.2 x 203.2 mm). There were a good distribution of the load resistance between the two rebar directions in box culverts in test results. Fatigue effect for flexural was minimal on RC box culvert sections. They concluded that, using recently proposed changes for fatigue design of RC box culverts will result in highly conservative and uneconomical designs. Therefore they suggested to waive the fatigue requirements in box culvert design and this recommendation is accepted by AASHTO (Maximos et al., 2010).

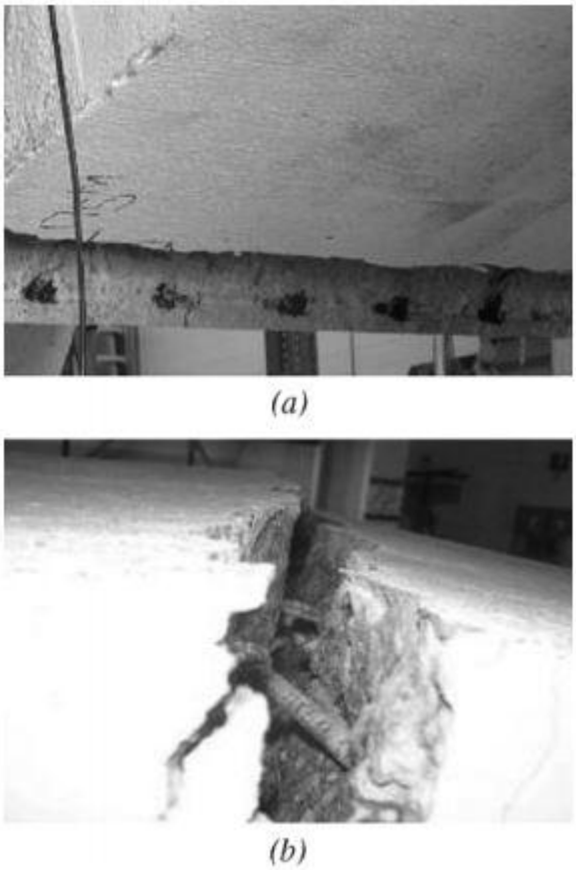


Figure 1.8 Positive and negative moment sections at failure for Specimen A: (a) midspan section of top slab; and (b) negative moment section of top slab (Maximos et al., 2010).

Oshati et al. (2012) studied a case history of a 2.60 m by 3.60 m double-cell reinforced cast-in-place box culvert buried under 25.10 m of fill to investigate effects of induced trench installation (ITI) method on earth pressures. They also conducted a controlled laboratory centrifuge model test for comparison purposes. This study concluded that centrifuge testing is suitable for evaluating earth pressures on culverts since centrifuge test results were close to the field-measurements. They also found that average vertical earth pressure measured on the top slab of the culvert was 42 percent of the design overburden pressure. Average lateral earth pressure was measured to be 52 percent of the overburden pressure at the middle height of the culvert. Results showed that the induced trench installation method is a feasible choice for box culverts under high embankment, no matter that the increased base soil pressure from side drag forces developed on the exterior walls of the culvert (Oshati et al., 2012).

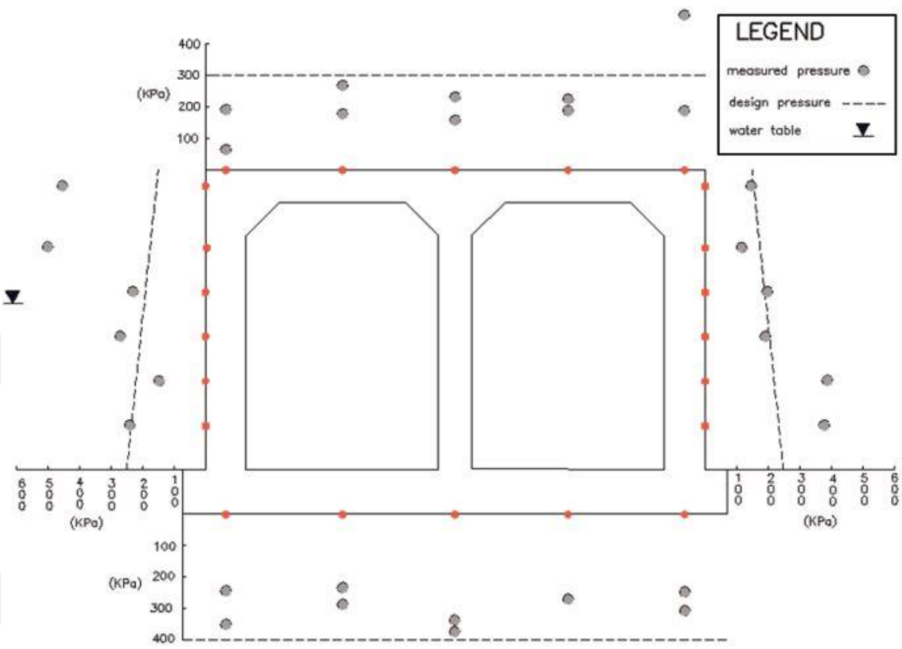


Figure 1.9 Measured and assumed design earth pressures on McBean Brook culvert (Oshati et al., 2012).

Wood et al. (2015) performed analyses of two production-oriented culvert load-rating demand models by using live-load test data from three instrumented RCBC under four different soil depths. A two-dimensional (2D) structural-frame model (named as Level 1) with simple supports and uniform reaction loads as base soil and a 2D soil-structure interaction model (named as Level 3) were used as demand models. Increasing model sophistication generated higher precision and accuracy for predicted moments, as expected. However, Level 1 model had high precision and accuracy for predicting moment values at the top exterior wall corners and the top midspans of culverts, too. Predicted moment demands for bottom slabs and corners were conservative in both model groups (Wood et al., 2015). However, increasing model sophistication of Level 1 group by adding linear springs as base soil could improve precision and accuracy for predicted moments at bottom slabs and corners.

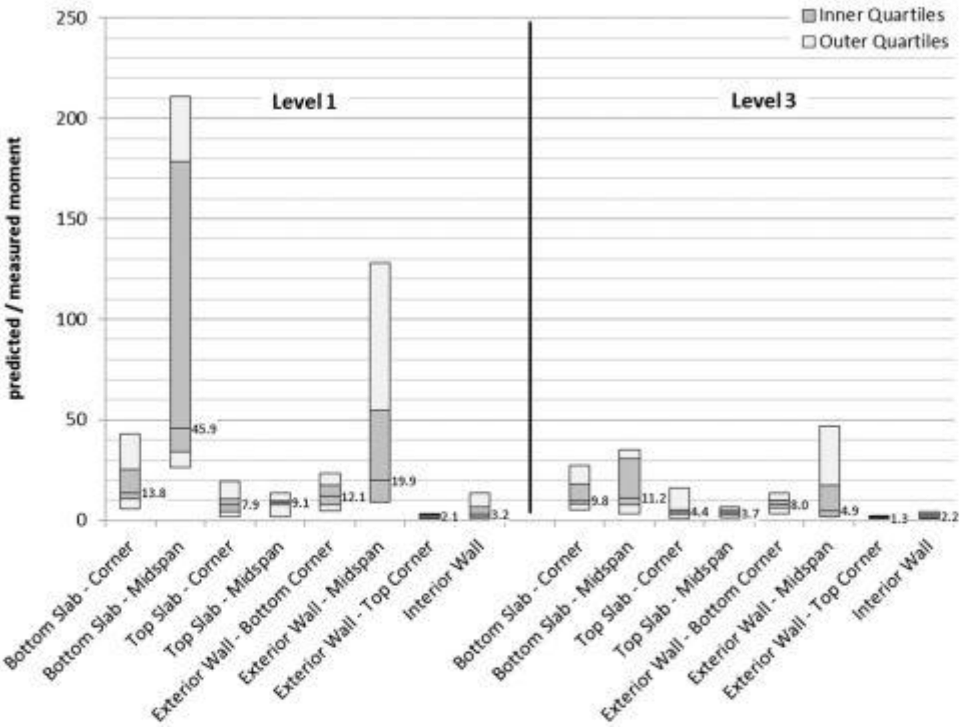


Figure 1.10 Evaluation modelling accuracy for each critical-section type in primary bending direction factor (Wood et al., 2015).

1.2.2 Theoretical Studies

Rund and McGrath (2000) presented a study about comparison of AASHTO Standard and LRFD Code Provisions for Buried Concrete Box Culverts. Both the Standard and LFTD Specifications are used to evaluate several combinations of culvert sizes and fill depths. A comparison of results showed that in general, LRFD provisions results gave increased loads and reinforcement areas. After 2 ft (0.61 m) fill depth reinforcement areas of LRFD were generally greater than those of M 259. 20-plus years of convincing performance of culverts that constructed with reinforcement areas from M 259 and M273 seems to contradict LRFD’s noticeably larger reinforcement areas and need for shear reinforcement for fill depths less than 2 ft (0.61 m). They concluded that LRFD provisions may be conservative and suggested more study should be done to better define structural behaviour of culverts related to distribution of wheel loads through earth fills to slabs (Rund and McGrath, 2000).

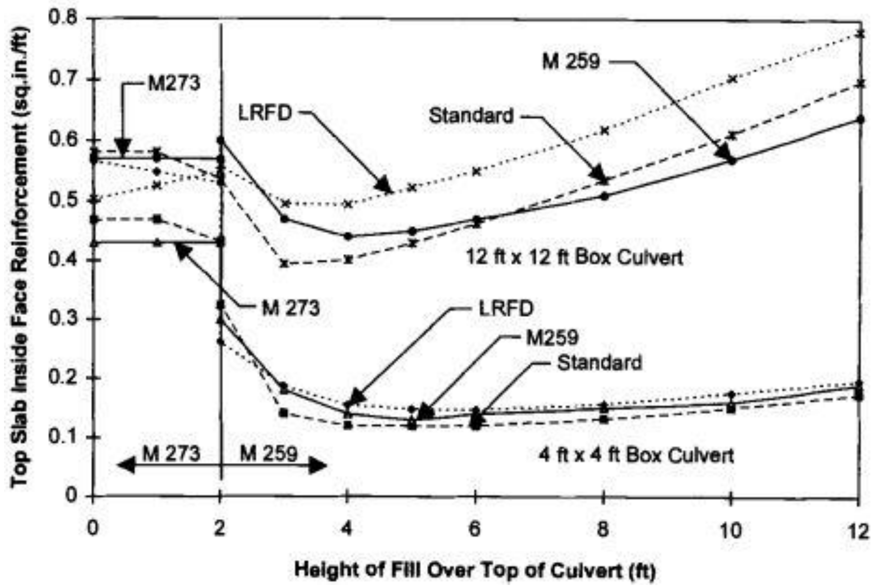


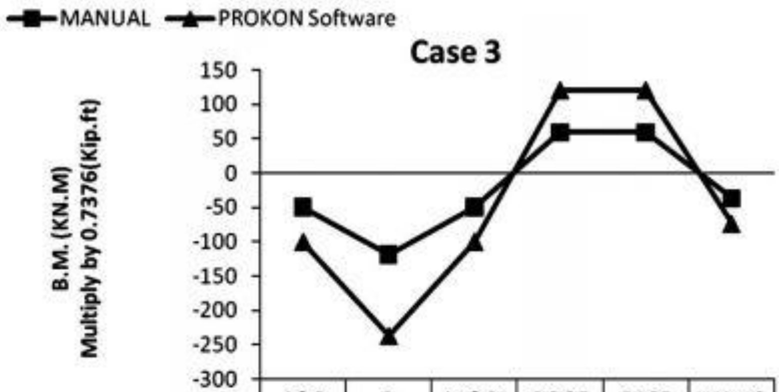
Figure 1.11 Top slab inside face reinforcement areas (Rund and McGrath, 2000).

Ahmed et al. (2011) discussed development a formulation for structural design of concrete box culverts. They used the standard requirements in the Design Manual for Roads and Bridges (DMRB) to formulate structural design of concrete box culverts including single, twin and multiple cellular culverts and also made a reference to the AASHTO SSHB. The formulations had been applied to many box culvert problems. They generated close results with commercially available software solutions like PROKON by using this formulation and a very good agreement had been achieved. They also reached following conclusions:

(1) Box culverts are analysed and designed as rigid frames with equal bending moments at the end supports, thus their method of analysis is different from that for other bridges.

(2) Accurate results were obtained from the analysis of single box culverts by using the moment distribution coefficients when compared analysis using commercially available software (PROKON).

(3) Acceptable results were obtained from the analysis of both twin and multiple culverts by using the moment distribution coefficients proposed by Janayni (1986) when compared analysis using commercially available software (PROKON) (Ahmed et al., 2011).



	A&C	B	A1&C1	ROOF	BASE	WALLS
PROKON Software	-49.82	-118	-49.82	61.2	61.1	-36.65
MANUAL	-49.68	-118.33	-49.68	59.17	59.17	-36.83

Figure 1.12 Comparison between manual solution and PROKON software results for Case 3 (Ahmed et al., 2011).

Jayawickrama et al. (2012) did a study that aimed to evaluate the significance of soil structure interactions effects on culvert load rating. They used three in-service culverts structures which were instrumented and the load response behaviour monitored. Two fully loaded truck with known axle loads passed the culverts. They took concrete core samples from culverts and tested them in laboratory to find out concrete strengths and stiffnesses of the culverts. They drilled 3 exploratory boreholes at each site and conducted five different test procedures for characterizing the surrounding soil envelop. 3D FE model was used to simulate the load-response behaviour of the culverts. They obtained following conclusions:

(a) There was a high degree of variability in material used as backfill, foundation soil and there were uncertainties about soil characterization tests.

(b) Predicted strains, load and moment demands by using 3D finite element model analysis weren’t affected much by variability in properties of foundation soil. Contrarily, the backfill soil properties greatly affected the results. Nevertheless, considering the high degree of variability in material properties the impact was modest.

(c) Simple 2D frame analysis models used in routine practise was more conservative than 3D finite element model in predicting strains.

(d) There were significant limitation in prediction of strains stem accurately from the unknown condition – cracked versus uncracked of the sections being analyzed. They concluded that assuming cracked condition caused the maximum strains to occur for the culvert is a reasonable approach for culvert load rating (Jayawickrama et al., 2012).

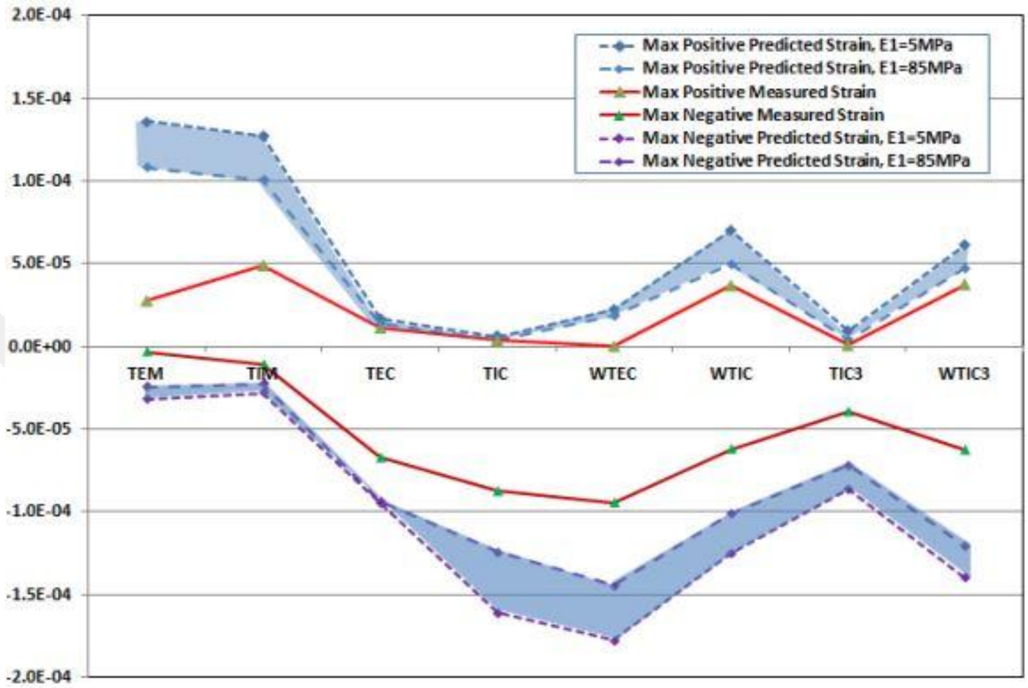


Figure 1.13 Measured versus predicted strains for the most critical sections in shallow water culvert (Jayawickrama et al., 2012).

Xia et al. (2014) did a research to specify and compare different ground deformation by Box culvert affected by mining subsidence is exposed to damage potential in relation to the lateral earth pressure. They created a finite-element model in ANSYS to generate combined soil and box culvert for this purpose. A better determination of the different behaviour of ground and box culvert due to different components of the ground movements is achieved by this study. The main results of this study are summarized below:

(1) The lateral earth pressure was found to be related to the compression displacement under the case of compression of the ground. With the increment of compression displacement, lateral earth pressure increased from earth pressure to at rest to the passive earth pressure of Rankine.

(2) Under the tension of the ground, the lateral earth pressure decreased from the earth pressure at rest to the active earth pressure of Rankine while tension displacement increased.

(3) For the slope of the ground, different distributions of lateral earth pressure was seen between left side and the right side of the culvert. While one side's lateral earth pressure increased from the earth pressure at rest to the passive earth pressure of Rankine, the other side's lateral earth pressure decreased from the earth pressure at rest to the active earth pressure of Rankine.

(4) The distribution and the value of lateral earth pressure and the limit displacement were affected by the kind of soils were used. Lesser limit displacement value was detected for clay compared to the sand (Xia et al., 2014).

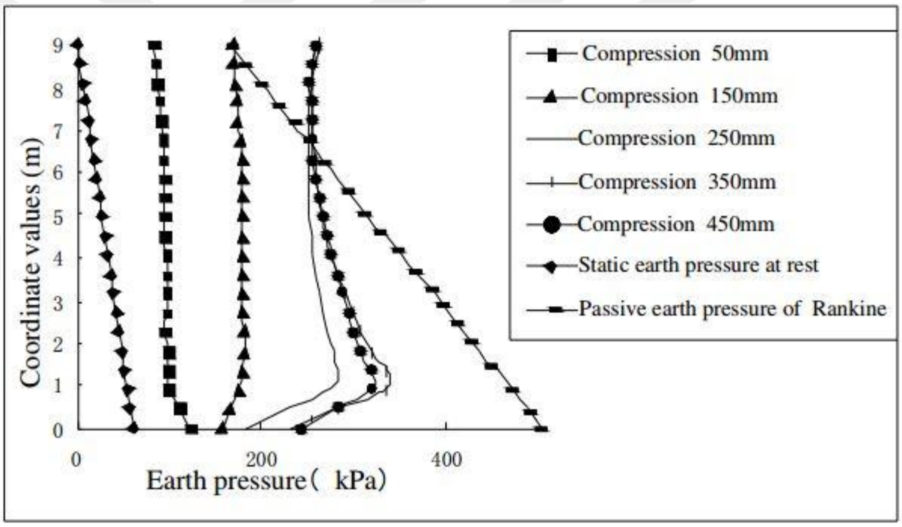


Figure 1.14 Lateral Earth Pressure as a Result of the Ground Horizontal Compression (clay) (Xia et al., 2014).

CHAPTER 2

CULVERT MODELS AND PARAMETERS

2.1 Material Properties

The embankment used for the sides and above culverts was assumed to have ɣ=18 kN/m³ unit weight and ϕ=30° friction angle. To model base soil, springs with 30x10³ kN/m³ stiffness constant were used. The concrete used to model the culverts had 25 MPa characteristic compressive strength, 30 GPa modulus of elasticity and 0.2 Poisson's ratio.

2.2 Geometry

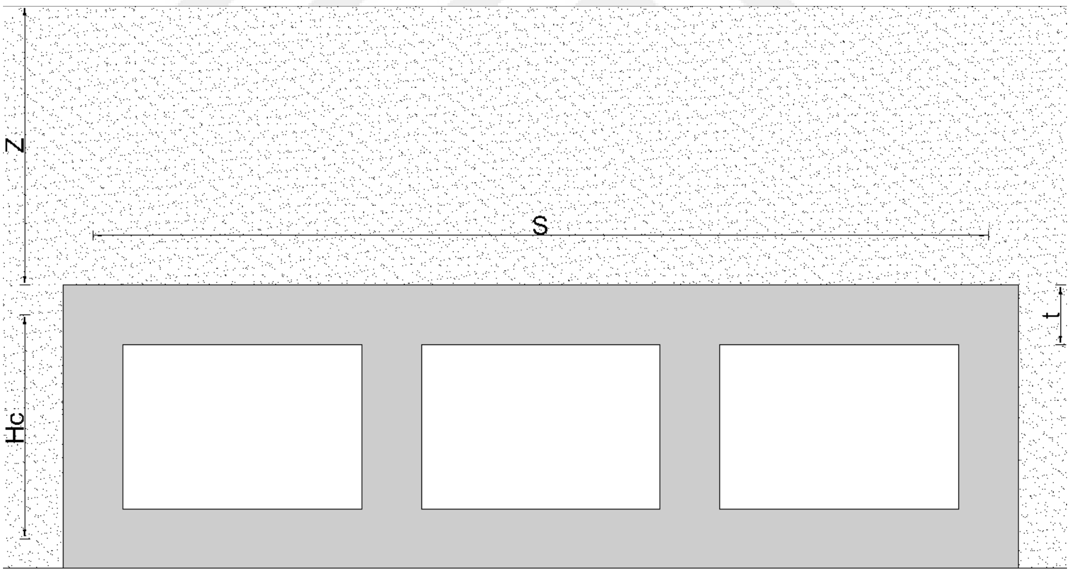


Figure 2.1 Typical reinforced concrete box culvert model and symbols.

A typical reinforced concrete box culvert model and geometric symbols used in this study are shown in Figure 2.1. Z is fill depth above culvert, which is measured between the outer face of top slab and top of the fill. S is effective span width of culvert, which is measured between centers of exterior walls. Hc is effective height of culvert, which is measured between centers of top and bottom slabs. t is section thickness of culvert elements.

Section thickness (t) for culverts is assumed to have minimum value of 15 cm and calculated as one twenty of span width (15 cm ≤ S/20). Section thickness for each model is constant for slabs and walls. Design length (L) of culvert models was kept constant as 1 m for all models.

As shown in Table 2.1, three model groups and 88 models were used for the analysis. In the first group, one cell concrete box culverts were considered. First model group consisted of four cases, which were categorized according to the fill depth. 0.50 m, 0.70 m, 1.50 m, and 3 m of fill depths were considered for Case I, Case II, Case III and Case IV, respectively. 2.40 m of constant culvert height was used for first group. Span width was changed between 0.60 m and 9.60 m.

Table 2.1 Parameters of reinforced concrete box culvert models.

