Georgia Department of Transportation

COMPUTER MANUAL
FOR
SERVICE LOAD DESIGN
OF
CONCRETE BRIDGE SLABS

BRSLAB99

ORIGINAL FORTRAN IV - 1971
GLENN H. SIKES, P.E.

REVISIONS 1986 - 1996
EDWARD J. STROUGAL, JR., P.E.

REVISED 1999 AND CREATED MANUAL
JUDY L. MEISNER, E.I.T.

OFFICE OF BRIDGE AND STRUCTURAL DESIGN

ATLANTA, GEORGIA
January 1999

TABLE OF CONTENTS

DISCLAIMER

Although this program has been subjected to many rigorous tests – all with excellent results – no warranty, expressed or implied, is made by the Georgia Department of Transportation as to the accuracy and functioning of the program; nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the Georgia Department of Transportation in any connection therewith.

REVISIONS

January 1999

Judy L. Meisner, E.I.T.

Revisions to BRSLAB:

- Renamed BRSLAB to BRSLAB99
- Added an option for omitting the continuity factor
- Added check for minimum slab thickness
- Added header to program
- Retitled column headers
- Removed "FLANGE WIDTH" option
- Corrected calculation of n, modular ratio
- Adjusted calculation of the Dead Load Moment to use the "Actual Slab Thickness"

FOREWORD

This program was originally written by Glenn H. Sikes, P.E. in 1971.

From 1986 through 1996, Edward J. Strougal, Jr., P.E. made revisions as needed to the program.

PROGRAMMING ASSUMPTIONS

1. Service Load Design Method (Allowable Stress Method)
   Balanced Design -- no compression reinforcement considered.
   Article 8.15

2. Case A - Main Reinforcement Perpendicular to Traffic
   Article 3.24.3.1 Spans from 3.5 to 12 feet in 1-inch increments

3. Design is based on the effective span length by 1' width of slab.

4. Impact value is 30%.
   Article 3.8.2.1 Maximum of 30%

5. Weight of concrete:
   Article 8.7.1 145 pcf for calculating the modulus of elasticity
   Article 3.3.6 150 pcf for computing the dead load moment

6. The bottom slab cover is 1".

7. Assumed value used to compute initial slab thickness (first iteration) is based on the sum of the following:
   Top slab cover
   Diameter of a #5 reinforcement bar
   Diameter of a #4 reinforcement bar
   3/4" clearance between top and bottom mats of reinforcement steel
   Diameter of a #4 reinforcement bar
   Diameter of a #5 reinforcement bar
   1" bottom slab cover

8. Distribution reinforcement steel is one bar size smaller than main reinforcement steel.

9. Bar size for main reinforcement steel used to compute initial slab thickness is #5.

10. Bar size for distribution reinforcement steel used to compute initial slab thickness is #4.

11. Minimum main reinforcement spacing is 5". When the required spacing is less than 5", the size of the main reinforcement steel and the distribution reinforcement steel is increased by one bar size.

INPUTS

The program was written to prompt the user for inputs. This is a discussion of these inputs.

1. **Enter the output file name:**
   The file name should not exceed 14 characters and should include a period. The program will create the output with this file name, which may be printed or typed to the screen.

2. **How many wheel loadings do you want?**
   The program will accept up to 5 different wheel loadings.

3. **Enter wheel loading(s) in kips: 16 [for H 20]:**
   The Office of Bridge and Structural Design current policy is to design all concrete bridge slabs for H 20 loading.

Article 3.24.3	P = 16 kips for H 20 loading
	P = 12 kips for H 15 loading

4. **How many top covers do you want?**
   The program will accept up to 5 different covers.

5. **Enter top cover(s) in inches: 2, 2.25, 2.5, 2.75**
   The Office of Bridge and Structural Design current policy is to select the top cover based on the location of the bridge and the type of route.

6. **How many future paving weights do you want?**
   The program will accept up to 5 different future paving weights.

7. **Enter future paving weight(s) in kips/ft^2: .015, .03**
   The Office of Bridge and Structural Design current policy is to select the future paving weight based on the type of route.

8. **How many allowable reinforcement stresses , fs, do you want?**
   The program will accept up to 5 different allowable steel stresses.

9. **Enter allowable reinforcement stress(es), fs, in ksi: 24 [for Grade 60] reinforcement**
   The Office of Bridge and Structural Design current policy is to design all concrete bridge slabs with Grade 60 reinforcement.

