

Date: _____

Class: _____

Assignment: _____

NON COMPOSITE CMD + GRAVEL

LENGTH = 70 ft

TWO STRIPED LANES

USER VEHICLE

DIAPHRAM @ ϕ

AASHTO 9th UPDATED WITH AASHTO 10th



Date: _____

Class: _____

Assignment: _____

DESIGN EXAMPLE

NON-COMPOSITE

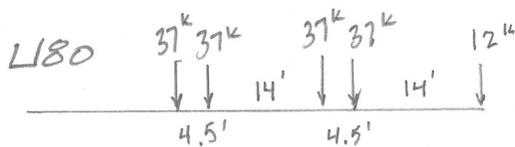
THIS IS A FICTITIOUS BRIDGE TO SHOW THE CALCULATIONS

OWNER WANTS 32 FT ROADWAY WIDTH

RAILINGS / BARRIERS ARE 1 FT

NUMBER OF STRIPED LANES = 2

ESTIMATED OVERTHANG IS 15% OF GIRDER SPACING



$F_y = 50 \text{ ksi}$ $L = 70 \text{ ft}$

CORRUGATED METAL DECK + GRAVEL
80 psf - (MD) 6000 FOR 6 FT

DECKING DOES NOT BRACE FLANGES

WEARING SURFACE 25 psf

RAILINGS / BARRIERS 75 lb/ft
50% TO CRITICAL GIRDER

ADD'L DC, LOADING = 30 lb/ft
100% TO CRITICAL GIRDER

CONSTRUCTION $W = 275 \text{ lb/ft}$
 $P = 3000 \text{ lb}$

5% MISC. STEEL FOR DIAPHRAGMS

FATIGUE $ADT_{SL} = 200$

USER TRUCK L180 LOGGING

USE STRENGTH II LLF = 1.35
NO LANE LOAD
USE SINGLE LANE LLDF
IMPACT FACTOR = 1.33

Bridge Layout

Bridge Length (ft)	70		Type of Bridge			NonComposite
Roadway Width (ft)	32		Bridge Width = Roadway Width + 2 * Barrier Width			
Number Striped Lanes	2					
Barrier Width (ft)	1					
Est. Overhang = XX% GS	15%					
	Number of Girders	Girder Spacing (ft)	Overhang	Roadway Width	Bridge Width	
	4	10.30	1.55	32.00	34.00	
	5	7.91	1.19	32.00	34.00	
	6	6.42	0.96	32.00	34.00	
	7	5.40	0.81	32.00	34.00	
	8	4.66	0.70	32.00	34.00	
	9	4.10	0.61	32.00	34.00	
	10	3.66	0.55	32.00	34.00	
	11	3.30	0.50	32.00	34.00	
	12	3.01	0.45	32.00	34.00	
	13	2.76	0.41	32.00	34.00	
Cross Section Trial						
Number of Girders	Girder Spacing	Calculated Overhang	Overhang	Roadway	Bridge	
7	5.25	1.25	1.25	32.00	34.00	
Overhang = 23.8% of Girder Spacing						
8.00 ft of Shoulder						

NonComposite Bridge Information

Type of Decking	Corrugated Metal Deck (gravel or other)
DC1 Deck Only Loading (psf)	80

Composite Bridge Information

Deck Fc (psi)	4000	Check For LLDf (Warning if Violation)
Structural Deck Thickness (in)	8	
Sacrificial Concrete Deck (in)	0.5	
Haunch from Top of Web (in)	2	
Stay-in-Place (SIP) Forms?	Yes	
Weight of SIP (psf)	15	
Depth of SIP (in)	2	
Shear Connector Diameter (in)	0.875	
Shear Connector Fu (ksi)	60	
DC1 Deck Only Loading (psf)	108.75	

Fatigue (AASHTO 10th Edition Applied)

Design Life (yrs)	75	
Average Daily Truck Traffic Single Lane (ADTT) _s	200	Fatigue II Controls
If ADTT > 974 Fatigue I Controls		

User Defined Truck? (up to 9 Axles)

1st Axle (kips) and Spacing to Next Axle (ft)	12	14
2nd Axle (kips) and Spacing to Next Axle (ft)	37	4.5
3rd Axle (kips) and Spacing to Next Axle (ft)	37	14
4th Axle (kips) and Spacing to Next Axle (ft)	37	4.5
5th Axle (kips) and Spacing to Next Axle (ft)	37	
6th Axle (kips) and Spacing to Next Axle (ft)		
7th Axle (kips) and Spacing to Next Axle (ft)		
8th Axle (kips) and Spacing to Next Axle (ft)		
9th Axle (kips)		
User Vehicle Live Load Factor	1.35	
Apply Lane Load to User Truck?	No	
Single Lane or 2 or More Lane Distribution Factor?	Single Lane	
User Vehicle Impact Factor for Str I / Serv II Design	1.38	

Line Girder Dead Loading

DC1 Girder Deck (lb/ft)	388.6
DC2 Barrier (lb/ft)	37.5
DC1 (no stl) + Additional DC1 (lb/ft)	418.6
DC2 + Additional DC2 (lb/ft)	37.5
DW (lb/ft)	114.3
Add'l DC1 on Bridge (Overhang, Haunch, Utilities, etc) (lb/ft)	30
Max % on Additional DC1 on Girder	100%
DC2 Barrier Load (lb/ft)	75
Max % on Girder	50%
Add'l DC2 on Bridge Utilities, etc) (lb/ft)	0
Max % Additional DC2 on Girder	100%
Wearing Surface (psf)	25
% Misc Stl for Diaphragms, etc	5%

Construction Loading

AT END OF OVERHANG FOR LATERAL BENDING	May be 0 for many types of decking
Construction w (lb/ft)	275
Construction p (lb)	3000
1/2 of Deck Overhang Weight (lb/ft)	50