Group	Case	No	Z	S	Hc	t	Cells	Aspect Ratio
			m	m	m	m	Number	S/Hc
1. Group	WIDTH CASE I Z=0.5 m	1	0.50	0.60	2.40	0.15	1	0.25
		2	0.50	1.20	2.40	0.15	1	0.50
		3	0.50	2.00	2.40	0.15	1	0.83
		4	0.50	3.00	2.40	0.15	1	1.25
		5	0.50	4.00	2.40	0.20	1	1.67
		6	0.50	5.00	2.40	0.25	1	2.08
		7	0.50	7.00	2.40	0.35	1	2.92
		8	0.50	9.60	2.40	0.48	1	4.00
	WIDTH CASE II Z=0.7 m	9	0.70	0.60	2.40	0.15	1	0.25
		10	0.70	1.20	2.40	0.15	1	0.50
		11	0.70	2.00	2.40	0.15	1	0.83
		12	0.70	3.00	2.40	0.15	1	1.25
		13	0.70	4.00	2.40	0.20	1	1.67
		14	0.70	5.00	2.40	0.25	1	2.08
		15	0.70	7.00	2.40	0.35	1	2.92
		16	0.70	9.60	2.40	0.48	1	4.00
	WIDTH CASE III Z=1.5 m	17	1.50	0.60	2.40	0.15	1	0.25
		18	1.50	1.20	2.40	0.15	1	0.50
		19	1.50	2.00	2.40	0.15	1	0.83
		20	1.50	3.00	2.40	0.15	1	1.25
		21	1.50	4.00	2.40	0.20	1	1.67
		22	1.50	5.00	2.40	0.25	1	2.08
		23	1.50	7.00	2.40	0.35	1	2.92
		24	1.50	9.60	2.40	0.48	1	4.00
	WIDTH CASE IV Z=3.0 m	25	3.00	0.60	2.40	0.15	1	0.25
		26	3.00	1.20	2.40	0.15	1	0.50
		27	3.00	2.00	2.40	0.15	1	0.83
		28	3.00	3.00	2.40	0.15	1	1.25
		29	3.00	4.00	2.40	0.20	1	1.67
		30	3.00	5.00	2.40	0.25	1	2.08
		31	3.00	7.00	2.40	0.35	1	2.92
		32	3.00	9.60	2.40	0.48	1	4.00
2. Group	HEIGHT CASE I Z=0.5 m	33	0.50	1.00	0.60	0.15	1	1.67
		34	0.50	1.00	1.00	0.15	1	1.00
		35	0.50	1.00	1.50	0.15	1	0.67
		36	0.50	1.00	2.00	0.15	1	0.50
		37	0.50	1.00	2.50	0.15	1	0.40
		38	0.50	1.00	3.00	0.15	1	0.33
		39	0.50	1.00	3.50	0.15	1	0.29
		40	0.50	1.00	4.00	0.15	1	0.25
	HEIGHT CASE II Z=0.7 m	41	0.70	1.00	0.60	0.15	1	1.67
		42	0.70	1.00	1.00	0.15	1	1.00
		43	0.70	1.00	1.50	0.15	1	0.67
		44	0.70	1.00	2.00	0.15	1	0.50

Group	Case	No	Z	S	Hc	t	Cells	Aspect Ratio
			m	m	m	m	Number	S/Hc
		45	0.70	1.00	2.50	0.15	1	0.40
		46	0.70	1.00	3.00	0.15	1	0.33
		47	0.70	1.00	3.50	0.15	1	0.29
		48	0.70	1.00	4.00	0.15	1	0.25
	HEIGHT CASE III Z=1.5 m	49	1.50	1.00	0.60	0.15	1	1.67
		50	1.50	1.00	1.00	0.15	1	1.00
		51	1.50	1.00	1.50	0.15	1	0.67
		52	1.50	1.00	2.00	0.15	1	0.50
		53	1.50	1.00	2.50	0.15	1	0.40
		54	1.50	1.00	3.00	0.15	1	0.33
		55	1.50	1.00	3.50	0.15	1	0.29
		56	1.50	1.00	4.00	0.15	1	0.25
	HEIGHT CASE IV Z=3.0 m	57	3.00	1.00	0.60	0.15	1	1.67
		58	3.00	1.00	1.00	0.15	1	1.00
		59	3.00	1.00	1.50	0.15	1	0.67
		60	3.00	1.00	2.00	0.15	1	0.50
		61	3.00	1.00	2.50	0.15	1	0.40
		62	3.00	1.00	3.00	0.15	1	0.33
		63	3.00	1.00	3.50	0.15	1	0.29
		64	3.00	1.00	4.00	0.15	1	0.25
3. Group	ONE CELL Z is 0 to 5 m	65	0.00	9.60	2.40	0.48	1	4.00
		66	0.50	9.60	2.40	0.48	1	4.00
		67	0.70	9.60	2.40	0.48	1	4.00
		68	1.00	9.60	2.40	0.48	1	4.00
		69	2.00	9.60	2.40	0.48	1	4.00
		70	3.00	9.60	2.40	0.48	1	4.00
		71	4.00	9.60	2.40	0.48	1	4.00
		72	5.00	9.60	2.40	0.48	1	4.00
	DOUBLE CELL Z is 0 to 5 m	73	0.00	9.60	2.40	0.48	2	4.00
		74	0.50	9.60	2.40	0.48	2	4.00
		75	0.70	9.60	2.40	0.48	2	4.00
		76	1.00	9.60	2.40	0.48	2	4.00
		77	2.00	9.60	2.40	0.48	2	4.00
		78	3.00	9.60	2.40	0.48	2	4.00
		79	4.00	9.60	2.40	0.48	2	4.00
		80	5.00	9.60	2.40	0.48	2	4.00
	TRIPPLE CELL Z is 0 to 5 m	81	0.00	9.60	2.40	0.48	3	4.00
		82	0.50	9.60	2.40	0.48	3	4.00
		83	0.70	9.60	2.40	0.48	3	4.00
		84	1.00	9.60	2.40	0.48	3	4.00
		85	2.00	9.60	2.40	0.48	3	4.00
		86	3.00	9.60	2.40	0.48	3	4.00
		87	4.00	9.60	2.40	0.48	3	4.00
		88	5.00	9.60	2.40	0.48	3	4.00

The second group was similar to the first group; however, in this group, culvert height was changed between 0.60 m and 4.00 m with a constant 1 m span width and a constant 15 cm section thickness.

In the third group, multiple numbered culvert cells were considered. 9.60 m constant span width and 2.40 m constant culvert height were used. Since the span width was constant, section thickness was constant too, and calculated as 48 cm (960/20). The one cell culvert with these dimensions was considered as Case I for the third group and this culvert was divided into double cells and triple cells, which were named as Case II and Case III, respectively. For the third group, fill depth was changed between 0 m and 5 m.

CHAPTER 3

LOADING

Figure 3.1 shows the static model and load types considered for concrete box culverts. Dead loads consist of vertical and lateral earth pressures and self weight of culvert. AASHTO HS20 vehicle load and lateral surcharge load were applied as live load. Base soil was modeled by using linear springs.

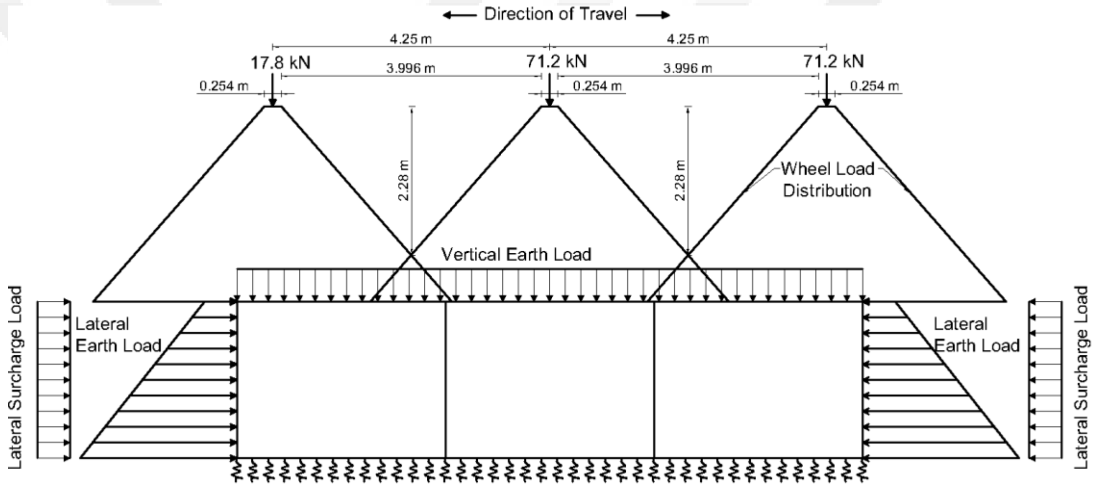


Figure 3.1 Static model and loads for concrete box culverts.

3.1 Dead Loads

3.1.1 Vertical Earth Pressure

Fill depth above culverts is an important factor that affects the design of reinforced box culverts since it affects both fill weight on culverts and distribution of vehicle loads. Previous studies have shown that overburden pressure caused by fill depth is greater than the normal weight of embankment above the culvert (Chen et al., 2010; Pimentel et al., 2009). Therefore, the AASHTO SSHB uses different soil-interaction factors according to the embankment installation type as stated in Articles 16.6.4.2.1 and 16.6.4.2.2 (AASHTO, 2002). In this study, embankment installation type with compacted side fills was considered.

Following interaction factor equation was used for culverts with compacted side fills (AASHTO, 2002):

$$F_e = 1 + 0.20\frac{Z}{B_C} \leq 1.15 \tag{3.1}$$

where F_e is soil-interaction factor, Z is fill depth and B_C is top slab width of box culvert, which is measured between outside faces of exterior walls.

As stated in the AASHTO SSHB Article 16.6.4.2, the total overburden pressure W_E on the box culvert is calculated as (AASHTO, 2002):

$$W_E = F_e \gamma B_C Z \text{ (kN/m)} \tag{3.2}$$

where γ is unit weight of soil used for embankment. This equation is converted to uniformly distributed vertical earth load by subtracting B_C:

$$DL = F_e \gamma Z \text{ (kN/m²)} \tag{3.3}$$

Vertical earth load was applied to the top slab of culvert as uniformly distributed load as shown in Figure 3.1.

3.1.2 Lateral Earth Pressure

Soil at the sides of box culvert was considered at rest condition. Following equation was used to calculate at rest earth coefficient (Jaky, 1948):

$$K_0 = 1 - \sin(\phi) \tag{3.4}$$

Since friction angle was taken ϕ=30° in the culvert models, K_0 was calculated as 0.5 by using Equation 3.4. As shown in Figure 3.1, lateral earth load was modeled as trapezoidal load, which starts from the center of top slab and finishes at the center of bottom slab. Lateral earth pressure at the start point EP_1 and lateral earth pressure at the end point EP_2 were calculated by using the following equations for 1 m design length:

$$EP_1 = K_0 \gamma (Z + \frac{t}{2}) \text{ (kN/m²)} \tag{3.5a}$$

$$EP_2 = K_0\gamma(Z + \frac{t}{2} + H_C) \text{ (kN/m}^2\text{)} \quad (3.5b)$$

3.1.3 Self Weight

The self weight of concrete box culvert was also considered in the analyses. Concrete members were modeled with 25 kN/m³ unit weight.

3.2 Live Loads

3.2.1 Vehicle Load

AASHTO HS20 vehicle loading was considered at this study. AASHTO HS20 truck has two different sizes of wheels. These are single wheel with 0.254 m x 0.254 m (10 inches x 10 inches) dimensions and dual wheel with 0.254 m x 0.508 m (10 inches x 20 inches) dimensions as shown in Figure 3.2 (ASTM, 2013). Front wheels have 17.8 kN load while middle and rear wheels have 71.2 kN load as shown in Figure 3.1. These wheel loads are applied as uniformly distributed load and moved all together along the span until wheel load projection in the first place exits the span.

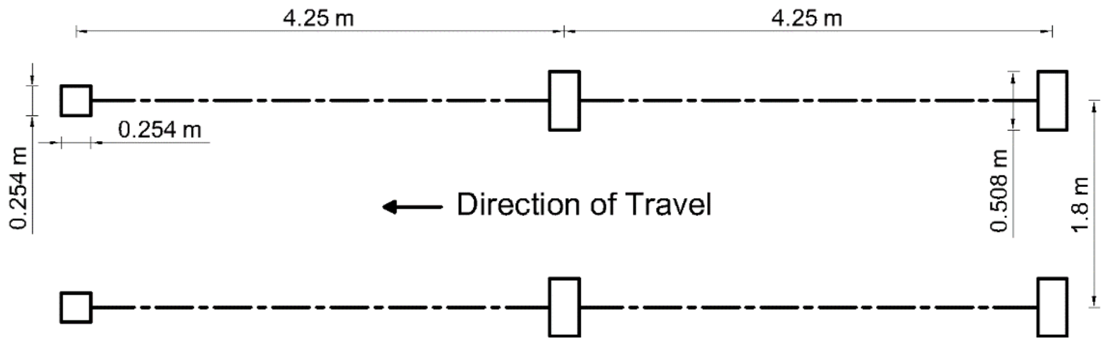


Figure 3.2 Spacing and dimensions for HS20 truck wheels and axles (ASTM, 2013).

3.2.1.1 *Distribution Area for Uniformly Distributed Vehicle Load*

There are two main equations for the distribution width of wheel loads. The first one is stated in AASHTO SSHB Article 16.7.4.1 and 3.24.3.2. When the fill cover is equal or less than 0.6 m (2 ft.), wheel loads shall be distributed over a distribution width calculated by the following equation (AASHTO, 2002):

$$E_1 = 1.2 + 0.06S \leq 2.13m \quad (3.6a)$$

where E_1 is distribution width for the first distribution case and S is effective span width. E_1 shall not exceed 2.13 m (7 ft.). Uniformly distributed vehicle loads for this distribution case can be written as for 1 m design length:

$$LL_{\max 1} = \frac{P_{\max}}{E_1} \text{ (kN/m}^2\text{)} \tag{3.6b}$$

$$LL_{\min 1} = \frac{P_{\min}}{E_1} \text{ (kN/m}^2\text{)} \tag{3.6c}$$

where P_{max} is maximum wheel load, which is 71.2 kN for HS20 truck, P_{min} is minimum wheel load, which is 17.8 kN for HS20 truck. LL_{max} and LL_{min} are uniformly distributed vehicle loads for maximum and minimum wheel loads, respectively.

The second main distribution width equation is for embankments, which have depth greater than 0.6 m. ASTM C890-13 in Article 5.2.3.1 states that when embankment separates the truck wheels and top surface of the culvert, wheel loads shall be distributed over a rectangle area as shown in the following equation (ASTM, 2013):

$$A = (0.254 + 1.75Z) \times (0.508 + 1.75Z) \text{ (m}^2\text{)} \tag{3.7}$$

where A is wheel load area (m²). According to ASTM C890-13 Article 5.2.3.3, when projection areas of wheel loads intersect, the sum of wheel loads will be uniformly distributed over a combined area, which consists of exterior boundaries of the individual load areas. If load area exceeds area of top surface of concrete box culvert, only surface of the top slab shall be used for load area (ASTM, 2013).

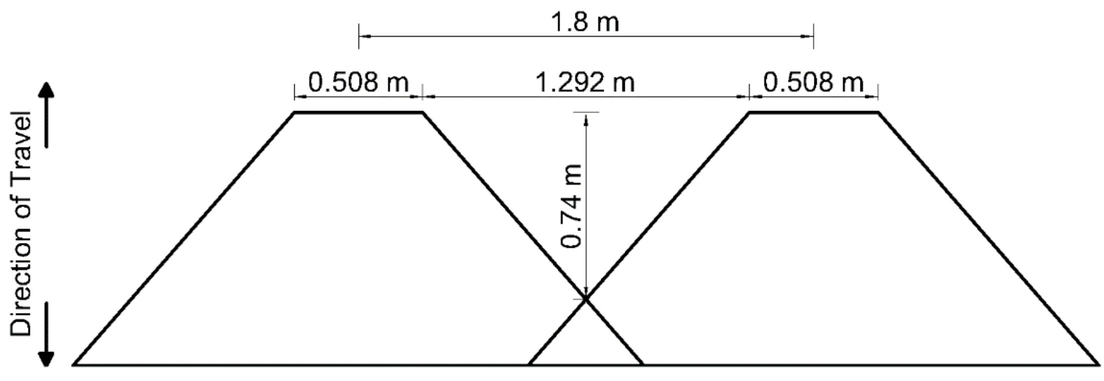


Figure 3.3 Wheel spacing and load projection for HS20 truck.

To formulate distribution areas, situations where load area intersections occur must be defined first. Since wheel spacing is less than axle spacing, the first intersection occurs between two wheels that are at the same axle as shown in Figure 3.3. First critical fill depth can be calculated as 0.74 m from the following geometric calculation knowing that the total slope of load projection lines is 1.75.

$$Z_{cr1} = \frac{1.8 - 0.508}{1.75} = \frac{1.292}{1.75} = 0.74m \quad (3.8a)$$

The second intersection occurs between two axles as shown in Figure 3.1. Calculation of the second critical fill depth ends up 2.28 m with the same method:

$$Z_{cr2} = \frac{4.25 - 0.254}{1.75} = \frac{3.996}{1.75} = 2.28m \quad (3.8b)$$

After defining critical fill depths for load projections, next distribution areas can be defined. The second distribution case is valid for 0.6 m < Z < 0.74 m. In this interval of fill depth, no intersection occurs between wheel load projections yet. The second distribution width and length are shown in the following equations:

$$E_2 = 0.254 + 1.75Z \text{ (m)} \quad (3.9a)$$

$$L_{D2} = 0.508 + 1.75Z \text{ (m)} \quad (3.9b)$$

where E_2 is second distribution width and L_{D2} is distribution length of dual wheels. Distribution length of single wheels L_{S2} equals to E_2 for this distribution case. Distribution area for dual wheels can be obtained by multiplying E_2 and L_{D2}. With the same way, distribution area for single wheels is obtained as square of E_2. Uniformly distributed vehicle loads are shown in the following equations:

$$LL_{\max2} = \frac{P_{\max}}{E_2 L_{D2}} \text{ (kN/m}^2\text{)} \quad (3.9c)$$

$$LL_{\min2} = \frac{P_{\min}}{{E_2}^2} \text{ (kN/m}^2\text{)} \quad (3.9d)$$

The third distribution case is defined for 0.74 m ≤ Z ≤ 2.28 m. In this interval of fill depth, while intersection occurs between wheels, intersection of different axles has not occurred yet. Thus, distribution width is not changed for this case. Since load projections of two wheels at the same axle overlap, distribution lengths for this case include wheel spacing (1.8 m) and wheel lengths. For the same reason two wheel loads are included in uniformly distributed vehicle load equations. Third distribution width and lengths are shown in the following equations:

$$E_3 = 0.254 + 1.75Z \text{ (m)} \tag{3.10a}$$

$$L_{S3} = 0.254 + 1.75Z + 1.8 \text{ (m)} \tag{3.10b}$$

$$L_{D3} = 0.508 + 1.75Z + 1.8 \text{ (m)} \tag{3.10c}$$

Uniformly distributed vehicle loads for the third case are shown in the following equations:

$$LL_{\text{max3}} = \frac{2P_{\text{max}}}{E_3 L_{D3}} \text{ (kN/m}^2\text{)} \tag{3.10d}$$

$$LL_{\text{min3}} = \frac{2P_{\text{min}}}{E_3 L_{S3}} \text{ (kN/m}^2\text{)} \tag{3.10e}$$

The forth distribution case is defined for 2.28 m < Z and divided in four sub cases. Since fill depth is greater than the second critical fill depth, all wheel load projection areas overlap. Span width of concrete box culvert is an important factor for this case to determine count of axles, which are in vertical projection of the span. Axles that are not in vertical projection of the span width are not considered for loading. For practicality, dual wheel length was considered when calculating distribution length in forth case and its sub cases as expressed in the following equation:

$$L_4 = 0.508 + 1.75Z + 1.8 \text{ (m)} \tag{3.11a}$$

If effective span width S is less than or equal to axle spacing (S ≤ 4.25 m), only one axle and two wheels at this axle are considered for loading. This case is a sub case and named as 4A. Since only one axle is considered, maximum wheel load is used for uniformly distributed vehicle load. As stated in the ASTM C890-13 Article 5.2.3.4, only portion of distributed vehicle load in range of span is considered for loading by reason of distributed load area exceeds top surface of culvert in this sub case (ASTM, 2013). Therefore, distribution width equation is used for only calculation of distributed load value for this sub case and vehicle load is distributed over whole span width knowing that span width is smaller than distribution width.

Distribution width and uniformly distributed vehicle load are defined in the following equations for sub case 4A:

$$E_{4A} = 0.254 + 1.75Z \text{ (m)} \tag{3.11b}$$

$$LL_{4A} = \frac{2P_{\max}}{E_{4A}L_4} \text{ (kN/m²)} \tag{3.11c}$$

When effective span width S is less than or equal to two axle spacing and greater than one axle spacing (4.25 m < S ≤ 8.5 m), two axles and four wheels at these axles are considered for loading. This sub case is named as 4B. Since front axle has not been considered yet, maximum wheel load is used for uniformly distributed vehicle load. Distribution width for this sub case contains axle spacing (4.25 m) due to inclusion of two axles. Vehicle load is distributed over whole span width in this sub case for the same reason as explained in sub case 4A. Distribution width and uniformly distributed vehicle load for sub case 4B are defined in the following equations:

$$E_{4B} = 0.254 + 1.75Z + 4.25 \text{ (m)} \tag{3.11d}$$

$$LL_{4B} = \frac{4P_{\max}}{E_{4B}L_4} \text{ (kN/m²)} \tag{3.11e}$$

When effective span width S is greater than two axle spacing (8.5 m < S), three axles and six wheels at these axles are considered for loading. This case is named as 4C. Four maximum and two minimum wheel loads are used for uniformly distributed vehicle load. Distribution width for this sub case contains two axle spacing (8.5 m) due to inclusion of three axles. Distributed vehicle loads are much smaller in forth case as shown in Figure 3.4. For this reason and practicality, although effective span width can be greater than calculated distribution width, vehicle load is distributed over whole span width in this sub case, too. Distribution width and uniformly distributed vehicle load for sub case 4C are defined in the following equations:

$$E_{4C} = 0.254 + 1.75Z + 8.5 \text{ (m)} \tag{3.11f}$$

$$LL_{4C} = \frac{(4P_{\max} + 2P_{\min})}{E_{4C}L_4} \text{ (kN/m²)} \tag{3.11g}$$

Distribution areas and distributed vehicle load formulas for all cases are summarized in Table 3.1.

Table 3.1 Distribution width, length and distributed vehicle load formulas.

