บทที่ 4

วิธีการออกแบบและขั้นตอนการทำงานของคอมพิวเตอร์

4.1 โปรแกรม Microsoft Excel

Microsoft Excel เป็นโปรแกรม ที่อำนวยความสะดวกในด้านการคำนวณ (Spreadsheet) โดยทำงานในรูปแบบของตาราง ซึ่งจะเรียกว่าตารางคำนวณ (Worksheet) ซึ่งถูกพัฒนาโดยบริษัทไมโครซอฟท์ หลังจากที่พัฒนาโปรแกรมควบคุมการทำงานโดยใช้ Windows เป็นโปรแกรมระบบปฏิบัติการ (Operating System) ที่ทำหน้าที่ดำเนินการจัดการเกี่ยวกับระบบคอมพิวเตอร์ทำให้ Microsoft Excel เข้ามามีบทบาท ในการใช้งานบนเครื่องไมโครคอมพิวเตอร์ กันอย่างแพร่หลาย เนื่องจาก สามารถแสดงผล ด้วยรูปภาพ (Chart) รวมทั้งการทำงานเกี่ยวกับการพิมพ์ข้อมูล และยังสามารถใช้งานได้โดยง่าย

ในการเขียนโปรแกรม เพื่อการออกแบบพื้นสะพานนี้ ได้เขียนโปรแกรมโดยใช้ Microsoft Excel version 5.0 a โดยใช้งานใน Microsoft Windows version 3.11 ซึ่งสามารถใช้งานได้ในเครื่องไมโครคอมพิวเตอร์ ขนาด 32 บิต มีแผงควบคุมจอภาพที่แสดงผลด้านกราฟฟิคได้ มีหน่วยความจำเครื่องไม่น้อยกว่า 4 MB.

4.2 การใช้งานโปรแกรม

ในการใช้งานในขั้นตอนแรกจะต้องเข้าสู่โปรแกรม Microsoft Excel ก่อนแล้ว หลังจากนั้น ก็เปิดแฟ้มข้อมูล โดยมีชื่อแฟ้มข้อมูลที่เป็นโปรแกรมการออกแบบ พื้นสะพาน ดังต่อไปนี้

1. โปรแกรม Slab.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตเสริมเหล็ก แบบ slab type

2. โปรแกรม Mbeam1.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตอัดแรง แบบ precast prestressed multibeam bridge ซึ่งมีลักษณะของหน้าตัดคานแบบ non-void rectangular beams

3. โปรแกรม Mbeam2.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตอัดแรง แบบ precast prestressed multibeam bridge ซึ่งมีลักษณะของหน้าตัดคานแบบ rectangular beams with circular void

4. โปรแกรม Mbeam3.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตอัดแรง แบบ precast prestressed multibeam bridge ซึ่งมีลักษณะของหน้าตัดคานแบบ แบบ box section beams

5. โปรแกรม T-Beam.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตเสริมเหล็ก แบบ T-beam

6. โปรแกรม I-Beam.xls เป็นโปรแกรมที่ใช้ออกแบบพื้นสะพานคอนกรีตอัดแรง แบบ precast prestressed I-beam with cast-in-place deck slab

หลังจากที่เปิดแฟ้มข้อมูลแล้ว ก็สามารถใช้งานโปรแกรมได้โดยการเลื่อน cell pointer ไปที่ตำแหน่งที่เป็นค่าที่จะต้องใช้ในการออกแบบ ซึ่งจะสังเกตได้ง่าย เนื่องจากได้ทำเป็นกรอบและลักษณะของสีเฉพาะเอาไว้แล้ว หลังจากนั้นก็สามารถกรอกข้อมูลทับลงได้ทันที ซึ่งในการออกแบบก็จะสามารถตรวจสอบข้อมูลได้โดยง่าย เนื่องจากโปรแกรมได้แบ่งเป็นส่วนของลำดับการออกแบบไว้แล้ว เมื่อกรอกข้อมูล เสร็จแล้วก็สามารถที่จะตรวจสอบผลการออกแบบจากจอภาพที่แสดงผล หรือสามารถที่จะให้แสดงผลทางเครื่องพิมพ์ ลักษณะของผลการออกแบบที่ปรากฏบนจอภาพ กับผลการออกแบบที่ปรากฏบนเครื่องพิมพ์จะให้ค่าที่เหมือนกัน ซึ่งผลที่ได้ก็จะนำไปใช้เพื่อการประกอบรายการคำนวณได้อีกด้วย

4.3 ผลการใช้งานของโปรแกรม

ลักษณะตัวอย่างของผลการออกแบบ พื้นสะพานโดยใช้โปรแกรมคอมพิวเตอร์ ทั้ง 6 โปรแกรม แสดงได้ดังรายการต่อไปนี้

โปรแกรมออกแบบ

slab bridge

SLAB BRIDGE

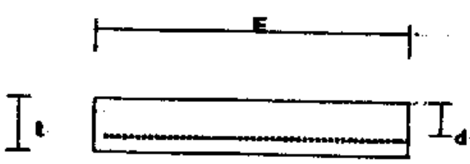
DESIGN

>>>>>> This program is for study purpose only <<<<<<

1> Design Condition					
Span length (L) =	[illegible]	m.	Loads		
Width of bridge (B) =	[illegible]	m.	(1) HS15		
Number of lane (NI) =	2		(2) HS20		
			Design Live load no. >>	2	

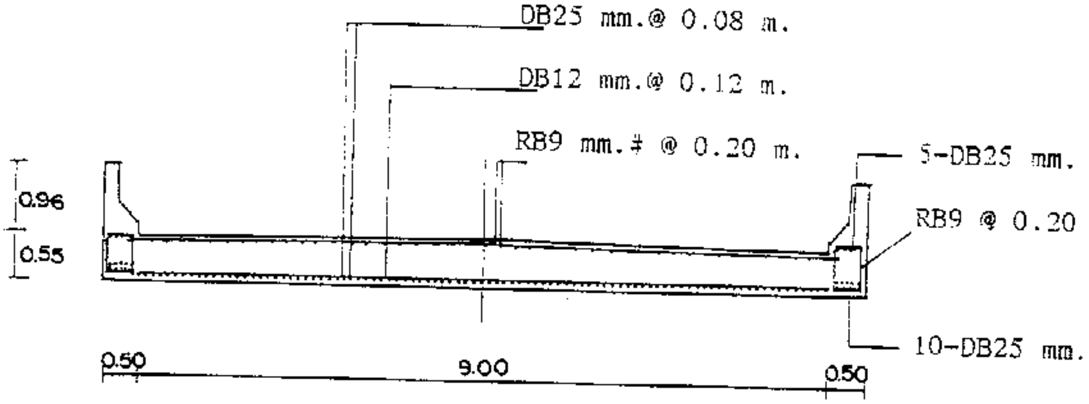
2> Materials					
Concrete			Reinfocing Steel		
fc' =	[illegible]	ksc.	yield strength (fy) =	[illegible]	ksc.
fc =	112	ksc.	allowable stress (fs) =	1,800	ksc.
Ec =	252,902	ksc.	Modulus of elasticity (Es)=	2,040,000	cm^2
			ratio of elasticity (n) =	8	
			(k) =	0.332	
			(j)	0.889	

3> Sectional Properties



t =	[illegible]	m.
>> Minimum depth =	[illegible]	m.
d =	[illegible]	m.

