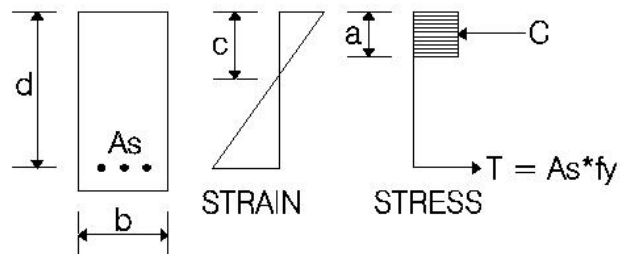


STRUCTWARE[®]
←—————→
Program Documentation

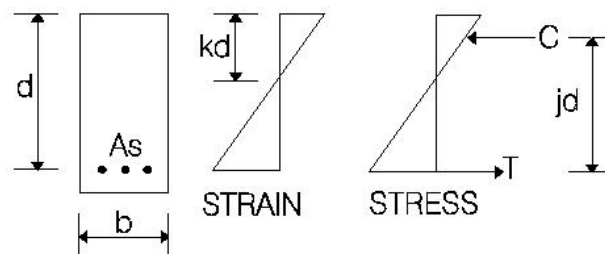
for

REBEAM[®]

Reinforced Concrete Beam Design Program



STRENGTH DESIGN



WORKING STRESS DESIGN

STRUCTWARE

SHEET _____ OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 9/11/2005

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CONTENTS

ITEM	PAGE
Introduction	A-1
Program Information	
Online help file	B1-1
Graphical interface	B2-1
Verification problems	C-1

STRUCTWARE

SHEET A-1 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 9/11/2005

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INTRODUCTION

REBEAM may be used to design or review a reinforced concrete beam section in accordance with any American or Canadian concrete code. Design criteria include ACI-318, AASHTO, AREMA, AASHTO LRFD, CSA A23.3, CAN/CSA-S6 or OHBDC (Note: OHBDC was removed in REBEAM version 5.00). The program has built in default values for material strength, stress block, strength reduction factors and resistance factors which are set based on the selected design criteria. These factors may be modified as needed by the user. Review options include checks for ultimate strength, service load stresses, fatigue and crack control.

The online help file and graphical interface is shown in Section B. Verification problems are included in Section C. Additional information is contained in the following files installed in the program directory.

License.txt - The license agreement contains the terms and conditions for use of this program and documentation.

Readme.txt – The installation instructions, copyright and trademark notices and version history is contained in this file.

The following steps are recommended for users new to the program or specific features.

1. To learn how to use the program, view the Flash Demonstration Movie that is installed along with the program and read the "Instructions" section of the help file.
2. To apply this program to a specific problem, find a similar case in the Verification Problems section of this document. Run the program to see if you can reproduce the results. If your problem varies significantly from the Verification Problem, you should perform manual calculations for verification.

STRUCTWARE

SHEET B1-1 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

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ONLINE HELP FILE

[Rebeam help](#)

GRAPHICAL INTERFACE

R REINFORCED CONCRETE BEAM DESIGN

File Edit Define View Reset Help

TYPE

Design Tensile Steel
 Design Shear Steel
 Review

UNITS

English
 Metric

MATERIAL PROPERTIES

Conc Compressive Strength:

Reinforcing Steel Strength:

Modular Ratio:

DESIGN LOADS

Factored (ultimate) Moment:

Max Service Load Moment:

Min Service Load Moment:

Factored (ultimate) Shear:

SECTION PROPERTIES

Section Type: RECTANGULAR

Set Section Dimensions

REINFORCING STEEL

Tensile Steel Area: Calc

Compressive Steel Area:

Depth to Tensile Steel:

Depth to Compressive Steel:

Shear Steel Area: Calc

Shear Steel Spacing:

CRACK CONTROL

Conc Cover to Center of Bar:

Effective Tension Area:

Exposure Factor:

Input file undefined
Output file undefined
Code = AASHTO (2002)

Set Section Dimensions

RECTANGULAR SECTION DIMENSIONS

B = Width:

H = Height:

BOX SECTION DIMENSIONS

H = Height:

Btop = Top Flange Width:

Htop = Top Flange Thickness:

Bbot = Bottom Flange Width:

Hbot = Bottom Flange Thickness:

Bweb = Total Web Thickness:

TEE SECTION DIMENSIONS

H = Height:

Btop = Top Flange Width:

Htop = Top Flange Thickness:

Bweb = Total Web Thickness:

STRUCTWARE

SHEET B2-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Default Code Parameters

File

SECTION **STRAIN** **STRESS**

STRESS BLOCK

ε:

α1:

β1:

PHI FACTORS

Flexure:

Shear:

MODULUS OF ELASTICITY

Reinforcing:

Concrete:

RESISTANCE FACTORS

Reinforcing:

Concrete:

MODULUS OF RUPTURE

Concrete:

SHEAR PARAMETER

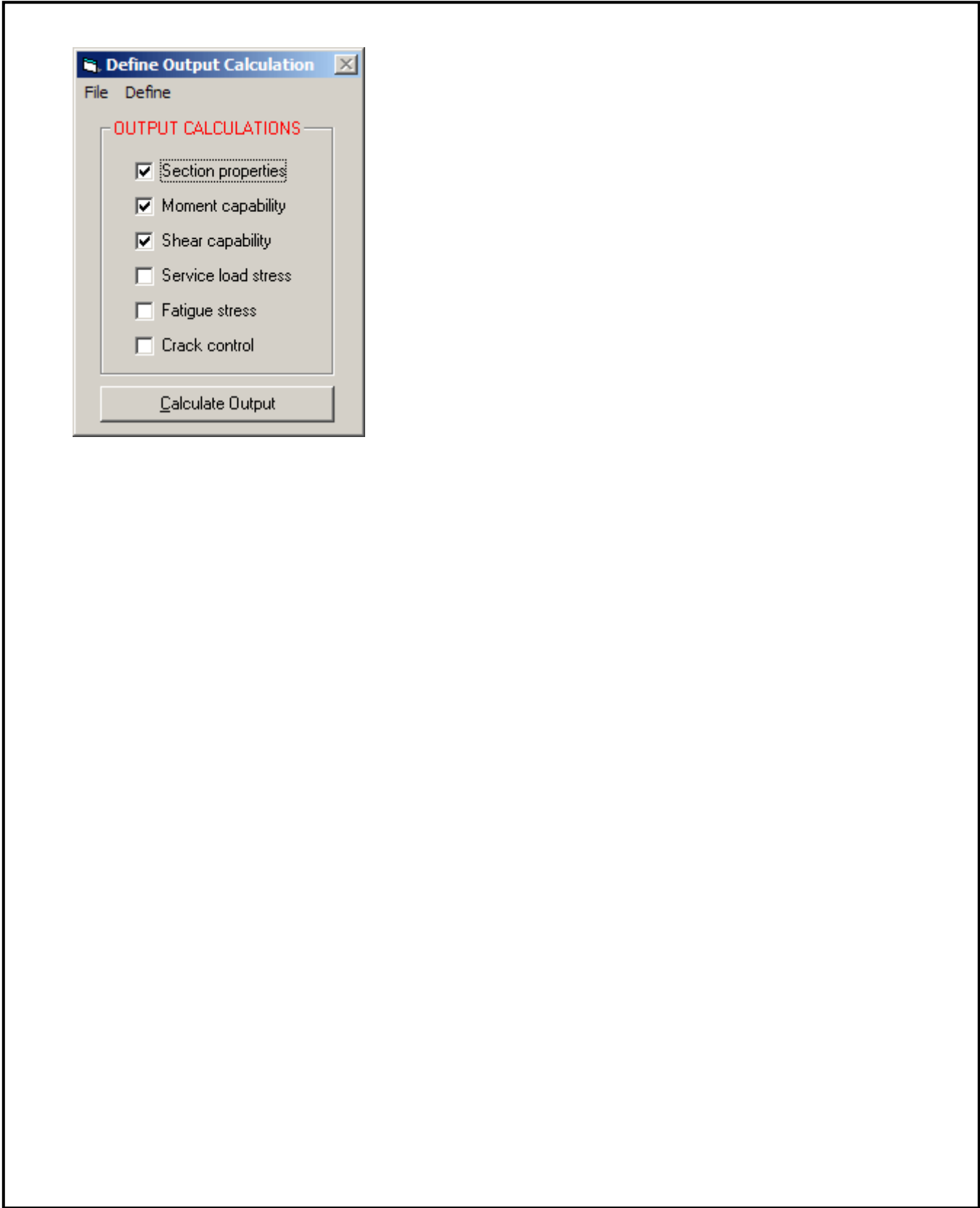
Max aggreg:

STRUCTWARE

SHEET B2-4 OF

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VERIFICATION PROBLEMS

1. [Rectangular section \(AASHTO\)](#)
 - A. Review problem
 - B. Tension steel
 - C. Moment capability

2. [Rectangular section \(AASHTO\)](#)
 - A. Review problem
 - B. Tension and compression steel
 - C. Moment capability

3. [Tee section \(AASHTO\)](#)
 - A. Review problem
 - B. Tension steel
 - C. Service load stresses

4. [Rectangular section \(AASHTO\)](#)
 - A. Review problem
 - B. Tension and compression steel
 - C. Service load stresses

5. [Rectangular section \(AASHTO\)](#)
 - A. Design problem
 - B. Required tension steel

6. [Tee section \(AASHTO\)](#)
 - A. Design and review problem
 - B. Required tension steel
 - C. Moment capability
 - D. Service load stresses
 - E. Fatigue stresses
 - F. Crack control stresses

7. [Tee section \(CSA A23.3\)](#)
 - A. Design and review problem
 - B. Required tension steel
 - C. Moment capability
 - D. Service load stresses
 - E. Crack control stresses

STRUCTWARE

SHEET C-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 9/11/2005

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

8. [Tee section \(ACI 318\)](#)
 - A. Design and review problem
 - B. Required tension steel
 - C. Moment capability
 - D. Crack control calculations

9. [Rectangular section \(OHBD\)](#) (Removed in version 5.00)
 - A. Review problem
 - B. Tension steel
 - C. Moment capability
 - D. Service load stresses
 - E. Crack control calculations

10. [Box section \(AASHTO LRFD\)](#)
 - A. Design and review problem
 - B. Required tension steel
 - C. Moment capability
 - D. Service load stresses
 - E. Fatigue stresses
 - F. Crack control stresses

11. [Shear calculations](#) (Added in version 5.00)

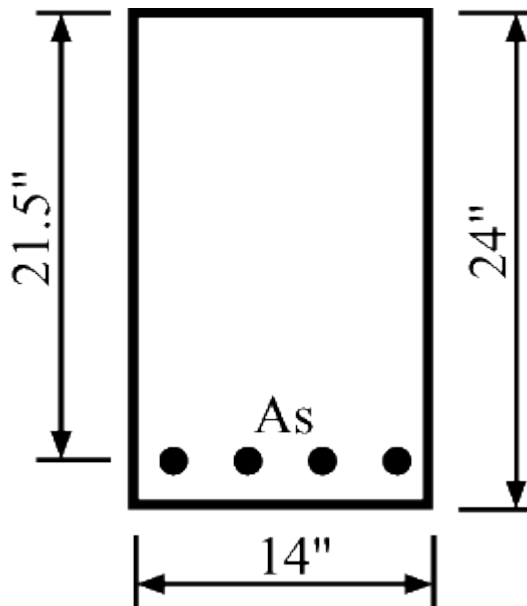
12. [LRFD shear calculation with stress less than table minimum](#)

13. [Tee section \(CAN/CSA S-6\)](#)
 - A. Review problem
 - B. Moment capability
 - C. Service load stresses
 - D. Crack control