Article 8.15.2.2	fs = 24 ksi for Grade 60 reinforcement
	fs = 20 ksi for Grade 40 reinforcement

10. How many allowable concrete stresses, fc, do you want?
The program will accept up to 5 different allowable concrete stresses.

11. Enter allowable concrete stress(es), fc, in ksi: 1.4 [for f'c = 3.5 ksi]
The Office of Bridge and Structural Design current policy is to design all concrete bridge slabs with f'c = 3.500 ksi.

Article 8.15.2.1.1	fc = .4f'c
	fc = 1.4 ksi for f'c = 3.5 ksi
	fc = 1.2 ksi for f'c = 3.0 ksi

12. Use continuity factor? Enter Y for yes or N for no
If the continuity factor is in use, the dead load and live load moments will be reduced by 20%.

Article 3.24.3.1	In slabs continuous over three or more supports, a continuity factor of 0.8 shall be applied. Otherwise, the continuity factor is 1.

OUTPUTS

If the user selects 2 or more wheel loadings, covers, future paving weights, allowable reinforcement stresses, or allowable concrete stresses, the program will create a series of tables.

At the beginning of each table the design data will be printed. The design data consists of the standard header for the Bridge Office, the time and date, inputs and n, modular ratio. The distribution reinforcement in the outer quarters is the total number of bars in both quarters and will always be an even number.

```
              SERVICE LOAD DESIGN OF BRIDGE SLAB

             Georgia Department of Transportation              20-JAN-99
            Office of Bridge and Structural Design              07:49:13
                         January 1999
```

WHEEL LOAD (kips)	fc (ksi)	fs (ksi)	n	SLAB COVER (in)	FUTURE PAVING (ksf)	CONTINUITY FACTOR
16.00	1.400	24.000	9	2.250	0.030	0.8

Following the design data and at the top of each page will be the output data.

EFFECTIVE SPAN LENGTH (ft-in)	SLAB THICKNESS		SIZE AND SPACING OF MAIN REINFORCEMENT (in)	DISTRIBUTION REINFORCEMENT	
	MINIMUM (in)	ACTUAL (in)		MIDDLE HALF	OUTER QUARTERS
3- 6	6.3090	6.375	#5 AT 8.375	3-#4	2-#4

The following page shows the slab details for this output example.

SERVICE LOAD DESIGN OF BRIDGE SLAB

Georgia Department of Transportation
Office of Bridge and Structural Design

19-JAN-99
10:46:24

January 1999

WHEEL LOAD (kips)	fc (ksi)	fs (ksi)	n	SLAB COVER (in)	FUTURE PAVING (ksf)	CONTINUITY FACTOR
16.00	1.400	24.000	9	2.250	0.030	0.8