ADDITIONAL CONSTRUCTION VERTICAL BENDING ON GIRDER

Construction w (lb/ft)	275
Construction p (lb)	3000

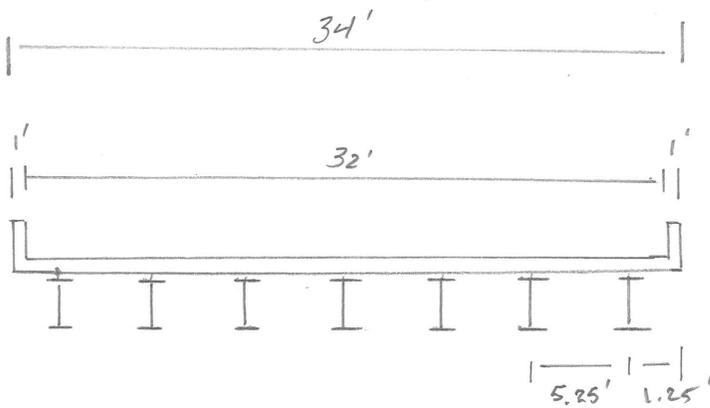
CHOOSE 7 GIRDERS @ 5'-3" SPACING

OVERHANG = 1'-3"

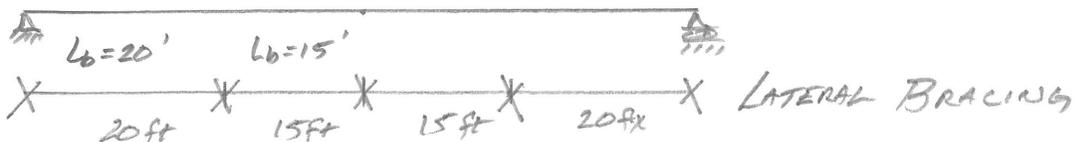
SHARE BARRIER 50% EXT & 50% INT/INTERIOR

OVERHANG 23.8% GS

24 ft LANES + 8 ft SHOULDER AVAILABLE



L = 70 ft



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DC₁ LOADING

$$\frac{80 \text{ psf}(34)}{7} = 388.6 \text{ lb/ft}$$

$$\text{ADD'L DC}_1 = 30 \text{ lb/ft}$$

$$\text{TOTAL DC}_1 = 418.6$$

DC₂ LOADING

$$\text{EXTERIOR} = 75 \text{ lb/ft}(0.5) = 37.5 \text{ lb/ft}$$

$$\text{INTERIOR} = 75 \text{ lb/ft}(1-0.5) = 37.5 \text{ lb/ft}$$

$$\text{TOTAL DC}_2 = 37.5 \text{ lb/ft}$$

DW LOADING

$$\frac{25 \text{ psf}(32)}{7} = 114.3 \text{ lb/ft}$$

$$\text{TOTAL DW} = 114.3 \text{ lb/ft}$$

ADD'L VERTICAL BENDING FOR CONSTRUCTION LOADING

$$W = 275 \text{ lb/ft}$$

$$P = 3000 \text{ lb}$$

CAN USE W40 OR W44

$$\frac{L}{d_{\text{MAX}}} = 25 \quad d_{\text{MIN}} = 12'' \quad d_{\text{MAX}} = 44''$$

DEFLECTION LIMIT $\frac{L}{800}$

COMPRESSION FLANGE NOT BRACED

USE AASHTO APPENDIX A6

Yield Strength (ksi)	50	Consider W40 & W44?	Yes
Bridge Length (ft)	70	Limit Maximum L/D to	25 $d \geq 33.6$
Girder Spacing (ft)	5.25	For Diaphragms Min Depth (in) (If want min WXX use XX)	12 $\geq W12$
Number of Girders	7	For Approach/Clearance Max Depth (in) (If want max WXX use XX)	44 $\leq W44$
Overhang (23.8% of Girder Spacing) (ft)	1.25	x for Deflection Limit in L/x (If Deflections not Considered enter Low Number)	800
Barrier Width (ft)	1	Is Compression Flange Fully Braced For Construction?	No
Lateral Bracing Locations in Span (ft)		Is Compression Flange Fully Braced For Final State?	No
Enter Support Bracing at End of Span (ft)		Maximum Accepted Performance Ratio	1.00
Distance from End to 1ST Brace (ft) = 0	0	Override Calculated Lateral Distribution Factors?	No
Distance from End to 2nd Brace (ft)	20	Single Lane Moment	
Distance from End to 3rd Brace (ft)	35	Two Lane Moment	
Distance from End to 4th Brace (ft)	50	Fatigue Moment	
Distance from End to 5th Brace (ft)	70	Single Lane Shear	
Distance from End to 6th Brace (ft)		Two Lane Shear	
Distance from End to 7th Brace (ft)			
Distance from End to 8th Brace (ft)			
Use AASHTO Appendix A.6 for Strength? (No Limits Strengths to AASHTO 6.10.8)	Yes		
Calculate Cb Factors or Use $C_b = 1$?	Calc Cb		

Bridge Width (ft) 34
 Roadway Width (ft) 32
 Shoulders (ft each side) 4 Double for One-Sided Shoulder
2 Striped Lanes and 2 Design Lanes

ANYTIME A VALUE IS CHANGED IN THE YELLOW, HIT RUN DESIGN FOR UPDATED RESULTS

Run Design

Lightest 10 Sections (see to the right for additional Information)

Str I, Serv II, Constr	Fatigue	Deflection	L/D	Defl	Mn/My	Weight (tons)
W40X183	W40X183	W40X183	21.5	L/1054	0.99	44.8
W36X194	W36X194	W36X194	23.0	L/966	1.01	47.5
W40X199	W40X199	W40X199	21.7	L/1190	1.06	48.8
W33X201	W33X201	W33X201	24.9	L/926	1.07	49.2
W36X210	W36X210	W36X210	22.9	L/1054	1.02	51.5
W40X211	W40X211	W40X211	21.3	L/1238	1.00	51.7
W40X215	W40X215	W40X215	21.5	L/1334	1.07	52.7
W33X221	W33X221	W33X221	24.8	L/1030	1.08	54.1
W44X230	W44X230	W44X230	19.6	L/1661	1.07	56.4
W36X231	W36X231	W36X231	23.0	L/1246	1.08	56.6

If No Section is Shown that Meets all the Criteria, See Sections to the Right

If No Sections are Shown to the Right, There is No W Section that Meets Design and Criteria

If Mn/My is Low (~0.70 is Elastic LTB), Lighter Section Possible with Cross-Frame Changes for Unbraced Lengths