VERIFICATION PROBLEM NO. 1

AASHTO code

Ref. Wang and Salmon, "Reinforced Concrete Design", 5th edition, Example 3.4.1



$$f'_c = 5000 \text{ psi (34.5 MPa)}$$

$$f_y = 50 \text{ ksi (345 MPa)}$$

(4) #10 bars

$$A_s = 5.08 \text{ in}^2 (3277 \text{ mm}^2)$$

Results to check:

$$a = 4.27" (108 \text{ mm})$$

$$M_n = 410 \text{ k-ft (556 kN-m)}$$

Perform calculations to verify other results:

$$E_c = 57000(5000)^{1/2} = 4.0305\text{E}+06 \text{ psi}$$

$$E_c = 4700(34.5)^{1/2} = 27606 \text{ MPa}$$

$$\alpha_1 = 0.85$$

$$\beta_1 = 0.85 - (5000 - 4000) \times 0.05 / 1000 = 0.800$$

STRUCTWARE

SHEET C1-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength = 5000
Concrete modulus of elasticity = 4.0305E+06
Concrete modulus of rupture = 530.3
Reinforcing yield strength = 50000
Reinforcing modulus of elasticity = 2.9000E+07
Modular ratio = 7
Maximum aggregate size = 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area = 5.08
Depth to tensile reinf = 21.5
Compressive reinf area = 0
Depth to compressive reinf = 0
Shear reinf area = 0
Shear reinf spacing = 0

D E S I G N L O A D S

=====

Factored (ultimate) moment = 0
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

S E C T I O N P R O P E R T I E S

=====

RECTANGULAR SECTION:

Width = 14
Height = 24

PROPERTIES:

Gross moment of inertia = 1.6128E+04
Gross section modulus = 1.3440E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.8632E+03

M O M E N T R E V I E W C A L C U L A T I O N S

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 7.1272E+01

STRUCTWARE

SHEET C1-4 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

MAXIMUM REINFORCING:

Maximum tensile reinf area = 9.7484E+00

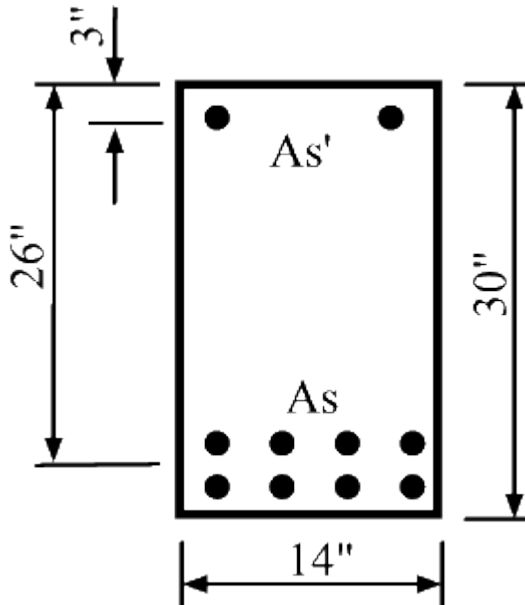
MOMENT CAPABILITY:

Ultimate moment capability = 4.0990E+02
Stress block depth = 4.2689E+00

VERIFICATION PROBLEM NO. 2

AASHTO code

Ref. Wang and Salmon, "Reinforced Concrete Design", 5th edition, Example 3.10.1



$$f'_c = 5000 \text{ psi (34.5 MPa)}$$

$$f_y = 60 \text{ ksi (414 MPa)}$$

(8) #10 bars

$$A_s = 10.16 \text{ in}^2 (6555 \text{ mm}^2)$$

(2) #8 bars

$$A_{s'} = 1.58 \text{ in}^2 (1019 \text{ mm}^2)$$

Results to check:

$$a = 8.77" (223 \text{ mm})$$

$$M_n = 1110 \text{ k-ft (1505 kN-m)}$$

Perform calculations to verify other results:

$$I_g = 14(30)^3/12 = 31500 \text{ in}^4 (1.311\text{E}+10 \text{ mm}^4)$$

$$14y^2/2 + 6 \times 1.58(y - 3) = 7 \times 10.16(26 - y)$$

$$7y^2 + 80.6y - 1878 = 0$$

$$y = 11.60 \text{ in}$$

$$I_{cr} = 14(11.6)^3/3 + 7 \times 10.16(26 - 11.6)^2 + 6 \times 1.58(11.6 - 3)^2 = 22733 \text{ in}^4 (9.462\text{E}+9 \text{ mm}^4)$$

STRUCTWARE

SHEET C2-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

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$$\rho_b = (0.85 \times 0.80 \times 5 / 60)[29000 \times 0.003 / (29000 \times 0.003 + 60)] = 0.0335$$
$$A_{smax} = 0.75 \times 0.0335 \times 14 \times 26 + 1.58 = 10.74 \text{ in}^2 (6929 \text{ mm}^2)$$

$$1.2M_{cr} = 1.2 \times 31500 \times 7.5(5000)^{1/2} / (15 \times 12000) = 111.4 \text{ k-ft (151.0 kN-m)}$$

$$c = 8.77 / 0.8 = 11.0 \text{ in}$$

$$\text{Stress in compression steel} = 29000(11.0 - 3)(.003) / 11.0 = 63.3 > 60 \text{ ksi}$$

Verification problem 2

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*                   O U T P U T   D A T A
*
* * * * *
* (Version 5)                               10/28/06, 7:45 pm
```

Output file = v2.out

Moment review problem

D E S I G N C R I T E R I A
=====

Code = AASHTO (2002)
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8000
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S
=====

Concrete compressive strength	= 5000
Concrete modulus of elasticity	= 4.0305E+06
Concrete modulus of rupture	= 530.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 7
Maximum aggregate size	= 1.000

STRUCTWARE

SHEET C2-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING STEEL

=====

Tensile reinf area = 10.16
Depth to tensile reinf = 26
Compressive reinf area = 1.58
Depth to compressive reinf = 3
Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 0
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 14
Height = 30

PROPERTIES:

Gross moment of inertia = 3.1500E+04
Gross section modulus = 2.1000E+03
Distance to neutral axis = 1.5000E+01
Cracked moment of inertia = 2.2733E+04

MOMENT REVIEW CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 1.1136E+02

MAXIMUM REINFORCING:

Maximum tensile reinf area = 1.0736E+01

MOMENT CAPABILITY:

Ultimate moment capability = 1.1091E+03
Stress block depth = 8.7650E+00
Stress in compression steel = 6.0000E+04

STRUCTWARE

SHEET _____ C3-1 of _____

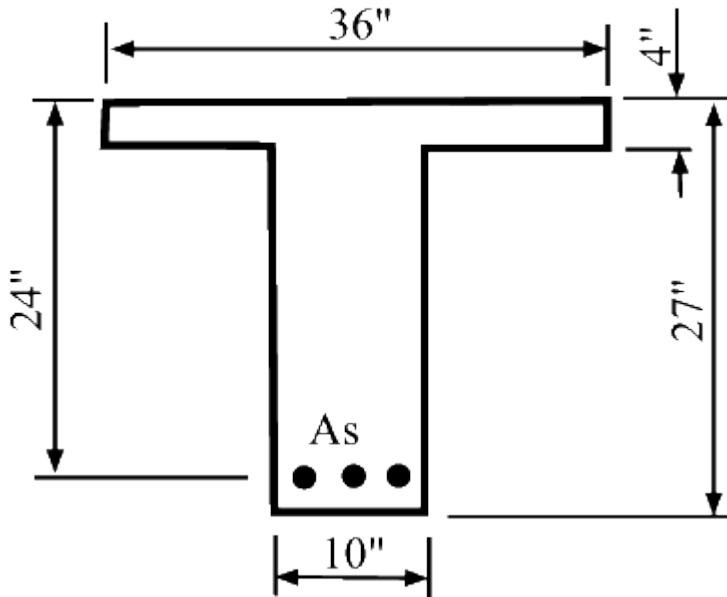
JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

VERIFICATION PROBLEM NO. 3

AASHTO code

Ref. McCormac, "Design of Reinforced Concrete", Example 2.5



$$f'_c = 3000 \text{ psi (20.7 MPa)}$$

$$f_y = 60 \text{ ksi (414 MPa)}$$

(3) #9 bars

$$A_s = 3.00 \text{ in}^2 (1935 \text{ mm}^2)$$

$$M_s = 110 \text{ k-ft (149 kN-m)}$$

Results to check:

$$f_c = 638 \text{ psi (4.40 MPa)}$$

$$f_s = 19696 \text{ psi (136 MPa)}$$

Perform calculations to verify other results:

$$E_c = 57000(3000)^{1/2} = 3.122\text{E}+06 \text{ psi}$$

$$E_c = 4700(20.7)^{1/2} = 21384 \text{ MPa}$$

$$\alpha_1 = 0.85$$

$$\beta_1 = 0.85$$

STRUCTWARE

SHEET C3-2 of

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

$$y_{cg} = (26 \times 4 \times 2 + 10 \times 27 \times 13.5) / 374 = 10.3$$
$$I_g = 26(4)^3/12 + 10(27)^3/12 + 104(10.3 - 2)^2 + 270(13.5 - 10.3)^2 = 26470 \text{ in}^4 (1.102\text{E}+10 \text{ mm}^4)$$
$$10y^2/2 + 36 \times 4(y - 2) = 9 \times 3.0(24 - y)$$
$$5y^2 + 171y - 936 = 0$$
$$y = 4.8 \text{ in}$$
$$I_{cr} = 10(4.8)^3/3 + 26(4)^3/12 + 104(4.8 - 2)^2 + 9 \times 3.0(24 - 4.8)^2 = 11276 \text{ in}^4 (4.693\text{E}+9 \text{ mm}^4)$$

$$c_b = 24 \times 0.003 / (0.003 + 60 / 29000) = 14.2 \text{ in}$$
$$a_b = 14.2 \times 0.85 = 12.07 \text{ in}$$
$$A_{sflange} = 26 \times 4 \times 0.85 \times 3 / 60 = 4.42 \text{ in}^2$$
$$A_{sweb} = 10 \times 12.07 \times 0.85 \times 3 / 60 = 5.13 \text{ in}^2$$
$$A_{smax} = 0.75(4.42 + 5.13) = 7.16 \text{ in}^2 (4619 \text{ mm}^2)$$

$$1.2M_{cr} = 1.2 \times 26470 \times 7.5(3000)^{1/2} / (16.7 \times 12000) = 65.1 \text{ k-ft (88.3 kN-m)}$$
$$I_e = (54.25 / 110)^3(26470) + [1 - (54.25 / 110)^3](11276) = 13099 \text{ in}^4 (5.452\text{E}+9 \text{ mm}^4)$$

Verification problem 3

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*                   O U T P U T   D A T A
*
* * * * *
(Version 5.1)                10/31/07, 6:19 pm
```

Output file = v3.out

Moment review problem

D E S I G N C R I T E R I A

Code = AASHTO (2002)
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor = 0.90
Shear reduction factor = 0.85
Concrete resistance factor = 1.00
Reinforcing resistance factor = 1.00

STRESS BLOCK:

Ratio of average concrete strength = 0.8500
Ratio of depth of compression block = 0.8500
Maximum concrete strain = 0.0030

STRUCTWARE

SHEET C3-3 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1220E+06
Concrete modulus of rupture	= 410.8
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 3
Depth to tensile reinf	= 24
Compressive reinf area	= 0
Depth to compressive reinf	= 0
Shear reinf area	= 0
Shear reinf spacing	= 0

D E S I G N L O A D S

=====

Factored (ultimate) moment	= 0
Maximum service load moment	= 110
Minimum service load moment	= 0
Factored (ultimate) shear	= 0

S E C T I O N P R O P E R T I E S

=====

TEE SECTION:

Height	= 27
Top flange width	= 36
Top flange thickness	= 4
Total web thickness	= 10

PROPERTIES:

Gross moment of inertia	= 2.6471E+04
Gross section modulus	= 1.5853E+03
Distance to neutral axis	= 1.0302E+01
Cracked moment of inertia	= 1.1207E+04
Effective moment of inertia	= 1.3040E+04

M O M E N T R E V I E W C A L C U L A T I O N S

=====

MINIMUM REINFORCING:

1.2 * Cracking moment	= 6.5123E+01
-----------------------	--------------

STRUCTWARE

SHEET C3-4 of

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

MAXIMUM REINFORCING:

Maximum tensile reinf area = 7.1634E+00

MOMENT CAPABILITY:

Ultimate moment capability = 3.1076E+02

Stress block depth = 1.9608E+00

SERVICE LOAD STRESS:

Maximum steel stress = 1.9702E+04

Minimum steel stress = 0.0000E+00

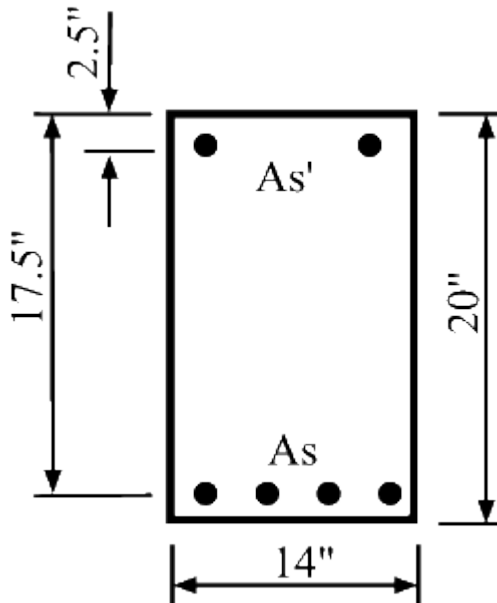
Maximum concrete stress = 6.3783E+02

Minimum concrete stress = 0.0000E+00

VERIFICATION PROBLEM NO. 4

AASHTO code

Ref. McCormac, "Design of Reinforced Concrete", Example 2.6



$$f'_c = 2500 \text{ psi (17.2 MPa)}$$

$$f_y = 60 \text{ ksi (414 MPa)}$$

$$(4) \#9 \text{ bars}$$

$$A_s = 4.00 \text{ in}^2 (2581 \text{ mm}^2)$$

$$(2) \#9 \text{ bars}$$

$$A_s = 2.00 \text{ in}^2 (1290 \text{ mm}^2)$$

$$M_s = 118 \text{ k-ft (160 kN-m)}$$

Results to check:

$$f_c = 1357 \text{ psi (9.36 MPa)}$$

$$f_s = 23253 \text{ psi (160 MPa)}$$

STRUCTWARE

SHEET C4-2 OF

JOB TITLE Rebeam Program Documentation

ORIGINATOR RM

DATE 4/10/2004

JOB No. CALCULATION No.

REVIEWER

DATE

Verification problem 4

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 6:20 pm

Output file = v4.out

Moment review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 2500
Concrete modulus of elasticity	= 2.8500E+06
Concrete modulus of rupture	= 375
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 10
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 4
Depth to tensile reinf	= 17.5
Compressive reinf area	= 2

STRUCTWARE

SHEET C4-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Depth to compressive reinf = 2.5
Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 0
Maximum service load moment = 118
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 14
Height = 20

PROPERTIES:

Gross moment of inertia = 9.3333E+03
Gross section modulus = 9.3333E+02
Distance to neutral axis = 1.0000E+01
Cracked moment of inertia = 6.3751E+03
Effective moment of inertia = 6.4197E+03

MOMENT REVIEW CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 3.5000E+01

MAXIMUM REINFORCING:

Maximum tensile reinf area = 5.2738E+00

MOMENT CAPABILITY:

Ultimate moment capability = 2.7054E+02
Stress block depth = 4.8985E+00
Stress in compression steel = 4.9259E+04

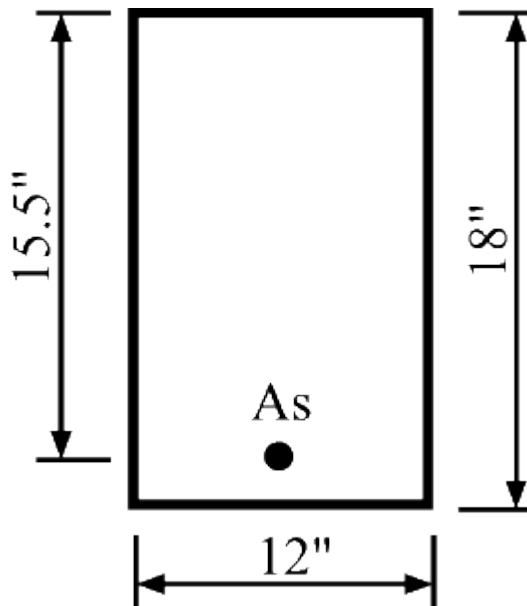
SERVICE LOAD STRESS:

Maximum steel stress = 2.3243E+04
Minimum steel stress = 0.0000E+00
Maximum concrete stress = 1.3581E+03
Minimum concrete stress = 0.0000E+00

VERIFICATION PROBLEM NO. 5

AASHTO code

Ref. McCormac, "Design of Reinforced Concrete", Example 4.4



$$f'_c = 3000 \text{ psi (20.7 MPa)}$$

$$f_y = 40 \text{ ksi (276 MPa)}$$

$$M_u = 100 \text{ k-ft (136 kN-m)}$$

Results to check:

$$\text{Required } A_s = 2.39 \text{ in}^2 \text{ (1542 mm}^2\text{)}$$

STRUCTWARE

SHEET C5-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification problem 5

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 6:20 pm

Output file = v5.out

Moment design problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1220E+06
Concrete modulus of rupture	= 410.8
Reinforcing yield strength	= 40000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Depth to tensile reinf	= 15.5
Compressive reinf area	= 0
Depth to compressive reinf	= 0
Shear reinf area	= 0
Shear reinf spacing	= 0

STRUCTWARE

SHEET C5-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 12
Height = 18

PROPERTIES:

Gross moment of inertia = 5.8320E+03
Gross section modulus = 6.4800E+02
Distance to neutral axis = 9.0000E+00
Cracked moment of inertia = 2.8055E+03

MOMENT DESIGN CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 2.6620E+01
Design moment = 1.0000E+02

MAXIMUM REINFORCING:

Maximum tensile reinf area = 5.1783E+00

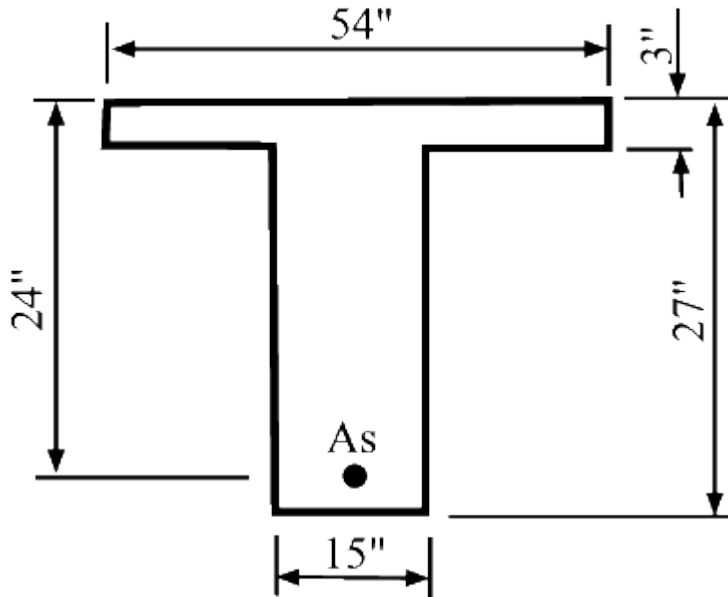
COMPUTED REINFORCING:

Stress block depth = 3.1265E+00
Required tensile reinf area = 2.3920E+00

VERIFICATION PROBLEM NO. 6

AASHTO code

Ref. McCormac, "Design of Reinforced Concrete", Example 5.4



$$f'_c = 3000 \text{ psi (20.7 MPa)}$$

$$f_y = 50 \text{ ksi (345 MPa)}$$

$$M_u = 858 \text{ k-ft (1163 kN-m)}$$

Results to check:

$$\text{Required } A_s = 10.41 \text{ in}^2 (6716 \text{ mm}^2)$$

STRUCTWARE

SHEET C6-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification problem 6

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* * * * *
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*           P R O G R A M   R E B E A M
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*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/28/06, 7:53 pm

Output file = v6.out

Moment design problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1220E+06
Concrete modulus of rupture	= 410.8
Reinforcing yield strength	= 50000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Depth to tensile reinf	= 24
Compressive reinf area	= 0
Depth to compressive reinf	= 0
Shear reinf area	= 0
Shear reinf spacing	= 0

STRUCTWARE

SHEET C6-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 858
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

TEE SECTION:

Height = 27
Top flange width = 54
Top flange thickness = 3
Total web thickness = 15

PROPERTIES:

Gross moment of inertia = 3.7763E+04
Gross section modulus = 2.3326E+03
Distance to neutral axis = 1.0810E+01
Cracked moment of inertia = 3.1470E+04

MOMENT DESIGN CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 9.5821E+01
Design moment = 8.5800E+02

MAXIMUM REINFORCING:

Maximum tensile reinf area = 1.1908E+01

COMPUTED REINFORCING:

Stress block depth = 5.8663E+00
Required tensile reinf area = 1.0455E+01

STRUCTWARE

SHEET C6-4 OF JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004JOB No. CALCULATION No. REVIEWER DATE

Perform design review to verify remaining REBEAM calculations:

$$A_s = 10.16 \text{ in}^2 (6555 \text{ mm}^2)$$
$$M_{\max} = 200 + 340 = 540 \text{ k-ft (732 kN-m)}$$
$$M_{\min} = 200 \text{ k-ft (271 kN-m)}$$

Verify $A_{s\max} = 11.9 \text{ in}^2 (7677 \text{ mm}^2)$ per original example.

Verify other output with the following calculations:

$$\rho = A_s / (B_{\text{top}} * d) = 0.00784$$
$$k = [(\rho * n)^2 + 2 * \rho * n]^{1/2} - \rho * n = 0.312$$
$$k * d = 7.5" > 3" \text{ Therefore neutral axis in web}$$

$$C1 = B_{\text{web}} / 2 = 7.5$$
$$C2 = (B_{\text{top}} - B_{\text{web}}) * H_{\text{top}} + n * A_s = 208.44$$
$$C3 = -(B_{\text{top}} - B_{\text{web}}) * H_{\text{top}}^2 / 2 - n * A_s * d = -2370$$

$$x = (-C2 + \text{Sqr}(C2^2 - 4 * C1 * C3)) / (2 * C1) = 8.67$$

$$XI = (B_{\text{top}} - B_{\text{web}}) * H_{\text{top}}^3 / 12 + B_{\text{web}} * x^3 / 12 + (B_{\text{top}} - B_{\text{web}}) * H_{\text{top}} * (x - H_{\text{top}} / 2)^2 + B_{\text{web}} * x * (x / 2)^2 + n * A_s * (d - x)^2$$

$$XI = 30792$$

$$Sc = XI / x = 3552$$
$$Ss = XI / ((d - x) * n) = 223.2$$

$$f_{\max} = M_{\max} * 12000 / Sc = 1824 \text{ psi (12.58 MPa)}$$
$$f_{s\max} = M_{\max} * 12000 / Ss = 29032 \text{ psi (200.2 MPa)}$$
$$f_{\min} = M_{\min} * 12000 / Sc = 676 \text{ psi (4.661 MPa)}$$
$$f_{s\min} = M_{\min} * 12000 / Ss = 10753 \text{ psi (74.14 MPa)}$$

$$\text{Fatigue stress range} = 29032 - 10753 = 18279 \text{ psi (126 MPa)}$$
$$\text{Allow stress} = 23400 - 0.33 * 10753 = 19852 \text{ psi (137 MPa)}$$

$$\text{Allow crack stress} = 170 * 1000 / (3 * 90)^{1/3} = 26351 \text{ psi (182 MPa)}$$
$$\text{Maximum stress at crack} = 29032 \text{ psi (200.2 MPa)}$$