EFFECTIVE SPAN LENGTH (ft-in)	SLAB THICKNESS MINIMUM (in)	SLAB THICKNESS ACTUAL (in)	SIZE AND SPACING OF MAIN REINFORCEMENT (in)	DISTRIBUTION REINFORCEMENT MIDDLE HALF	DISTRIBUTION REINFORCEMENT OUTER QUARTERS
3- 6	6.3090	6.375	#5 AT 8.375	3-#4	2-#4
3- 7	6.3400	6.375	#5 AT 8.125	3-#4	2-#4
3- 8	6.3709	6.375	#5 AT 8.000	3-#4	2-#4
3- 9	6.4030	6.500	#5 AT 8.125	3-#4	2-#4
3-10	6.4336	6.500	#5 AT 8.000	3-#4	2-#4
3-11	6.4641	6.500	#5 AT 7.875	4-#4	2-#4
4- 0	6.4944	6.500	#5 AT 7.750	4-#4	2-#4
4- 1	6.5261	6.625	#5 AT 7.875	4-#4	2-#4
4- 2	6.5562	6.625	#5 AT 7.750	4-#4	2-#4
4- 3	6.5862	6.625	#5 AT 7.625	4-#4	2-#4
4- 4	6.6160	6.625	#5 AT 7.625	4-#4	2-#4
4- 5	6.6474	6.750	#5 AT 7.625	4-#4	2-#4
4- 6	6.6771	6.750	#5 AT 7.625	4-#4	2-#4
4- 7	6.7066	6.750	#5 AT 7.500	4-#4	2-#4
4- 8	6.7360	6.750	#5 AT 7.375	4-#4	2-#4
4- 9	6.7672	6.875	#5 AT 7.500	4-#4	2-#4
4-10	6.7964	6.875	#5 AT 7.375	5-#4	4-#4
4-11	6.8255	6.875	#5 AT 7.250	5-#4	4-#4
5- 0	6.8545	6.875	#5 AT 7.125	5-#4	4-#4
5- 1	6.8856	7.000	#5 AT 7.250	5-#4	4-#4
5- 2	6.9144	7.000	#5 AT 7.125	5-#4	4-#4
5- 3	6.9432	7.000	#5 AT 7.125	5-#4	4-#4
5- 4	6.9718	7.000	#5 AT 7.000	5-#4	4-#4
5- 5	7.0028	7.125	#5 AT 7.125	5-#4	4-#4
5- 6	7.0313	7.125	#5 AT 7.000	5-#4	4-#4
5- 7	7.0597	7.125	#5 AT 6.875	5-#4	4-#4
5- 8	7.0880	7.125	#5 AT 6.875	6-#4	4-#4
5- 9	7.1162	7.125	#5 AT 6.750	6-#4	4-#4
5-10	7.1471	7.250	#5 AT 6.875	6-#4	4-#4
5-11	7.1752	7.250	#5 AT 6.750	6-#4	4-#4
6- 0	7.2032	7.250	#5 AT 6.625	6-#4	4-#4
6- 1	7.2311	7.250	#5 AT 6.625	6-#4	4-#4
6- 2	7.2619	7.375	#5 AT 6.625	6-#4	4-#4
6- 3	7.2898	7.375	#5 AT 6.625	6-#4	4-#4
6- 4	7.3175	7.375	#5 AT 6.500	6-#4	4-#4
6- 5	7.3452	7.375	#5 AT 6.375	7-#4	4-#4
6- 6	7.3728	7.375	#5 AT 6.375	7-#4	4-#4
6- 7	7.4036	7.500	#5 AT 6.500	7-#4	4-#4
6- 8	7.4311	7.500	#5 AT 6.375	7-#4	4-#4
6- 9	7.4586	7.500	#5 AT 6.250	7-#4	4-#4
6-10	7.4859	7.500	#5 AT 6.250	7-#4	4-#4
6-11	7.5168	7.625	#5 AT 6.250	7-#4	4-#4