4. Design Loads and Moment					
Dead load			Live load		
Slab =	1,320	kg/m./m.	Ml =	16,078	kg-m./lane
			Live load Impact (i) =	0.30	
Md =	23,760	kg-m.	Ml =	20,901	kg-m.
Main reinforcement			Dist. reinforcement		
Moment =	44,661	kg-m./m.	Area of steel rq. (A*s) =	9	cm.^2/m.
Area of steel rq. (As) =	56	cm.^2/m.	diameter of steel (d*s) =	[illegible]	mm.
diameter of steel (ds) =	25	mm.	Spacing of steel (s*) =	0.127	m.
Spacing of steel (s) =	0.088	m.	temperature steel		
			diameter of steel	9	mm.
			spacing =	0.24	m.
5. Edge Beams					
Width of beams =	0.40	m.	Dead load		
depth of beam =	[illegible]	m.	Dead Load (Wd) =	576	kg./m.
			Sidewalk & Rail =	[illegible]	kg./m.
Live Load			Total =	1,326	kg./m.
Moment (Ml) =	17,418	kg.-m.	Moment (Md) =	23,868	kg.-m.
Main reinforcement			Dist. reinforcement		
Moment =	41,286	kg.-m.	Mc =	20,025	kg.-m.
Area of steel rq. (As) =	47	cm.^2	Area of steel rq. (Asc) =	26	cm.^2
diameter of steel =	[illegible]	mm.	diameter of steel =	25	mm.
Number of steel rq. =	10		Number of steel rq. =	5	
Shear >>> V =	7,956	kg.	Stirrupt		
per.shear cr.by concrete =	4.22	ksc.	diameter of steel (d*s) =	9	mm.
Shear provd. by concrete =	9,277	kg.	Spacing of steel (s*) =	Not needed	
Vs =	-	kg.	Design spacing =	[illegible]	m.



รูปที่ 4.1

แสดงหน้าตัด Slab Bridge ช่วง 12.00 ม.

จากผลการออกแบบของโปรแกรม

โปรแกรมออกแบบ

precast prestressed

multibeam bridge

Case 1#

non - void

rectangular beams

	MULTIBEAM BRIDGE DESIGN (Case 1)		

>>>>> This program is for study purpose only <<<<<<

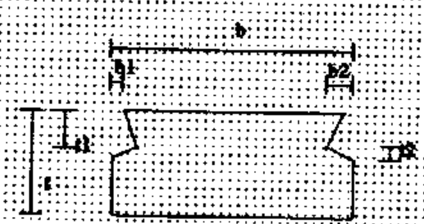
1> Design Conditions

Span length (L) =	[illegible]	m.	Loads		
Width of bridge (B) =	[illegible]	m.	(1) H15		
Number of lanes (Nl) =	2		(2) HS15		
			(3) H20		
			(4) HS20		
			Design live load no. >>	[illegible]	

2> Materials

Precast concrete			Cast-in-place concrete		
fc' =	420	ksc.	fc' =	240	ksc.
fc'i =	336	ksc.	Ecs =	234,142	ksc.
Ec =	309,740	ksc.	Nc =	0.756	>> (Ecs/Ec)
Prestressing Steel			Reinfocing Steel		
diameter d =	9	mm.	diameter d =	12	mm.
f's =	14,200	ksc.	f's =	2,400	ksc.
as =	0.636	cm^2	as =	1.131	cm^2

3> Sectional Properties



Sections of Beam

t =	[illegible]	m.
t1 =	[illegible]	m.
t2 =	[illegible]	m.
b =	[illegible]	m.
b1 =	[illegible]	m.
b2 =	[illegible]	m.
topping =	[illegible]	m.
No. of Beam (Nl) =	12	
Area Ac =	0.3247	m^2
yb =	0.170	m.
yt =	0.180	m.
I =	0.0033	m^4
Sb =	0.0193	m^3
St =	0.0183	m^3

4> Loads and Moment					
Dead load			Live load		
Beam =	779	kg/m.	Ml =	45,318	kg-m./lane
Side walk & rail =		kg/m.	k =	0.7	
Topping =	238	kg/m.	(kB/L) ; c =	0.117	
Total	1,017	kg/m.	D =	7.443	
			(12Nl+9)/Ng ; S =	2.723	
			Load fraction (S/D) =	0.366	
			Live load Impact I =	0.300	=< 03.0
Md =	12,710	kg-m./beam	*Ml* =	10,774	kg-m./beam
5> Prestressing Strands					
Bottom fiberstress due to loads					
fb =	121.44	ksc.			
Allowable tensile stress					
fct =	32.58	ksc.			
Required prestress stress in bottom fiber					
fbe =	88.86	ksc.			
Centriod of steel from bottom fiber					
c =	0.113	m.			
Strand eccentricity					
e =	0.057	m.			
Effective prestress force after loss					
Pse =	202,159	kg.			
Final prestress per strand >> assuming	[illegible]	% loss			
Psf =	4,787	kg.			
Number of strand required			Try Number of Strands		
n =	43		Use >>>	[illegible]	
6> Flexural strength					
Combinations of loads (AASHTO. 3.22)					
Mu =	39,914	kg-m.			
Approximate Value for stress in prestressed reinforcement					
f*su =	12,511	ksc.			
p* =	0.007				
@Mu =	62,301	kg-m.			
@Mu > Mu	OK				

7- Maximum and Minimum Steel Percentage					
Maximum Steel (AASHTO 9.18.4)			Minimum Steel (AASHTO 9.18.2)		
reinforcement index =	0.216		for =	40.76	ksc.
			Pse =	202,159	kg.
			Mcr =	31,366	kg.-m.
reinforcement index < 0.30		OK	@ Mu / Mcr > 1.2	OK	

8- Prestressed Losses					
(a.) Shrinkage			(b) Elastic shortening		
Rh =	78	%	Psi =	246,027	kg.
Sh =	460	ksc.	fcir =	83	ksc.
			Eci =	277,040	ksc.
			Es =	590	ksc.
(c) Creep of concrete			(d) Relaxation of Prestressing Steel		
fcds =	22	ksc.	1. stress relieved strand		
CRc =	843	ksc.	2. low relaxation strand		
(e) Total loss of Prestress			>>>> Use (1 or 2)	2	
Sh + Es + Crc + Crs =	2,204	ksc.	CRs =	312	ksc.
Dfs =	22.06	%			
Effective prestress	fse =	7,785	ksc.		