Verification problem 6 review

```
* * * * *
*
*           P R O G R A M   R E B E A M
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*           O U T P U T   D A T A
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* * * * *
(Version 5)                               10/28/06, 9:08 pm
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Output file = v6r.out

Moment review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1220E+06
Concrete modulus of rupture	= 410.8
Reinforcing yield strength	= 50000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 10.16
Depth to tensile reinf	= 24
Compressive reinf area	= 0

STRUCTWARE

SHEET C6-6 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

Depth to compressive reinf = 0
Shear reinf area = 0
Shear reinf spacing = 0

D E S I G N L O A D S

=====

Factored (ultimate) moment = 858
Maximum service load moment = 540
Minimum service load moment = 200
Factored (ultimate) shear = 0

S E C T I O N P R O P E R T I E S

=====

TEE SECTION:

Height = 27
Top flange width = 54
Top flange thickness = 3
Total web thickness = 15

PROPERTIES:

Gross moment of inertia = 3.7763E+04
Gross section modulus = 2.3326E+03
Distance to neutral axis = 1.0810E+01
Cracked moment of inertia = 3.0850E+04
Effective moment of inertia = 3.0873E+04

M O M E N T R E V I E W C A L C U L A T I O N S

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 9.5821E+01
Design moment = 8.5800E+02

MAXIMUM REINFORCING:

Maximum tensile reinf area = 1.1908E+01

MOMENT CAPABILITY:

Ultimate moment capability = 8.3774E+02
Stress block depth = 5.4810E+00

*** Design moment exceeds capacity ***

STRUCTWARE

SHEET C6-7 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

SERVICE LOAD STRESS:

Maximum steel stress = 2.8985E+04
Minimum steel stress = 1.0735E+04
Maximum concrete stress = 1.8206E+03
Minimum concrete stress = 6.7428E+02

FATIGUE:

Steel stress range = 1.8250E+04
Allowable fatigue stress range = 1.9857E+04

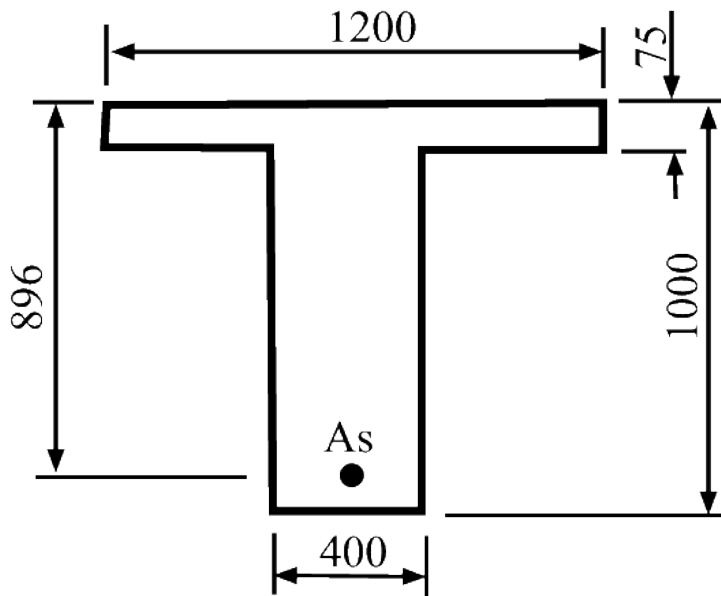
CRACK CONTROL:

Concrete cover = 3
Effective tension area = 90
Exposure factor = 170000
Maximum steel stress = 2.8985E+04
Allowable cracking stress = 2.6351E+04

VERIFICATION PROBLEM NO. 7

CSA A23.3 code

Ref. CPCA, "Concrete Design Handbook", 2nd edition, Example 2.7



$f'_c = 30 \text{ MPa}$
 $f_y = 400 \text{ MPa}$

$M_f = 1500 \text{ kN-m}$

$d_c = 66 \text{ mm}$
 $A = 240 \text{ MPa}$
 $z = 30000 \text{ N/mm}$

STRUCTWARE

SHEET C7-2 OF _____JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

The design calculation determined the required steel area $A_s = 5221 \text{ mm}^2$
Perform review calculations with: $A_s = 5600 \text{ mm}^2$ and $M_{\max} = 1000 \text{ kN-m}$.

$$\alpha_1 = 0.85 - 0.0015 \times 30 = 0.805$$

$$\beta_1 = 0.97 - 0.0025 \times 30 = 0.895$$

$$E_c = 4500(30)^{1/2} = 24648 \text{ MPa}$$

$$y_{cg} = (800 \times 75 \times 37.5 + 400 \times 1000 \times 500) / 460000 = 440 \text{ mm}$$

$$I_g = 800(75)^3/12 + 400(1000)^3/12 + 60000(402.5)^2 + 400000(60)^2$$

$$I_g = 4.452\text{E}+10 \text{ mm}^4$$

$$1.2M_{cr} = 1.2 \times 0.6(30)^{1/2} \times 4.452\text{E}+10 / [(1000 - 440) \times 1000000] = 314 \text{ kN-m}$$

$$400y^2/2 + 60000(y - 37.5) = 8 \times 5600(896 - y)$$

$$200y^2 + 104800y - 42390800 = 0$$

$$y = 268 \text{ mm}$$

$$I_{cr} = 400(268)^3 / 3 + 800(75)^3 / 12 + 60000(230.5)^2 + 8 \times 5600(628)^2$$

$$I_{cr} = 2.345\text{E}+10 \text{ mm}^4$$

$$S_c = I_{cr} / y = 87500000$$

$$S_s = I_{cr} / ((896 - 268) \times 8) = 4667596$$

$$f_{c\max} = 1000 \times 1000000 / 87500000 = 11.43 \text{ MPa}$$

$$f_{s\max} = 1000 \times 1000000 / 4667596 = 214 \text{ MPa}$$

$$f_{cr} = 30000 / (66 \times 10400)^{1/3} = 342 \text{ MPa} > 0.6 \times 400 = 240 \text{ MPa}$$

Tension steel is assumed to yield.

with $a = 153.2 \text{ mm}$

$$c = 153.2 / 0.895 = 171 \text{ mm}$$

$$c/d = 171 / 896 = 0.191$$

$$\text{Max } c/d = 700 / (700 + 400) = 0.636$$

$$T = 0.85 \times 400 \times 5600 = 1904000 \text{ N}$$

$$C_{\text{web}} = 0.65 \times 0.805 \times 30 \times 153.2 \times 400 = 961943 \text{ N}$$

$$C_{\text{flange}} = 0.65 \times 0.805 \times 30 \times 800 \times 75 = 941850 \text{ N}$$

$$M_r = 961.943 \times (0.896 - 0.1532 / 2) + 941.85 \times (0.896 - 0.075 / 2) = 1597 \text{ kN-m}$$

STRUCTWARE

SHEET C7-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification problem 7

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*           P R O G R A M   R E B E A M
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(Version 5.1)                10/31/07, 6:22 pm
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Output file = v7.out

Moment design problem

D E S I G N C R I T E R I A

Code = CSA A23.3 (2004)
Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.65
Reinforcing resistance factor	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.8050
Ratio of depth of compression block	= 0.8950
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

Concrete compressive strength	= 30
Concrete modulus of elasticity	= 2.4648E+04
Concrete modulus of rupture	= 3.286
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

Depth to tensile reinf	= 896
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C7-4 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 1500
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

TEE SECTION:

Height = 1000
Top flange width = 1200
Top flange thickness = 75
Total web thickness = 400

PROPERTIES:

Gross moment of inertia = 4.4522E+10
Gross section modulus = 7.9457E+07
Distance to neutral axis = 4.3967E+02
Cracked moment of inertia = 2.2237E+10

MOMENT DESIGN CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 3.1331E+02
Design moment = 1.5000E+03

MAXIMUM REINFORCING:

c/d = 1.6551E-01
Maximum c/d = 6.3636E-01

COMPUTED REINFORCING:

Stress block depth = 1.3273E+02
Required tensile reinf area = 5.2210E+03

STRUCTWARE

SHEET C7-5 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification problem 7 review

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*           O U T P U T   D A T A
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* * * * *
```

(Version 5) 10/28/06, 9:02 pm

Output file = v7r.out

Moment review problem

D E S I G N C R I T E R I A

=====

Code = CSA A23.3 (2004)

Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.65
Reinforcing resistance factor	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.8050
Ratio of depth of compression block	= 0.8950
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 30
Concrete modulus of elasticity	= 2.4648E+04
Concrete modulus of rupture	= 3.286
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5600
Depth to tensile reinf	= 896
Compressive reinf area	= 0

STRUCTWARE

SHEET C7-6 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

Depth to compressive reinf = 0
Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 1500
Maximum service load moment = 1000
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

TEE SECTION:

Height = 1000
Top flange width = 1200
Top flange thickness = 75
Total web thickness = 400

PROPERTIES:

Gross moment of inertia = 4.4522E+10
Gross section modulus = 7.9457E+07
Distance to neutral axis = 4.3967E+02
Cracked moment of inertia = 2.3451E+10
Effective moment of inertia = 2.3826E+10

MOMENT REVIEW CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 3.1331E+02
Design moment = 1.5000E+03

MAXIMUM REINFORCING:

c/d = 1.9108E-01
Maximum c/d = 6.3636E-01

MOMENT CAPABILITY:

Ultimate moment capability = 1.5969E+03
Stress block depth = 1.5323E+02

SERVICE LOAD STRESS:

Maximum steel stress = 2.1433E+02
Minimum steel stress = 0.0000E+00

STRUCTWARE

SHEET C7-7 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

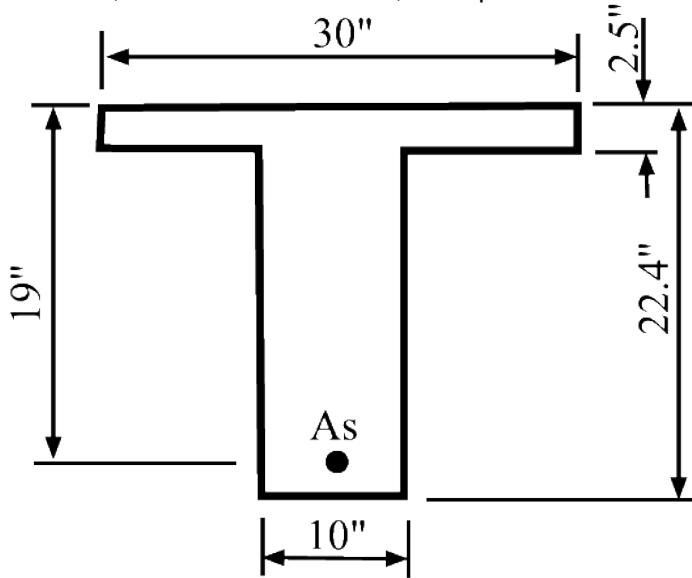
Maximum concrete stress = 1.1416E+01
Minimum concrete stress = 0.0000E+00

CRACK CONTROL:

Concrete cover = 66
Effective tension area = 10400
Exposure factor = 30000
Maximum steel stress = 2.1433E+02
Allowable cracking stress = 2.4000E+02

VERIFICATION PROBLEM NO. 8

ACI 318 code
 Ref. PCA, "Notes on ACI 318-99", Example 10.5



$f'_c = 4000$ psi
 $f_y = 60000$ psi

$M_u = 400$ k-ft

Results to check:

Required $A_s = 5.11$ in²
 $a = 4.02$ in

The design calculation determined the required steel area $A_s = 5.10$ in². Perform review calculations with: $M_{max} = 265$ k-ft and $A_s = 5.00$ in²

$\alpha_1 = 0.85$
 $\beta_1 = 0.85$

$E_c = 57000(4000)^{1/2} = 3605000$ psi

Tension steel is assumed to yield.

Minimum tensile steel =>
 $3(4000)^{1/2} / 60000 = 0.00316 < 200 / 60000 = 0.00333$
 $A_{smin} = 0.00333 \times 10 \times 19 = 0.633$ in

STRUCTWARE

SHEET C8-3 OF

JOB TITLE Rebeam Program Documentation

ORIGINATOR RM

DATE 4/10/2004

JOB No.

CALCULATION No.