EFFECTIVE SPAN LENGTH (ft-in)	SLAB THICKNESS MINIMUM (in)	SLAB THICKNESS ACTUAL (in)	SPACING OF MAIN REINFORCEMENT (in)	DISTRIBUTION REINFORCEMENT MIDDLE HALF	DISTRIBUTION REINFORCEMENT OUTER QUARTERS
7- 0	7.5441	7.625	#5 AT 6.250	7-#4	4-#4
7- 1	7.5713	7.625	#5 AT 6.125	8-#4	4-#4
7- 2	7.5985	7.625	#5 AT 6.125	8-#4	4-#4
7- 3	7.6294	7.750	#5 AT 6.125	8-#4	4-#4
7- 4	7.6565	7.750	#5 AT 6.125	8-#4	4-#4
7- 5	7.6835	7.750	#5 AT 6.000	8-#4	4-#4
7- 6	7.7105	7.750	#5 AT 6.000	8-#4	4-#4
7- 7	7.7374	7.750	#5 AT 5.875	8-#4	4-#4
7- 8	7.7684	7.875	#5 AT 6.000	8-#4	4-#4
7- 9	7.7953	7.875	#5 AT 5.875	9-#4	6-#4
7-10	7.8221	7.875	#5 AT 5.875	9-#4	6-#4
7-11	7.8489	7.875	#5 AT 5.750	9-#4	6-#4
8- 0	7.8800	8.000	#5 AT 5.875	9-#4	6-#4
8- 1	7.9067	8.000	#5 AT 5.875	9-#4	6-#4
8- 2	7.9333	8.000	#5 AT 5.750	9-#4	6-#4
8- 3	7.9599	8.000	#5 AT 5.750	9-#4	6-#4
8- 4	7.9865	8.000	#5 AT 5.625	10-#4	6-#4
8- 5	8.0178	8.125	#5 AT 5.750	10-#4	6-#4
8- 6	8.0443	8.125	#5 AT 5.625	10-#4	6-#4
8- 7	8.0708	8.125	#5 AT 5.625	10-#4	6-#4
8- 8	8.0972	8.125	#5 AT 5.500	10-#4	6-#4
8- 9	8.1235	8.125	#5 AT 5.500	10-#4	6-#4
8-10	8.1550	8.250	#5 AT 5.500	10-#4	6-#4
8-11	8.1813	8.250	#5 AT 5.500	10-#4	6-#4
9- 0	8.2076	8.250	#5 AT 5.500	11-#4	6-#4
9- 1	8.2339	8.250	#5 AT 5.375	11-#4	6-#4
9- 2	8.2655	8.375	#5 AT 5.500	11-#4	6-#4
9- 3	8.2918	8.375	#5 AT 5.375	11-#4	6-#4
9- 4	8.3180	8.375	#5 AT 5.375	11-#4	6-#4
9- 5	8.3441	8.375	#5 AT 5.250	11-#4	6-#4
9- 6	8.3702	8.375	#5 AT 5.250	12-#4	6-#4
9- 7	8.4021	8.500	#5 AT 5.375	12-#4	6-#4
9- 8	8.4282	8.500	#5 AT 5.250	12-#4	6-#4
9- 9	8.4542	8.500	#5 AT 5.250	12-#4	6-#4
9-10	8.4803	8.500	#5 AT 5.125	12-#4	6-#4
9-11	8.5123	8.625	#5 AT 5.250	12-#4	6-#4
10- 0	8.5383	8.625	#5 AT 5.125	12-#4	6-#4
10- 1	8.5643	8.625	#5 AT 5.125	13-#4	8-#4
10- 2	8.5903	8.625	#5 AT 5.125	13-#4	8-#4
10- 3	8.6162	8.625	#5 AT 5.000	13-#4	8-#4
10- 4	8.6485	8.750	#5 AT 5.125	13-#4	8-#4
10- 5	8.6744	8.750	#5 AT 5.000	13-#4	8-#4
10- 6	8.7003	8.750	#5 AT 5.000	13-#4	8-#4
10- 7	8.7261	8.750	#5 AT 5.000	14-#4	8-#4
10- 8	8.7587	8.875	#5 AT 5.000	14-#4	8-#4
10- 9	8.7845	8.875	#5 AT 5.000	14-#4	8-#4
10-10	8.8728	8.875	#6 AT 7.000	9-#5	6-#5
10-11	8.9056	9.000	#6 AT 7.000	9-#5	6-#5
11- 0	8.9314	9.000	#6 AT 7.000	9-#5	6-#5
11- 1	8.9572	9.000	#6 AT 6.875	9-#5	6-#5
11- 2	8.9830	9.000	#6 AT 6.875	10-#5	6-#5
11- 3	9.0159	9.125	#6 AT 6.875	10-#5	6-#5
11- 4	9.0417	9.125	#6 AT 6.875	10-#5	6-#5
11- 5	9.0675	9.125	#6 AT 6.750	10-#5	6-#5
11- 6	9.0932	9.125	#6 AT 6.750	10-#5	6-#5
11- 7	9.1189	9.125	#6 AT 6.750	10-#5	6-#5
11- 8	9.1522	9.250	#6 AT 6.750	10-#5	6-#5
11- 9	9.1779	9.250	#6 AT 6.750	10-#5	6-#5
11-10	9.2036	9.250	#6 AT 6.625	10-#5	6-#5
11-11	9.2293	9.250	#6 AT 6.625	10-#5	6-#5
12- 0	9.2628	9.375	#6 AT 6.625	10-#5	6-#5

DEFINITIONS AND DESIGN EQUATIONS

S = effective span length in feet — Article 3.24.3

P = load on one rear wheel of truck in kips — Article 3.24.3

P = 16 kips for H 20 loading
Or
P = 12 kips for H 15 loading

I = impact fraction (maximum 30 percent) — Article 3.8.2.1

I = 1.30

t = thickness of slab in inches

CF = continuity factor — Article 3.24.3.1

CF = .8 In slabs continuous over three or more supports, a continuity factor of .8 shall be applied