9- Concrete Stresses					
			Io =	0.0066	m.^4
Psi =	246,027	kg.	Md =	12,710	kg-m./beam
Pse =	213,049	kg.	Ml =	10,774	kg-m./beam
e =	5.661	cm.	Ac =	3,247	cm^2
St =	18,265	cm.^3	Sb =	19,338	cm.^3
Sct =	27,805	cm.^3	Scb =	30,913	cm.^3

LOAD	Span end at Prestress Transfer		Midspan at service Load	
	P = Psi		P = Pse	
	fb	ft	fb	ft
P/Ac	75.78	75.78	65.62	69.59
Pe/S	72.02	-13.47	39.01	-38.75
Md/S			-41.12	45.71
Ml/S			-34.85	38.75
Total Stress	147.79	62.81	28.66	115.30
Allowable Stress	0.6f'ci	1.988(f'ci)^0.5	1.59(f'c)^0.5	0.4f'c
(AASHTO 9.15.2)	201.6	-30.45	-32.60	168.00
	OK	OK	OK	OK
		Debonded not needed		

10> Shear Strength					
Vd =	5,084	kg./beam.	(WL/2)		
vl =	23,405	kg/lane	from Table		
Vl =	5,565	kg/beam	included impact & fraction		
Vu =	18,690	kg/beam	1.3(Vd+1.67Vl)		
Vc =	51,353	kg/beam			
Vs =	-	kg./beam	>> Use diameter =	9	mm.
Av =	-	cm.^2/m.	av =	1.273	cm.^2
Av minimum =	14.5	cm.^2/m.	Spacing s =	0.088	m.

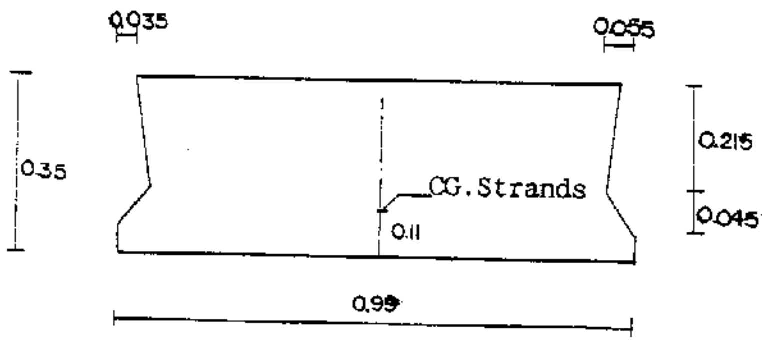
11> Deflections

SUGGESTED MULTIPLIERS TO BE USED AS A GUIDE IN ESTIMATING LONG - TIME CAMBERS AND DEFLECTIONS FOR TYPICAL MEMBERS

Deflection to be considered	without composit topping	with composit topping
At erection		
(1). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	1.85	1.85
(2). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestess	1.80	1.80
Final		
(3). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	2.70	2.40
(4). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestess	2.45	2.20
(5). Deflection (downward) - apply to elastic deflection due to supercimpose dead load only	3.00	3.00
(6). Deflection (downward) - apply to elastic deflection Caused by composite topping		2.30

(a) Prestress at transfer			(b) Beam dead load	(deflection due to dead load)	
deflection at prestress transfer			dd =	0.010	m.
dps =	-0.019	m.	At transfer =	-0.009	m.
(c) Growth in storage			(d) S.imposed dead load	(deflection due to s.imped.dL)	
Camber component at erection	-0.0169	m.	dsd =	0.00401909	m.
			Net after construction =	-0.0129	m.
(e) Long term dead load			(f) Live load deflection		
(dd * 2.70) =	0.027	m.	=	0.0010	m.
(dps * 2.45) =	-0.047	m.	Allowable deflection		
(dsd * 3.00) =	0.012	m.	=	0.0186	m.
>>> Net long term =	-0.008	m.		OK	

38 Strands 9 mm.



รูปที่ 4.2

แสดงหน้าตัดคานช่วง 10.00 ม.

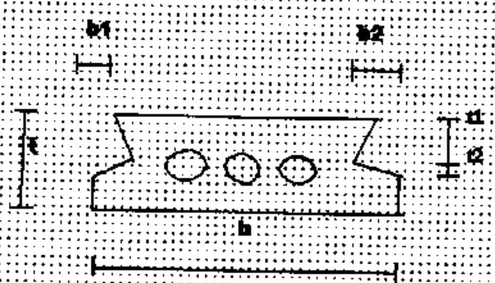
จาผลการออกแบบของโปรแกรม

Case 2#

rectangular beams

with circular void

	MULTIBEAM BRIDGE DESIGN (Case 2)				
>>>>>> This program is for study purpose only <<<<<<					
1> Design Conditions					
Span length (L) =	15	m.	Loads		
Width of bridge (B) =	9	m.	(1) H15		
Number of lanes (Nl) =	2		(2) HS15		
			(3) H20		
			(4) HS20		
			Design live load no. >>	4	
2> Materials					
Precast concrete			Cast-in-place concrete		
fc' =	350	ksc.	fc' =	240	ksc.
fc'i =	280	ksc.	Ecs =	234,142	ksc.
Ec =	282,753	ksc.	Nc =	0.828	>> (Ecs/Ec)
Prestressing Steel			Reinforcing Steel		
diameter d =	9.53	mm.	diameter d =	12	mm.
f's =	12,700	ksc.	f's =	2,400	ksc.
as =	0.714	cm^2	as =	1.131	cm^2
3> Sectional Properties					
			t =	0.700	m.
			t1 =	0.360	m.
			t2 =	0.080	m.
			b =	0.990	m.
			b1 =	0.030	m.
			b2 =	0.050	m.
			r =	0.150	m.
			topping =	0.150	m.
			no. of void =	1	
			Area Ac =	0.5983	m^2
			yb =	0.3415	m.
			yt =	0.3585	m.
			I =	0.0267	m^4
			Sb =	0.0782	m^3
No. of Beam (Nl) =	9		St =	0.0745	m^3



Sections of Beam

4> Loads and Moment					
Dead load			Live load		
Beam =	1,436	kg/m.	Ml =	36,807	kg-m./lane
Side walk & rail =		kg/m.	k =	0.8	
Topping =	238	kg/m.	C =	0.178	(kW/L)
Total	1,673	kg/m.	D =	7.349	
			S =	3.630	(12 Nl +9)/ Ng
			Load fraction >>>>	0.494	(S/D)
			Live load Impact I =	0.288	
Md =	47,067	kg-m./beam	*Ml* =	27,603	kg-m./beam
5> Prestressing Strands					
Bottom fiberstress due to loads					
	fb =	95.44	ksc.		
Allowable tensile stress					
	fct =	29.74	ksc.		
Required prestress stress in bottom fiber					
	fbs =	65.70	ksc.		
Centriod of steel from bottom fiber					
	c =	0.100	m.		
Strand eccentricity					
	e =	0.241	m.		
Effective prestress force after loss					
	Pse =	200,595	kg.		
Final prestress per strand >>assuming		25.5	% loss		
	Psf =	4,726	kg.		
Number of strand required			>> Try Number of Strands		
	n =	43	n =	40	
6> Flexural strength)					
Combinations of loads (AASHTO. 3.22)					
	Mu =	121,112	kg-m.		
Approximate Value for stress in prestressed reinforcement					
	f*su =	11,751	kg.		
	p* =	0.00412			
	@Mn =	184,551	kg-m.		
@Mn > Mu	OK				