REVIEWER

DATE

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength = 4000
Concrete modulus of elasticity = 3.6050E+06
Concrete modulus of rupture = 474.3
Reinforcing yield strength = 60000
Reinforcing modulus of elasticity = 2.9000E+07
Modular ratio = 8
Maximum aggregate size = 1.000

R E I N F O R C I N G S T E E L

=====

Depth to tensile reinf = 19
Compressive reinf area = 0
Depth to compressive reinf = 0
Shear reinf area = 0
Shear reinf spacing = 0

D E S I G N L O A D S

=====

Factored (ultimate) moment = 400
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

S E C T I O N P R O P E R T I E S

=====

TEE SECTION:

Height = 22.4
Top flange width = 30
Top flange thickness = 2.5
Total web thickness = 10

PROPERTIES:

Gross moment of inertia = 1.3439E+04
Gross section modulus = 1.0325E+03
Distance to neutral axis = 9.3843E+00
Cracked moment of inertia = 0.0000E+00

M O M E N T D E S I G N C A L C U L A T I O N S

=====

MINIMUM REINFORCING:

Minimum tensile reinf area = 5.1040E+00

STRUCTWARE

SHEET C8-4 OF _____

JOB TITLE Rebeam Program Documentation

ORIGINATOR RM

DATE 4/10/2004

JOB No. _____ CALCULATION No. _____

REVIEWER _____

DATE _____

MAXIMUM REINFORCING:

Strain in tensile reinf = 9.0898E-03
Minimum strain = 4.0000E-03

COMPUTED REINFORCING:

Stress block depth = 4.0075E+00
Required tensile reinf area = 5.1043E+00

Verification Problem 8 review

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*          P R O G R A M   R E B E A M          *  
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(Version 5)                                10/28/06, 3:00 pm
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Output file = v8r.out

Shear and moment review problem

D E S I G N C R I T E R I A

Code = ACI-318 (2005)
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor = 0.90
Shear reduction factor = 0.75
Concrete resistance factor = 1.00
Reinforcing resistance factor = 1.00

STRESS BLOCK:

Ratio of average concrete strength = 0.8500
Ratio of depth of compression block = 0.8500
Maximum concrete strain = 0.0030

M A T E R I A L P R O P E R T I E S

Concrete compressive strength = 4000
Concrete modulus of elasticity = 3.6050E+06
Concrete modulus of rupture = 474.3

STRUCTWARE

SHEET C8-5 OF

JOB TITLE Rebeam Program Documentation

ORIGINATOR RM

DATE 4/10/2004

JOB No. CALCULATION No.

REVIEWER

DATE

Reinforcing yield strength = 60000
Reinforcing modulus of elasticity = 2.9000E+07
Modular ratio = 8
Maximum aggregate size = 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area = 5.104
Depth to tensile reinf = 19
Compressive reinf area = 0
Depth to compressive reinf = 0
Shear reinf area = 0
Shear reinf spacing = 0

D E S I G N L O A D S

=====

Factored (ultimate) moment = 400
Maximum service load moment = 265
Minimum service load moment = 0
Factored (ultimate) shear = 0

S E C T I O N P R O P E R T I E S

=====

TEE SECTION:

Height = 22.4
Top flange width = 30
Top flange thickness = 2.5
Total web thickness = 10

PROPERTIES:

Gross moment of inertia = 1.3439E+04
Gross section modulus = 1.0325E+03
Distance to neutral axis = 9.3843E+00
Cracked moment of inertia = 8.6910E+03
Effective moment of inertia = 8.7083E+03

M O M E N T R E V I E W C A L C U L A T I O N S

=====

MINIMUM REINFORCING:

Minimum tensile reinf area = 6.3333E-01

MAXIMUM REINFORCING:

Strain in tensile reinf = 9.0912E-03
Minimum strain = 4.0000E-03

STRUCTWARE

SHEET C8-6 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

MOMENT CAPABILITY:

Ultimate moment capability = 3.9998E+02
Stress block depth = 4.0071E+00

*** Design moment exceeds capacity ***

SERVICE LOAD STRESS:

Maximum steel stress = 3.5906E+04
Minimum steel stress = 0.0000E+00
Maximum concrete stress = 2.4637E+03
Minimum concrete stress = 0.0000E+00

CRACK CONTROL:

Clear concrete cover = 2
Maximum rebar spacing = 1.1710E+01

STRUCTWARE

SHEET _____ C9-1 of _____

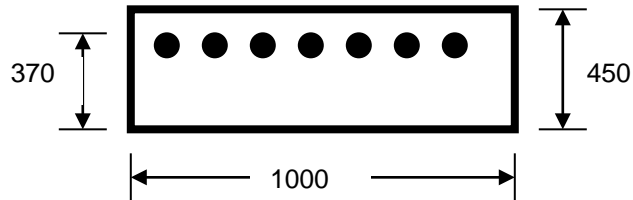
JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

VERIFICATION PROBLEM NO. 9

OHBDC code

Ref. MTO, "A Practical Guide to the Design of Post-Tensioned Decks", Section 7.1



$$f'_c = 35 \text{ MPa}$$
$$f_y = 400 \text{ MPa}$$

$$A_s = 1200 \text{ mm}^2$$
$$s_c = 105 \text{ mm}$$
$$c_c = 70 \text{ mm}$$

$$M_{uls} = 139.41 \text{ kN-m}$$
$$M_{sls} = 87.23 \text{ kN-m}$$

Results to check:

$$1.2M_{cr} = 1.2 \times 99.8 \text{ kN-m} = 119.76 \text{ kN-m}$$
$$f_s = 206.8 \text{ MPa}$$
$$M_w = 27.0 \text{ kN-m}$$
$$\beta_2 = 26566 \text{ N/mm}$$

Perform calculations to check results:

$$\alpha_1 = 0.85$$
$$\beta_1 = 0.85 - (35 - 30) \times 0.08 / 10 = 0.81$$

$$E_c = 5000(35)^{1/2} = 29580 \text{ MPa}$$

$$I_g = 1000(450)^3/12 = 7.594\text{E}+09 \text{ mm}^4$$
$$1000y^2/2 = 7 \times 1200(370 - y)$$
$$500y^2 + 8400y - 3108000 = 0$$
$$y = 70.89 \text{ mm}$$
$$I_{cr} = 1000(70.89)^3/3 + 7 \times 1200(370 - 70.89)^2 = 8.703\text{E}+08 \text{ mm}^4$$

$$f_s = 87.23 \times 299 \times 7 \times 1.0\text{E}+6 / 8.703\text{E}+08 = 209.8 \text{ MPa}$$

STRUCTWARE

SHEET C9-2 of _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Tension steel is assumed to yield.

with $a = 19.36$ mm
 $c = 19.36 / 0.81 = 23.9$ mm
 $c / d = 23.9 / 370 = 0.0646 < 0.5$ OK

$T = 0.9 \times 400 \times 1200 = 432000$ N
 $C = 0.75 \times 0.85 \times 35 \times 19.36 \times 1000 = 431970$ N
 $M_r = 432 \times (0.370 - 0.0239 / 2) = 155$ kN-m

Crack control =>

$1.2M_{cr} = 1.2 \times 0.5(35)^{1/2} \times 7.594E+09 / (225 \times 1.0E+06) = 119.8$ kN-m
 $M_w = 0.4 \times 119.8 / 1.2 = 39.9$ kN-m (Note value in reference is erroneous)
 $\beta_2 = 1.0(0.9 \times 105 + 2 \times 70) \times 209.8 \times [1 - (39.9 / 87.23)^2] = 38905$ N/mm

FILE = VER9.OUT (REVIEW PROBLEM)

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*                   O U T P U T   D A T A
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6/26/02, 5:24 pm
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D E S I G N C R I T E R I A

=====

Code = OHBDC (1991)
Units = Metric (Newtons, millimeters - moments in kN-m)

MATERIAL PROPERTIES:

Concrete compressive strength = 35
Concrete modulus of elasticity = 2.9580E+04
Reinforcing yield strength = 400
Reinforcing modulus of elasticity = 2.0000E+05
Modular ratio = 7

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor = 1.00
Concrete resistance factor = 0.75
Reinforcing resistance factor = 0.90

STRESS BLOCK:

Ratio of average concrete strength = 0.8500
Ratio of depth of compression block = 0.8100
Maximum concrete strain = 0.0030

STRUCTWARE

SHEET C9-3 of

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

SECTION PROPERTIES:

RECTANGULAR SECTION:

Width = 1000
Height = 450

PROPERTIES:

Gross moment of inertia = 7.5938E+09
Gross section modulus = 3.3750E+07
Distance to neutral axis = 2.2500E+02
Cracked moment of inertia = 8.7027E+08
Effective moment of inertia = 7.5938E+09

REVIEW CALCULATIONS:

REINFORCING STEEL:

Tensile steel area = 1200
Compressive steel area = 0
Depth to tensile steel = 370
Depth to Compressive steel = 0

c/d = 6.4602E-02
Maximum c/d = 5.0000E-01

DESIGN MOMENTS:

Factored ultimate moment = 139.41
Maximum service load moment = 87.23
Minimum service load moment = 0

MOMENT CAPABILITY:

Ultimate moment capability = 1.5566E+02
1.2 * Cracking moment = 1.1980E+02
Design moment = 1.3941E+02
Stress block depth = 1.9361E+01

SERVICE LOAD STRESS:

Maximum steel stress = 2.0987E+02
Minimum steel stress = 0.0000E+00
Maximum concrete stress = 7.1053E+00
Minimum concrete stress = 0.0000E+00

STRUCTWARE

SHEET C9-4 of

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 4/10/2004

JOB No. CALCULATION No. REVIEWER DATE

CRACK CONTROL:

Clear concrete cover	=	70
Clear rebar spacing	=	105
Moment at 40% fcrack	=	3.9934E+01
Computed exposure factor	=	3.8900E+04
Allowable exposure factor	=	5.0000E+04

STRUCTWARE

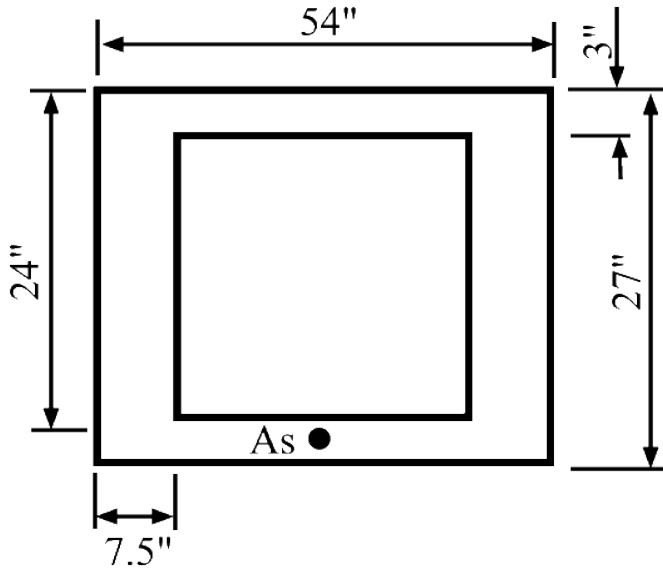
SHEET C10-1 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

VERIFICATION PROBLEM NO. 10

Design and review box using AASHTO LRFD code. Use dimensions similar to Tee section used in Verification problem 6.