Yield Strength (ksi)	50	Bridge Width (ft)	34.00	Consider W40 & W44 Beams?	Yes
Bridge Length (ft)	70	Roadway Width (ft)	32.00	L/D Limited to	25
Girder Spacing (ft)	5.25	Shoulders (ft) each side - Double for One Sided	4.00	Minimum Depth Beam (in)	W12
Number of Girders	7	2 Striped Lanes and 2 Design Lanes		Maximum Depth Beam (in)	W44
Overhang (23.8% of Girder Spacing) (ft)	1.25				
Barrier Width (ft)	1				
Barrier Load on Girder (lb/ft)	37.5	50% to Exterior Girder		NonComposite Design Deck is Corrugated Metal Deck (gravel or other)	
DC Deck Only Loading (psf)	80				
Wearing Surface (psf)	25				
Additional DC1 Load on Girder (lb/ft)	30				
Additional DC2 Load on Bridge (lb/ft)	0				
AT OVERHANG FOR LATERAL FLANGE BENDING					
Construction w (lb/ft)	275				
Construction p (lb)	3000				
1/2 of Deck Overhang Weight (lb/ft)	50				
ADDITIONAL VERTICAL BENDING ON GIRDERS					
Exterior - Construction p (lb)	3000				
Exterior - Construction w (lb/ft)	275				
% Misc Stl for Diaphragms, etc	5%				
DEFLECTION LIMIT (x for Deflection Limit in L/x)	800				

AASHTO HL93 Loading and User Defined Vehicle With
 LF=1.35 IM=1.33 Lane=No LLD=Single Lane

Strength Design Uses AASHTO Appendix A6

Unbraced Length #	1	Lb	20.00	Cb	1.47
	2		15.00		1.03
	3		15.00		1.03
	4		20.00		1.47

Fatigue Design Life (yrs) 75
Fatigue ADTT_{SL} 200 Fatigue II Controls

Limit States Checked
 Strength I & II
 Service II
 Constructability
 Fatigue
 Deflection

Section	L/D	Uniform Load w/Stl for DC1 (lb/ft)	Deflect L/Num	Girder Weight (tons)	Mn/My	Shear PR	STRENGTH I/II SERVICE II Constructability				Controlling	Fatigue Fatigue II Controls (ADTT) _{SL} = 200		Deflection PR	Overall for all criteria Maximum PR
							Strength I PR	Service II PR	Constructabil PR	Maximum PR		Section PR	Section PR		
W40X183	21.5	610.7	L/1054	44.8	0.99	0.25	0.96	0.89	0.32	0.96	Strength I/II	W40X183 0.57	W40X183 0.76	0.96	Strength I/II
W36X194	23.0	622.3	L/966	47.5	1.01	0.23	0.96	0.91	0.32	0.96	Strength I	W36X194 0.57	W36X194 0.83	0.96	Strength I/II
W40X199	21.7	627.5	L/1190	48.8	1.06	0.25	0.79	0.78	0.26	0.79	Strength I	W40X199 0.50	W40X199 0.67	0.79	Strength I/II
W33X201	24.9	629.6	L/926	49.2	1.07	0.27	0.88	0.88	0.30	0.88	Service II	W33X201 0.55	W33X201 0.86	0.88	Service II
W36X210	22.9	639.1	L/1054	51.5	1.02	0.21	0.88	0.84	0.29	0.88	Strength I	W36X210 0.53	W36X210 0.76	0.88	Strength I/II
W40X211	21.3	640.1	L/1238	51.7	1.00	0.22	0.82	0.77	0.27	0.82	Strength I	W40X211 0.48	W40X211 0.65	0.82	Strength I/II
W40X215	21.5	644.3	L/1334	52.7	1.07	0.25	0.71	0.71	0.24	0.71	Strength I	W40X215 0.45	W40X215 0.60	0.71	Strength I/II
W33X221	24.8	650.6	L/1030	54.1	1.08	0.25	0.79	0.80	0.27	0.80	Service II	W33X221 0.50	W33X221 0.78	0.80	Service II

W40X183

STRENGTH I/II PR = 0.96 ← CONTROLS DESIGN
 SERVICE II PR = 0.89
 CONSTRUCTION PR = 0.34
 FATIGUE II PR = 0.57 FINITE
 DEFLECTION PR = 0.76 $\frac{L}{1054}$



Date: _____

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NOMINAL MOMENTS (ft-k)

REACTIONS (k)

DC₁ (NO SL) + DC₂

228.0

279.3

16.01

DW

57.1

70

4.0

HL93 + LANE + IMP

1433

1701

105.4

USER TRUCK + IMP

2276.7

2685.6

132.7

FATIGUE

832.7 @ CRITICAL DIAPHRAGM

ADD'L CONSTR

180.4

220.9

Name: _____

Date: _____

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Assignment: _____

LATERAL DISTRIBUTION FACTORS

4.6.2.2.2c

MOMENT INTERIOR BEAM

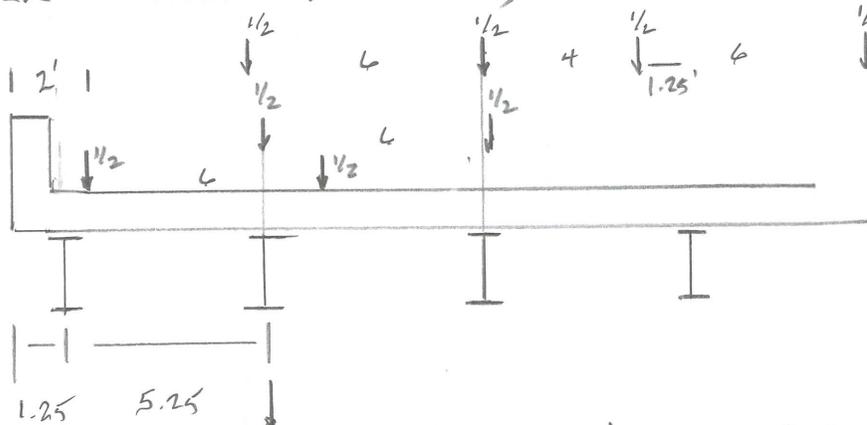
FOR $S \leq 5.5$

TABLE
4.6.2.2.2c -)