Case Name	**Fill Depth Interval**	**Span Width Interval**	**E m**	**L_S m**	**L_D m**	**LL_{max} kN/m²**	**LL_{min} kN/m²**
1	Z ≤ 0.6 m		1.2+0.006S ≤ 2.13 m			$\frac{P_{max}}{E_1}$	$\frac{P_{min}}{E_1}$
2	0.6 m < Z < 0.74 m		0.254+1.75Z	0.254+1.75Z	0.508+1.75Z	$\frac{P_{max}}{E_2 L_{D2}}$	$\frac{P_{min}}{E_2^{\,2}}$
3	0.74 m ≤ Z ≤ 2.28 m		0.254+1.75Z	0.254+1.75Z +1.8	0.508+1.75Z +1.8	$\frac{2P_{max}}{E_3 L_{D3}}$	$\frac{2P_{min}}{E_3 L_{S3}}$
4A	2.28 m < Z	S ≤ 4.25 m	0.254+1.75Z	0.508+1.75Z+1.8		$\frac{2P_{max}}{E_{4A} L_4}$	
4B	2.28 m < Z	4.25 m < S ≤ 8.5 m	0.254+1.75Z +4.25	0.508+1.75Z+1.8		$\frac{4P_{max}}{E_{4B} L_4}$	
4C	2.28 m < Z	8.5 m < S	0.254+1.75Z +8.5	0.508+1.75Z+1.8		$\frac{(4P_{max}+2P_{min})}{E_{4C} L_4}$	

After determination of distribution areas and distributed vehicle loads, an example graph of maximum uniformly distributed vehicle load variation with respect to fill depth was drawn in Figure 3.4. As it can be seen in Figure 3.4, vehicle load was at its maximum value and constant for the first case. After the first case, vehicle load was decreasing dramatically. Vertical earth load and vehicle load had the same value at fill depth of about 1 m. According to AASHTO SSHB Article 6.4.2, the effect of vehicle load can be ignored over 2.44 m (8 ft.) fill depth (AASHTO, 2002). At this depth of fill, LL_{max} had a value of 4.79 kN/m² while DL had a value of 50.51 kN/m² as shown in Figure 3.4. In other words, distributed vehicle load was 9.48 percent of distributed overburden load at 2.44 m fill depth. In this study vehicle load was not neglected at any depth of fill value.

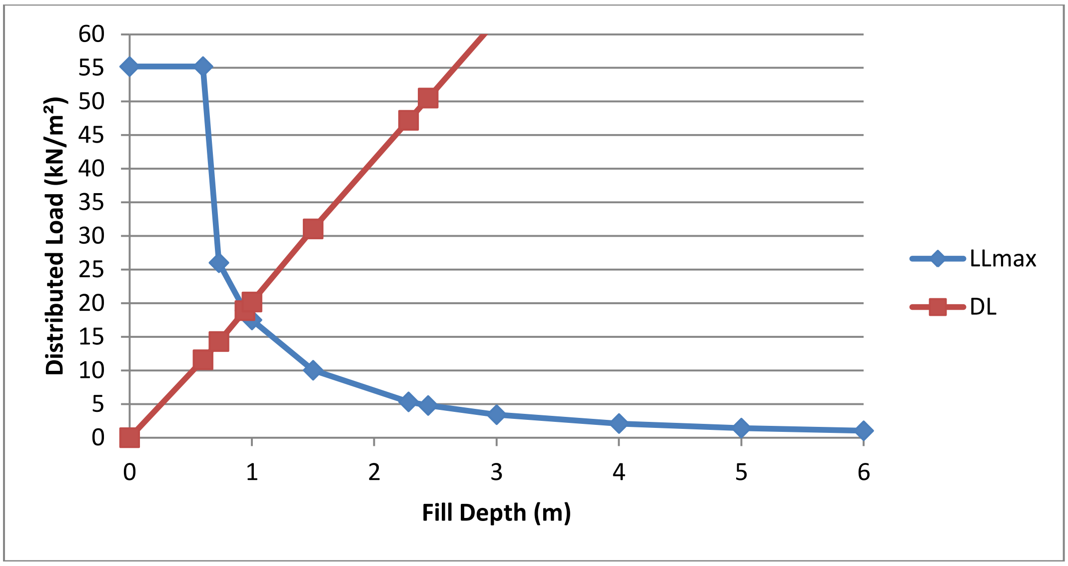


Figure 3.4 Vertical earth load and maximum distributed vehicle load variation for span width of 1.5 m.

3.2.1.2 *Impact Factor for Vehicle Load*

AASHTO SSHB also specifies an impact factor for live loads acting on span to consider dynamic, vibratory and impact effects in Article 3.8.2.3 (AASHTO, 2002).

Table 3.2 Impact factor table (AASHTO, 2002).

Fill Depth Interval	**Impact Factor I**
$Z \leq 0.3$ m	1.3
0.3 m $< Z \leq 0.6$ m	1.2
0.6 m $< Z \leq 0.9$ m	1.1
0.9 m $< Z$	1

3.2.2 Lateral Surcharge Load

According to the AASHTO SSHB Article 3.20.3, minimum 0.6 m (2 ft.) lateral earth pressure shall be applied to exterior walls of the culvert, when traffic can come from a distance equal to one half of the culvert height (AASHTO, 2002). Live load surcharge was not considered for depth of fill values greater than 2.44 m (8 ft.) as stated in the ASTM C890-13 Article 5.5.2 (ASTM, 2013). Live surcharge load was calculated from the following equation as stated in the AASHTO SSHB Article 5.5.2 (AASHTO, 2002):

$$LS = K_0 \gamma 0.6 \text{ (kN/m}^2\text{)} \tag{3.12}$$

3.3 Load Combinations

The following load combinations were used in the analysis of culvert models to evaluate maximum internal forces:

$$1.30 \times (\mathrm{DL} + \mathrm{EP} + 1.67 \times \mathrm{LS} + 1.67 \times \mathrm{I} \times \mathrm{LL}) \tag{3.13a}$$

$$1.30 \times (\mathrm{DL} + 0.5 \times \mathrm{EP} + 1.67 \times \mathrm{LS} + 1.67 \times \mathrm{I} \times \mathrm{LL}) \tag{3.13b}$$

$$\mathrm{DL} + \mathrm{EP} + \mathrm{LS} + \mathrm{I} \times \mathrm{LL} \tag{3.13c}$$

The first two combinations are listed in the AASHTO SSHB Table 3.22.1A (AASHTO, 2002). No load factors were used in the third combination except the impact factor.

CHAPTER 4

FINITE ELEMENT MODELING AND ANALYSIS

Two-dimensional (2D) structural-frame finite element analysis method is widely used for modelling RCBC as AASHTO suggests applying loads to directly on culvert structure models (Wood et al., 2015). For this reason, several departments of transportation (DOT) such as Alabama DOT, Wyoming DOT and Texas DOT have developed their own structural-frame analysis softwares for modelling RCBC. 2D structural-frame finite element analysis method has high precision and accuracy for predicting moment values at the top exterior wall corners and the top midspans of culverts (Wood et al., 2015). Thus, 2D structural-frame finite element analysis method was used in this study to analyze large quantities of culvert models efficiently.

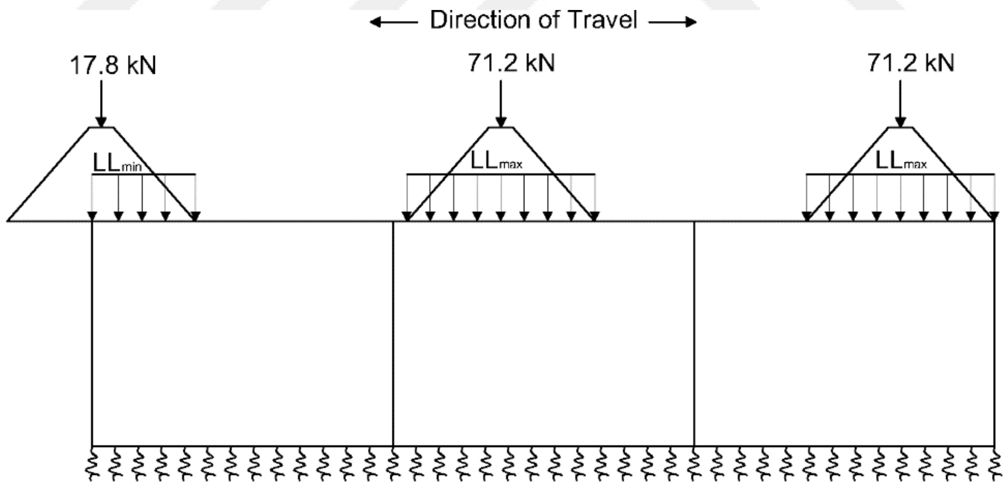


Figure 4.1 Wheel load projections and equivalent distributed vehicle loads.

The modeling process was automated by developing a Microsoft Excel sheet by using Visual Basic (VBA) and Application Programming Interface (‘CSI API’, 2015). Springs that were used to model base soil and to increase model sophistication was placed with 25 cm or lesser spacing and this spacing value was calculated as one fifteen of span width ($S/15 \leq 25$).

Vehicle loads were moved step by step and distributed vehicle loads were moved each step by a value equals to spring spacing. Location of distributed vehicle loads were checked at each step and only portion of distributed vehicle load that was in range of span was considered for loading. An example vehicle loading step is shown in Figure 4.1.

After typing material properties and section properties in the Excel sheet, loads and 2D finite element structural-frame model were automatically created in SAP2000 version 17.2.0 ('CSI SAP2000', 2015). With the completion of analysis, results were transferred from SAP2000 to the Excel sheet. Maximum and critical internal forces and soil stress were gathered in a table and base soil stress diagram was drawn automatically.

CHAPTER 5

ANALYSIS RESULTS

An example moment diagram, which was produced for a double cell RCBC by SAP2000, is shown in Figure 5.1. As it can be seen in this figure, while positive moment occurrence was clear at base and top slabs, positive moment did not occur for much cases at wall sections.

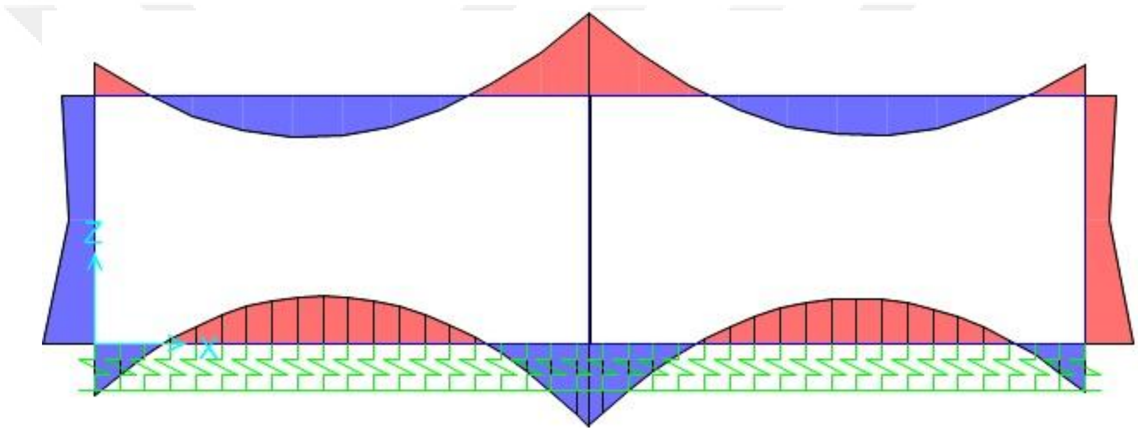


Figure 5.1 Moment diagram for a double cell RCBC.

Table 5.1 shows the analysis results of box culvert models. Maximum and critical internal forces and soil stress are shown in this table where Mt, Mw, and Mb are the maximum moment results of top slab, walls and base slab, respectively. Vt, Vw, and Vb are maximum shear force results of top slab, walls and base slab. qs shows maximum base soil stress results. Negative moment was considered for walls and base slab, positive moment was considered for top slab in Table 5.1 and in figures that show moment graphs. Moments that produce tension in the bottom fibers of slabs and in the inner fibers of walls were taken into account as positive moment. Minus sign in the moment results indicates that only the opposite moment values were generated as a result of the analysis. In this case moment values that were closest to zero shown in the results.

Table 5.1 Analysis results of RCBC models.

Group	Case	No	Mt	Mw	Mb	Vt	Vw	Vb	qs
			kNm	kNm	kNm	kN	kN	kN	kN/m²
1. Group	WIDTH CASE I Z=0.5 m	1	-1.420	14.608	0.953	50.466	45.450	58.132	117.066
		2	13.057	18.451	17.627	97.955	45.585	102.394	100.573
		3	43.406	29.832	34.311	142.774	44.460	138.712	124.119
		4	75.538	53.327	43.368	171.394	43.242	157.171	137.207
		5	110.012	82.165	58.497	193.371	47.584	179.697	130.876
		6	107.701	102.956	84.104	217.455	51.002	211.769	120.398
		7	230.061	227.271	139.876	297.339	65.541	297.498	135.995
		8	388.147	468.162	203.355	392.583	104.734	402.786	148.256
	WIDTH CASE II Z=0.7 m	9	-4.917	15.041	4.435	27.016	48.261	36.253	82.891
		10	3.825	16.307	7.075	53.580	48.428	61.125	67.078
		11	23.515	22.157	21.020	84.673	47.940	87.744	76.676
		12	45.869	36.863	28.939	108.478	46.877	104.564	92.511
		13	71.683	57.823	41.672	129.105	47.640	125.770	95.864
		14	77.381	77.376	61.999	151.123	50.791	153.203	95.071
		15	168.874	171.443	105.037	214.530	56.924	222.326	111.409
		16	300.855	359.509	159.990	296.030	84.910	313.190	126.008
	WIDTH CASE III Z=1.5 m	17	-7.612	18.499	7.124	20.105	59.494	29.812	79.078
		18	-0.339	18.444	2.531	40.209	59.678	48.737	64.166
		19	16.443	23.826	17.789	66.651	59.872	72.911	62.719
		20	39.625	36.776	31.615	97.624	57.509	97.263	88.067
		21	68.731	62.472	48.284	128.944	54.793	127.134	103.164
		22	101.275	96.622	68.902	159.654	56.889	160.986	111.442
		23	189.555	202.174	118.534	229.274	71.786	236.598	127.730
		24	347.715	424.742	181.856	328.713	106.694	344.064	148.177
	WIDTH CASE IV Z=3.0 m	25	-5.466	20.892	4.983	27.909	66.485	37.099	103.631
		26	3.719	21.336	7.042	55.818	66.663	63.289	88.501
		27	26.322	29.063	26.909	93.030	66.718	97.150	92.020
		28	59.538	50.117	46.242	139.545	63.158	133.944	135.974
		29	103.000	89.528	74.448	188.296	62.121	179.309	156.375
		30	154.943	144.762	104.441	236.815	69.655	229.769	170.007
		31	284.780	304.264	168.935	334.908	92.873	333.083	190.449
		32	504.907	609.748	257.642	463.445	140.563	470.205	210.509
2. Group	HEIGHT CASE I Z=0.5 m	33	11.860	9.097	12.103	82.404	7.439	79.717	90.882
		34	13.074	8.326	13.561	82.404	13.677	81.526	94.042
		35	13.110	9.242	13.902	82.404	23.239	83.804	97.666
		36	11.719	12.287	12.754	82.404	34.813	86.104	100.889
		37	8.931	17.720	10.072	82.404	48.415	88.427	103.932
		38	4.687	25.885	5.728	82.404	64.052	90.777	108.291
		39	-1.111	37.172	0.448	82.404	81.728	93.157	113.139
		40	-8.579	51.988	8.644	82.404	101.445	95.572	118.359
	HEIGHT CASE II Z=0.7 m	41	6.366	5.241	6.654	44.793	8.209	44.652	57.457
		42	6.764	5.324	7.302	44.793	14.887	46.469	60.501
		43	6.090	7.029	6.944	44.793	25.020	48.756	64.008
		44	4.154	10.747	5.257	44.793	37.172	51.062	67.260
		45	0.892	16.826	2.108	44.793	51.355	53.391	71.413
		46	-3.799	25.661	2.677	44.793	67.574	55.748	76.000
		47	-10.041	37.662	9.293	44.793	85.833	58.135	80.920
		48	-17.969	53.254	17.942	44.793	106.133	60.557	86.221
	HEIGHT CASE III Z=1.5 m	49	4.669	4.182	4.971	33.508	11.038	34.132	53.769
		50	4.690	4.785	5.245	33.508	19.581	35.954	56.737
		51	3.497	7.342	4.372	33.508	32.050	38.249	60.085
		52	0.923	12.214	2.052	33.508	46.540	40.567	63.784
		53	-3.129	19.786	1.880	33.508	63.063	42.911	68.247
		54	-8.778	30.472	7.616	33.508	81.622	45.285	73.037
		55	-16.156	44.695	15.357	33.508	102.220	47.694	78.202
		56	-25.401	62.884	25.313	33.508	124.861	50.142	83.791
	HEIGHT CASE IV Z=3.0 m	57	6.598	5.590	6.884	46.515	12.763	46.260	78.565
		58	6.978	6.100	7.515	46.515	22.481	48.081	81.535
		59	6.211	8.856	7.063	46.515	36.413	50.377	84.774

Group	Case	No	Mt	Mw	Mb	Vt	Vw	Vb	qs
			kNm	kNm	kNm	kN	kN	kN	kN/m²
		60	4.104	14.224	5.206	46.515	52.363	52.700	88.168
		61	0.597	22.569	1.814	46.515	70.344	55.051	92.793
		62	-4.414	34.290	3.289	46.515	90.361	57.436	97.799
		63	-11.049	49.804	10.294	46.515	112.417	59.857	103.231
		64	-19.442	69.536	19.405	46.515	136.515	62.320	109.137
3. Group	ONE CELL Z is 0 to 5 m	65	346.979	417.881	185.218	357.609	90.293	369.995	130.769
		66	388.147	468.162	203.355	392.583	104.734	402.786	148.256
		67	300.855	359.509	159.990	296.030	84.910	313.190	126.008
		68	305.225	370.583	161.634	294.686	91.034	312.104	130.761
		69	399.853	486.841	206.404	371.334	122.665	384.021	168.026
		70	504.907	609.748	257.642	463.445	140.563	470.205	210.509
		71	634.153	766.792	319.089	582.508	180.120	581.462	260.764
		72	772.045	934.226	384.640	709.502	221.398	700.125	313.731
	DOUBLE CELL Z is 0 to 5 m	73	116.161	121.187	110.779	219.152	67.085	215.025	82.218
		74	122.920	127.821	118.288	237.396	72.936	228.744	89.156
		75	88.465	102.332	89.889	177.247	72.655	180.260	74.834
		76	83.053	97.510	87.802	173.701	71.610	183.413	75.007
		77	94.892	108.352	103.550	210.942	80.390	231.257	88.698
		78	117.963	126.431	125.229	263.036	81.006	283.676	106.611
		79	147.835	152.592	153.973	329.396	94.694	350.036	128.977
		80	179.734	180.312	184.659	400.207	108.361	420.847	152.546
	TRIPPLE CELL Z is 0 to 5 m	81	68.705	75.525	62.144	157.228	64.881	165.506	80.213
		82	71.011	78.106	65.454	168.468	70.864	172.696	86.379
		83	50.577	64.159	48.524	119.212	70.655	133.488	72.717
		84	44.125	58.329	47.159	123.770	69.404	125.973	72.654
		85	46.054	60.027	53.635	142.897	78.861	146.899	84.595
		86	57.949	67.555	64.637	176.738	79.569	177.516	100.689
		87	72.469	80.050	79.007	220.528	93.583	217.820	120.955
		88	88.003	93.168	94.376	267.280	107.597	260.849	142.307

5.1 Effect of Span Width

Figure 5.2 shows the variation of maximum moment and shear force, which were occurred at top slab and maximum base soil stress with respect to span width. As expected internal forces were increasing as span width was increasing. Internal forces of Case II had lowest values at over 4 m span width. Although fill depth was 3 m for Case IV and 0.5 m for Case I, internal forces of Case IV were lesser than internal forces of Case I at 0.6 m to 4 m span width range. This was due to the fact that Case I had a greater distributed vehicle loads. After 4 m span width value, while Case I had limited vehicle load distribution width (E1 < 2.13 m), Case IV vehicle loads were distributed over whole span width. Thus, Case IV internal forces overtook internal forces of Case I after 4 m span width with contribution of 3 m fill depth.

Same trend is valid for base soil stress graph, but slope of this graph is increasing more slowly than internal forces. After 3 m span width value, base soil stress of Case IV overtook base soil stress of Case I.

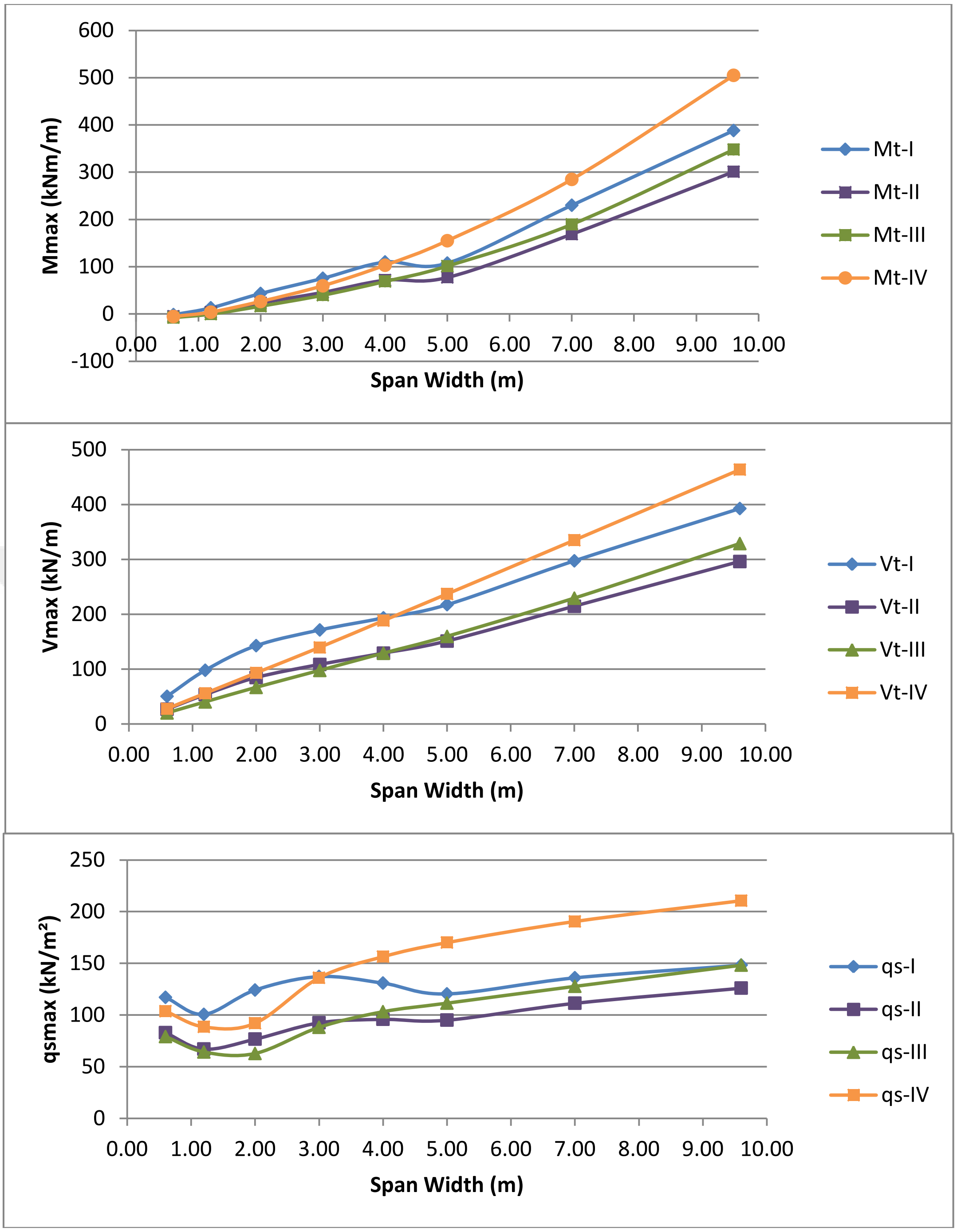


Figure 5.2 Internal forces and base soil stress with respect to span width.