$$f'_c = 3000 \text{ psi (20.7 MPa)}$$

$$f_y = 50 \text{ ksi (345 MPa)}$$

$$M_u = 858 \text{ k-ft (1163 kN-m)}$$

Results to check:

$$\text{Required } A_s = 10.41 \text{ in}^2 (6716 \text{ mm}^2)$$

STRUCTWARE

SHEET C10-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification Problem 10

```
* * * * *
*
*           P R O G R A M   R E B E A M
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*           O U T P U T   D A T A
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* * * * *
* (Version 5)                               10/28/06, 3:09 pm
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Output file = v10.out

Moment design problem

D E S I G N C R I T E R I A

Code = AASHTO LRFD (2004)
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.90
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1523E+06
Concrete modulus of rupture	= 415.7
Reinforcing yield strength	= 50000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

Depth to tensile reinf	= 24
Compressive reinf area	= 0
Depth to compressive reinf	= 0
Shear reinf area	= 0
Shear reinf spacing	= 0

STRUCTWARE

SHEET C10-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 858
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 0

SECTION PROPERTIES

=====

BOX or I SECTION:

Height = 27
Top flange width = 54
Top flange thickness = 3
Bottom flange width = 54
Bottom flange thickness = 3
Total web thickness = 15

PROPERTIES:

Gross moment of inertia = 5.8475E+04
Gross section modulus = 4.3315E+03
Distance to neutral axis = 1.3500E+01
Cracked moment of inertia = 0.0000E+00

MOMENT DESIGN CALCULATIONS

=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 1.8006E+02
Design moment = 8.5800E+02

MAXIMUM REINFORCING:

c/d = 2.8757E-01
Maximum c/d = 4.2000E-01

COMPUTED REINFORCING:

Stress block depth = 5.8663E+00
Required tensile reinf area = 1.0455E+01

STRUCTWARE

SHEET C10-4 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Perform design review to verify remaining REBEAM calculations:

Most of the output for this problem can be compared to Verification problem number 6 to check the results. Verify other output with the following calculations:

$$I_g = 15(27)^3 / 12 + 2 \times 39 \times (3)^3 / 12 + 2 \times 3 \times 39 \times (12)^2 = 58475 \text{ in}^4$$
$$1.2M_{cr} = 1.2 \times 7.5(3000)^{1/2} \times 58475 / (13.5 \times 12000) = 178 \text{ k-ft}$$

Fatigue:

$$\begin{aligned} \text{Maximum steel stress} &= 2.8985\text{E}+04 \\ \text{Minimum steel stress} &= 1.0735\text{E}+04 \\ \text{Stress range} &= 18250 \text{ psi} \\ \text{Allow range} &= (24000 - 0.33 \times 10735) / 1.5 = 13638 \text{ psi} \end{aligned}$$

Crack control:

$$\beta = 1 + 3 / (0.7(27-3)) = 1.18$$
$$S < 700000 \times 1.0 / (1.18 \times 28985) - 2 \times 3 = 14.5''$$

Maximum reinforcing:

$$\begin{aligned} a &= 5.48 \text{ in} \\ c &= 5.48 / 0.85 = 6.447 \text{ in} \\ \epsilon_r &= (24 - 6.447)(0.003) / 6.447 = 0.00817 \\ \text{Minimum strain} &= 0.005 < 0.00817 \text{ OK} \end{aligned}$$

Verification Problem 10 review