SINGLE LANE $\frac{S}{9.2} = \frac{5.25}{9.2} = 0.571$

MULTI-LANE $\frac{S}{9} = \frac{5.25}{9} = 0.583$

LEVER RULE NOT APPLICABLE, BUT SHOWN HERE



MDF = 1.2 SINGLE
1.0 TWO
0.8 > 2

SINGLE LANE $g = \frac{1}{2} \times 1.2 = 0.60$

TWO LANE $g = (\frac{1}{2} + \frac{1.25}{5.25} \frac{1}{2}) \times 1.0 = 0.619$

NOT USED
HERE
SINCE
 $S < 5.5$

FATIGUE = $\frac{\text{SINGLE LANE}}{1.2} = 0.476$

MOMENT	SINGLE	0.571
INTERIOR	TWO	0.583
	FATIGUE	0.476

4.6.2.2.3 INTERIOR SHEAR, USE LEVER RULE

SINGLE	0.600
TWO	0.619

Date: _____

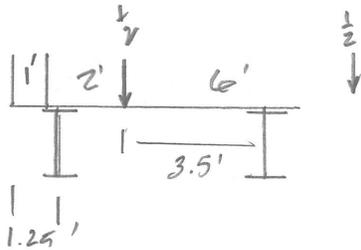
Class: _____

Assignment: _____

MOMENT EXTERIOR BEAM

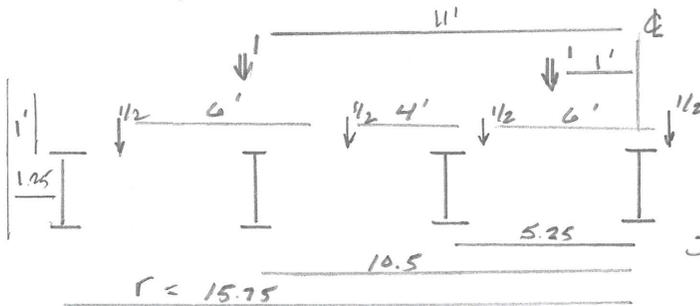
4.6.2.2.2d

LEVER RULE



$$\text{SINGLE LANE } g = \frac{1}{2} \left(\frac{3.5}{5.25} \right) * 1.2 = 0.400$$

RIGID ROTATION ANALYSIS



$$R = \frac{N_L}{N_D} + \frac{K_{ext} \sum E_i}{\sum X_i^2}$$

$$\sum E_i^2 = 2 [9.25^2 + 10.5^2 + 15.75^2] = 771.75$$

$$\text{SINGLE } g = \left[\frac{1}{7} + \frac{11(15.75)}{771.75} \right] * 1.2 = 0.441$$

$$\text{TWO } g = \left[\frac{2}{7} + \frac{(11+1)15.75}{771.75} \right] * 1.0 = 0.531$$

USE MAXIMUM FOR INTERIOR & EXTERIOR - CONSERVATISM

MOMENT SINGLE $g = 0.571$

TWO OR MORE $g = 0.583$

FATIGUE $g = 0.476$

SHEAR SINGLE $g = 0.600$

TWO OR MORE $g = 0.619$

FOR C_b USE $g = 0.619$

MAX RIGID
& INT LEVER

Date: _____

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Assignment: _____

LTB C_b FACTORS USES AASHTO 10th EDITION

IN $L_b = 20'$ $C_b = \frac{12.5 M_{max}}{2.5 M_{max} + 3 M_A + 4 M_B + 3 M_C}$

1st UNBRACED
 $L_b = 20$ ft

C_b BASED ON
 DC_1, DC_2, DW
+ HL93
MOMENTS
(NOT USER TRUCK)

$1.25(DC_1 + DC_2) + 1.5DW + 1.75(HL93 + IM)LLDF$

LLDF = 0.619

NO SELF WT
STL IN DC_1
FOR C_b

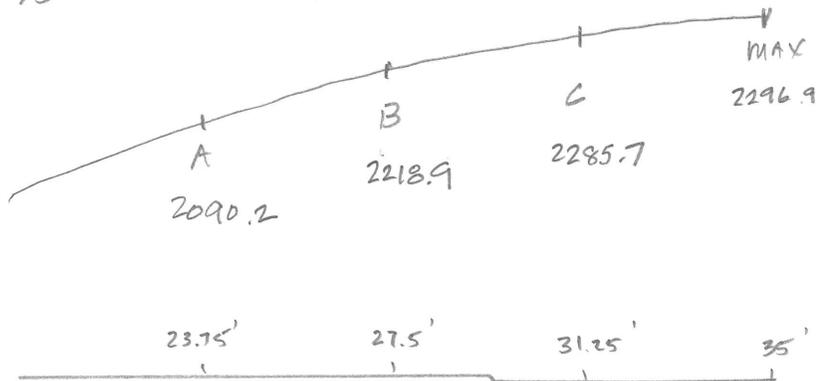
FOR LLDF, USE
MAX FOR
EXT. LEVER RULE
AND
INTERIOR LEVER RULE
AND
RIGID ROTATION

	A	B	C	MAX
	645.7	1181.4	1607.1	1922.9
	5'	10'	15'	20'
$1.25(DC_1 + DC_2) + 1.5DW$	120.5	222.5	305.9	370.8
$1.75 HL93 + IM LLDF$	525.2	958.9	1301.2	1552

AASHTO
10th EDITION

$C_b = \frac{12.5(1922.9)}{2.5(1922.9) + 3(645.7) + 4(1181.4) + 3(1607.1)} = 1.475$

IN $L_b = 15'$



	A	B	C	MAX
	2090.2	2218.9	2285.7	2296.9
	23.75'	27.5'	31.25'	35'
$1.25(DC_1 + DC_2) + 1.5DW$	407.3	433.3	449	454.2
$1.75 HL93 + IM LLDF$	1682.9	1785.6	1836.7	1836.9

$C_b = \frac{12.5(2296.9)}{2.5(2296.9) + 3(2090.2) + 4(2218.9) + 3(2285.7)} = 1.035$

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W40 x 18.3 ϕ NUMERICAL MOMENTS ON GIRDER

EXTRA $DC_1 = 0.183(1.05) = 0.192$

MOMENTS A SHEAR

$DC_1 + STL$ 228 + 279.3 16.01 +

+ 5% STL $0.192 \left(\frac{20(20)}{2} - \frac{20^2}{2} \right) + 0.192 \frac{(20)^2}{8}$ $0.192 \left(\frac{20}{2} \right) = 22.7$