5.2 Effect of Culvert Height

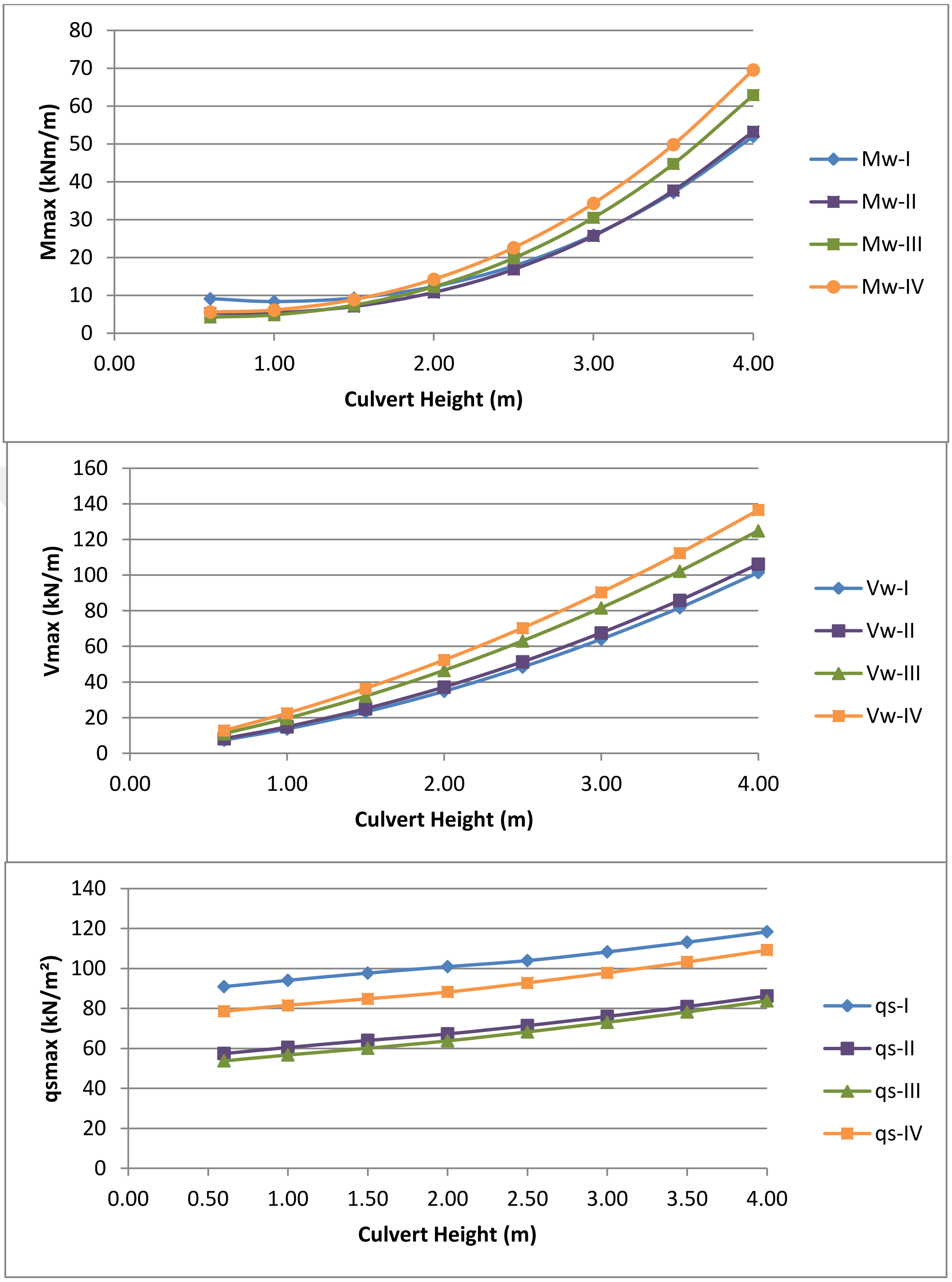


Figure 5.3 Internal forces and base soil stress with respect to culvert height.

Figure 5.3 shows the variation of maximum moment and shear force which were occurred at exterior walls and maximum base soil stress with respect to culvert height. Since increment at culvert height caused lateral earth pressure to increase according to Equation 3.5b, internal forces at exterior walls were increasing, too.

Similar to Figure 5.2, moments of Case IV were lesser than moments of Case I at 0.6 m to 2 m culvert height range. This is due to the fact that Case I had a greater distributed vehicle loads and moment continuity between top slab and walls increased moment values at walls. Besides, soil pressures of Case IV were lesser than soil pressures of Case I at all culvert height values. In contrast to these trends, shear force values of Case IV were greater than other cases, because shear forces at walls were affected directly by the lateral earth pressure.

5.3 Effect of Fill Depth

Variation of maximum moment, shear force and base soil stress with respect to fill depth is shown in Figure 5.4. Internal forces were increasing generally with the increment of fill depth for one cell, double cell and triple cell culvert models. Internal forces were decreasing after 0.60 m fill depth since distributed vehicle load starts to decrease sharply at this fill depth as shown in Figure 3.4. Internal forces and base soil pressures reached their minimum values at 0.70 – 1.0 m fill depth range. After 1 m of fill depth, as vertical earth load was overtaking vehicle load, internal forces were starting to increase again. Double and triple cell culvert models had close results while one cell culvert models had greater internal forces. Slopes of internal force graphs for one cell culverts were much greater than slopes of internal force graphs for double and triple cell culverts.

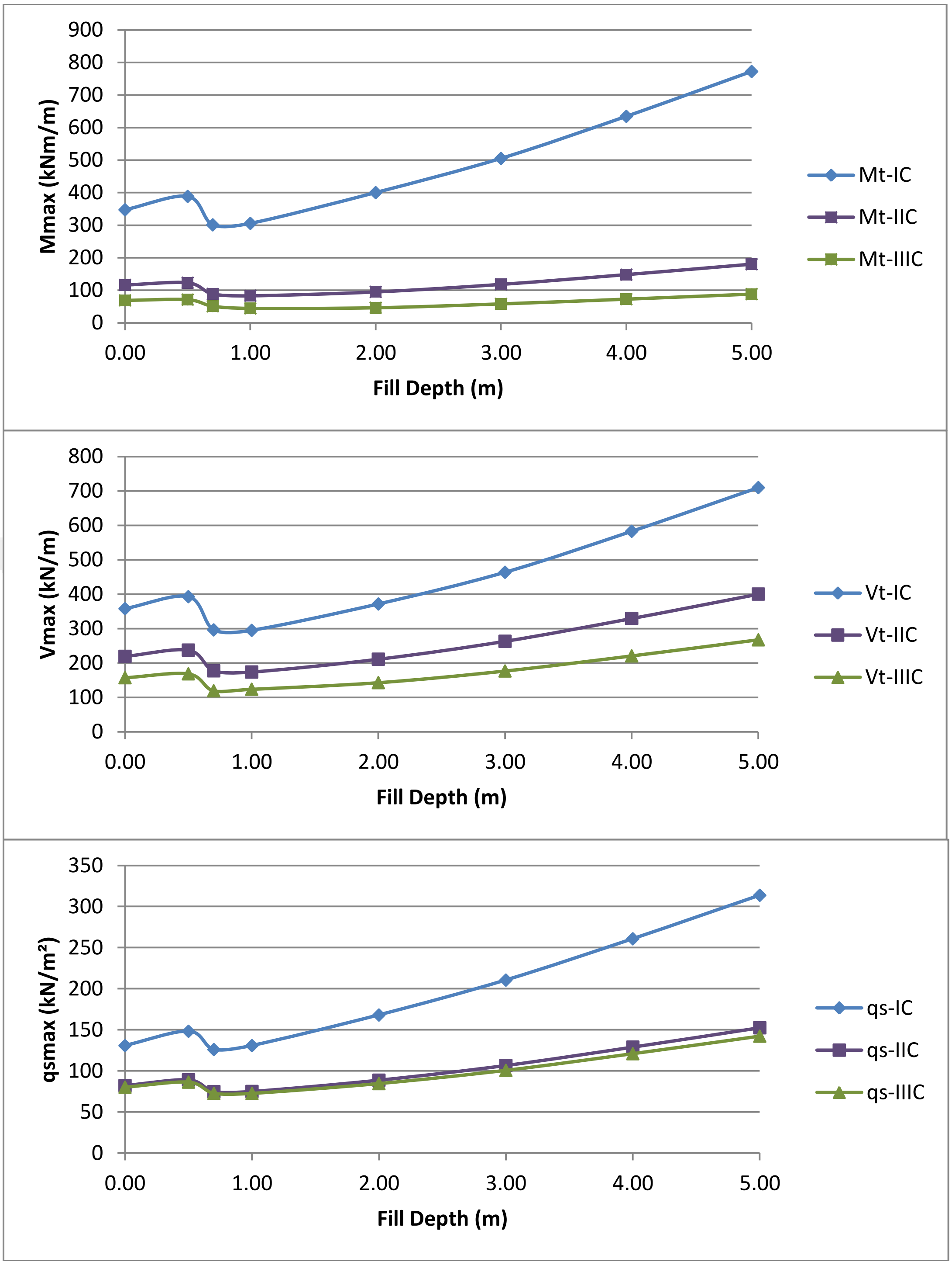


Figure 5.4 Internal forces and base soil stress with respect to fill depth.

CHAPTER 6

DESIGN OF REINFORCED CONCRETE BOX CULVERTS

Once internal forces of culvert sections were found, the next step was designing the sections for flexure and shear. Maximum and critical values of internal forces that were generated from load combinations were considered in the design calculations. Slabs were considered as one-way slabs. TS 500 standard was used in the design calculations (TS 500, 2000). An example reinforcement layout for RCBC is shown in Figure 6.1.

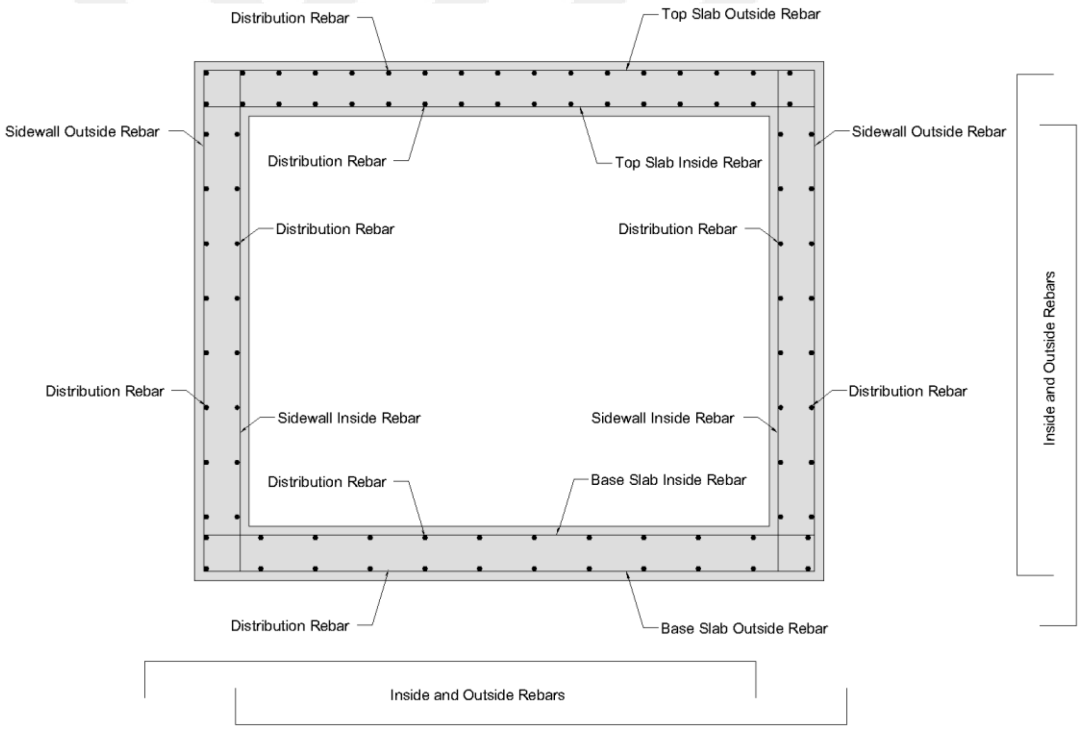


Figure 6.1 Reinforcement layout for RCBC.

6.1 Design for Flexure

Design procedure for flexure mainly consists of finding required reinforcement area for a given design moment. Equation 6.1a was used to find required reinforcement area (Celep, 2015):

$$M_d = k_1 \times f_{cd} \times b_w \times a \times (d - \frac{a}{2}) = A_S \times f_{yd} \times (d - \frac{a}{2}) \quad (6.1a)$$

where M_d is design moment, k_1 is equivalent rectangle compression block depth coefficient, f_{cd} is design compressive strength of concrete, b_w is section width, a is equivalent rectangle compression block depth, d is effective depth of section which is calculated by deducting concrete cover (5 cm), As is required rebar area for bending design and f_{yd} is minimum design yield stress of rebar (TS 500, 2000).

Table 6.1 k_1 values according to concrete class (TS 500, 2000).

Concrete Class	C16	C18	C20	C25	C30	C35	C40	C45	C50
$\mathbf{k_1}$	0.85	0.85	0.85	0.85	0.82	0.79	0.76	0.73	0.70

Design compressive strength of concrete was calculated by using the following equation according to TS 500 article 6.2.5 (TS 500, 2000):

$$f_{cd} = f_{ck}/\gamma_{mc} \quad (6.1b)$$

where γ_{mc} is material coefficient for concrete and equals to 1.5, f_{ck} is characteristic compressive strength of concrete. Minimum design yield stress of rebar was calculated with same method as shown in the following equation (TS 500, 2000):

$$f_{yd} = f_{yk}/\gamma_{ms} \quad (6.1c)$$

where γ_{ms} is material coefficient for rebar and equals to 1.15, f_{yk} is characteristic minimum yield stress of rebar (TS 500, 2000).

The only unknown parameter is value of a in Equation 6.1a. This equation is a quadratic equation and can be written with respect to a as following expression:

$$\frac{a^2}{2} - d \times a + \frac{M_d}{k_1 \times f_{cd} \times b_w} = 0 \quad (6.1d)$$

Solving this equation gives following roots:

$$a_1 = d - \sqrt{d^2 - \frac{2M_d}{\mathrm{k}_1 \times f_{cd} \times b_w}} \tag{6.1e}$$

$$a_2 = d + \sqrt{d^2 - \frac{2M_d}{\mathrm{k}_1 \times f_{cd} \times b_w}} \tag{6.1f}$$

Since equivalent rectangle compression block depth must be greater than zero and smaller than d, first root is valid solution for value of a. After finding value of a, required rebar area can be calculated as following expression by abbreviation of Equation 6.1a:

$$A_S = \frac{\mathrm{k}_1 \times f_{cd} \times b_w \times a}{f_{yd}} \tag{6.1g}$$

Minimum S420 major bending rebar ratio is 0.002 for slabs as stated in the TS 500 article 11.2.3 and 0.0015 for walls as stated in TS 500 article 12.3. Again, according to these articles major bending rebar spacing must be lesser than 1.5 times of section thickness or 20 cm for slabs and 30 cm for walls (TS 500, 2000).

Minor direction rebar (distribution reinforcement) area must be at least As/5 and rebar spacing must be smaller than 30 cm (TS 500, 2000).

6.2 Design for Shear

Shear capacity of concrete section was used to check shear design by using Equation 6.2a as stated in TS 500 article 8.1.3 (TS 500, 2000). Design shear force V_d must be lesser than critical shear force value V_{cr} for considered section. Reinforcement contribution to shear capacity is neglected in shear design of reinforced concrete box culverts.

$$V_{cr} = 0.65 \times f_{ctd} \times b_w \times d \times (1 + \gamma \frac{N_d}{A_C}) \tag{6.2a}$$

where f_{ctd} is design tensile strength of concrete, A_C is section area, N_d is design axial force, and γ is a coefficient that reflects axial force effect on fracture strength. This coefficient is 0.07 when axial force of member is compression and -0.3 when axial force of member is tensile. f_{ctd} is calculated by using the following equation according to TS 500 article 6.2.5 (TS 500, 2000):

$$f_{ctd} = f_{ctk}/\gamma_{mc} \tag{6.2b}$$

where f_{ctk} is characteristic tensile strength of concrete and can be calculated by using the following equation as stated in TS 500 article 3.3.2 (TS 500, 2000):

$$f_{ctk} = 0.35 \times \sqrt{f_{ck}} \text{ (MPa)} \tag{6.2c}$$

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

In this study, derivation of vehicle load distribution formulas are explained in detail and gathered in a table. This will help to reduce misusage of general vehicle load formulas of AASHTO SSHB. Analysis and design procedures of RCBC were also explained. The number of 88 finite element culvert models was created by using SAP2000. A Microsoft Excel sheet was developed by using VBA and CSI API to create SAP2000 models automatically. Effects of span width, culvert height and fill depth on RCBC design were investigated. Design of RCBC was explained according to TS 500 standard.

It was observed that span width is an important parameter for RCBC as it dramatically increased internal forces and base soil pressures of culvert models in the first model group.

It can be concluded that culvert height is an effective parameter for internal forces of wall members from the second model group results. However, it is not effective for base soil pressures that much since it did not increase base soil pressures sharply. Therefore, it can be observed that culvert height is not an important parameter unlike span width or fill depth for culver design.

The third model group results indicated that fill depth has an important effect on both internal forces and base soil pressures. Results for the third model group showed that vehicle load has a significant effect on the internal forces of culverts especially at lower fill depth values and while vehicle load was predominant for fills that did not have a depth value greater than 1 m, vertical earth load was predominant after 1 m fill depth. Since minimum values of internal forces and base soil pressures occurred at 0.70 – 1.0 m fill depth range, it can be concluded that designing RCBC with a fill depth value in the range of 0.70 – 1.00 m is preferred for more economical and reliable designing.

Adding interior walls to obtain multiple celled culverts greatly decreased internal forces and base soil pressures. Even analysis results of double cell culverts were much smaller than the results of single cell culverts. Since moment results of multiple cell RCBC were lesser, multiple cell RCBC need lesser reinforcement area. It must also be noted that equal section thicknesses were used to create same conditions for one, double and triple cell culvert models in the third model group. However, section thickness can be reduced for multiple cell culverts in practice since their actual effective span width values are smaller than single cell culverts. Besides, single cell RCBC can need base soil improvements due to higher base soil pressures. Therefore, using multiple cell culverts instead of using wider span width in single cell culverts is a more economical choice because of lesser reinforcement area, smaller section thickness and lower base soil pressure.

Conducting an experimental study for number of 88 RCBC can be very expensive. But a series of static scaled physical model centrifuge tests can be performed to verify findings of this study by using same models.

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APPENDICES

APPENDIX 1 Source Data of Figure 3.4

Table A.1 Vehicle load and vertical earth load graph source data

S	**t**	**Depth (Z)**	**Ls**	**E**	**L**	**LLmax**	**LLmin**	**DL**	**Total DL**
m	**m**	**m**	**m**	**m**	**m**	**kN/m²**	**kN/m²**	**kN/m²**	**kN/m²**
1.5	0.15	0	0	1.29	0	55.19	13.8	0	55.19
1.5	0.15	0.6	0	1.29	0	55.19	13.8	11.59	66.78
1.5	0.15	0.73	0	1.532	1.786	26.02	7.58	14.3	40.32
1.5	0.15	0.94258	3.704	1.904	3.958	18.9	5.05	18.9	37.8
1.5	0.15	1	3.804	2.004	4.058	17.51	4.67	20.18	37.69
1.5	0.15	1.5	4.679	2.879	4.933	10.03	2.64	31.05	41.08
1.5	0.15	2.28	6.044	4.244	6.298	5.33	1.39	47.2	52.53
1.5	0.15	2.44	0	0	0	4.79		50.51	55.3
1.5	0.15	3	0	0	0	3.42		62.1	65.52
1.5	0.15	4	0	0	0	2.11		82.8	84.91
1.5	0.15	5	0	0	0	1.43		103.5	104.93
1.5	0.15	6	0	0	0	1.03		124.2	125.23

APPENDIX 2 Example Analysis and Design Report

REINFORCED CONCRETE BOX CULVERT ANALYSIS REPORT

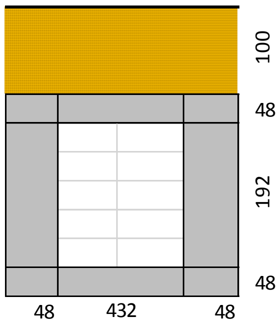
Model No 76

Material Properties:

Concrete		C	25	MPa
Rebar		S	420	MPa
Embankment	Friction angle	ϕ:	30	°
	At rest earth coefficient	K_0:	0.5	
	Unit weight	γ_d:	18.00	kN/m³

Geometrical Parameters

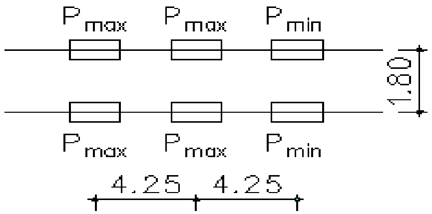
Fill Depth	Z	1.00	m		
Base slab thickness	Tb	0.48	m	Deflection check	
Top slab thickness	Tt	0.48	m	√	Wc/Tt>20 & Tt≥0.12 m
Wall thickness	Twa	0.48	m	Wall thickness check according to TS 500	
	Twb	0.48	m	√	t≥0.15 m
Clear span width	Wc	4.32	m		
Clear cell height	Hc	1.92	m		
Number of cells	n	2			
Total effective span width	S	9.60	m		
Design length	bw	1.00	m		



	Soil-structure interaction factor	Fe	1.02		$F_e = 1 + 0.20\dfrac{Z}{B_C} \le 1.15$
Loads:					
Dead	Vertical earth pressure	DL	18.36	kN/m	$DL = F_e \gamma Z$
Lateral earth pressure	Lateral earth pressure at the top slab	EP1	11.16	kN/m	$EP_1 = K_0 \gamma (Z + \dfrac{t}{2})$
	Lateral earth pressure at the bottom slab	EP2	32.76	kN/m	$EP_2 = K_0 \gamma (Z + \dfrac{t}{2} + H_C)$

Live Load

AASHTO HS20 vehicle loading was considered at this study. AASHTO HS20 truck has two different sizes of wheels. These are single wheel with 0.254 m x 0.254 m (10 inches x 10 inches) dimensions and dual wheel with 0.254 m x 0.508 m (10 inches x 20 inches) dimensions as shown in Figure 3.2 (ASTM, 2013: 2). Front wheels have 17.8 kN load while middle and rear wheels have 71.2 kN load.