```
* * * * *
*
*           P R O G R A M   R E B E A M
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*                   O U T P U T   D A T A
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(Version  5.1)                6/03/17, 3:15 pm
```

Output file = v10r.out

Shear and moment review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO LRFD
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor = 0.90

STRUCTWARE

SHEET C10-5 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reduction factor	= 0.90
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00
STRESS BLOCK:	
Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030
M A T E R I A L P R O P E R T I E S	
=====	
Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3.1523E+06
Concrete modulus of rupture	= 415.7
Reinforcing yield strength	= 50000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 9
Maximum aggregate size	= 1.000
R E I N F O R C I N G S T E E L	
=====	
Tensile reinf area	= 10.16
Depth to tensile reinf	= 24
Compressive reinf area	= 0
Depth to compressive reinf	= 0
Shear reinf area	= 0
Shear reinf spacing	= 0
D E S I G N L O A D S	
=====	
Factored (ultimate) moment	= 858
Maximum service load moment	= 540
Minimum service load moment	= 200
Factored (ultimate) shear	= 0
S E C T I O N P R O P E R T I E S	
=====	
BOX or I SECTION:	
Height	= 27
Top flange width	= 54
Top flange thickness	= 3
Bottom flange width	= 54
Bottom flange thickness	= 3
Total web thickness	= 15
PROPERTIES:	
Gross moment of inertia	= 5.8475E+04
Gross section modulus	= 4.3315E+03

STRUCTWARE

SHEET C10-6 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 6/04/2017

JOB No. CALCULATION No. REVIEWER DATE

Distance to neutral axis = 1.3500E+01
Cracked moment of inertia = 3.0850E+04
Effective moment of inertia = 3.1443E+04

M O M E N T R E V I E W C A L C U L A T I O N S
=====

MINIMUM REINFORCING:

1.2 * Cracking moment = 1.8006E+02
Design moment = 8.5800E+02

MAXIMUM REINFORCING:

Strain in tensile reinf = 8.1658E-03
Minimum strain = 5.0000E-03

MOMENT CAPABILITY:

Ultimate moment capability = 8.3774E+02
Stress block depth = 5.4810E+00

*** Design moment exceeds capacity ***

SERVICE LOAD STRESS:

Maximum steel stress = 2.8985E+04
Minimum steel stress = 1.0735E+04
Maximum concrete stress = 1.8206E+03
Minimum concrete stress = 6.7428E+02

FATIGUE:

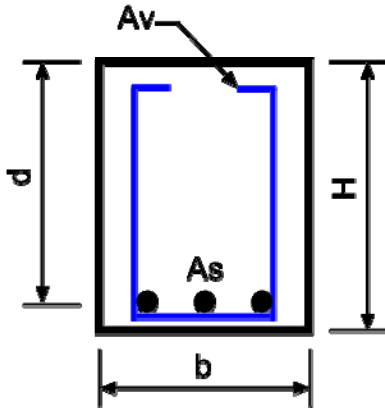
Steel stress range = 1.8250E+04
Allowable fatigue stress range = 1.3638E+04

CRACK CONTROL:

Concrete cover = 3
Exposure factor = 1
Maximum rebar spacing = 1.4491E+01

VERIFICATION PROBLEM NO. 11

Design and review reinforced concrete beam for shear using all supported codes. The capability was added in version 5.00.



$$f'_c = 4000 \text{ psi (27.6 MPa)}$$

$$f_y = 60000 \text{ psi (414 MPa)}$$

$$b = 12'' \text{ (305 mm)}$$

$$H = 24'' \text{ (610 mm)}$$

$$D = 21'' \text{ (533 mm)}$$

$$A_s = 5 \text{ in}^2 \text{ (3226 mm}^2\text{)}$$

$$A_v = 0.4 \text{ in}^2 \text{ (258 mm}^2\text{)} - \text{for review}$$

$$s = 5'' \text{ (127 mm)} - \text{for review}$$

$$M_u = 100 \text{ k-ft (136 kN-m)}$$

$$V_u = 100 \text{ kips (445 kN)}$$

Use $V_u = 50 \text{ kips (222 kN)}$ for checking w/no reinf

Minimum area of shear reinforcement

$$A_{v\min} = \frac{50bs}{f_y}$$

AASHTO (2002) 8.19.1.2

$$A_{v\min} = 50 \times 12 \times 5 / 60000 = 0.05 \text{ in}^2 \text{ (32 mm}^2\text{)}$$

$$A_{v\min} = 0.0316 \sqrt{f'_c} \frac{bs}{f_y}$$

AASHTO LRFD (2004) 5.8.2.5

$$A_{v\min} = 0.0316(4)^{1/2} \times 12 \times 5 / 60 = 0.063 \text{ in}^2 \text{ (41 mm}^2\text{)}$$

$$A_{v\min} = \frac{60bs}{f_y}$$

AREMA (2006) 8-2.10.1b

$$A_{v\min} = 60 \times 12 \times 5 / 60000 = 0.06 \text{ in}^2 \text{ (39 mm}^2\text{)}$$

$$A_{v\min} = 0.75 \sqrt{f'_c} \frac{bs}{f_y} \geq \frac{50bs}{f_y}$$

ACI 318 (2005) 11.5.6.3

$$A_{v\min} = 0.75(4000)^{1/2} \times 12 \times 5 / 60000 = 0.047 \text{ in}^2$$

$$A_{v\min} = 50 \times 12 \times 5 / 60000 = 0.05 \text{ in}^2 \text{ (32 mm}^2\text{)}$$

$$A_{v\min} = 0.06 \sqrt{f'_c} \frac{bs}{f_y}$$

CSA-A23.3 (2004) 11.2.8.2

$$A_{v\min} = 0.06(27.6)^{1/2} \times 305 \times 127 / 414 = 29 \text{ mm}^2$$

CAN/CSA-S6 (2006) 8.9.1.3

$$A_{vmin} = 0.15 f_r \left(\frac{bs}{f_y} \right)$$

$$f_r = 0.4(27.6)^{1/2} = 2.1 \text{ MPa}$$

$$A_{vmin} = 0.15 \times 2.1 \times 305 \times 127 / 414 = 29 \text{ mm}^2$$

Maximum spacing of shear reinforcement

$$s \leq \frac{d}{2} \leq 24''$$

 AASHTO (2002) 8.19.3
 AREMA (2006) 8-2.10.3
 ACI 318 (2005) 11.5.5.1

$$\text{If } \phi_v V_s > \phi_v 4\sqrt{f'_c} bd \text{ Then } s \leq \frac{d}{4} \leq 12''$$

$$V_s = 0.85 \times 4(4000)^{1/2} \times 12 \times 21 = 54.2 < 100 - 36.3 = 63.7$$

$$V_s = 0.75 \times 4(4000)^{1/2} \times 12 \times 21 = 47.8 < 100 - 32 = 68 \text{ (ACI)}$$

$$s = 21 / 4 = 5.25'' \text{ (133 mm)}$$

See strength of concrete section

$$s \leq 0.8d_v \leq 24 \text{ in}$$

AASHTO LRFD (2004) 5.8.2.7

$$\text{If } V_f > 0.125\phi_v f'_c b d_v \text{ Then } s \leq 0.4d_v \leq 12''$$

$$d_v = 0.9 \times 21 = 18.9'' \text{ (480 mm)}$$

$$V_f = 100 < 0.125 \times 0.9 \times 4 \times 12 \times 18.9 = 102 \text{ kips}$$

$$s = 0.8 \times 18.9 = 15.1'' \text{ (384 mm)}$$

$$s \leq 0.7d_v \leq 600 \text{ mm}$$

CSA-A23.3 (2004) 11.3.8.1

$$\text{If } V_f > 0.125\phi_v f'_c b d_v \text{ Then } s \leq 0.35d_v \leq 300 \text{ mm}$$

$$V_f = 445 > 0.125 \times 0.65 \times 27.6 \times 305 \times 480 / 1000 = 328 \text{ kN}$$

$$s = 0.35 \times 480 = 168 \text{ mm}$$

$$s \leq 0.75d_v \leq 600 \text{ mm}$$

CAN/CSA-S6 (2006) 8.14.6

$$\text{If } V_f \geq 0.10\phi_v f'_c b d_v \text{ Then } s \leq 0.33d_v \leq 300 \text{ mm}$$

$$V_f = 445 > 0.1 \times 0.75 \times 27.6 \times 305 \times 480 / 1000 = 303 \text{ kN}$$

$$s = 0.33 \times 480 = 158 \text{ mm}$$

Maximum shear strength

$$V_{max} = \phi_v \left[8\sqrt{f'_c} bd + V_c \right]$$

 AASHTO (2002) 8.16.6.3.9
 AREMA (2006) 8-2.35.3e
 ACI 318 (2005) 11.5.7.9

$$V_{max} = 0.85[8(4000)^{1/2} \times 12 \times 21]/1000 + 36.3 = 145 \text{ kips (644 kN)}$$

$$V_{max} = 0.75[8(4000)^{1/2} \times 12 \times 21]/1000 + 32 = 128 \text{ kips (568 kN)(ACI)}$$

$$V_{max} = \phi_v \left[0.25 f'_c b d_v \right]$$

 AASHTO LRFD (2004)
 5.8.3.3

$$V_{max} = 0.9 \times 0.25 \times 4 \times 12 \times 18.9 = 204 \text{ kips (907 kN)}$$

$$V_{max} = 0.25\phi_v f'_c b d_v$$

 CSA-A23.3 (2004) 11.3.3
 CAN/CSA-S6 (2006) 8.9.3.3

$$V_{max} = 0.25 \times .65 \times 27.6 \times 305 \times 480 / 1000 = 657 \text{ kN (A23.3)}$$

$$V_{max} = 0.25 \times .75 \times 27.6 \times 305 \times 480 / 1000 = 758 \text{ kN (S6)}$$

Shear strength of concrete

$$\phi_v V_c = \phi_v \left[1.9 \sqrt{f'_c} + 2500 \rho \frac{V_f d}{M_f} \right] b d \leq \phi_v 3.5 \sqrt{f'_c} b d$$

AASHTO (2002) 8.16.6.2.1
AREMA (2006) 8-2.35.2b
ACI 318 (2005) 11.3.2.1

$$\text{but } \frac{V_f d}{M_f} \leq 1.0$$

$$\rho = 5 / (12 \times 21) = 0.0198$$

$$V_c = 0.85 \times 3.5(4000)^{1/2} \times 12 \times 21 / 1000 = 47.4 \text{ kips}$$

$$V_c = 0.75 \times 3.5(4000)^{1/2} \times 12 \times 21 / 1000 = 41.8 \text{ kips (ACI)}$$

$$V_d/M = 100 \times 21 / (100 \times 12) = 1.75$$

$$V_c = 0.85[1.9(4000)^{1/2} \times 2500 \times 0.0198] \times 12 \times 21 / 1000 = 36.3 \text{ kips (161 kN)}$$

$$V_c = 0.75[1.9(4000)^{1/2} \times 2500 \times 0.0198] \times 12 \times 21 / 1000 = 32.0 \text{ kips (142 kN) (ACI)}$$

$$\phi_v V_c = \phi_v 0.0316 \beta \sqrt{f'_c} b d_v$$

AASHTO LRFD (2004) 5.8.3.3

$$\beta = f \left(\frac{v_f}{f'_c}, \varepsilon_x \right)$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + 0.5 |V_f| \cot \theta \right]}{2 E_s A_s} \leq 0.001$$

$$M_f > 100 \times 18.9 / 12 = 157.5$$

$$v_f/f'_c = 100 / (12 \times 18.9 \times 0.9 \times 4) = 0.122$$

For $v_f/f'_c < 0.125$, try 8th column $\theta = 34.4$

$$\varepsilon = \frac{157.5 \times 12/18.9 + 0.5 \times 100 \times \cot(34.4)}{2 \times 29000 \times 5} = 0.000597$$

Since 0.000597 falls in assumed range, then $\theta = 34.4$, $\beta = 2.26$.

$$V_c = 0.9 \times 0.0316 \times 2.26(4)^{1/2} \times 12 \times 18.9 = 29.2 \text{ kips (130 kN)}$$

$$V_c = \phi_c \beta \sqrt{f'_c} b d_v$$

CSA-A23.3 (2004) 11.3.4

$$\beta = \frac{0.40}{(1 + 1500 \varepsilon_x)} \times \frac{1300}{(1000 + s_{xe})}$$

$$\theta = 29 + 7000 \varepsilon_x$$

$$s_{xe} = 300 \text{ mm}$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + |V_f| \right]}{2 E_s A_s} \leq 0.003$$

$$M_f > 445 \times 480 / 1000 = 213.6$$

STRUCTWARE

SHEET C11-4 OF JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006JOB No. CALCULATION No. REVIEWER DATE

$$\varepsilon = \frac{213.6 \times 1000/480 + 445}{2 \times 200 \times 3226} = 0.000690$$
$$\theta = 29 + 7000 \times 0.000690 = 33.8$$
$$\beta = 0.4/(1+1500 \times 0.000690) \times 1300/(1000+300) = 0.197$$
$$V_c = 0.65 \times 0.197(27.6)^{1/2} \times 305 \times 480 / 1000 = 98.8 \text{ kN}$$

$$V_c = 2.5\beta\phi_c f_r b d_v$$

CAN/CSA-S6 (2006) 8.9.3.4

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + |V_f| \right]}{2E_s A_s} \leq 0.003$$

$$\beta = \frac{0.40}{(1+1500\varepsilon_x)} \times \frac{1300}{(1000 + s_{xe})}$$

$$\theta = (29 + 7000\varepsilon_x) \times \left(0.88 + \frac{s_{xe}}{2500} \right)$$

$$s_{xe} = 300 \text{ mm}$$

$$M_f > 213.6$$

$$\varepsilon = \frac{213.6 \times 1000/480 + 445}{200 \times 3226} = 0.000690$$

$$\beta = 0.4/(1+1500 \times 0.000690) \times 1300/(1000+300) = 0.197$$

$$\theta = (29 + 7000 \times 0.000690) (0.88+300/2500) = 33.8$$

$$V_c = 2.5 \times 0.197 \times 0.75 \times 2.1 \times 305 \times 480 / 1000 = 114 \text{ kN}$$

Shear strength of concrete with no shear reinforcement

$$\phi_v V_c = \phi_v 0.0316\beta\sqrt{f'_c} b d_v$$

AASHTO LRFD (2004) 5.8.3.3

$$\beta = f(s_{xe}, \varepsilon_x)$$

$$s_{xe} = s_x \frac{1.38}{a_g + 0.63} \leq 80 \text{ inches}$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + 0.5|V_f| \cot \theta \right]}{E_s A_s} \leq 0.002$$

$$s_{xe} = 18.9 \times 1.38 / (1 + 0.63) = 16.0 \text{ in}$$

For $s_{xe} < 20$, try 8th column $\theta = 45.5$

$$M_f > 50 \times 18.9 / 12 = 78.75 < 100$$

$$\varepsilon = \frac{100 \times 12/18.9 + 0.5 \times 50 \times \cot(45.5)}{29000 \times 5} = 0.000607$$

Since 0.000607 falls in assumed range, then $\beta = 2.09$

$$V_c = 0.9 \times 0.0316 \times 2.09(4)^{1/2} \times 12 \times 18.9 = 27.0 \text{ kips (120 kN)}$$

STRUCTWARE

SHEET C11-5 OF _____JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-A23.3 (2004) 11.3.4

$$V_c = \phi_c \beta \sqrt{f_c'} b d_v$$

$$\beta = \frac{0.40}{(1+1500\varepsilon_x)} \times \frac{1300}{(1000+s_{xe})}$$

$$\theta = 29 + 7000\varepsilon_x$$

$$s_{xe} = \frac{35s_x}{15+a_g} \geq 0.85s_x$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + |V_f| \right]}{2E_s A_s} \leq 0.003$$

$$M_f > 222 \times 480 / 1000 = 106.6 < 136$$

$$\varepsilon = \frac{136 \times 1000/480 + 222}{2 \times 200 \times 3226} = 0.000392$$

$$\theta = 29 + 7000 \times 0.000392 = 31.7$$

$$S_{xe} = 35 \times 480 / (15 + 20) = 480$$

$$\beta = 0.4 / (1 + 1500 \times 0.000392) \times 1300 / (1000 + 480) = 0.221$$

$$V_c = 0.65 \times 0.221 (27.6)^{1/2} \times 305 \times 480 / 1000 = 110 \text{ kN}$$

CAN/CSA-S6 (2006) 8.9.3.4

$$V_c = 2.5 \beta \phi_c f_r b d_v$$

$$\beta = \frac{0.40}{(1+1500\varepsilon_x)} \times \frac{1300}{(1000+s_{xe})}$$

$$\theta = (29 + 7000\varepsilon_x) \times \left(0.88 + \frac{s_{xe}}{2500} \right)$$

$$s_{xe} = \frac{35s_x}{15+a_g} \geq 0.85s_x$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + |V_f| \right]}{2E_s A_s} \leq 0.003$$

$$M_f > 106.6 < 136$$

$$\varepsilon = \frac{136 \times 1000/480 + 222}{2 \times 200 \times 3226} = 0.000392$$

$$\theta = (29 + 7000 \times 0.000392)(0.88 + 480/2500) = 34.0$$

$$S_{xe} = 35 \times 480 / (15 + 20) = 480$$

$$\beta = 0.4 / (1 + 1500 \times 0.000392) \times 1300 / (1000 + 480) = 0.221$$

$$V_c = 2.5 \times 0.221 \times 0.75 \times 2.1 \times 305 \times 480 / 1000 = 127 \text{ kN}$$

Strength of shear reinforcement

$$\phi V_s = \phi \frac{A_v f_y d}{s}$$

AASHTO (2002) 8.16.6.3.2
AREMA (2006) 8-2.35.3a
ACI 318 (2005) 11.5.7.2

$V_s = 0.85 \times 0.4 \times 60 \times 21 / 5 = 85.7$ kips (381 kN)
 $Av/s > (100 - 36.3)/(0.85 \times 60 \times 21) = 0.0595''$ (1.51 mm)
 $V_s = 0.75 \times 0.4 \times 60 \times 21 / 5 = 75.6$ kips (336 kN)(ACI)
 $Av/s > (100 - 32)/(0.75 \times 60 \times 21) = 0.072''$ (1.83 mm)(ACI)

$$\phi V_s = \phi \frac{A_v f_y d_v \cot \theta}{s}$$

AASHTO LRFD (2004) 5.8.3.3

$V_s = 0.9 \times 60 \times 0.4 \times 18.9 \times \cot(34.4) / 5 = 119$ kips (529 kN)
 $Av/s > (100 - 29.2)/(0.9 \times 60 \times 18.9 \times \cot(34.4)) = 0.0475''$ (1.21 mm)

$$V_s = \frac{\phi_s f_y A_v d_v \cot \theta}{s}$$

CSA-A23.3 (2004) 11.3.5
CAN/CSA-S6 (2006) 8.9.3.5

$V_s = 0.85 \times 414 \times 258 \times 480 \times \cot(33.8) / 127000 = 512$ kN (A23.3)
 $Av/s > (445 - 98.8) \times 1000 / (0.85 \times 414 \times 480 \times \cot(33.8)) = 1.37$ mm (A23.3)
 $V_s = 0.9 \times 414 \times 258 \times 480 \times \cot(33.8) / 127000 = 543$ kN (S6)
 $Av/s > (445 - 114) \times 1000 / (0.9 \times 414 \times 480 \times \cot(33.8)) = 1.24$ mm (S6)

Minimum longitudinal tension reinforcement

$$A_s \geq \frac{\frac{|M_f|}{\phi d_v} + \left(\frac{|V_f|}{\phi_v} - 0.5V_s \right) \cot \theta}{f_y}$$

AASHTO LRFD (2004) 5.8.3.5

$$\phi V_s \leq V_f$$

$119 > 100$ kips, therefore use $\phi V_s = V_f$
 $A_s = \frac{100 \times 12 / (0.9 \times 18.9) + (100 / 0.9 - 0.5 \times 100 / 0.9) \cot(34.4)}{60} = 2.53$ in² (1631 mm²)

$A_s = \frac{100 \times 12 / (0.9 \times 18.9) + (50 / 0.9) \cot(45.5)}{60} = 2.09$ in² (1346 mm²) (No shear reinforcement)

$$A_s \geq \frac{\frac{|M_f|}{d_v} + (V_f - 0.5V_s) \cot \theta}{\phi_s f_y}$$

CSA-A23.3 (2004) 11.3.9.2
CAN/CSA-S6 (2006) 8.9.3.11

$$V_s \leq V_f$$

512 and $543 > 445$ kips, therefore use $V_s = V_f$
 $A_s = \frac{136000 / 480 + (445 - 0.5 \times 445) \cot(33.8)}{0.85 \times 0.414} = 1750$ mm² (A23.3)
 $A_s = \frac{136000 / 480 + (445 - 0.5 \times 445) \cot(33.8)}{0.9 \times 0.414} = 1652$ mm² (S6)

STRUCTWARE

SHEET C11-7 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

$$A_s = \frac{136000}{480} + \frac{(222)\cot(31.7)}{0.85 \times 0.414} = 1827 \text{ mm}^2 \text{ (A23.3) (No shear reinforcement)}$$

$$A_s = \frac{136000}{480} + \frac{(222)\cot(34)}{0.9 \times 0.414} = 1644 \text{ mm}^2 \text{ (S6) (No shear reinforcement)}$$

REBEAM Output Files

The following output files are included below for the calculations performed in this section.

FILE	DESCRIPTION
Aashto-vde.out	AASHTO Shear design English units
Aashto-vre.out	AASHTO Shear review English units
Aci-vde.out	ACI-318 Shear design English units
Aci-vre.out	ACI-318 Shear review English units
Arema-vde.out	AREMA Shear design English units
Arema-vre.out	AREMA Shear review English units
Csa-uvrm.out	CSA-A23.3 Unreinforced concrete shear review metric units
Csa-vdm.out	CSA-A23.3 Shear design metric units
Csa-vrm.out	CSA-A23.3 Shear review metric units
Lrfd-uvre.out	AASHTO LRFD Unreinforced concrete shear review English units
Lrfd-vde.out	AASHTO LRFD Shear design English units
Lrfd-vre.out	AASHTO LRFD Shear review English units
S6-uvrm.out	CAN/CSA-S6 Unreinforced concrete shear review metric units
S6-vdm.out	CAN/CSA-S6 Shear design metric units
S6-vrm.out	CAN/CSA-S6 Shear review metric units

STRUCTWARE

SHEET C11-8 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AASHTO Shear design english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:21 pm

Output file = aashto-vde.out

Shear design problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-9 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.6365E+01
Maximum shear strength = 1.4474E+02

COMPUTED REINFORCING:

Required Av / s = 5.9400E-02
Minimum Av / s = 1.0000E-02
Max reinf spacing = 5.2500E+00

STRUCTWARE

SHEET C11-10 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AASHTO Shear review english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:30 pm

Output file = aashto-vre.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO (2002)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-11 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0.4
Shear reinf spacing = 5

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.6365E+01

SHEAR REINFORCING:

Min shear reinf area = 5.0000E-02
Max shear reinf spacing = 5.2500E+00

Shear reinf strength = 8.5680E+01
Ultimate shear capability = 1.2204E+02
Maximum shear capability = 1.4474E+02

STRUCTWARE

SHEET C11-12 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

ACI-318 Shear design english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:23 pm

Output file = aci-vde.out

Shear design problem

D E S I G N C R I T E R I A

=====

Code = ACI-318 (2005)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.75
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-13 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.2086E+01
Maximum shear strength = 1.2771E+02

COMPUTED REINFORCING:

Required Av / s = 7.1900E-02
Minimum Av / s = 1.0000E-02
Max reinf spacing = 5.2500E+00

STRUCTWARE

SHEET C11-14 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

ACI-318 Shear review english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:28 pm

Output file = aci-vre.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = ACI-318 (2005)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.75
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-15 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0.4
Shear reinf spacing = 5

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.2086E+01

SHEAR REINFORCING:

Min shear reinf area = 5.0000E-02
Max shear reinf spacing = 5.2500E+00

Shear reinf strength = 7.5600E+01
Ultimate shear capability = 1.0769E+02
Maximum shear capability = 1.2771E+02

STRUCTWARE

SHEET C11-16 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AREMA Shear design english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:23 pm

Output file = arema-vde.out

Shear design problem

D E S I G N C R I T E R I A

=====

Code = AREMA (2006)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-17 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.6365E+01
Maximum shear strength = 1.4474E+02

COMPUTED REINFORCING:

Required Av / s = 5.9400E-02
Minimum Av / s = 1.2000E-02
Max reinf spacing = 5.2500E+00

STRUCTWARE

SHEET C11-18 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AREMA Shear review english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5) 10/29/06, 12:29 pm

Output file = arema-vre.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = AREMA (2006)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.85
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6050E+06
Concrete modulus of rupture	= 474.3
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-19 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0.4
Shear reinf spacing = 5

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 2.1000E+01
Concrete shear strength = 3.6365E+01

SHEAR REINFORCING:

Min shear reinf area = 6.0000E-02
Max shear reinf spacing = 5.2500E+00

Shear reinf strength = 8.5680E+01
Ultimate shear capability = 1.2204E+02
Maximum shear capability = 1.4474E+02

STRUCTWARE

SHEET C11-20 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-A23.3 Unreinforced shear review metric

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* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
(Version 5.1)                               10/31/07, 6:02 pm
```