+ DC_2 = 324 = 397

DW 57.1 70 4

ADD'L CONSTR 180.4 220.9 X

HL93+1M 1433 (0.583) 1701 (0.583) 105.4 (0.619)^{TWO}

* LLDF 835.4 991.7 65.2

(0.583)
TWO

USER+1M 2276.7 (0.57) 2485.9 (0.570) 172 (0.600)^{SINGLE}

* LLDF = 1297.7 = 1531 103.2

(0.570)
SINGLE

C_b 1.475 1.035

AT ϕ 1.75 HL93+1M LLDF = 1.75(991.7) = 1735.5

1.35 USER+1M LLDF = 1.35(1530.8) = 2066.6 ← USER TRIL CONTROLS

$M_u =$ V_u

1.25 ($DC_1 + DC_2$) 2245^{1K} 2670^{1K} 173.7^{1K}

+ 1.5 DW

+ 1.35 USER+1M ϕ CRITICAL FOR FATIGUE HL93+1M^{15%} = 832.7

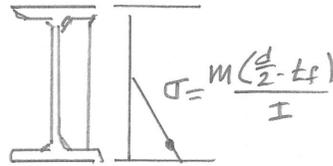
* LLDF LLDF = 0.475 FATIGUE $M = 832.7 (0.475) = 395.5^{1K}$

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STIFFENER
TYPE C'
FATIGUE
DETAIL



$ADT_{SL} = 200$ IS LESS THAN
AASHTO 10th ED LIMIT OF
INFINITE LIFE

CHECK FOR FINITE LIFE $\delta_L = 0.80$

$$N = 365 (75445) (1) (200) = 5.475 \times 10^6 \text{ CYCLES/TRK}$$

STRESS FROM 0.80 LL+IM = $0.80 \cdot 395.5' \times 12'' \cdot \left(\frac{34}{2 - 1.20} \right) = 5.27 \text{ ksi}$
13200

FOR DETAIL C' $(AF)_n = \left(\frac{A}{N} \right)^{1/3} = \left(\frac{44 \times 10^8}{5.475 \times 10^6} \right)^{1/3} = 9.30 \text{ ksi}$

PERFORMANCE RATIO = $\frac{5.27}{9.30} = 0.567$
FATIGUE OK.

DEFLECTION CHECK

LINE LOAD DEFL $\leq \frac{L}{800} = 1.125''$

BEST FIT POLYNOMIAL FOR DEFLECTION OF TWO DESIGN LANE BRIDGE
* NUMBER OF GIRDERS * I_x

$$C = 2.8 \times 10^{-6} L^5 - 0.00094 L^4 + 0.3585 L^3 - 7.0859 L^2 + 46.369 L$$

MPF FOR

DEFL

2 LANE MPF = 1

3 LANE MPF = 0.85

4 LANE MPF = 0.65

$C = 73626.98$ L IN FT
 $A = \frac{\text{MPF} * C \left(\frac{L}{2} \right)}{\text{NUMBER GIRDERS} * I_x} = \frac{1 (73627) \left(\frac{L}{2} \right)}{7 (13200)} = 0.80''$

PERFORMANCE RATIO = $\frac{0.80}{1.125} = 0.71$

DEFLECTION O.K.



Name: _____

Date: _____

Class: _____

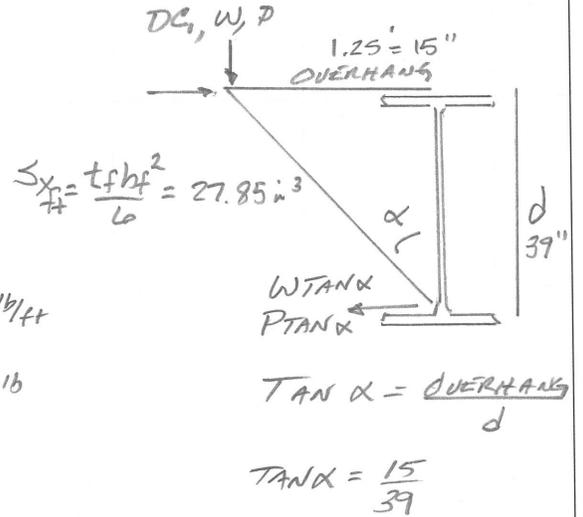
Assignment: _____

CONSTRUCTION Use 1.25 DC₁ + 1.50 CONSTR. LOADING FOR LATERAL LOADING ON FLANGE

FLANGE LATERAL BENDING $f_{l1} = \frac{M_l}{S_x f_1}$
ASSUME BRACED BETWEEN BRACE PTS

$DC_1 = \frac{1}{2}$ OF OVERHANG = $\frac{30(1.25)}{2} = 50 \frac{lb}{ft}$
 $W_{CL} = 275 \frac{lb}{ft}$ $P_{CL} = 3000 \frac{lb}{ft}$

$$M_l = \frac{(1.25 DC_1 + 1.50 W_{CL}) T \text{AN} \alpha L_b^2}{12} + \frac{1.50 P_{CL} T \text{AN} \alpha L_b}{8}$$



$S_{x \frac{1}{4}} = \frac{t f h^2}{6} = 27.85 \text{ in}^3$

$(1.25 DC_1 + 1.50 W_{CL}) T \text{AN} \alpha = 475 \left(\frac{15}{39} \right) = 182.7 \frac{lb}{ft}$
 $1.50 P_{CL} T \text{AN} \alpha = 4500 \left(\frac{15}{39} \right) = 1730.8 \frac{lb}{ft}$

For $L_b = 20'$ $M_l = \frac{0.1827(20)^2}{12} + \frac{1.731(20)}{8} = 10.42 \text{ k'}$

$f_{l1} = \frac{10.42(12)}{27.85} = 4.49 \text{ ksi}$

For $L_b = 15'$ $M_l = \frac{0.1827(15)^2}{12} + \frac{1.731(15)}{8} = 6.67 \text{ k'}$

$f_{l1} = \frac{6.67(12)}{27.85} = 2.87 \text{ ksi}$

STRONG AXIS BENDING WITH ADDITIONAL VERTICAL CONSTR. LOADING
1.25 DC₁ + 1.50 CONSTR. LOADING

1ST ORDER LATERAL FLANGE BENDING

$S_x = 675 \text{ in}^3$

For $L_b = 20'$ $1.25(324) + 1.50(180.4) = 675.6 \text{ k'}$

$f_{bu} = \frac{675.6(12)}{S_x} = 12.01 \text{ ksi}$

For $L_b = 15'$ $1.25(397) + 1.50(220.9) = 827.6$

$f_{bu} = \frac{827.6(12)}{S_x} = 14.71 \text{ ksi}$

2nd ORDER (P-S) LATERAL FLANGE AMPLIFICATION FACTOR

$$AF = \frac{0.85}{1 - \frac{f_{bu}}{\left(\frac{C_b \pi^2 E}{(L_b/r_x)^2}\right)}} \geq 1 \quad \text{THEN } f_l = AF f_l$$