if not

CF = 1

f'c = compressive strength of concrete in ksi

f_c = allowable concrete stress in ksi — Article 8.15.2.1.1

$f_c = .4f'_c$

f_s = allowable reinforcement stress in ksi — Article 8.15.2.2

f_s = 24 ksi for Grade 60 reinforcement

f_s = 20 ksi for Grade 40 reinforcement

E_c = modulus of elasticity for concrete in psi — Article 8.7.1

$E_c = (145^{1.5}) * 33 * (f'_c)^{.5}$

E_s = modulus of elasticity for steel reinforcing in psi — Article 8.7.2

E_s = 29,000,000 psi

n = modular ratio rounded to the nearest whole number — Article 8.15.3.4

$n = E_s/E_c$

k and j are Service Load Design Constants and are unitless

$k = f_c / [f_c + (f_s / n)]$

$j = 1 - k / 3$

w_s = uniform load due to slab in ksf

$w_s = (t / 12) * .150$

w_{fp} = uniform load due to future paving in ksf

M_{ll} = live load moment including Impact in k*ft/ft — Article 3.24.3.1

$M_{ll} = [(S + 2) / 32] * P * I$

M_{dl} = dead load moment in k*ft/ft

$M_{dl} = (w_s + w_{fp}) * S^2 / 8$

M_d = design moment in k*ft/ft

$M_d = (M_{ll} + M_{dl}) * CF$

d = distance from extreme compression fiber of the concrete to the centroid of tension reinforcement in inches

d_{min} = minimum d in inches

$d_{min} = [(2 * M_d) / (f_c * k * j * b)]^{.5}$

d_{bm} = diameter of main reinforcement bar in inches

a_{bm} = area of main reinforcement bar in inches

C = top slab cover in inches

$t_{min} = d_{min} + d_{bm} / 2 + C$

Round t_{min} up to the nearest 1/8" increment. If t_{min} doesn't equal t, set t equal to t_{min} and recalculate M_{dl}, M_d, d_{min} and t_{min}; continue this loop until t_{min} equals t

d_{act} = actual d

$d_{act} = t - d_{bm} / 2 - C$

A_s = area of tension reinforcement required to resist M_d in in^2/ft

$A_s = M_d / (f_s * j * d)$

s = main reinforcement bar spacing in inches

$s = [1 / (A_s / 12)]*a_{bm}$

Round down to the nearest 1/8" increment

d_{bd} = diameter of distribution reinforcement bar in inches

a_{bd} = area of distribution reinforcement bar in in^2

% of distribution reinforcement in middle half of the slab span — Article 3.24.10.2

% = 220 / $S^{.5}$ Maximum 67%

$\#b_h$ = number of distribution reinforcement bars in the middle half of the slab span — Article 3.24.10.2

$\#b_h = (\% / 100) * A_s * S / 2$

Round up to nearest whole number

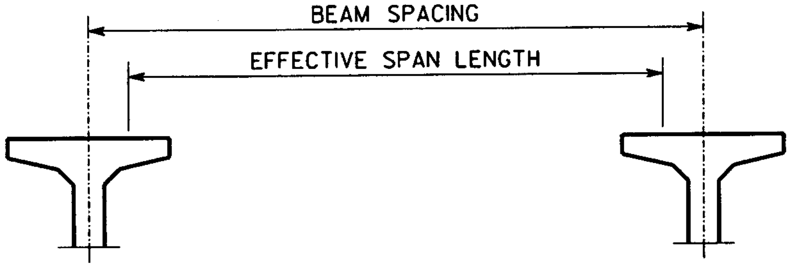
$\#b_o$ = total number of distribution reinforcement bars in both outer quarters of the slab — Article 3.24.10.3