Case Name	Fill Depth Interval	Span Width Interval	E m	L_S m	L_D m	LL_{max} kN/m²	LL_{min} kN/m²
1	Z ≤ 0.6 m		1.2+0.006S ≤ 2.13 m			$\dfrac{P_{max}}{E_1}$	$\dfrac{P_{min}}{E_1}$
2	0.6 m < Z < 0.74 m		0.254+1.75Z	0.254+1.75Z	0.508+1.75Z	$\dfrac{P_{max}}{E_2 L_{D2}}$	$\dfrac{P_{min}}{E_2^{\,2}}$
3	0.74 m ≤ Z ≤ 2.28 m		0.254+1.75Z	0.254+1.75Z+ 1.8	0.508+1.75Z+ 1.8	$\dfrac{2P_{max}}{E_3 L_{D3}}$	$\dfrac{2P_{min}}{E_3 L_{S3}}$
4A	2.28 m < Z	S ≤ 4.25 m	0.254+1.75Z	0.508+1.75Z+1.8		$\dfrac{2P_{max}}{E_{4A} L_4}$	
4B	2.28 m < Z	4.25 m < S ≤ 8.5 m	0.254+1.75Z+ 4.25	0.508+1.75Z+1.8		$\dfrac{4P_{max}}{E_{4B} L_4}$	
4C	2.28 m < Z	8.5 m < S	0.254+1.75Z+ 8.5	0.508+1.75Z+1.8		$\dfrac{(4P_{max} + 2P_{min})}{E_{4C} L_4}$	

	W	178	kN
Rear wheel load	Pmax	71.2	kN
Front wheel load	Pmin	17.8	kN

Case I: Z ≤ 0.60 m

E 1.776 m <2.13

Distributed vehicle load has a distribution width of E — LLmax 40.09 kN/m — LLmin 10.02 kN/m

Case II: 0.60 m < Z < 0.74 m

E 2.004 m — L 2.258 m

Distributed vehicle load has a distribution width of E — LLmax 15.73 kN/m — LLmin 4.43 kN/m

Case III: 0.74 m ≤ Z ≤ 2.28 m

E 2.004 m — L 4.058 m — Lsingle 3.80

Distributed vehicle load has a distribution width of E — LLmax 17.51 kN/m — LLmin 4.67 kN/m

Case IV: Z>2.28 m Vehicle load is distributed over whole span width

a) S≤ 4.25 m

Only rear wheel load exists — LL1 17.51 kN/m

b) 4.25 m < S ≤ 8.5 m

Rear and middle wheel loads exist — LL1 11.22 kN/m

c) S > 8.5 m

Rear, middle and front wheel loads exist — LL1 7.52 kN/m

Surcharge load Z<2.44 m — LS 5.40 kN/m

Load combinations:

AASHTO Table 3.22.1A Group I load combinations:

1.30x(DL+EP+1.67xLS+1.67xIxLL)

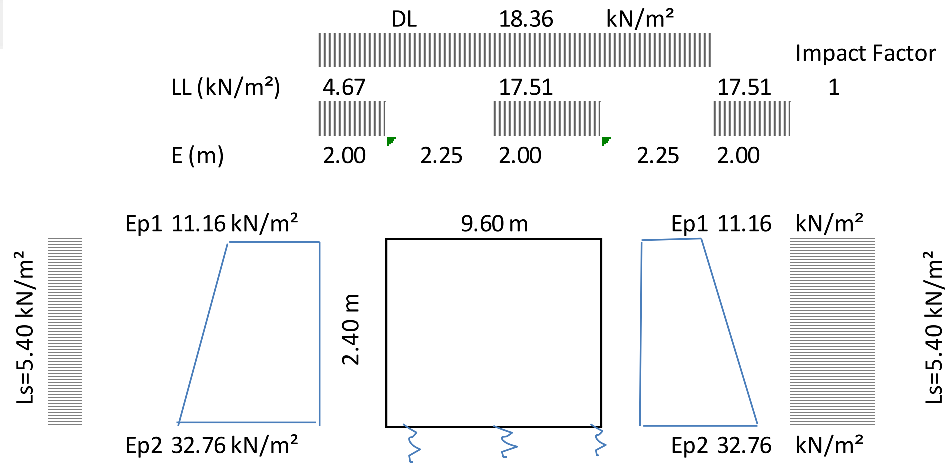
1.30x(DL+0.5xEP+1.67xLS+1.67xIxLL)

Unfactored load combination:

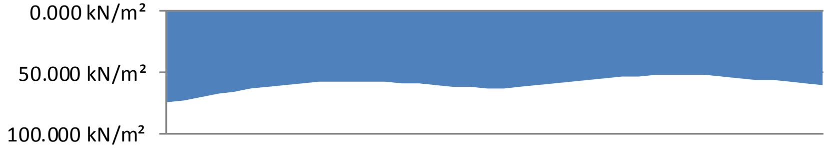
DL +EP +LS+ I x LL

Impact Factor	**I**
Z ≤ 0.30 m	1.3
0.30 m <Z ≤ 0.60 m	1.2
0.60 m <Z ≤ 0.90 m	1.1
Z > 0.90 m	1

Analysis Model



				Max Displacements at springs and max soil stress			Max Reaction Forces at springs and max soil stress	
Horizontal spring constant	Kh	0	kN/m³	2E-05	0.00	kN/m²	0.00 t	0.00 kN/m²
Vertical spring constant	Kv	30000	kN/m³	0.0025	75.01	kN/m²	18.46 t	75.01 kN/m²



Spring area		0.25 m²	√	Mean soil stress	67.07 kN/m²	
Horizontal spring constant for given area	U1	0	kN/m			
Vertical spring constant for given area	U3	7384.615	kN/m	Safety stress of soil	200 kN/m²	√

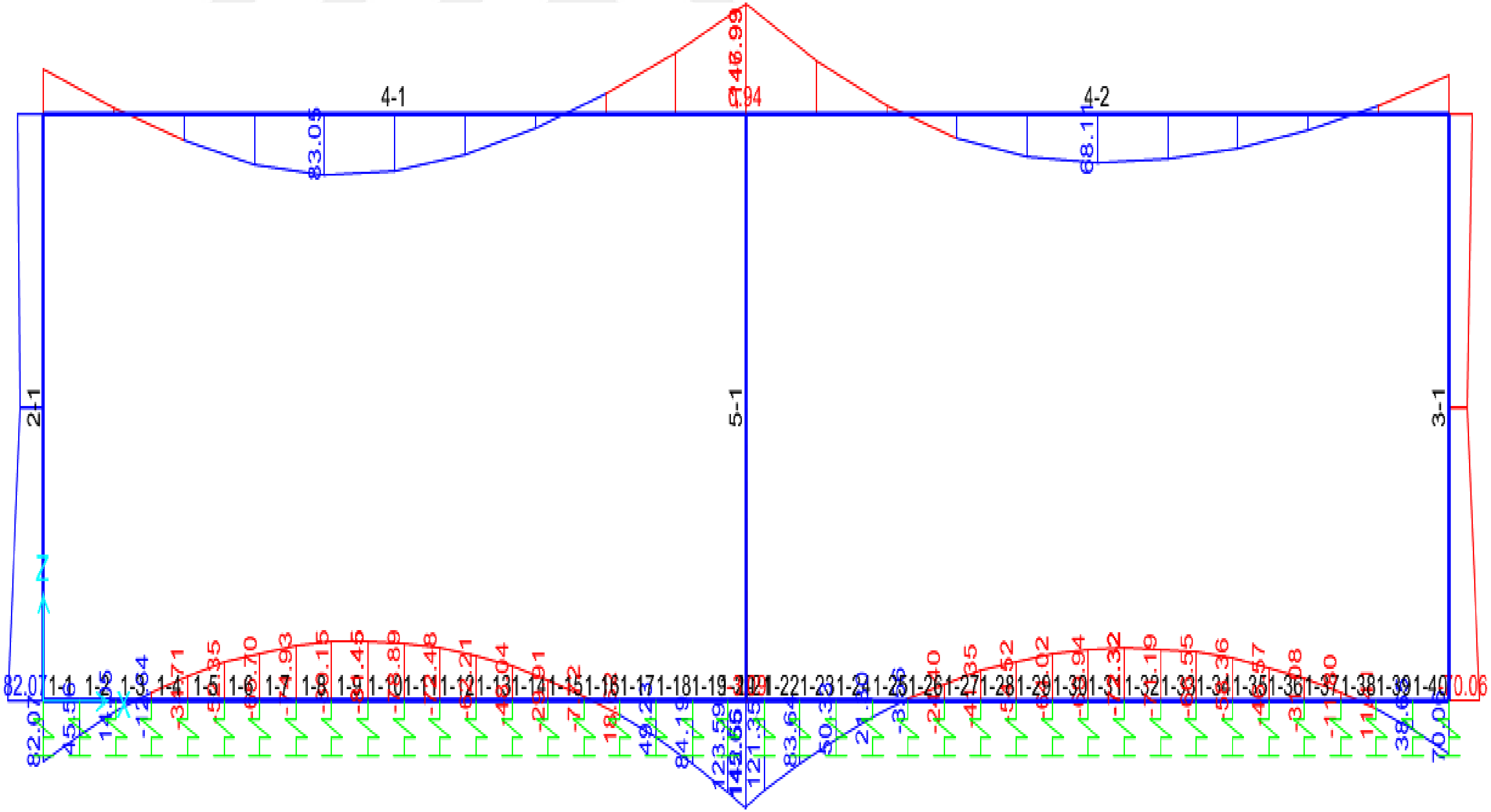


Figure A.2.1 Moment 3-3 diagram of Model 76 for load combination COMBB4 (1.3xDL+0.65xEP+2.171xLS+2.171xLL4).

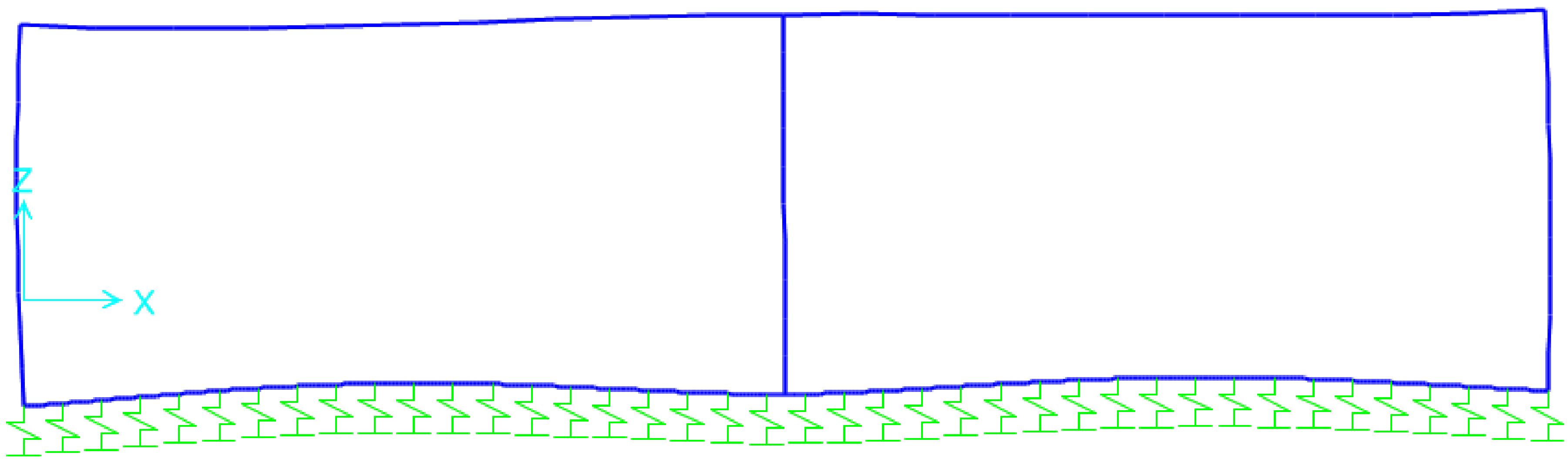


Figure A.2.2 Deformed shape of Model 76 for load combination COMBB4 (1.3xDL+0.65xEP+2.171xLS+2.171xLL4).

Concrete Design

fcd : 16.67 N/mm² Concrete Cover (0.05 m fctk : 1.75 N/mm² k1 0.85

fyd : 365.22 N/mm² fctd : 1.17 N/mm²

Base slab: Max Min Internal Forces

bw : 1.00 m d: 0.43 m Max M3: 145.65 kNm Max V2: 173.29 kN Max N -71.61 kN

h : 0.48 m Min M3: -87.80 kNm Min V2: -183.41 kN Allowable Axial Forc 12,000.00 kN

√

Shear Design:

Vcr= 0.65xfctdxbwxd x [1+ɣx(Nd/Ac)] ɣ=0.07 (mm²/N) axial force is compression

ɣ=-0.3 (mm²/N) axial force is tension

Note: In SAP2000 If P value is negative than axial force is compression and if P value is positive than axial force is tension.

	Case	ɣ (mm²/N)	N (kN)	Vd(kN)	Vmax(kN)	Vcr(kN)
√	Max V2	0.07	-41.27	173.29	1576.67	328.05
√	Min V2	0.07	-51.69	183.41	1576.67	328.54

Note: Vcr>Vd condition must be met.

Flexure Design:

	Case	Description	Md(kNm))	a (cm)	As (cm²)	Asmin (cm²)	ρ min	Ø	S (cm)	Asd (cm²)
√	Max M3	At the bottom	145.65	2.46	9.55	8.60	0.002	14	16	9.62
√	Min M3	At the top	87.80	1.47	5.69	8.60	0.002	14	16	9.62

Distribution rebar Asd>As/5= 1.92 cm²

Selected Asd: 2.62 cm² Ø10 \30 √

Top Slab:

Max Min Internal Forces

bw	:	1.00 m	d:	0.43 m	Max M3:	83.05 kNm	Max V2:	147.28 kN	Max N		-35.46 kN
h	:	0.48 m			Min M3:	-147.93 kNm	Min V2:	-173.70 kN	Allowable Axial For		12,000.00 kN
											√

Shear Design:

Vcr= 0.65xfctdxbwxd x [1+ɣx(Nd/Ac)]

ɣ=0.07 (mm²/N) axial force is compression

ɣ=-0.3 (mm²/N) axial force is tension

Note: In SAP2000 If P value is negative than axial force is compression and if P value is positive than axial force is tension.

	Case	ɣ (mm²/N)	N (kN)	Vd(kN)	Vmax(kN)	Vcr(kN)
√	Max V2	0.07	-10.71	147.28	1576.67	326.59
√	Min V2	0.07	-18.15	173.70	1576.67	326.95

Note: Vcr>Vd condition must be met.

Flexure Design:

	Case	Description	Md(kNm))	a (cm)	As (cm²)	Asmin (cm²)	ρ_{min}	Ø	S (cm)	Asd (cm²)
√	Max M3	At the bottom	83.05	1.39	5.38	8.60	0.002	14	17	9.06
√	Min M3	At the top	147.93	2.50	9.70	8.60	0.002	14	15	10.26

Distribution rebar Asd>As/5= 2.05 cm²

Selected Asd: 2.62 cm² Ø10 \30 √

Wall

bw :	1.00 m	d:	0.42 m	Max M3:	97.51 kNm	Max V2:	71.61 kN	Max N	-349.66 kN
h :	0.48 m	d':	0.06	Min M3:	0.00 kNm	Min V2:	-67.81 kN	Allowable Axial Forc	12,000.00 kN

Max Min Internal Forces

√

Shear Design:

Vcr= 0.65xfctdxbwxd x [1+ɣx(Nd/Ac)]

ɣ=0.07 (mm²/N) axial force is compression

ɣ=-0.3 (mm²/N) axial force is tension

Note: In SAP2000 If P value is negative than axial force is compression and if P value is positive than axial force is tension.

	Case	ɣ (mm²/N)	N (kN)	Vd(kN)	Vmax(kN)	Vcr(kN)
√	Max V2	0.07	-177.76	71.61	1540.00	326.76
√	Min V2	0.07	-131.98	67.81	1540.00	324.63

Note: Vcr>Vd condition must be met.

Flexure Design:

	Case	Description	Md(kNm))	a (cm)	As (cm²)	Asmin (cm²)	ρ min	Ø	S (cm)	Asd (cm²)
√	Max M3	Outside Rebar	97.51	1.67	6.49	6.30	0.0015	14	22	7.00
√	Min M3	Inside Rebar	0.00	0.00	0.00			10	20	3.93

Distribution rebar Asd>As/5= 1.40 cm²

Selected Asd: 3.93 cm² Ø10 \20 √

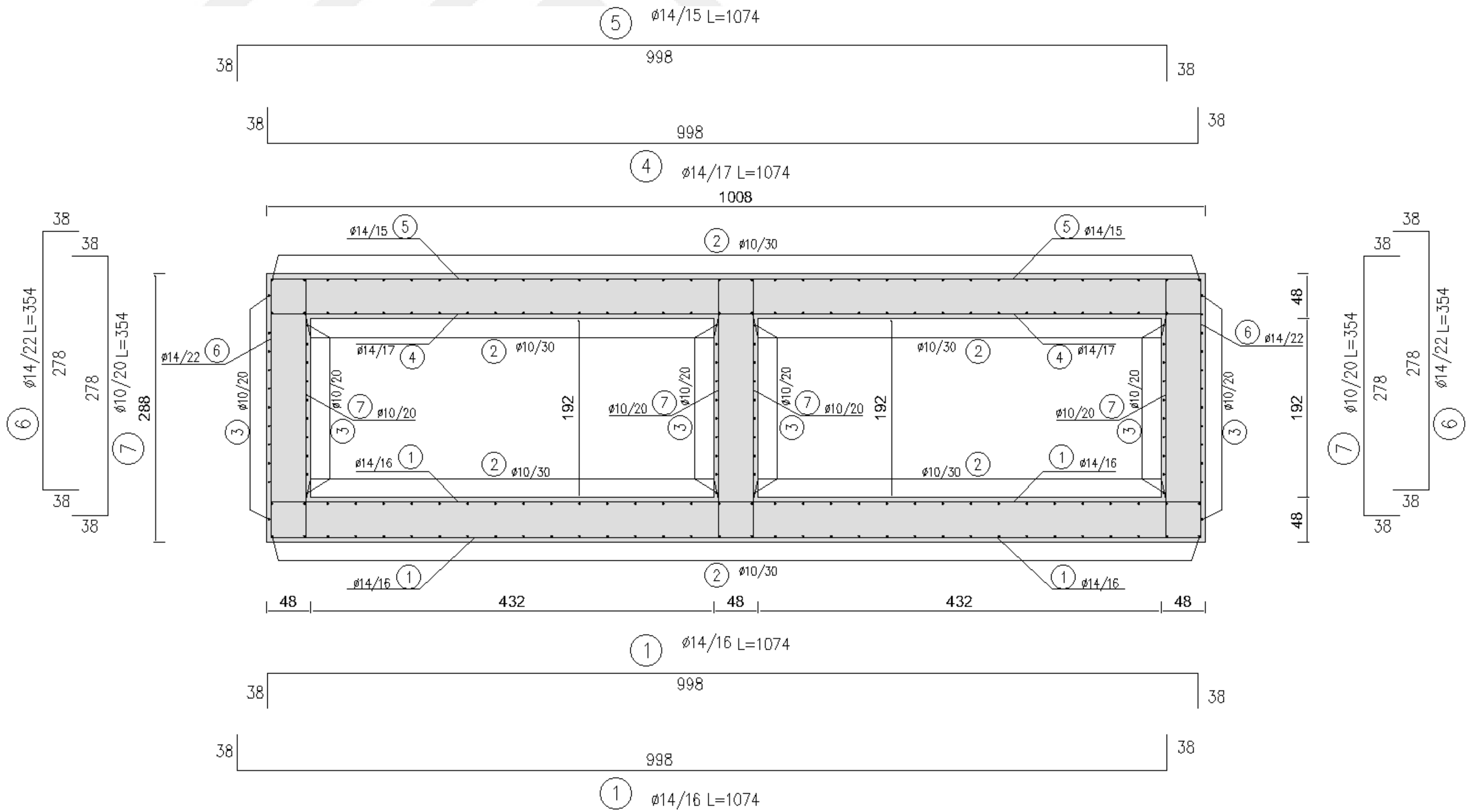


Figure A.2.3 Reinforcement design drawing for Model 76.

APPENDIX 3 Element Forces of the Example Model

Table A.3 Internal force results of Model 76 for critical combinations.