7- Maximum and Minimum Steel Percentage					
Maximum Steel (AASHTO 9.18.4)			Minimum Steel (AASHTO 9.18.2)		
reinforcement index =	0.138		fcr =	37.20	ksc.
			Pse =	200,595	kg.
			Mcr =	103,776	kg.-m.
reinforcement index < 0.30		OK	@ Mu / Mcr > 1.2	OK	

8- Prestressed Losses					
(a.) Shrinkage			(b) Elastic shortening		
Rh =	70	%	Psi =	245,507	kg.
Sh =	460	ksc.	fcir =	58	ksc.
			Eci =	252,902	ksc.
			Es =	452	ksc.
(c) Creep of concrete			(d) Relaxation of Prestressing Steel		
fcds =	43	ksc.	1. stress relieved strand		
CRc =	400	ksc.	2. low relaxation strand		
(e) Total loss of Prestress			>>>> Use (1 or 2)	2	
Sh + Es + Crc + Crs =	1,621	ksc.	CRs =	309	ksc.
Dfs =	18.24	%			
Effective prestress	fse =	7,269	ksc.		

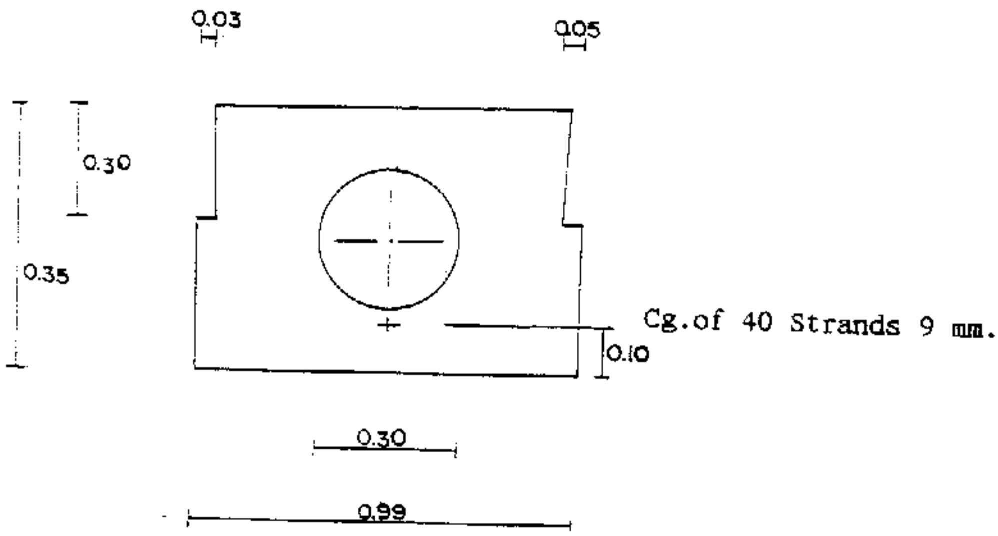
9- Concrete Stresses			Ic =	0.0388	m.^4
Psi =	245,507	kg.	Md =	47,066.8	kg-m./beam
Pse =	223,040	kg.	Ml =	27,602.7	kg-m./beam
e =	24.148	cm.	Ac =	5982.85714	cm^2
St =	74,514	cm.^3	Sb =	78,234	cm.^3
Sct =	94,873	cm.^3	Scb =	99,385	cm.^3

LOAD	Span end at Prestress Transfer		Midspan at service Load	
	P = Psi		P = Pse	
	fb	ft	fb	ft
P/Ac	41.04	41.04	37.28	63.16
Pe/S	75.78	-3.29	54.19	-29.09
Md/S			-47.36	49.61
Ml/S			-27.77	29.09
Total Stress	116.81	37.74	16.34	112.78
Allowable Stress	0.6f'ci	1.988(f'ci)^0.5	1.59(f'c)^0.5	0.4f'c
(AASHTO 9.15.2)	168	-33.28	-29.76	140.00
	OK	OK	OK	OK
		Debonded Not needed		

10> Shear Strength					
Vd =	12,551	kg./beam.	(WL/2)		
vl =	26,535	kg/lane	from Table		
Vl =	8,438	kg/beam	included impact & fraction		
Vu =	34,634	kg/beam	1.3(Vd+1.67Vl)		
Vc =	105,840	kg.			
Vs =	-	kg.	Use		
Av =	9	cm.^2/m.	diameter d =	12	mm.
Av minimum =	10	cm.^2/m.	av =	2.263	cm^2
			Spacing s =	0.224	m.

11> Deflections		
SUGGESTED MULTIPLIERS TO BE USED AS A GUIDE IN ESTIMATING LONG - TIME CAMBERS AND DEFLECTIONS FOR TYPICAL MEMBERS		
Deflection to be considered	without composit topping	with composit topping
At erection		
(1). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	1.85	1.85
(2). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestess	1.80	1.80
At Final		
(3). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestess	2.70	2.40
(4). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestess	2.45	2.20
(5). Deflection (downward) - apply to elastic deflection due to superimpose dead load only	3.00	3.00
(6). Deflection (downward) - apply to elastic deflection Caused by composite topping		2.30

(a) Prestress at transfer			(b) Beam dead load	(deflection due to dead load)	
deflection at prestress transfer			dd =	0.013	m.
dps =	-0.025	m.	At transfer =	-0.012	m.
(c) Growth in storage			(d) S.imposed dead load	(deflection due to s.imps.dl.)	
Camber component at erection	-0.022	m.	dsd =	0.003	m.
			Net after construction =	-0.020	m.
(e) Long term dead load			(f) Live load deflection		
(dd * 2.70) =	0.034	m.	=	0.001	m.
(dps * 2.45) =	-0.060	m.			
(dsd * 3.00) =	0.008	m.	Allow. deflection =	0.019	m.
>>> Net long term =	-0.019	m.		OK	



รูปที่ 4.3

แสดงผลการออกแบบของโปรแกรม

Case 3#

box section beams

MULTIBEAM BRIDGE

DESIGN [illegible]

>>>>>> This program is for study purpose only <<<<<<

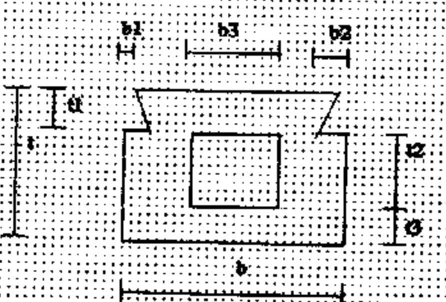
1> Design Conditions

Span length (L) =	[illegible]	m.	Loads		
Width of bridge (B) =	9	m.	(1) H15		
Number of lanes (Nl) =	2		(2) HS15		
			(3) H20		
			(4) HS20		
			Design live load no. >>	4	