$\#b_o = \#b_h / 2$

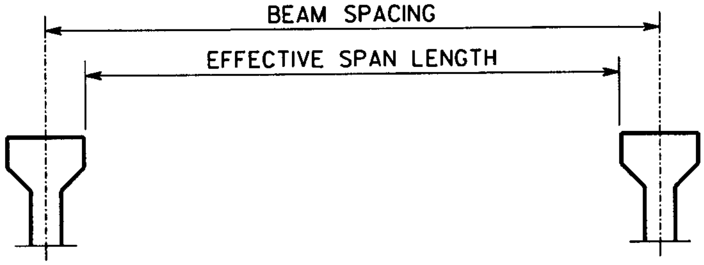
Round up to the nearest even number

$\#b_o/2$ = number of distribution bars in each outer quarter of the slab span

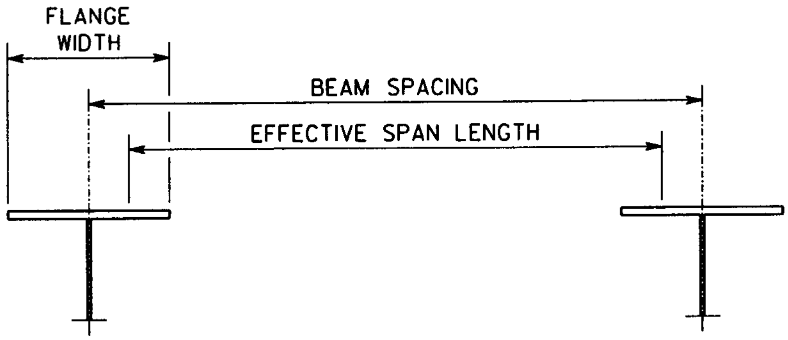
APPENDIX I
CHARTS - EFFECTIVE SPAN LENGTHS FOR SLAB DESIGN



TYPE OF BEAM	EFFECTIVE SPAN LENGTH
PSC TYPE V	BEAM SPACING - 1'-9"
72" BULB TEE	BEAM SPACING - 1'-9"
63" BULB TEE	BEAM SPACING - 1'-9"
54" BULB TEE	BEAM SPACING - 1'-9"



TYPE OF BEAM	EFFECTIVE SPAN LENGTH
PSC TYPE IV	BEAM SPACING - 1'-8"
PSC TYPE III	BEAM SPACING - 1'-4"
PSC TYPE II	BEAM SPACING - 1'-0"
PSC TYPE I MOD	BEAM SPACING - 1'-2"
RCDG	BEAM SPACING - STEM WIDTH



TYPE OF BEAM	EFFECTIVE SPAN LENGTH
W SHAPE	BEAM SPACING - (FLANGE WIDTH)/2
PLATE GIRDER	BEAM SPACING - (FLANGE WIDTH)/2

APPENDIX II
DESIGN CALCULATIONS

DESIGN CRITERIA

GIVEN:

HS20 LOADING
USE CONTINUITY
GRADE 60 REINFORCEMENT
$W_{FP} = 30$ psf
$f'_c = 3500$ psi
$s = 7$ ft
TOP COVER = 2.25 in
BOTTOM COVER = 1 in
USE NORMAL WEIGHT CONCRETE

ASSUME:

	ARTICLE
$P_{20} = 16$ K	3.24.3
$w_c = 145$ pcf for E_c	8.7.1
$w_c = 150$ pcf for w_{SLAB}	8.7.1
$f_s = 24$ ksi	8.15.2.2
$f_c = 0.4 f'_c$	8.15.1.1
$E_c = w_c^{1.5} \cdot 33\sqrt{f'_c}$ psi	8.7.1
$E_s = 29 \times 10^6$ psi	8.7.2
$n = \frac{E_s}{E_c}$ → ROUND UP TO WHOLE #	8.15.3.4

MAIN REINFORCEMENT IS PERPENDICULAR TO TRAFFIC FLOW

INITIAL SLAB THICKNESS IS 8 in

USE #5's FOR MAIN REINFORCEMENT

$$M_{LL} = \left[\frac{S+2}{32}\right] P_{20}$$ 3.24.3.1

CONTINUITY FACTOR, CF = 0.8 — 3.24.3.1

IMPACT = 30% — 3.8.2

USE #4's FOR DISTRIBUTION REINFORCEMENT

$$f_c = 0.4 f'_c = \frac{0.4\,(3500\ psi)}{1000} = 1.4\ ksi$$

$$E_c = 145^{1.5}\,(33)\sqrt{3500}$$

$$E_c = 3408787.7886\ psi$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{3408787.7886} = 8.51 \rightarrow \text{USE } 9$$

$$K = \frac{f_c}{f_c + f_s/n} = \frac{1.4}{1.4 + \frac{24}{9}}$$

$$k = 0.3443$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.3443}{3} = 0.8852$$

$$M_{LL} = I \cdot P_{20}\left[\frac{S+2}{32}\right] = 1.3(16)\left[\frac{7+2}{32}\right]$$

$$M_{LL} = 5.8500\ k \cdot ft/ft$$

$$M_{DL} = \left[\frac{W_{SLAB} + W_{FP}}{1000}\right]\frac{S^2}{8}$$

$$= \left[\frac{(8in)\left(\frac{1ft}{12in}\right)\left(150\frac{lb}{ft^3}\right) + 30\frac{lb}{ft^2}}{1000\ lb/k}\right]\left(\frac{7ft}{8}\right)^2$$

$$M_{DL} = 0.7962\ k \cdot ft/ft$$

$$M_{DESIGN} = (M_{LL} + M_{DL})CF = (5.8500 + 0.7962)0.8$$

$$M_{DESIGN} = 5.3170\ k \cdot ft/ft$$

$$d_{min} = \sqrt{\frac{2\,M_{DESIGN}}{f_c \cdot k \cdot j \cdot b}} = \sqrt{\frac{2(5.3170\text{ k}\cdot\text{ft})\text{ in}^2}{(1.4\text{k})(0.3443)(0.8852)(1\text{ ft})}}$$

$$d_{min} = 4.9922\text{ in}$$

$$t_{min} = 4.9922 + \frac{0.625}{2} + 2.25 = 7.5547$$ → ROUND UP TO NEAREST $\frac{1}{8}$"