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	0	COMBA0	Combination	-71.61	164.039	97.5097	0
1	0.24615	COMBA0	Combination	-71.61	167.879	56.6583	0.24615
1	0.24615	COMBA0	Combination	-71.61	141.26	56.6583	0
1	0.49231	COMBA0	Combination	-71.61	145.1	21.4139	0.24615
1	0.49231	COMBA0	Combination	-71.61	119.398	21.4139	0
1	0.73846	COMBA0	Combination	-71.61	123.238	-8.4491	0.24615
1	0.73846	COMBA0	Combination	-71.61	98.481	-8.4491	0
1	0.98462	COMBA0	Combination	-71.61	102.321	-33.1632	0.24615
1	0.98462	COMBA0	Combination	-71.61	78.489	-33.1632	0
1	1.23077	COMBA0	Combination	-71.61	82.329	-52.9563	0.24615
1	1.23077	COMBA0	Combination	-71.61	59.363	-52.9563	0
1	1.47692	COMBA0	Combination	-71.61	63.203	-68.0413	0.24615
1	1.47692	COMBA0	Combination	-71.61	41.011	-68.0413	0
1	1.72308	COMBA0	Combination	-71.61	44.851	-78.609	0.24615
1	1.72308	COMBA0	Combination	-71.61	23.318	-78.609	0
1	1.96923	COMBA0	Combination	-71.61	27.158	-84.8215	0.24615
1	1.96923	COMBA0	Combination	-71.61	6.152	-84.8215	0
1	2.21538	COMBA0	Combination	-71.61	9.992	-86.8084	0.24615
1	2.21538	COMBA0	Combination	-71.61	-10.63	-86.8084	0
1	2.46154	COMBA0	Combination	-71.61	-6.79	-84.6645	0.24615
1	2.46154	COMBA0	Combination	-71.61	-27.173	-84.6645	0
1	2.70769	COMBA0	Combination	-71.61	-23.333	-78.4484	0.24615
1	2.70769	COMBA0	Combination	-71.61	-43.618	-78.4484	0
1	2.95385	COMBA0	Combination	-71.61	-39.778	-68.1842	0.24615
1	2.95385	COMBA0	Combination	-71.61	-60.098	-68.1842	0
1	3.2	COMBA0	Combination	-71.61	-56.258	-53.8634	0.24615
1	3.2	COMBA0	Combination	-71.61	-76.728	-53.8634	0
1	3.44615	COMBA0	Combination	-71.61	-72.888	-35.449	0.24615
1	3.44615	COMBA0	Combination	-71.61	-93.599	-35.449	0
1	3.69231	COMBA0	Combination	-71.61	-89.759	-12.8818	0.24615
1	3.69231	COMBA0	Combination	-71.61	-110.775	-12.8818	0
1	3.93846	COMBA0	Combination	-71.61	-106.935	13.9132	0.24615
1	3.93846	COMBA0	Combination	-71.61	-128.279	13.9132	0
1	4.18462	COMBA0	Combination	-71.61	-124.439	45.0171	0.24615
1	4.18462	COMBA0	Combination	-71.61	-146.097	45.0171	0
1	4.43077	COMBA0	Combination	-71.61	-142.257	80.5067	0.24615
1	4.43077	COMBA0	Combination	-71.61	-164.158	80.5067	0
1	4.67692	COMBA0	Combination	-71.61	-160.318	120.4422	0.24615
1	4.67692	COMBA0	Combination	-71.61	-182.339	120.4422	0
1	4.8	COMBA0	Combination	-71.61	-180.419	142.7658	0.12308
1	4.8	COMBA0	Combination	-67.811	164.562	133.4847	0
1	4.92308	COMBA0	Combination	-67.811	166.482	113.1128	0.12308
1	4.92308	COMBA0	Combination	-67.811	144.589	113.1128	0
1	5.16923	COMBA0	Combination	-67.811	148.429	77.049	0.24615
1	5.16923	COMBA0	Combination	-67.811	126.904	77.049	0
1	5.41538	COMBA0	Combination	-67.811	130.744	45.3386	0.24615
1	5.41538	COMBA0	Combination	-67.811	109.705	45.3386	0
1	5.66154	COMBA0	Combination	-67.811	113.545	17.8616	0.24615
1	5.66154	COMBA0	Combination	-67.811	93.063	17.8616	0
1	5.90769	COMBA0	Combination	-67.811	96.903	-5.5188	0.24615
1	5.90769	COMBA0	Combination	-67.811	77	-5.5188	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	6.15385	COMBA0	Combination	-67.811	80.84	-24.9453	0.24615
1	6.15385	COMBA0	Combination	-67.811	61.504	-24.9453	0
1	6.4	COMBA0	Combination	-67.811	65.344	-40.5572	0.24615
1	6.4	COMBA0	Combination	-67.811	46.528	-40.5572	0
1	6.64615	COMBA0	Combination	-67.811	50.368	-52.4829	0.24615
1	6.64615	COMBA0	Combination	-67.811	32.004	-52.4829	0
1	6.89231	COMBA0	Combination	-67.811	35.844	-60.8335	0.24615
1	6.89231	COMBA0	Combination	-67.811	17.842	-60.8335	0
1	7.13846	COMBA0	Combination	-67.811	21.682	-65.6981	0.24615
1	7.13846	COMBA0	Combination	-67.811	3.94	-65.6981	0
1	7.38462	COMBA0	Combination	-67.811	7.78	-67.1406	0.24615
1	7.38462	COMBA0	Combination	-67.811	-9.813	-67.1406	0
1	7.63077	COMBA0	Combination	-67.811	-5.973	-65.1978	0.24615
1	7.63077	COMBA0	Combination	-67.811	-23.529	-65.1978	0
1	7.87692	COMBA0	Combination	-67.811	-19.689	-59.8787	0.24615
1	7.87692	COMBA0	Combination	-67.811	-37.318	-59.8787	0
1	8.12308	COMBA0	Combination	-67.811	-33.478	-51.1654	0.24615
1	8.12308	COMBA0	Combination	-67.811	-51.28	-51.1654	0
1	8.36923	COMBA0	Combination	-67.811	-47.44	-39.0153	0.24615
1	8.36923	COMBA0	Combination	-67.811	-65.503	-39.0153	0
1	8.61538	COMBA0	Combination	-67.811	-61.663	-23.3641	0.24615
1	8.61538	COMBA0	Combination	-67.811	-80.053	-23.3641	0
1	8.86154	COMBA0	Combination	-67.811	-76.213	-4.1312	0.24615
1	8.86154	COMBA0	Combination	-67.811	-94.974	-4.1312	0
1	9.10769	COMBA0	Combination	-67.811	-91.134	18.7743	0.24615
1	9.10769	COMBA0	Combination	-67.811	-110.275	18.7743	0
1	9.35385	COMBA0	Combination	-67.811	-106.435	45.4462	0.24615
1	9.35385	COMBA0	Combination	-67.811	-125.93	45.4462	0
1	9.6	COMBA0	Combination	-67.811	-122.09	75.9719	0.24615
1	0	COMBB0	Combination	-51.687	162.94	94.1187	0
1	0.24615	COMBB0	Combination	-51.687	166.78	53.5378	0.24615
1	0.24615	COMBB0	Combination	-51.687	140.135	53.5378	0
1	0.49231	COMBB0	Combination	-51.687	143.975	18.5705	0.24615
1	0.49231	COMBB0	Combination	-51.687	118.265	18.5705	0
1	0.73846	COMBB0	Combination	-51.687	122.105	-11.0135	0.24615
1	0.73846	COMBB0	Combination	-51.687	97.356	-11.0135	0
1	0.98462	COMBB0	Combination	-51.687	101.196	-35.4507	0.24615
1	0.98462	COMBB0	Combination	-51.687	77.382	-35.4507	0
1	1.23077	COMBB0	Combination	-51.687	81.222	-54.9713	0.24615
1	1.23077	COMBB0	Combination	-51.687	58.282	-54.9713	0
1	1.47692	COMBB0	Combination	-51.687	62.122	-69.7902	0.24615
1	1.47692	COMBB0	Combination	-51.687	39.959	-69.7902	0
1	1.72308	COMBB0	Combination	-51.687	43.799	-80.0988	0.24615
1	1.72308	COMBB0	Combination	-51.687	22.296	-80.0988	0
1	1.96923	COMBB0	Combination	-51.687	26.136	-86.0597	0.24615
1	1.96923	COMBB0	Combination	-51.687	5.158	-86.0597	0
1	2.21538	COMBB0	Combination	-51.687	8.998	-87.8021	0.24615
1	2.21538	COMBB0	Combination	-51.687	-11.598	-87.8021	0
1	2.46154	COMBB0	Combination	-51.687	-7.758	-85.4198	0.24615
1	2.46154	COMBB0	Combination	-51.687	-28.121	-85.4198	0
1	2.70769	COMBB0	Combination	-51.687	-24.281	-78.9703	0.24615
1	2.70769	COMBB0	Combination	-51.687	-44.553	-78.9703	0
1	2.95385	COMBB0	Combination	-51.687	-40.713	-68.4761	0.24615
1	2.95385	COMBB0	Combination	-51.687	-61.026	-68.4761	0
1	3.2	COMBB0	Combination	-51.687	-57.186	-53.9268	0.24615
1	3.2	COMBB0	Combination	-51.687	-77.657	-53.9268	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	3.44615	COMBB0	Combination	-51.687	-73.817	-35.2839	0.24615
1	3.44615	COMBB0	Combination	-51.687	-94.537	-35.2839	0
1	3.69231	COMBB0	Combination	-51.687	-90.697	-12.4859	0.24615
1	3.69231	COMBB0	Combination	-51.687	-111.728	-12.4859	0
1	3.93846	COMBB0	Combination	-51.687	-107.888	14.5438	0.24615
1	3.93846	COMBB0	Combination	-51.687	-129.256	14.5438	0
1	4.18462	COMBB0	Combination	-51.687	-125.416	45.888	0.24615
1	4.18462	COMBB0	Combination	-51.687	-147.102	45.888	0
1	4.43077	COMBB0	Combination	-51.687	-143.262	81.625	0.24615
1	4.43077	COMBB0	Combination	-51.687	-165.196	81.625	0
1	4.67692	COMBB0	Combination	-51.687	-161.356	121.8161	0.24615
1	4.67692	COMBB0	Combination	-51.687	-183.413	121.8161	0
1	4.8	COMBB0	Combination	-51.687	-181.493	144.2718	0.12308
1	4.8	COMBB0	Combination	-47.888	165.635	134.9907	0
1	4.92308	COMBB0	Combination	-47.888	167.555	114.4866	0.12308
1	4.92308	COMBB0	Combination	-47.888	145.627	114.4866	0
1	5.16923	COMBB0	Combination	-47.888	149.467	78.1674	0.24615
1	5.16923	COMBB0	Combination	-47.888	127.909	78.1674	0
1	5.41538	COMBB0	Combination	-47.888	131.749	46.2096	0.24615
1	5.41538	COMBB0	Combination	-47.888	110.682	46.2096	0
1	5.66154	COMBB0	Combination	-47.888	114.522	18.4922	0.24615
1	5.66154	COMBB0	Combination	-47.888	94.016	18.4922	0
1	5.90769	COMBB0	Combination	-47.888	97.856	-5.1229	0.24615
1	5.90769	COMBB0	Combination	-47.888	77.938	-5.1229	0
1	6.15385	COMBB0	Combination	-47.888	81.778	-24.7801	0.24615
1	6.15385	COMBB0	Combination	-47.888	62.432	-24.7801	0
1	6.4	COMBB0	Combination	-47.888	66.272	-40.6207	0.24615
1	6.4	COMBB0	Combination	-47.888	47.456	-40.6207	0
1	6.64615	COMBB0	Combination	-47.888	51.296	-52.7748	0.24615
1	6.64615	COMBB0	Combination	-47.888	32.939	-52.7748	0
1	6.89231	COMBB0	Combination	-47.888	36.779	-61.3554	0.24615
1	6.89231	COMBB0	Combination	-47.888	18.791	-61.3554	0
1	7.13846	COMBB0	Combination	-47.888	22.631	-66.4534	0.24615
1	7.13846	COMBB0	Combination	-47.888	4.909	-66.4534	0
1	7.38462	COMBB0	Combination	-47.888	8.749	-68.1342	0.24615
1	7.38462	COMBB0	Combination	-47.888	-8.819	-68.1342	0
1	7.63077	COMBB0	Combination	-47.888	-4.979	-66.436	0.24615
1	7.63077	COMBB0	Combination	-47.888	-22.507	-66.436	0
1	7.87692	COMBB0	Combination	-47.888	-18.667	-61.3685	0.24615
1	7.87692	COMBB0	Combination	-47.888	-36.265	-61.3685	0
1	8.12308	COMBB0	Combination	-47.888	-32.425	-52.9143	0.24615
1	8.12308	COMBB0	Combination	-47.888	-50.199	-52.9143	0
1	8.36923	COMBB0	Combination	-47.888	-46.359	-41.0303	0.24615
1	8.36923	COMBB0	Combination	-47.888	-64.396	-41.0303	0
1	8.61538	COMBB0	Combination	-47.888	-60.556	-25.6516	0.24615
1	8.61538	COMBB0	Combination	-47.888	-78.928	-25.6516	0
1	8.86154	COMBB0	Combination	-47.888	-75.088	-6.6957	0.24615
1	8.86154	COMBB0	Combination	-47.888	-93.841	-6.6957	0
1	9.10769	COMBB0	Combination	-47.888	-90.001	15.931	0.24615
1	9.10769	COMBB0	Combination	-47.888	-109.149	15.931	0
1	9.35385	COMBB0	Combination	-47.888	-105.309	42.3258	0.24615
1	9.35385	COMBB0	Combination	-47.888	-124.831	42.3258	0
1	9.6	COMBB0	Combination	-47.888	-120.991	72.5808	0.24615
1	0	COMBB2	Combination	-46.717	154.542	88.1723	0
1	0.24615	COMBB2	Combination	-46.717	158.382	49.6587	0.24615
1	0.24615	COMBB2	Combination	-46.717	133.023	49.6587	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	0.49231	COMBB2	Combination	-46.717	136.863	16.442	0.24615
1	0.49231	COMBB2	Combination	-46.717	112.344	16.442	0
1	0.73846	COMBB2	Combination	-46.717	116.184	-11.6845	0.24615
1	0.73846	COMBB2	Combination	-46.717	92.526	-11.6845	0
1	0.98462	COMBB2	Combination	-46.717	96.366	-34.9327	0.24615
1	0.98462	COMBB2	Combination	-46.717	73.544	-34.9327	0
1	1.23077	COMBB2	Combination	-46.717	77.384	-53.5083	0.24615
1	1.23077	COMBB2	Combination	-46.717	55.336	-53.5083	0
1	1.47692	COMBB2	Combination	-46.717	59.176	-67.602	0.24615
1	1.47692	COMBB2	Combination	-46.717	37.81	-67.602	0
1	1.72308	COMBB2	Combination	-46.717	41.65	-77.3817	0.24615
1	1.72308	COMBB2	Combination	-46.717	20.852	-77.3817	0
1	1.96923	COMBB2	Combination	-46.717	24.692	-82.9871	0.24615
1	1.96923	COMBB2	Combination	-46.717	4.331	-82.9871	0
1	2.21538	COMBB2	Combination	-46.717	8.171	-84.5258	0.24615
1	2.21538	COMBB2	Combination	-46.717	-11.891	-84.5258	0
1	2.46154	COMBB2	Combination	-46.717	-8.051	-82.0715	0.24615
1	2.46154	COMBB2	Combination	-46.717	-27.956	-82.0715	0
1	2.70769	COMBB2	Combination	-46.717	-24.116	-75.6626	0.24615
1	2.70769	COMBB2	Combination	-46.717	-44.002	-75.6626	0
1	2.95385	COMBB2	Combination	-46.717	-40.162	-65.304	0.24615
1	2.95385	COMBB2	Combination	-46.717	-60.155	-65.304	0
1	3.2	COMBB2	Combination	-46.717	-56.315	-50.9693	0.24615
1	3.2	COMBB2	Combination	-46.717	-76.526	-50.9693	0
1	3.44615	COMBB2	Combination	-46.717	-72.686	-32.6047	0.24615
1	3.44615	COMBB2	Combination	-46.717	-93.203	-32.6047	0
1	3.69231	COMBB2	Combination	-46.717	-89.363	-10.1351	0.24615
1	3.69231	COMBB2	Combination	-46.717	-110.242	-10.1351	0
1	3.93846	COMBB2	Combination	-46.717	-106.402	16.5286	0.24615
1	3.93846	COMBB2	Combination	-46.717	-127.665	16.5286	0
1	4.18462	COMBB2	Combination	-46.717	-123.825	47.4812	0.24615
1	4.18462	COMBB2	Combination	-46.717	-145.451	47.4812	0
1	4.43077	COMBB2	Combination	-46.717	-141.611	82.8118	0.24615
1	4.43077	COMBB2	Combination	-46.717	-163.527	82.8118	0
1	4.67692	COMBB2	Combination	-46.717	-159.687	122.592	0.24615
1	4.67692	COMBB2	Combination	-46.717	-181.765	122.592	0
1	4.8	COMBB2	Combination	-46.717	-179.845	144.8449	0.12308
1	4.8	COMBB2	Combination	-44.244	168.951	139.5614	0
1	4.92308	COMBB2	Combination	-44.244	170.871	118.6493	0.12308
1	4.92308	COMBB2	Combination	-44.244	148.883	118.6493	0
1	5.16923	COMBB2	Combination	-44.244	152.723	81.5284	0.24615
1	5.16923	COMBB2	Combination	-44.244	131.075	81.5284	0
1	5.41538	COMBB2	Combination	-44.244	134.915	48.7912	0.24615
1	5.41538	COMBB2	Combination	-44.244	113.732	48.7912	0
1	5.66154	COMBB2	Combination	-44.244	117.572	20.3232	0.24615
1	5.66154	COMBB2	Combination	-44.244	96.928	20.3232	0
1	5.90769	COMBB2	Combination	-44.244	100.768	-4.0087	0.24615
1	5.90769	COMBB2	Combination	-44.244	80.692	-4.0087	0
1	6.15385	COMBB2	Combination	-44.244	84.532	-24.3441	0.24615
1	6.15385	COMBB2	Combination	-44.244	65.013	-24.3441	0
1	6.4	COMBB2	Combination	-44.244	68.853	-40.8199	0.24615
1	6.4	COMBB2	Combination	-44.244	49.846	-40.8199	0
1	6.64615	COMBB2	Combination	-44.244	53.686	-53.5624	0.24615
1	6.64615	COMBB2	Combination	-44.244	35.122	-53.5624	0
1	6.89231	COMBB2	Combination	-44.244	38.962	-62.6804	0.24615
1	6.89231	COMBB2	Combination	-44.244	20.748	-62.6804	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	7.13846	COMBB2	Combination	-44.244	24.588	-68.2603	0.24615
1	7.13846	COMBB2	Combination	-44.244	6.621	-68.2603	0
1	7.38462	COMBB2	Combination	-44.244	10.461	-70.3626	0.24615
1	7.38462	COMBB2	Combination	-44.244	-7.376	-70.3626	0
1	7.63077	COMBB2	Combination	-44.244	-3.536	-69.0195	0.24615
1	7.63077	COMBB2	Combination	-44.244	-21.36	-69.0195	0
1	7.87692	COMBB2	Combination	-44.244	-17.52	-64.2343	0.24615
1	7.87692	COMBB2	Combination	-44.244	-35.446	-64.2343	0
1	8.12308	COMBB2	Combination	-44.244	-31.606	-55.9817	0.24615
1	8.12308	COMBB2	Combination	-44.244	-49.743	-55.9817	0
1	8.36923	COMBB2	Combination	-44.244	-45.903	-44.21	0.24615
1	8.36923	COMBB2	Combination	-44.244	-64.345	-44.21	0
1	8.61538	COMBB2	Combination	-44.244	-60.505	-28.8438	0.24615
1	8.61538	COMBB2	Combination	-44.244	-79.328	-28.8438	0
1	8.86154	COMBB2	Combination	-44.244	-75.488	-9.7895	0.24615
1	8.86154	COMBB2	Combination	-44.244	-94.743	-9.7895	0
1	9.10769	COMBB2	Combination	-44.244	-90.903	13.0593	0.24615
1	9.10769	COMBB2	Combination	-44.244	-110.611	13.0593	0
1	9.35385	COMBB2	Combination	-44.244	-106.771	39.814	0.24615
1	9.35385	COMBB2	Combination	-44.244	-126.914	39.814	0
1	9.6	COMBB2	Combination	-44.244	-123.074	70.5819	0.24615
1	0	COMBA4	Combination	-62.867	147.501	85.4647	0
1	0.24615	COMBA4	Combination	-62.867	151.341	48.6841	0.24615
1	0.24615	COMBA4	Combination	-62.867	127.217	48.6841	0
1	0.49231	COMBA4	Combination	-62.867	131.057	16.8965	0.24615
1	0.49231	COMBA4	Combination	-62.867	107.667	16.8965	0
1	0.73846	COMBA4	Combination	-62.867	111.507	-10.0787	0.24615
1	0.73846	COMBA4	Combination	-62.867	88.872	-10.0787	0
1	0.98462	COMBA4	Combination	-62.867	92.712	-32.4274	0.24615
1	0.98462	COMBA4	Combination	-62.867	70.81	-32.4274	0
1	1.23077	COMBA4	Combination	-62.867	74.65	-50.3302	0.24615
1	1.23077	COMBA4	Combination	-62.867	53.425	-50.3302	0
1	1.47692	COMBA4	Combination	-62.867	57.265	-63.9535	0.24615
1	1.47692	COMBA4	Combination	-62.867	36.628	-63.9535	0
1	1.72308	COMBA4	Combination	-62.867	40.468	-73.4423	0.24615
1	1.72308	COMBA4	Combination	-62.867	20.313	-73.4423	0
1	1.96923	COMBA4	Combination	-62.867	24.153	-78.9151	0.24615
1	1.96923	COMBA4	Combination	-62.867	4.355	-78.9151	0
1	2.21538	COMBA4	Combination	-62.867	8.195	-80.4598	0.24615
1	2.21538	COMBA4	Combination	-62.867	-11.378	-80.4598	0
1	2.46154	COMBA4	Combination	-62.867	-7.538	-78.1318	0.24615
1	2.46154	COMBA4	Combination	-62.867	-27.02	-78.1318	0
1	2.70769	COMBA4	Combination	-62.867	-23.18	-71.9533	0.24615
1	2.70769	COMBA4	Combination	-62.867	-42.703	-71.9533	0
1	2.95385	COMBA4	Combination	-62.867	-38.863	-61.9144	0.24615
1	2.95385	COMBA4	Combination	-62.867	-58.548	-61.9144	0
1	3.2	COMBA4	Combination	-62.867	-54.708	-47.9753	0.24615
1	3.2	COMBA4	Combination	-62.867	-74.659	-47.9753	0
1	3.44615	COMBA4	Combination	-62.867	-70.819	-30.0703	0.24615
1	3.44615	COMBA4	Combination	-62.867	-91.119	-30.0703	0
1	3.69231	COMBA4	Combination	-62.867	-87.279	-8.1137	0.24615
1	3.69231	COMBA4	Combination	-62.867	-107.981	-8.1137	0
1	3.93846	COMBA4	Combination	-62.867	-104.141	17.9935	0.24615
1	3.93846	COMBA4	Combination	-62.867	-125.263	17.9935	0
1	4.18462	COMBA4	Combination	-62.867	-121.423	48.3548	0.24615
1	4.18462	COMBA4	Combination	-62.867	-142.941	48.3548	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	4.43077	COMBA4	Combination	-62.867	-139.101	83.0677	0.24615
1	4.43077	COMBA4	Combination	-62.867	-160.942	83.0677	0
1	4.67692	COMBA4	Combination	-62.867	-157.102	122.2116	0.24615
1	4.67692	COMBA4	Combination	-62.867	-179.137	122.2116	0
1	4.8	COMBA4	Combination	-62.867	-177.217	144.141	0.12308
1	4.8	COMBA4	Combination	-61.19	170.295	141.0527	0
1	4.92308	COMBA4	Combination	-61.19	172.215	119.9752	0.12308
1	4.92308	COMBA4	Combination	-61.19	150.238	119.9752	0
1	5.16923	COMBA4	Combination	-61.19	154.078	82.5208	0.24615
1	5.16923	COMBA4	Combination	-61.19	132.41	82.5208	0
1	5.41538	COMBA4	Combination	-61.19	136.25	49.4549	0.24615
1	5.41538	COMBA4	Combination	-61.19	115.019	49.4549	0
1	5.66154	COMBA4	Combination	-61.19	118.859	20.6699	0.24615
1	5.66154	COMBA4	Combination	-61.19	98.139	20.6699	0
1	5.90769	COMBA4	Combination	-61.19	101.979	-3.96	0.24615
1	5.90769	COMBA4	Combination	-61.19	81.8	-3.96	0
1	6.15385	COMBA4	Combination	-61.19	85.64	-24.568	0.24615
1	6.15385	COMBA4	Combination	-61.19	65.989	-24.568	0
1	6.4	COMBA4	Combination	-61.19	69.829	-41.2842	0.24615
1	6.4	COMBA4	Combination	-61.19	50.664	-41.2842	0
1	6.64615	COMBA4	Combination	-61.19	54.504	-54.2278	0.24615
1	6.64615	COMBA4	Combination	-61.19	35.752	-54.2278	0
1	6.89231	COMBA4	Combination	-61.19	39.592	-63.5009	0.24615
1	6.89231	COMBA4	Combination	-61.19	21.161	-63.5009	0
1	7.13846	COMBA4	Combination	-61.19	25.001	-69.1823	0.24615
1	7.13846	COMBA4	Combination	-61.19	6.785	-69.1823	0
1	7.38462	COMBA4	Combination	-61.19	10.625	-71.325	0.24615
1	7.38462	COMBA4	Combination	-61.19	-7.493	-71.325	0
1	7.63077	COMBA4	Combination	-61.19	-3.653	-69.9532	0.24615
1	7.63077	COMBA4	Combination	-61.19	-21.792	-69.9532	0
1	7.87692	COMBA4	Combination	-61.19	-17.952	-65.0615	0.24615
1	7.87692	COMBA4	Combination	-61.19	-36.23	-65.0615	0
1	8.12308	COMBA4	Combination	-61.19	-32.39	-56.6161	0.24615
1	8.12308	COMBA4	Combination	-61.19	-50.915	-56.6161	0
1	8.36923	COMBA4	Combination	-61.19	-47.075	-44.5557	0.24615
1	8.36923	COMBA4	Combination	-61.19	-65.945	-44.5557	0
1	8.61538	COMBA4	Combination	-61.19	-62.105	-28.7958	0.24615
1	8.61538	COMBA4	Combination	-61.19	-81.394	-28.7958	0
1	8.86154	COMBA4	Combination	-61.19	-77.554	-9.2329	0.24615
1	8.86154	COMBA4	Combination	-61.19	-97.315	-9.2329	0
1	9.10769	COMBA4	Combination	-61.19	-93.475	14.249	0.24615
1	9.10769	COMBA4	Combination	-61.19	-113.727	14.249	0
1	9.35385	COMBA4	Combination	-61.19	-109.887	41.7708	0.24615
1	9.35385	COMBA4	Combination	-61.19	-130.612	41.7708	0
1	9.6	COMBA4	Combination	-61.19	-126.772	73.4487	0.24615
1	0	COMBB4	Combination	-42.944	146.402	82.0736	0
1	0.24615	COMBB4	Combination	-42.944	150.242	45.5636	0.24615
1	0.24615	COMBB4	Combination	-42.944	126.091	45.5636	0
1	0.49231	COMBB4	Combination	-42.944	129.931	14.0532	0.24615
1	0.49231	COMBB4	Combination	-42.944	106.534	14.0532	0
1	0.73846	COMBB4	Combination	-42.944	110.374	-12.6431	0.24615
1	0.73846	COMBB4	Combination	-42.944	87.746	-12.6431	0
1	0.98462	COMBB4	Combination	-42.944	91.586	-34.7149	0.24615
1	0.98462	COMBB4	Combination	-42.944	69.703	-34.7149	0
1	1.23077	COMBB4	Combination	-42.944	73.543	-52.3453	0.24615
1	1.23077	COMBB4	Combination	-42.944	52.343	-52.3453	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	1.47692	COMBB4	Combination	-42.944	56.183	-65.7024	0.24615
1	1.47692	COMBB4	Combination	-42.944	35.576	-65.7024	0
1	1.72308	COMBB4	Combination	-42.944	39.416	-74.9322	0.24615
1	1.72308	COMBB4	Combination	-42.944	19.291	-74.9322	0
1	1.96923	COMBB4	Combination	-42.944	23.131	-80.1534	0.24615
1	1.96923	COMBB4	Combination	-42.944	3.362	-80.1534	0
1	2.21538	COMBB4	Combination	-42.944	7.202	-81.4535	0.24615
1	2.21538	COMBB4	Combination	-42.944	-12.346	-81.4535	0
1	2.46154	COMBB4	Combination	-42.944	-8.506	-78.8871	0.24615
1	2.46154	COMBB4	Combination	-42.944	-27.968	-78.8871	0
1	2.70769	COMBB4	Combination	-42.944	-24.128	-72.4752	0.24615
1	2.70769	COMBB4	Combination	-42.944	-43.638	-72.4752	0
1	2.95385	COMBB4	Combination	-42.944	-39.798	-62.2063	0.24615
1	2.95385	COMBB4	Combination	-42.944	-59.476	-62.2063	0
1	3.2	COMBB4	Combination	-42.944	-55.636	-48.0388	0.24615
1	3.2	COMBB4	Combination	-42.944	-75.588	-48.0388	0
1	3.44615	COMBB4	Combination	-42.944	-71.748	-29.9052	0.24615
1	3.44615	COMBB4	Combination	-42.944	-92.056	-29.9052	0
1	3.69231	COMBB4	Combination	-42.944	-88.216	-7.7178	0.24615
1	3.69231	COMBB4	Combination	-42.944	-108.934	-7.7178	0
1	3.93846	COMBB4	Combination	-42.944	-105.094	18.6241	0.24615
1	3.93846	COMBB4	Combination	-42.944	-126.239	18.6241	0
1	4.18462	COMBB4	Combination	-42.944	-122.399	49.2258	0.24615
1	4.18462	COMBB4	Combination	-42.944	-143.946	49.2258	0
1	4.43077	COMBB4	Combination	-42.944	-140.106	84.186	0.24615
1	4.43077	COMBB4	Combination	-42.944	-161.98	84.186	0
1	4.67692	COMBB4	Combination	-42.944	-158.14	123.5854	0.24615
1	4.67692	COMBB4	Combination	-42.944	-180.21	123.5854	0
1	4.8	COMBB4	Combination	-42.944	-178.29	145.647	0.12308
1	4.8	COMBB4	Combination	-41.267	171.368	142.5587	0
1	4.92308	COMBB4	Combination	-41.267	173.288	121.3491	0.12308
1	4.92308	COMBB4	Combination	-41.267	151.276	121.3491	0
1	5.16923	COMBB4	Combination	-41.267	155.116	83.6392	0.24615
1	5.16923	COMBB4	Combination	-41.267	133.415	83.6392	0
1	5.41538	COMBB4	Combination	-41.267	137.255	50.3259	0.24615
1	5.41538	COMBB4	Combination	-41.267	115.995	50.3259	0
1	5.66154	COMBB4	Combination	-41.267	119.835	21.3005	0.24615
1	5.66154	COMBB4	Combination	-41.267	99.093	21.3005	0
1	5.90769	COMBB4	Combination	-41.267	102.933	-3.5641	0.24615
1	5.90769	COMBB4	Combination	-41.267	82.737	-3.5641	0
1	6.15385	COMBB4	Combination	-41.267	86.577	-24.4028	0.24615
1	6.15385	COMBB4	Combination	-41.267	66.918	-24.4028	0
1	6.4	COMBB4	Combination	-41.267	70.758	-41.3476	0.24615
1	6.4	COMBB4	Combination	-41.267	51.592	-41.3476	0
1	6.64615	COMBB4	Combination	-41.267	55.432	-54.5197	0.24615
1	6.64615	COMBB4	Combination	-41.267	36.686	-54.5197	0
1	6.89231	COMBB4	Combination	-41.267	40.526	-64.0227	0.24615
1	6.89231	COMBB4	Combination	-41.267	22.109	-64.0227	0
1	7.13846	COMBB4	Combination	-41.267	25.949	-69.9376	0.24615
1	7.13846	COMBB4	Combination	-41.267	7.753	-69.9376	0
1	7.38462	COMBB4	Combination	-41.267	11.593	-72.3187	0.24615
1	7.38462	COMBB4	Combination	-41.267	-6.5	-72.3187	0
1	7.63077	COMBB4	Combination	-41.267	-2.66	-71.1914	0.24615
1	7.63077	COMBB4	Combination	-41.267	-20.77	-71.1914	0
1	7.87692	COMBB4	Combination	-41.267	-16.93	-66.5514	0.24615
1	7.87692	COMBB4	Combination	-41.267	-35.178	-66.5514	0