$r_{L_b} = 3.04"$ USED FOR r_x
 $R_b = 1$ FOR ROLLED SHAPES

FOR $L_b = 20'$ $C_b = 1.475$ $f_{bu} = 12.01 \text{ ksi}$

$$AF = \frac{0.85}{1 - \frac{12.01}{\left(\frac{1.475 \pi^2 29000}{\left(\frac{20 \times 12}{3.04}\right)^2}\right)}} = 1.03$$

$$f_l = 1.03(4.49) = 4.64 \text{ ksi}$$

REQUIREMENT

$$f_l < 0.6F_y \quad \checkmark$$

FOR $L_b = 15'$ $C_b = 1.035$ $f_{bu} = 14.71 \text{ ksi}$

$$AF = \frac{0.85}{1 - \frac{14.71}{\left(\frac{1.035 \pi^2 29000}{\left(\frac{15 \times 12}{3.04}\right)^2}\right)}} = 1.03$$

$$f_l = 1.03(2.87) = 2.95 \text{ ksi}$$

$$f_l < 0.6F_y \quad \checkmark$$

DESIGN FLANGE YIELDING CHECK $f_{bu} + f_l < F_y$

$$\text{FOR } L_b = 20' \quad 12.01 + 4.64 = 16.65 < F_y \quad pr = \frac{16.65}{50} = 0.33$$

$$\text{FOR } L_b = 15' \quad 14.71 + 2.95 = 17.66 < F_y \quad pr = \frac{17.66}{50} = 0.35$$

Date: _____

Class: _____

Assignment: _____

DESIGN FLANGE LTB $f_{bu} + \frac{1}{3} f_l \leq F_{nc}$ $F_{nc} = \frac{M_{nc}}{S_x}$

W40x183

M_{nc} FOR LTB

A6.2

$$\lambda_{ws} = \frac{2D_{cp}}{t_{ws}} = \frac{2 \left(\frac{39}{2} - 1.2 \right)}{0.65} = 56.3 < \lambda_{p0.5F_y} = \frac{\sqrt{E}}{F_y} \left(0.54 \frac{M_P}{M_y} - 0.09 \right)^2$$

$$= \frac{\sqrt{29000}}{50} = 86$$

$$\left(0.54 \frac{3225}{2813} - 0.09 \right)^2$$

$$\leq \lambda_{rw} \left(\frac{D_{cp}}{D_c} \right) = 5.7 \sqrt{\frac{E}{F_y}} = 137$$

$$\therefore R_{pc} = \frac{M_P}{M_y} = \frac{3225}{2813} = 1.146$$

A6.3.3 AASHTO 10th EDITION

$$L_p = 1.07 E \sqrt{\frac{E}{F_y}} = 1.1 (3.04) \sqrt{\frac{29000}{50}} = 80.53'' = 6.71'$$

$$L_r = 1.95 E \sqrt{\frac{J}{F_y S_x h}} \sqrt{1 + \sqrt{1 + 6.76 \left(\frac{F_y S_x h}{E J} \right)^2}}$$

$F_{yr} = 0.7 F_y = 35 \text{ ksi}$

$$= 1.95 (3.04) \frac{29000}{35} \sqrt{\frac{19.3}{675 (37.8)}} \sqrt{1 + \sqrt{1 + 6.76 \left(\frac{35 \cdot 675 (37.8)}{29000 \cdot 19.3} \right)^2}} = 310'' = 25.84'$$

2.295

For $L_b = 20' < L_r$ $C_b = 1.475$ $F_{yr} = 0.7 F_y$

$$M_{nc} = C_b \left[1 - \left(1 - \frac{0.7 F_y S_x}{R_{pc} M_y} \right) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right] R_{pc} M_y = 1.475 \left[1 - \left(1 - \frac{0.7}{1.146} \right) \left(\frac{20 - 6.71}{25.84 - 6.71} \right) \right] \times 1.146 (2813)$$

$$M_{nc} = 1.475 (0.729) (1.146) 2813 \leq 1.233 (2813) = 3469 \text{ k} \leq R_{pc} M_y = 3225 \text{ k}$$

$$M_{nc} = 3225 \text{ k}$$

$$F_{nc} = \frac{M_{nc}}{S_x} = 57.33 \text{ ksi}$$



Date: _____

Class: _____

Assignment: _____

$$f_{bu} + \frac{1}{3}f_r = 12.01 + \frac{4.64}{3} = 13.56 < F_{nc} = 57.33$$

$$pr = \frac{13.56}{57.33} = 0.24$$

FOR $L_b = 15'$ $C_D = 1.035$

$$M_{nc} = 1.035 \left[1 - \left(1 - \frac{0.7}{1.146} \right) \left(\frac{15 - 6.71}{25.84 - 6.71} \right) \right] 1.146 (2813)$$

$$M_{nc} = 1.035 (0.831) (1.146) 2813 = 0.860 (1.146) 2813 = 2773.8 \text{ k}$$

USED $M_{nc} = 2773.83 \text{ k}$ $F_{nc} = 49.3 \text{ ksi}$

$$f_{bu} + \frac{1}{3}f_r = 14.71 + \frac{2.95}{3} = 15.69 < F_{nc} = 49.3$$

$$pr = \frac{15.69}{49.3} = 0.32$$

CONSTRUCTION O.K.



Name: _____

Date: _____

Class: _____

Assignment: _____

SERVICE II LIMIT AT ϕ

$$DC_1 + DC_2 + DW + 1.30 \text{ MAX}$$

{ USER TRIL + IM
LLDF
HL93 + IM
LLDF }

$$\text{STRESSES} \leq 0.80F_y$$

$$DC_1 + 5\% + DC_2 = 397.1^k$$

$$DW = 70$$

$$HL93 + IM + LLDF = 1761 (0.583) = 991.7$$

$$USER + IM * LLDF = 2072 (0.571) = 1183.1 \leftarrow \text{CONTROLS}$$

$$\text{SERVICE II } M_s = 397 + 70 + 1.30(1183.1) = 2004^k$$

$$f_s = \frac{2004(12)}{675} = 35.63 \text{ ksi} \leq 0.80F_y = 40 \text{ ksi}$$

$$pr = \frac{35.63}{40} = 0.89$$

SERVICE II O.K.