2> Materials

Precast concrete			Cast-in-place concrete		
fc' =	400	ksc.	fc' =	240	ksc.
fc'i =	336	ksc.	Ecs =	234,142	ksc.
Ec =	309,740	ksc.	Nc =	0.756	>> (Ecs/Ec)
Prestressing Steel			Reinforcing Steel		
diameter d =	9	mm.	diameter d =	12	mm.
f's =	17,600	ksc.	f's =	2,400	ksc.
as =	0.636	cm^2	as =	1.131	cm^2

3> Sectional Properties



Sections of Beam

t =	0.700	m.
t1 =	0.300	m.
t2 =	0.400	m.
t3 =	0.120	m.
b =	1.000	m.
b1 =	0.050	m.
b2 =	0.050	m.
b3 =	0.640	m.
topping =	0.150	m.
Area Ac =	0.4200	m^2
yb =	0.3561	m.
yt =	0.3439	m.
I =	0.0237	m^4
Sb =	0.0664	m^3
St =	0.0688	m^3

no. of beams (Ng) =	9	

4- Loads and Moment					
Dead load			Live load		
Beam =	1,008	kg/m.	Ml =	126,361	kg-m./lane
Side walk & rail =		kg/m.	k =	1.0	
Topping =	360	kg/m.	C =	0.222	(kW/L)
Total	1,368	kg/m.	D =	7.282	
			S =	3.667	(12 Nl +9)/ Ng
			Load fraction >>>>	0.504	(S/D)
			Live load Impact I =	0.263	=< 0.30
Md =	68,400	kg-m./beam	*Ml* =	40,171	kg-m./beam

5- Prestressing Strands					
Bottom fiberstress due to loads					
	fb =	163.45	ksc.		
Allowable tensile stress					
	fct =	32.58	ksc.		
Required prestress stress in bottom fiber					
	fbs =	130.87	ksc.		
Centriod of steel from bottom fiber					
	c =	0.100	m.		
Strand eccentricity					
	e =	0.256	m.		
Effective prestress force after loss					
	Pse =	262,063	kg.		
Final prestress per strand >>assuming		24.5	% loss		
	Psf =	5,920	kg.		
Number of strand required			>>Try number of strands		
	n =	45	=	46	

6- Flexural strength					
Combinations of loads (AASHTO. 3.22)					
	Mu =	176,132	kg-m.		
Approximate Value for stress in prestressed reinforcement					
	f*su =	16,223	kg.		
	p* =	0.00373			
	@Mu =	248,990	kg-m.		
@Mu > Mu	OK				

7- Maximum and Minimum Steel Percentage

Maximum Steel (AASHTO 9.18.4)			Minimum Steel (AASHTO 9.18.2)		
reinforcement index =	0.144		fcr =	40.76	ksc.
			Pse =	262,063	kg.
			Mcr =	135,643	kg.-m.
reinforcement index < 0.30		OK	@ Mu / Mcr > 1.2	OK	

8- Prestressed Losses

(a.) Shrinkage			(b) Elastic shortening		
Rh =	70	%	Psi =	317,552	kg.
Sh =	460	ksc.	fcir =	109	ksc.
			Eci =	277,040	ksc.
			Es =	775	ksc.
(c) Creep of concrete			(d) Relaxation of Prestressing Steel		
fcds =	74	ksc.	1. stress relieved strand		
CRc =	791	ksc.	2. low relaxation strand		
(e) Total loss of Prestress			>>>> Use (1 or 2)	1	
Sh + Es + Crc + Crs =	3,160	ksc.	CRs =	1,134	ksc.
Dfs =	25.65	%			
Effective prestress	fse =	9,160 ksc.			

9- Concrete Stresses

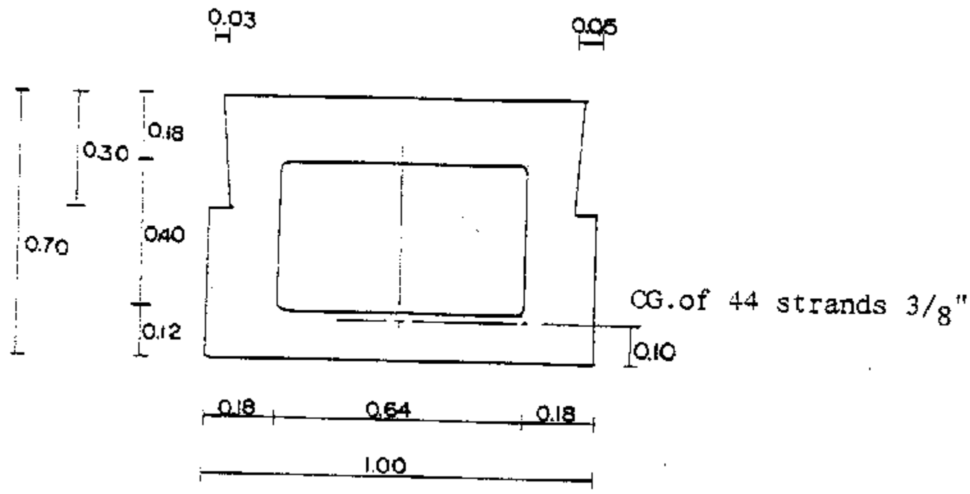
			Ic =	0.0419	m.^4
Psi =	317,552	kg.	Md =	68,400.0	kg-m./beam
Pse =	262,331	kg.	Ml =	40,171.3	kg-m./beam
e =	25.614	cm.	Ac =	4200	cm^2
St =	68,797	cm.^3	Sb =	66,424	cm.^3
Sct =	103,434	cm.^3	Sb =	94,055	cm.^3

LOAD	Span end at Prestress Transfer		Midspan at service Load	
	P = Psi		P = Pse	
	fb	ft	fb	ft
P/Ac	75.61	75.61	62.46	99.42
Pe/S	122.45	-4.62	71.44	-38.84
Md/S			-72.72	66.13
Ml/S			-42.71	38.84
Total Stress	198.06	70.99	18.47	165.55
Allowable Stress	0.6f'ci	1.988(f'ci)^0.5	1.59(f'c)^0.5	0.4f'c
(AASHTO 9.15.2)	201.6	-36.45	-32.80	168.00
	OK	OK	OK	OK
		Debonded Not needed		

10> Shear Strength					
Vd =	13,680	kg./beam.	(WL/2)		
vl =	28,077	kg/lane	from Table		
Vl =	8,926	kg/beam	include impact & fraction		
Vu =	37,163	kg/beam	1.3(Vd+1.67Vl)		
Vc =	54,432	kg.			
Vs =	-	kg.	diameter d =	[illegible]	mm.
Av =	0	cm.^2/m.	av =	1.273	cm^2
Av minimum =	5	cm.^2/m.	*Spacing* s =	0.24	m.