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
1	8.12308	COMBB4	Combination	-41.267	-31.338	-58.3649	0.24615
1	8.12308	COMBB4	Combination	-41.267	-49.834	-58.3649	0
1	8.36923	COMBB4	Combination	-41.267	-45.994	-46.5707	0.24615
1	8.36923	COMBB4	Combination	-41.267	-64.838	-46.5707	0
1	8.61538	COMBB4	Combination	-41.267	-60.998	-31.0833	0.24615
1	8.61538	COMBB4	Combination	-41.267	-80.269	-31.0833	0
1	8.86154	COMBB4	Combination	-41.267	-76.429	-11.7974	0.24615
1	8.86154	COMBB4	Combination	-41.267	-96.182	-11.7974	0
1	9.10769	COMBB4	Combination	-41.267	-92.342	11.4057	0.24615
1	9.10769	COMBB4	Combination	-41.267	-112.601	11.4057	0
1	9.35385	COMBB4	Combination	-41.267	-108.761	38.6503	0.24615
1	9.35385	COMBB4	Combination	-41.267	-129.512	38.6503	0
1	9.6	COMBB4	Combination	-41.267	-125.672	70.0576	0.24615
2	0	COMBA0	Combination	-177.764	71.61	97.5097	0
2	1.2	COMBA0	Combination	-159.044	14.86	47.3129	1.2
2	2.4	COMBA0	Combination	-140.324	-25.042	55.1069	2.4
2	0	COMBB0	Combination	-176.69	51.687	94.1187	0
2	1.2	COMBB0	Combination	-157.97	16.278	54.1823	1.2
2	2.4	COMBB0	Combination	-139.25	-10.707	51.6822	2.4
2	0	COMBB2	Combination	-167.604	46.717	88.1723	0
2	1.2	COMBB2	Combination	-148.884	11.308	54.1994	1.2
2	2.4	COMBB2	Combination	-130.164	-15.677	57.6626	2.4
2	0	COMBA4	Combination	-159.893	62.867	85.4647	0
2	1.2	COMBA4	Combination	-141.173	6.118	45.7585	1.2
2	2.4	COMBA4	Combination	-122.453	-33.784	64.0433	2.4
2	0	COMBB4	Combination	-158.82	42.944	82.0736	0
2	1.2	COMBB4	Combination	-140.1	7.536	52.628	1.2
2	2.4	COMBB4	Combination	-121.38	-19.449	60.6186	2.4
3	0	COMBA0	Combination	-131.981	-67.811	-75.9719	0
3	1.2	COMBA0	Combination	-113.261	-11.061	-30.3338	1.2
3	2.4	COMBA0	Combination	-94.541	28.841	-42.6866	2.4
3	0	COMBB0	Combination	-130.907	-47.888	-72.5808	0
3	1.2	COMBB0	Combination	-112.187	-12.479	-37.2032	1.2
3	2.4	COMBB0	Combination	-93.467	14.506	-39.2619	2.4
3	0	COMBB2	Combination	-133.334	-44.244	-70.5819	0
3	1.2	COMBB2	Combination	-114.614	-8.835	-39.5764	1.2
3	2.4	COMBB2	Combination	-95.894	18.149	-46.0072	2.4
3	0	COMBA4	Combination	-137.339	-61.19	-73.4487	0
3	1.2	COMBA4	Combination	-118.619	-4.44	-35.7558	1.2
3	2.4	COMBA4	Combination	-99.899	35.462	-56.0538	2.4
3	0	COMBB4	Combination	-136.265	-41.267	-70.0576	0
3	1.2	COMBB4	Combination	-117.545	-5.858	-42.6252	1.2
3	2.4	COMBB4	Combination	-98.825	21.127	-52.6291	2.4
4	0	COMBA0	Combination	-25.042	-140.324	-55.1069	0
4	0.48	COMBA0	Combination	-25.042	-103.133	3.3227	0.48
4	0.96	COMBA0	Combination	-25.042	-65.941	43.9004	0.96
4	1.44	COMBA0	Combination	-25.042	-28.75	66.6262	1.44
4	1.92	COMBA0	Combination	-25.042	8.442	71.5001	1.92
4	2.4	COMBA0	Combination	-25.042	30.58	61.5028	2.4
4	2.88	COMBA0	Combination	-25.042	49.524	42.2778	2.88
4	3.36	COMBA0	Combination	-25.042	68.469	13.9595	3.36
4	3.84	COMBA0	Combination	-25.042	87.414	-23.4523	3.84
4	4.32	COMBA0	Combination	-25.042	109.019	-70.0506	4.32
4	4.8	COMBA0	Combination	-25.042	146.211	-131.3058	4.8
4	4.8	COMBA0	Combination	-28.841	-161.33	-131.1422	0
4	5.28	COMBA0	Combination	-28.841	-124.139	-62.6295	0.48

Frame Text	Station m	OutputCase Text	CaseType Text	P KN	V2 KN	M3 KN-m	ElemStation m
4	5.76	COMBA0	Combination	-28.841	-86.948	-11.9687	0.96
4	6.24	COMBA0	Combination	-28.841	-49.756	20.8401	1.44
4	6.72	COMBA0	Combination	-28.841	-30.279	39.9246	1.92
4	7.2	COMBA0	Combination	-28.841	-11.335	49.912	2.4
4	7.68	COMBA0	Combination	-28.841	7.61	50.8059	2.88
4	8.16	COMBA0	Combination	-28.841	26.555	42.6063	3.36
4	8.64	COMBA0	Combination	-28.841	46.919	25.214	3.84
4	9.12	COMBA0	Combination	-28.841	70.73	-3.0216	4.32
4	9.6	COMBA0	Combination	-28.841	94.541	-42.6866	4.8
4	0	COMBB0	Combination	-10.707	-139.25	-51.6822	0
4	0.48	COMBB0	Combination	-10.707	-102.059	6.2321	0.48
4	0.96	COMBB0	Combination	-10.707	-64.867	46.2944	0.96
4	1.44	COMBB0	Combination	-10.707	-27.676	68.5049	1.44
4	1.92	COMBB0	Combination	-10.707	9.515	72.8634	1.92
4	2.4	COMBB0	Combination	-10.707	31.653	62.3507	2.4
4	2.88	COMBB0	Combination	-10.707	50.598	42.6104	2.88
4	3.36	COMBB0	Combination	-10.707	69.543	13.7767	3.36
4	3.84	COMBB0	Combination	-10.707	88.487	-24.1505	3.84
4	4.32	COMBB0	Combination	-10.707	110.093	-71.2642	4.32
4	4.8	COMBB0	Combination	-10.707	147.284	-133.0347	4.8
4	4.8	COMBB0	Combination	-14.506	-162.404	-132.8711	0
4	5.28	COMBB0	Combination	-14.506	-125.213	-63.8431	0.48
4	5.76	COMBB0	Combination	-14.506	-88.021	-12.6669	0.96
4	6.24	COMBB0	Combination	-14.506	-50.83	20.6573	1.44
4	6.72	COMBB0	Combination	-14.506	-31.353	40.2571	1.92
4	7.2	COMBB0	Combination	-14.506	-12.408	50.7598	2.4
4	7.68	COMBB0	Combination	-14.506	6.536	52.1691	2.88
4	8.16	COMBB0	Combination	-14.506	25.481	44.485	3.36
4	8.64	COMBB0	Combination	-14.506	45.845	27.608	3.84
4	9.12	COMBB0	Combination	-14.506	69.656	-0.1123	4.32
4	9.6	COMBB0	Combination	-14.506	93.467	-39.2619	4.8
4	0	COMBB2	Combination	-15.677	-130.164	-57.6626	0
4	0.48	COMBB2	Combination	-15.677	-111.22	0.2695	0.48
4	0.96	COMBB2	Combination	-15.677	-74.496	44.9507	0.96
4	1.44	COMBB2	Combination	-15.677	-37.305	71.7829	1.44
4	1.92	COMBB2	Combination	-15.677	-0.113	80.7632	1.92
4	2.4	COMBB2	Combination	-15.677	37.078	71.8916	2.4
4	2.88	COMBB2	Combination	-15.677	59.684	47.9663	2.88
4	3.36	COMBB2	Combination	-15.677	78.629	14.7713	3.36
4	3.84	COMBB2	Combination	-15.677	97.573	-27.5172	3.84
4	4.32	COMBB2	Combination	-15.677	116.518	-78.8991	4.32
4	4.8	COMBB2	Combination	-15.677	137.656	-139.4376	4.8
4	4.8	COMBB2	Combination	-18.149	-173.701	-140.0892	0
4	5.28	COMBB2	Combination	-18.149	-136.509	-65.6388	0.48
4	5.76	COMBB2	Combination	-18.149	-99.318	-9.0403	0.96
4	6.24	COMBB2	Combination	-18.149	-62.126	29.7063	1.44
4	6.72	COMBB2	Combination	-18.149	-24.935	50.601	1.92
4	7.2	COMBB2	Combination	-18.149	-4.99	57.5562	2.4
4	7.68	COMBB2	Combination	-18.149	13.954	55.4048	2.88
4	8.16	COMBB2	Combination	-18.149	32.899	44.1599	3.36
4	8.64	COMBB2	Combination	-18.149	51.844	23.8217	3.84
4	9.12	COMBB2	Combination	-18.149	72.083	-5.6927	4.32
4	9.6	COMBB2	Combination	-18.149	95.894	-46.0072	4.8
4	0	COMBA4	Combination	-33.784	-122.453	-64.0433	0
4	0.48	COMBA4	Combination	-33.784	-103.509	-9.8123	0.48
4	0.96	COMBA4	Combination	-33.784	-84.564	35.3252	0.96

Frame	Station	OutputCase	CaseType	P	V2	M3	ElemStation
Text	m	Text	Text	KN	KN	KN-m	m
4	1.44	COMBA4	Combination	-33.784	-48.308	67.4277	1.44
4	1.92	COMBA4	Combination	-33.784	-11.117	81.6898	1.92
4	2.4	COMBA4	Combination	-33.784	26.074	78.1	2.4
4	2.88	COMBA4	Combination	-33.784	63.266	56.6583	2.88
4	3.36	COMBA4	Combination	-33.784	86.34	19.9862	3.36
4	3.84	COMBA4	Combination	-33.784	105.284	-26.0034	3.84
4	4.32	COMBA4	Combination	-33.784	124.229	-81.0865	4.32
4	4.8	COMBA4	Combination	-33.784	143.173	-145.2631	4.8
4	4.8	COMBA4	Combination	-35.462	-166.898	-146.2013	0
4	5.28	COMBA4	Combination	-35.462	-146.228	-70.6761	0.48
4	5.76	COMBA4	Combination	-35.462	-109.037	-9.4125	0.96
4	6.24	COMBA4	Combination	-35.462	-71.845	33.9991	1.44
4	6.72	COMBA4	Combination	-35.462	-34.654	59.5589	1.92
4	7.2	COMBA4	Combination	-35.462	2.538	67.2667	2.4
4	7.68	COMBA4	Combination	-35.462	22.95	60.8257	2.88
4	8.16	COMBA4	Combination	-35.462	41.895	45.2628	3.36
4	8.64	COMBA4	Combination	-35.462	60.84	20.6065	3.84
4	9.12	COMBA4	Combination	-35.462	79.784	-13.1432	4.32
4	9.6	COMBA4	Combination	-35.462	99.899	-56.0538	4.8
4	0	COMBB4	Combination	-19.449	-121.38	-60.6186	0
4	0.48	COMBB4	Combination	-19.449	-102.435	-6.903	0.48
4	0.96	COMBB4	Combination	-19.449	-83.49	37.7192	0.96
4	1.44	COMBB4	Combination	-19.449	-47.235	69.3063	1.44
4	1.92	COMBB4	Combination	-19.449	-10.043	83.053	1.92
4	2.4	COMBB4	Combination	-19.449	27.148	78.9479	2.4
4	2.88	COMBB4	Combination	-19.449	64.34	56.9908	2.88
4	3.36	COMBB4	Combination	-19.449	87.413	19.8034	3.36
4	3.84	COMBB4	Combination	-19.449	106.358	-26.7016	3.84
4	4.32	COMBB4	Combination	-19.449	125.302	-82.3001	4.32
4	4.8	COMBB4	Combination	-19.449	144.247	-146.992	4.8
4	4.8	COMBB4	Combination	-21.127	-167.972	-147.9302	0
4	5.28	COMBB4	Combination	-21.127	-147.302	-71.8896	0.48
4	5.76	COMBB4	Combination	-21.127	-110.11	-10.1107	0.96
4	6.24	COMBB4	Combination	-21.127	-72.919	33.8163	1.44
4	6.72	COMBB4	Combination	-21.127	-35.727	59.8914	1.92
4	7.2	COMBB4	Combination	-21.127	1.464	68.1146	2.4
4	7.68	COMBB4	Combination	-21.127	21.877	62.1889	2.88
4	8.16	COMBB4	Combination	-21.127	40.821	47.1414	3.36
4	8.64	COMBB4	Combination	-21.127	59.766	23.0005	3.84
4	9.12	COMBB4	Combination	-21.127	78.711	-10.2338	4.32
4	9.6	COMBB4	Combination	-21.127	98.825	-52.6291	4.8
5	0	COMBA0	Combination	-344.981	-3.799	-9.2812	0
5	1.2	COMBA0	Combination	-326.261	-3.799	-4.7224	1.2
5	2.4	COMBA0	Combination	-307.541	-3.799	-0.1636	2.4
5	0	COMBB0	Combination	-347.128	-3.799	-9.2812	0
5	1.2	COMBB0	Combination	-328.408	-3.799	-4.7224	1.2
5	2.4	COMBB0	Combination	-309.688	-3.799	-0.1636	2.4
5	0	COMBB2	Combination	-348.796	-2.473	-5.2835	0
5	1.2	COMBB2	Combination	-330.076	-2.473	-2.316	1.2
5	2.4	COMBB2	Combination	-311.356	-2.473	0.6515	2.4
5	0	COMBA4	Combination	-347.511	-1.678	-3.0883	0
5	1.2	COMBA4	Combination	-328.791	-1.678	-1.0751	1.2
5	2.4	COMBA4	Combination	-310.071	-1.678	0.9382	2.4
5	0	COMBB4	Combination	-349.659	-1.678	-3.0883	0
5	1.2	COMBB4	Combination	-330.939	-1.678	-1.0751	1.2
5	2.4	COMBB4	Combination	-312.219	-1.678	0.9382	2.4