Date: _____

Class: _____

Assignment: _____

STRENGTH I/II DESIGN

FOR $L_b = 20'$ $C_b = 1.475$ $M_n = R_{pc} M_y = M_p = 3225 \text{ 'k}$

$$1.25(DC_1 + 5\% + DC_2) + 1.50 DW + \max \left\{ \begin{array}{l} 1.75 H_{L93} + 1M \cdot LLOF \\ 1.35 User + 1M \cdot LLOF \end{array} \right\}$$

$$= 1.25(324) + 1.50(57.1) + \max \left\{ \begin{array}{l} 1.75(1433)(0.583) = 1462.0 \\ 1.35(2216.7)(0.571) = 1755 \end{array} \right\} = 2245.6 \text{ 'k}$$

PREVIOUS $M_n = R_{pc} M_y = 3225$

$$pr = \frac{2245.6}{3225} = 0.70$$

FOR $L_b = 15'$ $C_b = 1.035$ $M_n = R_{pc} M_y = 2774 \text{ 'k}$

$$1.25(397) + 1.50(70) + \max \left\{ \begin{array}{l} 1.75(1701)(0.583) = 1735.4 \\ 1.35(2685.6)(0.571) = 2070.2 \end{array} \right\} = 2671.4 \text{ 'k}$$

$$pr = \frac{2671.4}{2774} = 0.96$$

STRENGTH I/II OK



Date: _____

Class: _____

Assignment: _____

SHEAR $1.25(DC_1 + 5\% + DC_2) + 1.50DW + \max \left\{ \begin{array}{l} 1.75HL93 + 1M \cdot LLDF \\ 1.35USER + 1M \cdot LLDF \end{array} \right\}$

$$V_u = 1.25(22.7) + 1.50(4) + \left\{ \begin{array}{l} 1.75(105.4)(0.619) = 114.2 \\ 1.35(172.0)(0.600) = 139.3 \end{array} \right\} = 173.7^k$$

$$\frac{D}{t_w} = \frac{39 - 2(1.2)}{0.65} = 56.3$$

$$V_n = C V_p$$

$$V_p = 0.58 F_y D t_w$$

IF $\frac{D}{t_w} < 1.12 \sqrt{\frac{E K}{F_y}}$ $K=5$

$$V_p = 0.58(50)(39 - 2(1.2))0.65 = 689.9^k$$

$$= 1.12 \sqrt{\frac{29000(5)}{50}} = 60$$

THEN $C = 1$

$$\phi V_n = 689.9^k > V_u = 173.7^k$$

$$PR = \frac{173.7}{689.9} = 0.25$$

SHEAR O.K.

Date: _____

Class: _____

Assignment: _____

SUMMARY - ALL MATCH PROGRAM.

STRENGTH I/II PR = 0.96 2nd L_b

SERVICE II PR = 0.89 ϕ

CONSTRUCTION PR = 0.35 2nd L_b

FATIGUE II PR = 0.57 ϕ STIFFENER

DEFLECTION PR = 0.76 4/1050

SHEAR PR = 0.25 SUPPORT

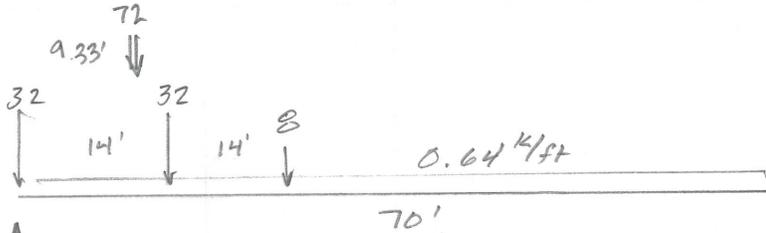
Date: _____

Class: _____

Assignment: _____

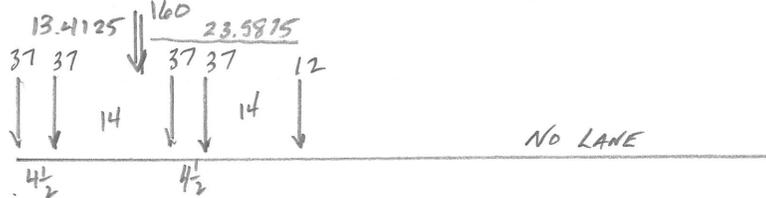
ABUTMENT LOADS

HL93
+1M



$$R = \frac{70 - 9.33}{70} (72) (1.33) + \frac{0.64(70)}{2} = 105.4^k$$

USER
+1M



$$R = \frac{70 - 13.4125}{70} (160) (1.33) = 172.0^k$$

MPF

SINGLE	1.2
TWO	1.0
THREE	0.85
FOUR	0.65

ASSUME ADD'L DC₁, DC₂
AT CENTERLINE

DC₁

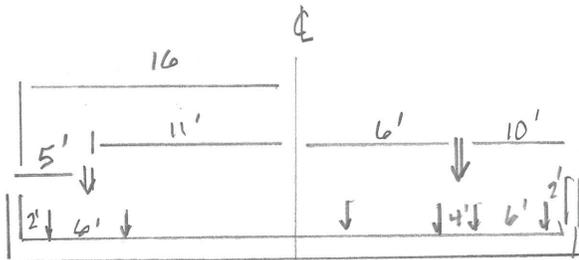
$$[80(34) + 30 + 7(183)(1.05)] \frac{70}{2} = 143.3^k$$