$7.625 \neq 8$

CHOOSE ANOTHER SLAB THICKNESS AND ITERATE

ASSUME 7.625 in SLAB

$M_{DL} = 0.7675$

$M_{DESIGN} = 5.2940$

$d_{min} = 4.9814$

$t_{min}^{*} = 7.5439 \rightarrow 7\frac{5}{8}\text{ in}$ ✓

$$d_{actual} = 7.625 - \frac{0.625}{2} - 2.25 = 5.0625$$

* t_{min} from BRSLAB99: 7.5441

t_{min} from HAND CALCULATIONS: 7.5439

THE DIFFERENCE IN THESE TWO NUMBERS IS DUE TO ROUNDING. HAND CALCULATIONS WERE DONE USING 4 DECIMALS.

MAIN REINFORCEMENT

$$A_s = \frac{M_{DESIGN}}{f_s \cdot j \cdot d} = \frac{(5.2940 k \cdot ft)(12 in/ft)\ in^2}{(24 k)(0.8852)(5.0625 in)}$$

$A_s = 0.5907\ in^2$

#5's → $A_s = 0.31$

$(0.31)(12) = 0.5907\ x$

$x = 6.2976$ → ROUND DOWN TO NEAREST 1/8 in

USE #5's @ $6\frac{1}{4}$ in

DISTRIBUTION REINFORCEMENT

$$\% = \frac{220}{\sqrt{S}} = \frac{220}{\sqrt{7}} = 83$$

USE 67% MAX 3.24.10.2

DIST STEEL = 0.67(0.5907) = 0.3958

#4's → $A_s = 0.20\ in^2$

$$MID = \left(\frac{S}{2}\right)\frac{DIST\ STEEL}{A_s} = \left(\frac{7}{2}\right)\frac{0.3958}{0.20}$$

MID = 6.9265 → USE 7 BARS MIDSPAN

OUTER = $\frac{7}{2}$ = 3.5 → USE 4 BARS OUTER QUARTERS

(2 IN EACH QUARTER)

TEMPERATURE REINFORCEMENT

$1/8 \text{ in}^2/\text{ft}$ IN LONGITUDINAL MAT 8.20.1

USE # 4's → $A_s = 0.20 \text{ in}^2$

$$\frac{x}{0.20} = \frac{12}{0.125} \Rightarrow x = 19.2 \text{ in}$$

USE 18 in MAX

DESIGN SUMMARY

$7\frac{5}{8}$ in THICKNESS

#5 AT $6\frac{1}{4}$ in

7 - #4 IN MIDSPAN

4 - #4 IN OUTER QUARTERS

$2\frac{1}{4}$ in COVER

APPENDIX III
ANALYSIS CALCULATIONS

FROM DESIGN:

$n = 9$

$M_{DESIGN} = 5.2940 \text{ k·ft}$

$d = 5.0625 \text{ in}$

#5's @ 6.25 in

ANALYSIS

$$A_s = \frac{0.31}{6.25} = \frac{x}{12} \Rightarrow x = 0.5952 \text{ in}^2/\text{ft}$$

$$\rho = \frac{A_s}{bd} = \frac{0.5952 \text{ in}^2}{(12 \text{ in})(5.0625 \text{ in})}$$

$$\rho = 0.0098$$

$$\rho n = 0.0882$$

$$(\rho n)^2 = 0.0078$$

$$k = \sqrt{2\rho n + (\rho n)^2} - \rho n$$

$$= \sqrt{2(0.0882) + 0.0078} - 0.0882$$

$$k = 0.3410$$

$$j = 1 - \frac{k}{3} = 0.8863$$

$$f_c = \frac{2 M_{DESIGN}}{b \cdot d^2 \cdot k \cdot j}$$

$$f_c = \frac{2(5.2940 \text{ k·ft})(12 \text{ in}/\text{ft})}{(12 \text{ in})(5.0625 \text{ in})^2 (0.3410)(0.8863)}$$

$$f_c = 1.3669 \text{ ksi} < 1.4 \quad \checkmark \text{OK}$$

$\text{Actual } f_c < f_c$ BY $< 1\%$

$$f_s = \frac{M_{DESIGN}}{A_c \cdot \gamma \cdot d} = \frac{5.2940\ k \cdot ft\ (12\ in/ft)}{(0.5952\ in^2)(0.8863)(5.0625\ in)}$$