APPENDIX 4 CSI API and VBA Codes of the Excel Sheet

```
Sub Analyze(path As String, CloseFile As Boolean)

      'defining variables
      Dim i As Integer
      Dim SapObject As SAP2000v17.cOAPI
      Dim SapModel As cSapModel
      Dim ret As Long
      Dim Conc As String 'concrete class
      Dim Reb As String 'rebar class
      Dim fck As Integer
      Dim Ec As Double 'modulus of elasticity of concrete
      Dim n As Integer 'number of culvert cells
      Dim s As Double 'span width

      n = Sayfa1.Range("E18").Value
      s = Sayfa1.Range("E19").Value
      fck = Sayfa1.Range("E4").Value
      Conc = "C" & fck
      Reb = "S" & Sayfa1.Range("E5").Value
      Ec = ElasticityModulus(fck) 'Ec defination

      'create an instance of the Sap2000 object
      Set SapObject = CreateObject("CSI.SAP2000.API.SapObject")
      SapObject.ApplicationStart 'start the Sap2000 application
      Set SapModel = SapObject.SapModel 'create the SapModel object
      ret = SapModel.InitializeNewModel(eUnits_kN_m_C) 'initialize
model
      'calling Sap2000 API functions here to perform desired tasks
      'create new blank model
      ret = SapModel.File.NewBlank
      'define material property
      'define rebar
      ret = SapModel.PropMaterial.SetMaterial(Reb, eMatType_Rebar)
      'Definerebar properties for S420
      ret = SapModel.PropMaterial.SetORebar(Reb, 365000, 420000,
500000, 462000, 2, 2, 0.01, 0.12, False)
      'define concrete
      ret = SapModel.PropMaterial.SetMaterial(Conc,
eMatType_Concrete)
      'Assign concrete unit weight
      ret = SapModel.PropMaterial.SetWeightAndMass(Conc, 1, 25)
      'assign isotropic mechanical properties to material
      ret = SapModel.PropMaterial.SetMPIsotropic(Conc, Ec * 1000,
0.2, 0.00001)
      ret = SapModel.PropMaterial.SetOConcrete(Conc, fck * 1000,
False, 0, 1, 2, 0.003, 0.005)

      'Define 3 different section types as DOSEME(top slab),
PERDE(walls) and TEMEL(base slab)
      ret = SapModel.PropFrame.SetRectangle("DOSEME", Conc,
Sayfa1.Range("E13"), 1)
      ret = SapModel.PropFrame.SetRectangle("PERDE", Conc,
Sayfa1.Range("E14"), 1)
      ret = SapModel.PropFrame.SetRectangle("TEMEL", Conc,
Sayfa1.Range("E12"), 1)

      'Defining spring properties here
      Dim kw As Double
```

```
        'getting spring spacing value from the excel sheet
        kw = Sayfa2.Range("F20").Value
        Dim k() As Double
        ReDim k(5)
        'getting horizontal and vertical spring constant values for
the first base point of base slab.
        'Since first spring is placing at the starting point of base
slab,
        'spring constant areas are half size of the real area
        k(0) = Sayfa2.Range("F21").Value / 2 'Horizontal spring
constant
        k(2) = Sayfa2.Range("F22").Value / 2 'Vertical spring constant
        ret = SapModel.GroupDef.SetGroup("spring")
        ret = SapModel.PointObj.AddCartesian(0, 0, 0, "1")
        ret = SapModel.PointObj.SetSpring("1", k)
        ret = SapModel.PointObj.SetGroupAssign("1", "spring")
        'getting horizontal and vertical spring constant values for
base points of base slab
        'apart from start and end points of base slab.
        k(0) = Sayfa2.Range("F21").Value 'Horizontal spring constant
        k(2) = Sayfa2.Range("F22").Value 'Vertical spring constant
        i = 1
        Dim pname As String

        While (i * kw + kw / 2) < s
        pname = "P" & i
        ret = SapModel.PointObj.AddCartesian(i * kw, 0, 0, pname)
        ret = SapModel.PointObj.SetSpring(pname, k)
        ret = SapModel.PointObj.SetGroupAssign(pname, "spring")
        i = i + 1
        Wend
        'getting horizontal and vertical spring constant values for
the last base point of base slab.
        'Since last spring is placing at the end point of base slab,
        'spring constant areas are half size of the real area
        k(0) = Sayfa2.Range("F21").Value / 2 'Horizontal spring
constant
        k(2) = Sayfa2.Range("F22").Value / 2 'Vertical spring constant
        pname = "P" & i
        ret = SapModel.PointObj.AddCartesian(i * kw, 0, 0, pname)
        ret = SapModel.PointObj.SetSpring(pname, k)
        ret = SapModel.PointObj.SetGroupAssign(pname, "spring")

        'Defining coordinates of sections
        Dim h As Double
        Dim w As Double
        w = Sayfa1.Range("E16").Value + Sayfa1.Range("E14").Value
        h = Sayfa1.Range("E17") + (Sayfa1.Range("E13") +
Sayfa1.Range("E12")) / 2
        ret = SapModel.FrameObj.AddByCoord(0, 0, 0, s, 0, 0, "",
"TEMEL")
        ret = SapModel.FrameObj.AddByCoord(0, 0, 0, 0, 0, h, "",
"PERDE")
        ret = SapModel.FrameObj.AddByCoord(s, 0, 0, s, 0, h, "",
"PERDE")
        ret = SapModel.FrameObj.AddByCoord(0, 0, h, s, 0, h, "",
"DOSEME")
        'If culvert is multiple cell, interior walls are being added
to the sap2000 model.
        If n > 1 Then
        i = 1
```

```
        While i * w < s
        ret = SapModel.FrameObj.AddByCoord(i * w, 0, 0, i * w, 0, h,
"", "PERDE")
        i = i + 1
        Wend
        End If

        'defining loads
        ret = SapModel.LoadCases.Delete("MODAL")
        ret = SapModel.LoadPatterns.Add("Ls",
eLoadPatternType_LiveLoadSurcharge)
        ret = SapModel.LoadPatterns.Add("Ep",
eLoadPatternType_HorizontalEarthPressure)
        'Assigning distributed vertical earhth pressure, lateral earth
pressure and live surcharge loads.
        ret = SapModel.FrameObj.SetLoadDistributed("4", "DEAD", 1, 10,
0, 1, Sayfa2.Range("G3"), Sayfa2.Range("G3"))
        ret = SapModel.FrameObj.SetLoadDistributed("2", "Ep", 1, 4, 0,
1, Sayfa2.Range("D15"), Sayfa2.Range("D9"))
        ret = SapModel.FrameObj.SetLoadDistributed("3", "Ep", 1, 4, 0,
1, -Sayfa2.Range("D15"), -Sayfa2.Range("D9"))
        ret = SapModel.FrameObj.SetLoadDistributed("2", "Ls", 1, 4, 0,
1, Sayfa2.Range("A10"), Sayfa2.Range("A10"))
        ret = SapModel.FrameObj.SetLoadDistributed("3", "Ls", 1, 4, 0,
1, -Sayfa2.Range("A10"), -Sayfa2.Range("A10"))

        'Defining vehicle loads, the projections of which don't
intersect and exceed span width
        If Sayfa2.Range("G7") >= s And Sayfa2.Range("F7") >= 0 Then
        ret = SapModel.LoadPatterns.Add("LL1", eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", "LL1", 1, 10,
0, 1, Sayfa2.Range("G5"), Sayfa2.Range("G5"))
        Call DefineCombs(SapModel, 1, "LL1", Sayfa2.Range("J5"))

        'Defining vehicle loads, the projections of which don't
intersect
        'and the distribution width of which are smaller than span
width and span width is smaller than 4.25 m
        ElseIf Sayfa2.Range("G7") < s And Sayfa2.Range("F7") >= 0 And
s <= 4.25 Then
        i = 0
        'Wheel loads are moving all together along the span until
wheel load projection in the first place exits the span
        'only LLmax is used for this case
        While i * kw + Sayfa2.Range("G7") < s
        pname = "LL" & i
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)

        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw, i * kw + Sayfa2.Range("G7"), Sayfa2.Range("G5"),
Sayfa2.Range("G5"), "Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))

        i = i + 1
        Wend

        'Defining vehicle loads, the projections of which don't
intersect
        'and span width range is 4.25 m to 8.5 m
        ElseIf s > 4.25 And s <= 8.5 And Sayfa2.Range("F7") >= 0 Then
```

```
        'Wheel loads are moving all together along the span until
wheel load projection in the first place exits the span
        'Two LLmax loads are used for this case
        i = 0
        While i * kw + Sayfa2.Range("G7") + Sayfa2.Range("H7") < s
        pname = "LL" & i & "_1"
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw, i * kw + Sayfa2.Range("G7"), Sayfa2.Range("G5"),
Sayfa2.Range("G5"), "Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))
        pname = "LL" & i & "_2"
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw + Sayfa2.Range("G7") + Sayfa2.Range("H7"), i * kw +
Sayfa2.Range("G7") + Sayfa2.Range("H7") + Sayfa2.Range("I7"),
Sayfa2.Range("I5"), Sayfa2.Range("I5"), "Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))
        i = i + 1
        Wend

        'Defining vehicle loads, the projections of which don't
intersect
        'and span width is greater than 8.5 m
        ElseIf s > 8.5 And Sayfa2.Range("F7") >= 0 Then

        'Wheel loads are moving all together along the span until
wheel load projection in the first place exits the span
        'Two LLmax and one LLmin loads are used for this case
        i = 0
        While i * kw + Sayfa2.Range("I7") + Sayfa2.Range("H7") +
Sayfa2.Range("G7") + Sayfa2.Range("F7") < s
        pname = "LL" & i & "_1"
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw, i * kw + Sayfa2.Range("I7"), Sayfa2.Range("I5"),
Sayfa2.Range("I5"), "Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))
        pname = "LL" & i & "_2"
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw + Sayfa2.Range("I7") + Sayfa2.Range("H7"), i * kw +
Sayfa2.Range("I7") + Sayfa2.Range("H7") + Sayfa2.Range("G7"),
Sayfa2.Range("G5"), Sayfa2.Range("G5"), "Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))
        pname = "LL" & i & "_3"
        ret = SapModel.LoadPatterns.Add(pname, eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", pname, 1, 10,
i * kw + Sayfa2.Range("I7") + Sayfa2.Range("H7") +
Sayfa2.Range("G7") + Sayfa2.Range("F7"), i * kw + Sayfa2.Range("I7")
+ Sayfa2.Range("H7") + Sayfa2.Range("G7") + Sayfa2.Range("F7") +
Sayfa2.Range("E7"), Sayfa2.Range("E5"), Sayfa2.Range("E5"),
"Global", False)
        Call DefineCombs(SapModel, i, pname, Sayfa2.Range("J5"))
        i = i + 1
        Wend

        Else

        'One distributed vehicle load is used and vehicle load is
distributed over whole span width.
```

```
        ret = SapModel.LoadPatterns.Add("LL1", eLoadPatternType_Live)
        ret = SapModel.FrameObj.SetLoadDistributed("4", "LL1", 1, 10,
0, 1, Sayfa2.Range("G5"), Sayfa2.Range("G5"))
        Call DefineCombs(SapModel, 1, "LL1", Sayfa2.Range("J5"))
        End If

        'Analysis options are being set
        Dim DOF() As Boolean
        ReDim DOF(5)
        DOF(0) = True
        DOF(2) = True
        DOF(4) = True
        ret = SapModel.Analyze.SetActiveDOF(DOF)
        ret = SapModel.File.Save(path)
        ret = SapModel.Analyze.RunAnalysis()

        'Getting results of maximum displacement, reactions and
internal forces
        Call GetMaxDisplandMaxReact(SapModel, "spring")
        Call GetFrameForces(SapModel)

        ret = SapModel.View.RefreshView(0, False)
        If CloseFile = True Then
        ret = SapModel.SetModelIsLocked(False)

        'closing the Sap2000 application
        SapObject.ApplicationExit True
        End If

        'set the objects to Nothing
        Set SapModel = Nothing
        Set SapObject = Nothing

End Sub

Sub DefineCombs(SapModel As cSapModel, i As Integer, pname As
String, Ik As Double)
        Dim ret As Long

          'load combinations and load factors are defined.
        ret = SapModel.RespCombo.Add("COMBA" & i, 0)
        ret = SapModel.RespCombo.SetCaseList("COMBA" & i, 0, "DEAD",
1.3)
        ret = SapModel.RespCombo.SetCaseList("COMBA" & i, 0, "Ep",
1.3)
        ret = SapModel.RespCombo.SetCaseList("COMBA" & i, 0, "Ls",
2.171) '2.171=1.3*1.67
        ret = SapModel.RespCombo.SetCaseList("COMBA" & i, 0, pname, Ik
* 2.171)

        ret = SapModel.RespCombo.Add("COMBB" & i, 0)
        ret = SapModel.RespCombo.SetCaseList("COMBB" & i, 0, "DEAD",
1.3)
        ret = SapModel.RespCombo.SetCaseList("COMBB" & i, 0, "Ep",
0.65)
        ret = SapModel.RespCombo.SetCaseList("COMBB" & i, 0, "Ls",
2.171) '2.171=1.3*1.67
        ret = SapModel.RespCombo.SetCaseList("COMBB" & i, 0, pname, Ik
* 2.171)

        ret = SapModel.RespCombo.Add("COMBC" & i, 0)
```

```
        ret = SapModel.RespCombo.SetCaseList("COMBC" & i, 0, "DEAD",
1)
        ret = SapModel.RespCombo.SetCaseList("COMBC" & i, 0, "Ep", 1)
        ret = SapModel.RespCombo.SetCaseList("COMBC" & i, 0, "Ls", 1)
        ret = SapModel.RespCombo.SetCaseList("COMBC" & i, 0, pname, Ik
* 1)

End Sub

Function ElasticityModulus(fck As Integer) As Double
Select Case fck

        Case 14
        ElasticityModulus = 26150

        Case 16
        ElasticityModulus = 27000

        Case 18
        ElasticityModulus = 27500

        Case 20
        ElasticityModulus = 28000

        Case 25
        ElasticityModulus = 30000

        Case 30
        ElasticityModulus = 32000

        Case 35
        ElasticityModulus = 33000

        Case 40
        ElasticityModulus = 34000

        Case 45
        ElasticityModulus = 36000

        Case 50
        ElasticityModulus = 37000

        End Select
End Function

Sub GetMaxDisplandMaxReact(SapModel As cSapModel, group As String)
        Dim ret As Long
        Dim NumberResults As Long
        Dim Obj() As String
        Dim Comb() As String
        Dim Elm() As String
        Dim LoadComb As String
        Dim LoadCase() As String
        Dim StepType() As String
        Dim StepNum() As Double
        Dim U1() As Double
        Dim U2() As Double
        Dim U3() As Double
        Dim R1() As Double
        Dim R2() As Double
        Dim R3() As Double
```

```
      Dim F1() As Double
      Dim F2() As Double
      Dim F3() As Double
      Dim m1() As Double
      Dim M2() As Double
      Dim M3() As Double
      Dim G() As Double
      Dim i As Integer

      'clear all case and combo output selections
      ret =
SapModel.Results.Setup.DeselectAllCasesAndCombosForOutput

      'set case and combo output selections
      ret = SapModel.RespCombo.GetNameList(NumberResults, Comb)
      For i = 0 To NumberResults - 1

      If InStr(1, Comb(i), "COMBC", vbTextCompare) > 0 Then
      ret =
SapModel.Results.Setup.SetComboSelectedForOutput(Comb(i))

      End If
      Next i
      'get point displacements
      ret = SapModel.Results.JointDispl(group,
eItemTypeElm_GroupElm, NumberResults, Obj, Elm, LoadCase, StepType,
StepNum, U1, U2, U3, R1, R2, R3)
      Sayfa2.Range("J17").Value =
WorksheetFunction.Max(Abs(WorksheetFunction.Max(U1)),
Abs(WorksheetFunction.Min(U1)))
      Sayfa2.Range("j18").Value = Abs(WorksheetFunction.Min(U3))
      i = WorksheetFunction.Match(WorksheetFunction.Min(U3), U3, 0)
      LoadComb = LoadCase(i - 1)

      'Get joint reactions
      ret = SapModel.Results.JointReact(group,
eItemTypeElm_GroupElm, NumberResults, Obj, Elm, LoadCase, StepType,
StepNum, F1, F2, F3, m1, M2, M3)

      Sayfa2.Range("N17").Value =
WorksheetFunction.Max(Abs(WorksheetFunction.Max(F1)),
Abs(WorksheetFunction.Min(F1)))

      If 2 * Abs(F1(0)) > Sayfa2.Range("N17").Value Then
      Sayfa2.Range("N17").Value = 2 * Abs(F1(0))
      End If

      Sayfa2.Range("N18").Value =
WorksheetFunction.Max(Abs(WorksheetFunction.Max(F3)),
Abs(WorksheetFunction.Min(F3)))

      If 2 * Abs(F3(0)) > Sayfa2.Range("N18").Value Then
      Sayfa2.Range("N18").Value = 2 * Abs(F3(0))
      End If

      ret =
SapModel.Results.Setup.DeselectAllCasesAndCombosForOutput
      ret =
SapModel.Results.Setup.SetComboSelectedForOutput(LoadComb)
```

```
	ret = SapModel.Results.JointDispl(group,
eItemTypeElm_GroupElm, NumberResults, Obj, Elm, LoadCase, StepType,
StepNum, U1, U2, U3, R1, R2, R3)

	'Drawing base soil stress graph
	Dim ch As Chart
	Set ch = Sayfa2.ChartObjects("18 Grafik").Chart
	If ch.SeriesCollection.Count = 1 Then
	ch.SeriesCollection(1).Delete
	End If

	ReDim G(NumberResults - 1)
	For i = 0 To NumberResults - 1
	G(i) = -U3(i) * Sayfa2.Range("F18").Value
	Next i
	ch.SeriesCollection.NewSeries
	ch.SeriesCollection(1).Values = G

End Sub

Sub GetFrameForces(SapModel As cSapModel)
	Dim ret As Long
	Dim NumberResults As Long
	Dim Obj() As String
	Dim ObjSta() As Double
	Dim Elm() As String
	Dim ElmSta() As Double
	Dim LoadCase() As String
	Dim StepType() As String
	Dim StepNum() As Double
	Dim P() As Double
	Dim PT() As Double
	Dim PTMax As Double
	Dim V2() As Double
	Dim V2T() As Double
	Dim V3() As Double
	Dim T() As Double
	Dim M2() As Double
	Dim M3() As Double
	Dim M3T() As Double
	Dim Comb() As String
	Dim i As Integer
	'clear all case and combo output selections
	ret =
SapModel.Results.Setup.DeselectAllCasesAndCombosForOutput
	'set case and combo output selections
	ret = SapModel.RespCombo.GetNameList(NumberResults, Comb)
	For i = 0 To NumberResults - 1
	ret =
SapModel.Results.Setup.SetComboSelectedForOutput(Comb(i))
	Next i
	'get frame forces for line object "1" Bottom Slab
	Dim a As Double
	ret = SapModel.Results.FrameForce("1", Object, NumberResults,
Obj, ObjSta, Elm, ElmSta, LoadCase, StepType, StepNum, P, V2, V3, T,
M2, M3)

	Sayfa2.Range("H30").Value = WorksheetFunction.Max(M3)
	Sayfa2.Range("H31").Value = WorksheetFunction.Min(M3)
	Sayfa2.Range("K30").Value = WorksheetFunction.Max(V2)
	Sayfa2.Range("K31").Value = WorksheetFunction.Min(V2)
```

```
        Sayfa2.Range("O30").Value = WorksheetFunction.Min(P)
        a = WorksheetFunction.Match(Sayfa2.Range("K30").Value, V2, 0)
        Sayfa2.Range("E38").Value = P(a - 1)
        a = WorksheetFunction.Match(Sayfa2.Range("K31").Value, V2, 0)
        Sayfa2.Range("E39").Value = P(a - 1)

        'get frame forces for line object "4" Top Slab
        ret = SapModel.Results.FrameForce("4", Object, NumberResults,
Obj, ObjSta, Elm, ElmSta, LoadCase, StepType, StepNum, P, V2, V3, T,
M2, M3)
        Sayfa2.Range("H53").Value = WorksheetFunction.Max(M3)
        Sayfa2.Range("H54").Value = WorksheetFunction.Min(M3)
        Sayfa2.Range("K53").Value = WorksheetFunction.Max(V2)
        Sayfa2.Range("K54").Value = WorksheetFunction.Min(V2)
        Sayfa2.Range("O53").Value = WorksheetFunction.Min(P)
        a = WorksheetFunction.Match(Sayfa2.Range("K53").Value, V2, 0)
        Sayfa2.Range("E61").Value = P(a - 1)
        a = WorksheetFunction.Match(Sayfa2.Range("K54").Value, V2, 0)
        Sayfa2.Range("E62").Value = P(a - 1)

        'get wall forces
        ReDim V2T(2)
        ReDim M3T(2)
        ReDim PT(2)

        For i = 2 To SapModel.FrameObj.Count
        If i <> 4 Then
        ret = SapModel.Results.FrameForce(i, Object, NumberResults,
Obj, ObjSta, Elm, ElmSta, LoadCase, StepType, StepNum, P, V2, V3, T,
M2, M3)

        If M3T(0) < WorksheetFunction.Max(M3) Then M3T(0) =
WorksheetFunction.Max(M3)
        If i = 2 And M3T(1) > WorksheetFunction.Min(M3) Then M3T(1) =
WorksheetFunction.Min(M3)
        If V2T(0) < WorksheetFunction.Max(V2) Then
        V2T(0) = WorksheetFunction.Max(V2)
        a = WorksheetFunction.Match(V2T(0), V2, 0)
        PT(0) = P(a - 1)
        End If
        If V2T(1) > WorksheetFunction.Min(V2) Then
        V2T(1) = WorksheetFunction.Min(V2)
        a = WorksheetFunction.Match(V2T(1), V2, 0)
        PT(1) = P(a - 1)
        End If
        If PTMax > WorksheetFunction.Min(P) Then PTMax =
WorksheetFunction.Min(P)
        End If
        Next i
              'Copy force result values to the concrete design sheet
        Sayfa2.Range("H76").Value = M3T(0)
        Sayfa2.Range("H77").Value = M3T(1)
        Sayfa2.Range("K76").Value = V2T(0)
        Sayfa2.Range("K77").Value = V2T(1)
        Sayfa2.Range("O76").Value = PTMax
        Sayfa2.Range("E84").Value = PT(0)
        Sayfa2.Range("E85").Value = PT(1)

End Sub
```