DC₂

$$[75 \times 2 + 0] \frac{70}{2} = 5.25^k$$

DW

$$[25(32)] \frac{70}{2} = 28.0^k$$



SINGLE LANE
USER TRUCK
CONTROLS

$$172 \times 1.2 = 206.4 @ 11ft$$

TWO LANE
(DONT USE USER
TRUCK - SINGLE
LANE)

$$2 \times 105.4 @ 6ft$$

W40X183 NonComposite

Overall IFR = 1.953 - strength I/II

Yield Strength (ksi)	50
Bridge Length (ft)	70
Bridge Spacing (ft)	5.25
Number of Girders	7
Overhang (23.8% of Girder Spacing) (ft)	1.25
Barrier Width (ft)	1
Barrier Load on Girder (lb/ft)	37.5
DC Deck Only Loading (psf)	80
Wearing Surface (psf)	25
Additional DC1 Load on Girder (lb/ft)	30
Additional DC2 Load on Bridge (lb/ft)	0
AT OVERHANG FOR LATERAL FLANGE BENDING	0
Construction w (lb/ft)	275
Construction p (lb)	3000
1/2 of Deck Overhang Weight (lb/ft)	50
ADDITIONAL VERTICAL BENDING ON GIRDERS	
Exterior - Construction p (lb)	3000
Exterior - Construction w (lb/ft)	275
% Misc Stl for Diaphragms, etc	5%
DEFLECTION LIMIT (x for Deflection Limit in L/x)	800
Fatigue Design Life (yrs)	75
Fatigue ADTSL	200 Fatigue II Controls

Consider W40 & W44 Beams? Yes

L/D limited to 25

Bridge Width (ft)	34.00
Roadway Width (ft)	32.00
Shoulders (ft) each side - Double for One Sided	4.00
2 Striped Lanes and 2 Design Lanes	
Deck is Corrugated Metal Deck (gravel or other)	
Nominal Girder DC1 (lb/ft)	610.7
Nominal Girder DC2 (lb/ft)	37.5
Nominal Girder DW (lb/ft)	114.3
AASHTO HL93 Loading and User Defined Vehicle With	
LF=1.35 IM=1.33 Lane=No LLD=Single Lane	
1st Axle (kips) and Spacing to Next Axle (ft)	12 14
2nd Axle (kips) and Spacing to Next Axle (ft)	37 4.5
3rd Axle (kips) and Spacing to Next Axle (ft)	37 14
4th Axle (kips) and Spacing to Next Axle (ft)	37 4.5
5th Axle (kips) and Spacing to Next Axle (ft)	37

Minimum Depth Beam W12

Maximum Depth Beam W44

Lateral Distribution Factors

Single Lane/Multi-Lane

Moment LLDLDF = 0.571, 0.583

Fatigue LLDLDF = 0.476

Shear LLDLDF = 0.600, 0.619

SERVICE II near Centerline

DC1 (ft-k)	374.1	Sx=675.0 in^3
DC2 (ft-k)	23.0	Sx=675.0 in^3
DW (ft-k)	70.0	Sx=675.0 in^3
HL93 LL+IM (ft-k) LLF = 1.75	992.4	Sx=675.0 in^3
User LL+IM (ft-k) LLF = 1.35	1532.5	Sx=675.0 in^3
Serv II Stress	35.6	User Truck Loading Controls
Serv II Allow	40.0	
SERVICES I/II PP	0.891	
LIVE LOAD DEFLECTION		lx=13200 in^4
LL Defl (in)	0.80	= L/1054
Allowable (in)	1.05	= L/800
SERVICES I/II PP	0.753	
FATIGUE Cat C' at Critical Brace		
Fat Moment (ft-k) LLF = 0.8	396.0	Sfat=721.3 in^3
Fat Stress (ksi)	5.27	
Fat Allow (ksi)	9.30	
FATIGUE PP	0.567	
STRENGTH I/II SHEAR at Support		
DC1 (k)	22.7	
DC2 (k)	1.3	
DW (k)	4.0	
HL93 LL+IM (k) LLF = 1.75	65.2	
User LL+IM (k) LLF = 1.35	103.2	
Vu (k)	173.7	User Truck Loading Controls
Vn (k)	689.9	
SHEAR PP	1.036	

Strength Design Uses AASHTO Appendix A6 **STRENGTH I/II**

	Lb (ft)	DC1 (ft-k)	DC2 (ft-k)	DW (ft-k)	LLF = 1.75	LLF = 1.35	User Truck Loading Controls		Mn (ft-k)	Perf Ratio
1	20	305.4	18.75	57.1	835.8	1299.2	2244.8	1.48	3225.0	0.696
2	15	374.1	22.96875	70.0	992.2	1532.5	2670.2	1.03	2773.8	0.963
3	15	374.1	22.96875	70.0	992.4	1532.5	2670.2	1.03	2773.8	0.963
4	20	305.4	18.75	57.1	835.6	1299.2	2244.8	1.48	3225.0	0.696

Strength Design Uses AASHTO Appendix A6 **CONSTRUCTION**

	Lb (ft)	Mconstr (ft-k)	Mlat (ft-k)	AF	Affl (ksi)	Perf Ratio	fbu+Affl (ksi)	Perf Ratio	fbc+1/3Affl (ksi)	Fnc (ksi)	Perf Ratio
1	20	675.7	10.4	1.0	4.6	0.15	16.6	0.33	13.6	57.3	0.24
2	15	827.7	6.7	1.0	3.0	0.10	17.7	0.35	15.7	49.3	0.32
3	15	827.7	6.7	1.0	3.0	0.10	17.7	0.35	15.7	49.3	0.32
4	20	675.7	10.4	1.0	4.6	0.15	16.6	0.33	13.6	57.3	0.24

DEAD LOAD DEFLECTIONS

	Distance (ft)	0	0.10L	0.20L	0.30L	0.40L	0.50L	0.60L	0.70L	0.80L	0.90L	L
lx (in^4) = 13200.0	DC1 (in)	0.000	0.271	0.512	0.701	0.821	0.862	0.821	0.701	0.512	0.271	0.000
lx (in^4) = 13200.0	DC2 (in)	0.000	0.017	0.031	0.043	0.050	0.053	0.050	0.043	0.031	0.017	0.000
lx (in^4) = 13200.0	DW (in)	0.000	0.051	0.096	0.131	0.154	0.161	0.154	0.131	0.096	0.051	0.000
	Total (in)	0.00	0.34	0.64	0.87	1.02	1.08	1.02	0.87	0.64	0.34	0.00

NOMINAL ABUTMENT REACTIONS

DC1 (k)	144.9	At Centerline
DC2 (k)	5.3	At Centerline
DW (k)	28.0	At Centerline
Single Lane LL+IM (k)	206.4	At 11.00 From Centerline
Two Lane LL+IM (k)	210.8	At 6.00 From Centerline