$f_s = 23.79\ ksi < 24$ ✓OK

ACTUAL $f_s < f_s$ BY $< 1\%$

DESIGN CRITERIA

GIVEN:

HS20 LOADING
USE CONTINUITY
GRADE 60 REINFORCEMENT
$W_{FP} = 30$ psf
$f'_c = 3500$ psi
$s = 7$ ft
TOP COVER = 2.25 in
BOTTOM COVER = 1 in
USE NORMAL WEIGHT CONCRETE

ASSUME:

	ARTICLE
$P_{20} = 16$ K	3.24.3
$w_c = 145$ pcf for E_c	8.7.1
$w_c = 150$ pcf for w_{SLAB}	8.7.1
$f_s = 24$ ksi	8.15.2.2
$f_c = 0.4 f'_c$	8.15.1.1
$E_c = w_c^{1.5} \cdot 33\sqrt{f'_c}$ psi	8.7.1
$E_s = 29 \times 10^6$ psi	8.7.2
$n = \frac{E_s}{E_c}$ → ROUND UP TO WHOLE #	8.15.3.4

MAIN REINFORCEMENT IS PERPENDICULAR TO TRAFFIC FLOW

INITIAL SLAB THICKNESS IS 8 in

USE #5's FOR MAIN REINFORCEMENT

$M_{LL} = \left[\frac{S+2}{32}\right] P_{20}$ — 3.24.3.1

CONTINUITY FACTOR, CF = 0.8 — 3.24.3.1

IMPACT = 30% — 3.8.2

USE #4's FOR DISTRIBUTION REINFORCEMENT

$$f_c = 0.4 f'_c = \frac{0.4(3500 \text{ psi})}{1000} = 1.4 \text{ ksi}$$

$$E_c = 145^{1.5}(33)\sqrt{3500}$$

$$E_c = 3408787.7886 \text{ psi}$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{3408787.7886} = 8.51 \rightarrow \text{USE } 9$$

$$k = \frac{f_c}{f_c + f_s/n} = \frac{1.4}{1.4 + \frac{24}{9}}$$

$$k = 0.3443$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.3443}{3} = 0.8852$$

$$M_{LL} = I \cdot P_{20}\left[\frac{S+2}{32}\right] = 1.3(16)\left[\frac{7+2}{32}\right]$$

$$M_{LL} = 5.8500 \text{ k}\cdot\text{ft/ft}$$

$$M_{DL} = \left[\frac{W_{SLAB} + W_{FP}}{1000}\right]\frac{S^2}{8}$$

$$= \left[\frac{(8\text{in})\left(\frac{1\text{ft}}{12\text{in}}\right)\left(150\frac{\text{lb}}{\text{ft}^3}\right) + 30\frac{\text{lb}}{\text{ft}^2}}{1000 \text{ lb/K}}\right]\left(\frac{7\text{ ft}}{8}\right)^2$$

$$M_{DL} = 0.7962 \text{ k}\cdot\text{ft/ft}$$

$$M_{DESIGN} = (M_{LL} + M_{DL})CF = (5.8500 + 0.7962)0.8$$

$$M_{DESIGN} = 5.3170 \text{ k}\cdot\text{ft/ft}$$

$$d_{min} = \sqrt{\frac{2\ M_{DESIGN}}{f_c \cdot k \cdot j \cdot b}} = \sqrt{\frac{2(5.3170\ k\cdot ft)\ in^2}{(1.4k)(0.3443)(0.8852)(1\ ft)}}$$

$$d_{min} = 4.9922\ in$$

$$t_{min} = 4.9922 + \frac{0.625}{2} + 2.25 = 7.5547$$ → ROUND UP TO NEAREST $\frac{1}{8}$"

$7.625 \neq 8$

CHOOSE ANOTHER SLAB THICKNESS AND ITERATE

ASSUME 7.625 in SLAB

$M_{DL} = 0.7675$

$M_{DESIGN} = 5.2940$

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ACTUAL $f_s < f_s$ BY $< 1\%$