11> Deflections	▼	+	
	SUGGESTED MULTIPLIERS TO BE USED AS A GUIDE IN ESTIMATING		
	LONG - TIME CAMBERS AND DEFLECTIONS FOR TYPICAL MEMBERS		
Deflection to be considered		without composit topping	with composit topping
At erection			
(1). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress		1.85	1.85
(2). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestress		1.80	1.80
At Final			
(3). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress		2.70	2.40
(4). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestress		2.45	2.20
(5). Deflection (downward) - apply to elastic deflection due to superimpose dead load only		3.00	3.00
(6). Deflection (downward) - apply to elastic deflection Caused by composite topping			2.30

(a) Prestress at transfer			(b) Beam dead load	(deflection due to dead load)	
deflection at prestress transfer			dd =	0.029	m.
dps =	-0.062	m.	At transfer =	-0.033	m.
(c) Growth in storage			(d) S.Imposed dead load	(deflection due to S.impe.dl.)	
Camber component at erection	-0.062	m.	dsd =	0.014	m.
			Net after construction =	-0.048	m.
(e) Long term dead load			(f) Live load deflection		
(dd * 2.70) =	0.077	m.	=	0.003	m.
(dps * 2.45) =	-0.152	m.			
(dsd * 3.00) =	0.041	m.	Allow. deflection =	0.025	m.
>>> Net long term =	-0.034	m.		OK	



รูปที่ 4.4

แสดงผลการออกแบบจากโปรแกรม

โปรแกรมออกแบบ

T - beam

bridge

T-BEAM BRIDGE DESIGN

>>>>>> This program is for study purpose only <<<<<<<

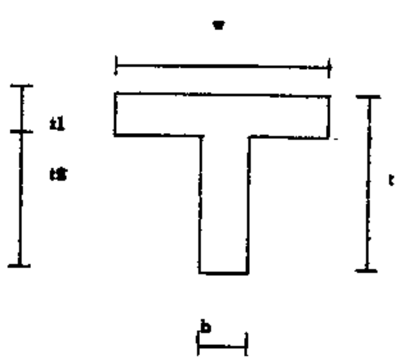
1> Design Conditions

Span length (L) =	15	m.	Loads		
Width of bridge (B) =	8	m.	(1) H15		
Number of lanes (Nl) =	2		(2) HS15		
			(3) H20		
			(4) HS20		
			Design live load no. >>	4	

2> Materials

Concrete			Reinforcing Steel		
fc' =	280	ksc.	yield strength (fy) =	[illegible]	ksc.
fc =	112	ksc.	allowable stress (fs) =	1,800	ksc.
Ec =	252,902	ksc.	Modulus of elasticity (Es)=	2,040,000	cm^2
			ratio of elasticity (n) =	8	
			(k) =	0.332	
			(j)	0.889	

3> Sectional Properties

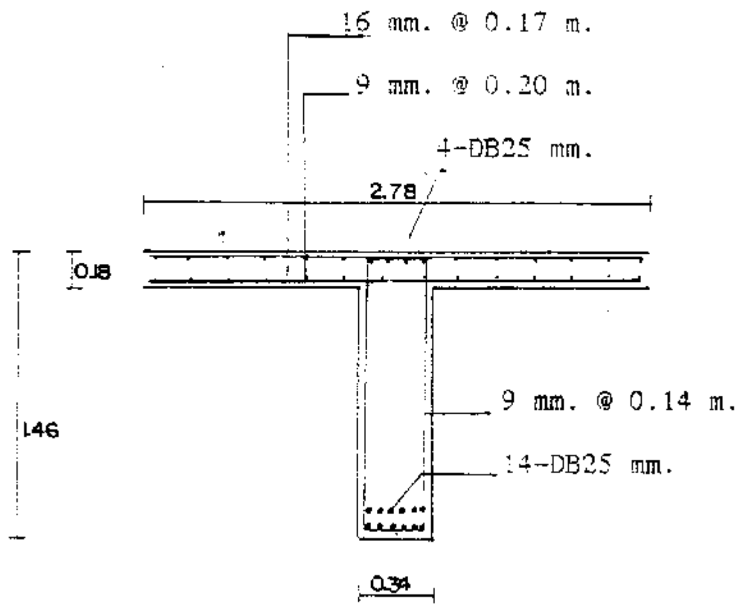


w =	2.78	m.
b =	0.34	m.
t1 =	[illegible]	m.
t2 =	[illegible]	m.
t =	1.46	m.
No. of beams (Nb) =	3	
Av.stringer spacing (s) =	2.78	
Ac =	0.95	
Yb =	1.036	m.
Yt =	0.428	m.
I =	0.1869	m.^4

4- Slab Design					
Dead load			Live load		
Slab =	442	kg/m./m.	Ml =	1,839	kg-m./m.
span =	2.44	m.	Live load Impact (i) =	0.29	=< 0.30
Md =	263	kg-m./m.	*Ml* =	2,368	kg-m.
Main reinforcement (positive & negative moment)			Dist. reinforcement		
Moment =	2,631	kg-m./m.	Area of steel rq. (A*s) =	2	cm.^2/m.
Area of steel rq. (As) =	11	cm.^2	diameter of steel (d*s) =	9	mm.
diameter of steel (ds) =	16	mm.	sectional area (a*s) =	0.636	cm.^2
sectional area (as) =	2.011	cm.^2	Spacing of steel (s*) =	0.283	m.
dist. top fiber to c.of steel (d) =	0.15	m.			
Number of steel (Ns) =	6				
Spacing of steel (s) =	0.17	m.	Concrete stress =	79	ksc.
			<< fc	OK	
5- Check Shear					
Dead load			Live load		
(Vd) =	539	kg.	Vl =	7,342	kg./m.
			Live load Impact (i) =	0.29	=< 0.30
			VL =	9,453	kg./beam
Shear strength V =	9,992	kg.			
permis.shear cr.by concrete =	4.22	ksc.			
Shear provd. by concrete =	33,107	kg.			
Vc > V	OK				

6- Design for Loads and Moment					
Dead load			Live load		
T-beam =	2,272	kg/m.	Ml =	86,807	kg-m./lane
Side walk & rail =		kg/m.	Live load Impact (i) =	0.300	=< 0.30
Total =	2,272	kg/m.	Load fraction (dw) =	1.447	
Md =	63,904	kg-m.	*Ml* =	81,656	kg-m.
Tension Steel			Compression steel		
Moment =	145,559	kg-m.	Mc =	110,286	kg.-m.
dist. top fiber to c.of steel (d) =	1.40	m.	M' =	35,273	kg.-m.
Area of steel sq. (As) =	65	cm.^2	dist.com.-tension steel =	1.30	m.
diameter of steel (ds) =	25	mm.	As' =	15.074	cm.^2
sectional area (as) =	4.911	cm.^2	diameter of steel (ds) =	25	mm.
Number of steel (Ns) =	14		sectional area (as) =	4.911	cm.^2
			Number of steel (Ns) =	4	
7- Design for Shear					
Dead load			Live load		
T-beam =	2,272	kg/m.	Vl =	26,535	kg-m./lane
Side walk & rail =		kg/m.	Live load Impact (i) =	0.30	=< 0.30
Total =	2,272	kg/m.	Load fraction (dw) =	1.521	
Vd =	17,041	kg.	*VL* =	26,230	kg./beam
Shear strength V =	43,271				
permis.shear cr.by concrete =	4.22	ksc.	diameter of steel (ds) =	9	mm.
Shear provd. by concrete =	20,072	kg.	sectional area (av) =	1.273	cm.^2
Vs =	23,200	kg.	*Spacing* =	0.14	m.
Av =	9	cm.^/m.			

Deflections	▼	+			
Dead Loads					
yd =	0.003	m.			
Live Load / Lane			Live Load /beam		
p1 =	14,685	kg.	p1	10,626	kg.
p2 =	14,685	kg.	p2	10,626	kg.
p3 =	3,671	kg.	p3	2,656	kg.
>> *Case 1#*			>> *Case 2#*		
d1 =	0.002	m.	d1 =	0.001	m.
d2 =	0.001	m.	d2 =	0.002	m.
d3 =	0.000	m.	d3 =	0.000	m.
Total =	0.003	m.	Total =	0.002	m.
>> *Case 2#*			Live Load deflection		
d1 =	0.002	m.	=	0.003	m.
d2 =	0.002	m.			
d3 =	0.000	m.			
Total =	0.003	m.	Allow. deflection =	0.019	m.
				OK	



รูปที่ 4.5

รูปแสดงหน้าตัดคานจากผลการออกแบบของโปรแกรม

โปรแกรมออกแบบ

precast prestressed

I - beam

with cast-in-place deck slab

I-BEAM DESIGN

with cast-in-place deck slab

>>>>>> This program is for study purpose only <<<<<<

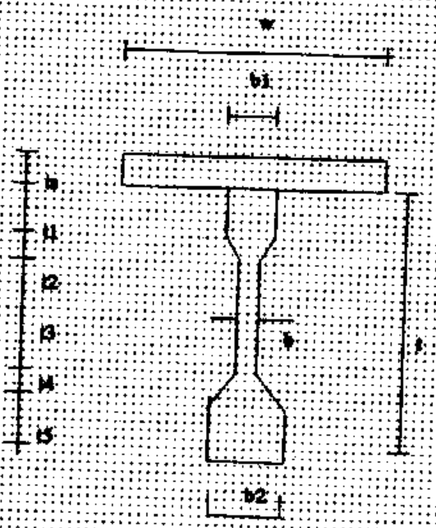
1> Design Conditions

Span length (L) =	22.8	m.	Loads	
Width of bridge (B) =	10.0	m.	(1) H15	
Number of lanes (Nl) =	2		(2) HS15	
Number of beams(Nb) =	4		(3) H20	
Spacing of beams (s) =	2.45	m.	(4) HS20	
			Design Live load no. >>	4

2> Materials

precast concrete			cast-in-place concrete		
			fc' =	280	ksc.
fc' =	350	ksc.	fc =	112	
fc'i =	280	ksc.	Ecs =	252,902	ksc.
Ec =	282,753	ksc.	Nc =	0.894	(Ecs/Ec)
Prestressing Steel			Reinforcing Steel		
			f's =	2,400	ksc.
diameter d =	12.7	mm.	fs =	1,200	ksc.
f's =	18,985	ksc.	n =	8	(Es/Ec)
as =	0.987	cm^2	k =	0.427	
			j =	0.858	

Sectional Properties



Section of Beam

w	=	2.450	m.
ts	=	[illegible]	m.
t1	=	[illegible]	m.
t2	=	[illegible]	m.
t3	=	[illegible]	m.
t4	=	[illegible]	m.
t5	=	[illegible]	m.
t	=	1.350	m.
b	=	[illegible]	m.
b1	=	[illegible]	m.
b2	=	[illegible]	m.

Beams Properties

Area	*A*	=	0.4963	m^2
	yb	=	0.6155	m.
	yt	=	0.7345	m.
	I	=	0.0946	m^4
	Sb	=	0.1538	m^3
	St	=	0.1288	m^3

Composite properties

	Nc	=	0.894	
Area	*Ac*	=	0.9126	m^2
	ycb	=	0.9939	m.
	yct	=	0.5260	m.
	Is	=	0.0014	m^4
	Ic	=	0.2604	m^4
	Scb	=	0.2620	m^3
	Sct	=	0.4951	m^3

[illegible]					
Dead load			Live load		
slab =	456	kg/m.	Ml =	1,544	kg-m./m.
span =	1.950	kg/m.	Live load Impact I =	0.300	
Md =	173	kg-m./m.	*Ml* =	2,007	kg-m./m.
Main reinforcement (positive & negative moment)			dist. reinforcement		
Moment =	2,180	kg-m./m.	Area of steel rq. (As) =	9	cm.^2
dis.top fiber to cg.of steel (d) =	[illegible]	m.	diameter of steel (ds) =	[illegible]	mm.
Area of steel rq. (As) =	13	cm.^2	Sectional area (as) =	0.636	cm.^2
diameter of steel (ds) =	12	mm.	Number of steel (n) =	14	
Sectional area (as) =	1.131	cm.^2	Spacing of steel (s) =	0.14	m.
Number of steel (n) =	12				
Spacing of steel (s) =	0.08	m.	Concrete stress =	46	ksc.
			< fc	OK	
6- Check Shear					
Dead load			Live load		
Vd =	445	kg.	Vl =	7,342	kg./m.
			impact (I) =	0.300	
			VL =	9,545	kg.
Shear strength V =	9,989	kg.			
per.shear provd.by concrete =	4.22	ksc.			
Shear provided by concrete =	34,187	kg.			
Vc > V	OK				

[illegible]					
Dead load			Live load		
girder (Wg) =	1,191	kg./m.	Ml =	148,633	kg-m./lane
slab (Ws) =	1,117	kg/m.	Live load Impact (I) =	0.251	
Side Walk & Rail (Wr) =	[illegible]	kg/m.	Mf =	185,889	kg-m./lane
Moment due to girder (Mg) =	77,391	kg-m.	dist.of wheel load (dw) =	1.462	
Moment due to Slab (Ms) =	72,596	kg-m.	ML =	135,883	kg.-m./beam
Moment due to S.& R.(Mr) =	33,140	kg-m.			
Moment due to DL. (Md) =	149,987	kg-m.			
[illegible]					
Bottom fiber			Top fiber		
girder =	50	ksc.	girder =	60	ksc.
girder + slab =	98	ksc.	girder + slab =	116	ksc.
Side walk & rail =	13	ksc.	Side walk & rail =	13	ksc.
Live Load =	52	ksc.	Live Load =	27	ksc.
Total (fb) =	212	ksc.	Total (ft) =	217	ksc.
Limits of prestress	Bottom fiber			Top fiber	
Initial					
Total stress =	110	ksc.	Total stress =	129	ksc.
Allowable stress =	168	ksc.	Allowable stress =	39	ksc.
Required prestress =	(58)	ksc.	Required prestress =	90	ksc.
Final					
Total stress =	149	ksc.	Total stress =	157	ksc.
Allowable stress =	30	ksc.	Allowable stress =	140	ksc.
Required prestress =	120	ksc.	Required prestress =	17	ksc.
dist.cg.of steel to bottom fiber =	[illegible]	m.	>> Use steel diameter	[illegible]	mm.
Strand eccentricity =	0.515	(yb-e)	as =	0.987	cm.^2
Effective prestress force after loss			Assuming =	[illegible]	% loss
Pse =	222,895	kg.	Final prestress per strand	10,497	kg.
			Number of strand required =	22	
			Try number of strands >>>>	24	

8- Flexural strength					
Combinations of loads (AASHTO. 3.22)					
	Mu =	533,068	kg-m.		
Approximate Value for stress in prestressed reinforcement					
	f*su =	18,639	kg.		
	p* =	0.00067			
	@Mu =	665,598	kg-m.		
@Mu > Mu	OK				
9- Maximum and Minimum Steel Percentage					
Maximum Steel (AASHTO 9.18.4)			Minimum Steel (AASHTO 9.18.2)		
reinforcement index =	0.036		fcr =	37.20	ksc.
			Pse =	230,939	kg.
			Mcr =	163,574	kg.-m.
reinforcement index < 0.30		OK	@ Mu / Mcr > 1.2	OK	
10- Prestressed Losses					
(a.) Shrinkage			(b) Elastic shortening		
Rh =	70	%	Psi =	259,806	kg.
Sh =	460	ksc.	fcir =	83	ksc.
			Eci =	252,902	ksc.
			Es =	647	ksc.
(c) Creep of concrete			(d) Relaxation of Prestressing Steel		
fcds =	19	ksc.	1. stress relieved strand		
CRc =	862	ksc.	2. low relaxation strand		
(e) Total loss of Prestress			>>>> Use (1 or 2)	1	
Sh + Es + Crc + Crs =	3,092	ksc.	CRs =	1,123	ksc.
Dfs =	23.27	%			
Effective prestress	fse =	10,197	ksc.		

11) Concrete Stresses					
			Mg =	77,391	kg-m./beam
Psi =	259,806	kg.	Ms =	72,596	kg-m./beam
Pse =	221,500	kg.	Md =	149,987	kg-m./beam
e =	0.515	m.	Mr =	33,140	kg-m./beam
			Ml =	135,883	kg-m./beam
Ac =	0.913	m.^2	A =	0.496	m.^2
Ic =	0.260	m.^4	I =	0.095	m.^4
Scb =	0.262	m.^3	Sb =	0.154	m.^3
Sct =	0.495	m.^3	St =	0.129	m.^3
		Span end at Prestress Transfer		Midspan at service Load	
LOAD		P = Psi		P = Pse	
		fb	ft	fb	ft
P/A		52	52	45	45
Pe/S		87	(104)	74	(89)
Md/S		(50)		(57)	30
Ml/S				(65)	34
Total Stress		89	(52)	(3)	20
Allowable Stress		0.6f'ci	1.988(f'ci)^0.5	1.59(f'c)^0.5	0.4f'c
(AASHTO 9.15.2)		168	-33.26	-29.76	140.00
		ok	Debonded is rq. +	ok	ok
			[illegible]		
12) Shear Strength					
Vd =	16,064	kg./beam.	(WL/2)		
vl =	28,622	kg/lane	from Table		
Vl =	26,167	kg/beam	included impact & fraction		
Vu =	77,691	kg/beam	1.3(Vd+1.67Vl)		
Vc =	327,116	kg.			
Vs =	-	kg.	Use		
>> Av =	-	cm.^2/m.	diameter d =	[illegible]	mm.
Av minimum =	6	cm.^2/m.	av =	1.273	cm^2
			s =	0.22	m.

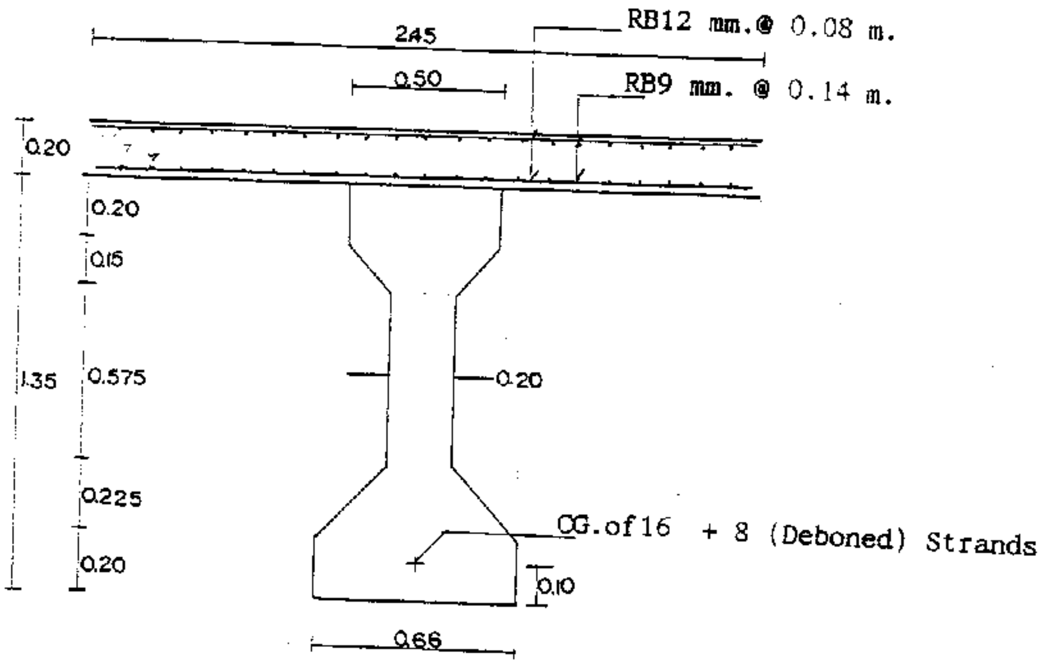
[illegible]	▼	+			

SUGGESTED MULTIPLIERS TO BE USED AS A GUIDE IN ESTIMATING:

LONG - TIME CAMBERS AND DEFLECTIONS FOR TYPICAL MEMBERS

Deflection to be considered	without composit topping	with composit topping
At erection		
(1). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	1.85	1.85
(2). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestress	1.80	1.80
At Final		
(3). Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	2.70	2.40
(4). Camber (upward) component - apply to the elastic Camber due to prestress at the time of release of prestess	2.45	2.20
(5). Deflection (downward) - apply to elastic deflection due to superimpose dead load only	3.00	3.00
(6). Deflection (downward) - apply to elastic deflection Caused by composite topping		2.30

(a) Prestress at transfer			**(b) Beam dead load (deflection due to dead load)**		
deflection at prestressed transfer			dd =	0.016	m.
dps =	-0.036	m.	At transfer =	-0.021	m.
(c) Growth in storage			**(d) S.imposed dead load**	(deflection due to s.imp. dl.)	
Camber component at erection	-0.0383	m.	dsd =	0.0027	m.
			Net after construction =	-0.0356	m.
(e) Long term dead load			**(f) Live load deflection**		
(dd * 2.70) =	0.042	m.	=	0.0082	m.
(dps * 2.45) =	-0.089	m.			
(dsd * 3.00) =	0.008	m.	Allow. deflection =	0.0285	m.
>>> Net long term =	-0.039	m.		OK	



รูปที่ 4.6

แสดงผลการออกแบบจากโปรแกรม