Output file = csa-uvrm.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = CSA A23.3 (2004)

Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.65
Reinforcing resistance factor	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.3641E+04
Concrete modulus of rupture	= 3.152
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-21 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 222

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

SHEAR REVIEW CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 1.1059E+02
Crack spacing parameter = 4.7970E+02
Longitudinal strain = 3.9175E-04
Theta = 3.1742E+01
Beta = 2.2135E-01

*** Design shear exceeds capacity ***

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 1.8254E+03

STRUCTWARE

SHEET C11-22 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-A23.3 Shear design metric

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 6:03 pm

Output file = csa-vdm.out

Shear design problem

D E S I G N C R I T E R I A
=====

Code = CSA A23.3 (2004)
Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.65
Reinforcing resistance factor	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S
=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.3641E+04
Concrete modulus of rupture	= 3.152
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L
=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-23 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 445

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 9.8226E+01
Maximum shear strength = 6.5619E+02

COMPUTED REINFORCING:

Required Av / s = 1.3800E+00
Minimum Av / s = 2.3222E-01
Max reinf spacing = 1.6790E+02

STRUCTWARE

SHEET C11-24 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-A23.3 Shear review metric

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 6:02 pm

Output file = csa-vm.out

Shear review problem

D E S I G N C R I T E R I A
=====

Code = CSA A23.3 (2004)
Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.65
Reinforcing resistance factor	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S
=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.3641E+04
Concrete modulus of rupture	= 3.152
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L
=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-25 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 258
Shear reinf spacing = 127

DESIGN LOADS

=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 445

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

SHEAR REVIEW CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 9.8226E+01
Crack spacing parameter = 3.0000E+02
Minimum moment = 2.1347E+02
Longitudinal strain = 6.8971E-04
Theta = 3.3828E+01
Beta = 1.9660E-01

SHEAR REINFORCING:

Min shear reinf area = 2.9492E+01
Max shear reinf spacing = 1.6790E+02

Shear reinf strength = 5.1172E+02
Ultimate shear capability = 6.0995E+02
Maximum shear capability = 6.5619E+02

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 1.7491E+03

STRUCTWARE

SHEET C11-26 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AASHTO LRFD Unreinforced shear review english

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/22/07, 4:46 pm

Output file = lrfd-uvre.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO LRFD (2004)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.90
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6400E+06
Concrete modulus of rupture	= 480
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-27 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0
Shear reinf spacing = 0

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 50

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 1.8900E+01
Concrete shear strength = 2.6981E+01
Crack spacing parameter = 1.6001E+01
Longitudinal strain = 6.0731E-04
Theta = 4.5500E+01
Beta = 2.0900E+00

*** Design shear exceeds capacity ***

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 2.0857E+00

STRUCTWARE

SHEET C11-28 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

```
AASHTO LRFD Shear design english

* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
*
* (Version 5.1)                               10/22/07, 4:46 pm

Output file = lrfd-vde.out

Shear design problem

D E S I G N   C R I T E R I A
=====

Code = AASHTO LRFD (2004)
Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor           = 0.90
Shear reduction factor             = 0.90
Concrete resistance factor         = 1.00
Reinforcing resistance factor      = 1.00

STRESS BLOCK:

Ratio of average concrete strength = 0.8500
Ratio of depth of compression block = 0.8500
Maximum concrete strain             = 0.0030

M A T E R I A L   P R O P E R T I E S
=====

Concrete compressive strength      = 4000
Concrete modulus of elasticity     = 3.6400E+06
Concrete modulus of rupture       = 480
Reinforcing yield strength         = 60000
Reinforcing modulus of elasticity  = 2.9000E+07
Modular ratio                      = 8
Maximum aggregate size             = 1.000

R E I N F O R C I N G   S T E E L
=====

Tensile reinf area                 = 5
Depth to tensile reinf             = 21
Compressive reinf area             = 0
Depth to compressive reinf         = 0
```

STRUCTWARE

SHEET C11-29 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 1.8900E+01
Concrete shear strength = 2.9176E+01
Maximum shear strength = 2.0412E+02

COMPUTED REINFORCING:

Required Av / s = 4.7500E-02
Minimum Av / s = 1.2649E-02
Max reinf spacing = 1.5120E+01

STRUCTWARE

SHEET C11-30 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AASHTO LRFD Shear review english

```
* * * * *  
*  
*           P R O G R A M   R E B E A M           *  
*  
*           O U T P U T   D A T A                 *  
*  
* * * * *  
* * * * *  
* * * * *
```

(Version 5.1) 10/31/07, 5:23 pm

Output file = lrfd-vre.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO LRFD (2004)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.90
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6400E+06
Concrete modulus of rupture	= 480
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-31 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0.4
Shear reinf spacing = 5

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 100

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 1.8900E+01
Concrete shear strength = 2.9176E+01
Minimum moment = 1.5750E+02
Longitudinal strain = 5.9663E-04
Theta = 3.4400E+01
Beta = 2.2600E+00

SHEAR REINFORCING:

Min shear reinf area = 6.3246E-02
Max shear reinf spacing = 1.5120E+01
Shear reinf strength = 1.1924E+02
Ultimate shear capability = 1.4842E+02
Maximum shear capability = 2.0412E+02

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 2.5281E+00

STRUCTWARE

SHEET C11-32 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-S6 Unreinforced shear review metric

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 11/01/07, 8:22 pm

Output file = s6-uvrm.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = CAN/CSA-S6 (2006)

Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.75
Reinforcing resistance factor	= 0.90

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.4913E+04
Concrete modulus of rupture	= 2.101
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-33 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0
Shear reinf spacing = 0

DESIGN LOADS

=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 222

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

SHEAR REVIEW CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 1.2758E+02
Crack spacing parameter = 4.7970E+02
Longitudinal strain = 3.9175E-04
Theta = 3.4024E+01
Beta = 2.2135E-01

*** Design shear exceeds capacity ***

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 1.6434E+03

STRUCTWARE

SHEET C11-34 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-S6 Shear design metric

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 5:21 pm

Output file = s6-vdm.out

Shear design problem

D E S I G N C R I T E R I A

=====

Code = CAN/CSA-S6 (2006)
Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.75
Reinforcing resistance factor	= 0.90

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.4913E+04
Concrete modulus of rupture	= 2.101
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-35 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

DESIGN LOADS

=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 445

SECTION PROPERTIES

=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

SHEAR DESIGN CALCULATIONS

=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 1.1331E+02
Maximum shear strength = 7.5715E+02

COMPUTED REINFORCING:

Required Av / s = 1.2400E+00
Minimum Av / s = 2.3218E-01
Max reinf spacing = 1.5830E+02

STRUCTWARE

SHEET C11-36 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

CSA-S6 Shear review metric

```
* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
```

(Version 5.1) 10/31/07, 5:18 pm

Output file = s6-vrm.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = CAN/CSA-S6 (2006)
Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.75
Reinforcing resistance factor	= 0.90

STRESS BLOCK:

Ratio of average concrete strength	= 0.8090
Ratio of depth of compression block	= 0.9010
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 27.6
Concrete modulus of elasticity	= 2.4913E+04
Concrete modulus of rupture	= 2.101
Reinforcing yield strength	= 414
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 3226
Depth to tensile reinf	= 533
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C11-37 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 10/21/2006

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 258
Shear reinf spacing = 127

D E S I G N L O A D S
=====

Factored (ultimate) moment = 136
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 445

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 305
Height = 610

PROPERTIES:

Gross moment of inertia = 5.7691E+09
Gross section modulus = 1.8915E+07
Distance to neutral axis = 3.0500E+02
Cracked moment of inertia = 3.6057E+09

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 4.7970E+02
Concrete shear strength = 1.1331E+02
Crack spacing parameter = 3.0000E+02
Minimum moment = 2.1347E+02
Longitudinal strain = 6.8971E-04
Theta = 3.3828E+01
Beta = 1.9660E-01

SHEAR REINFORCING:

Min shear reinf area = 2.9486E+01
Max shear reinf spacing = 1.5830E+02

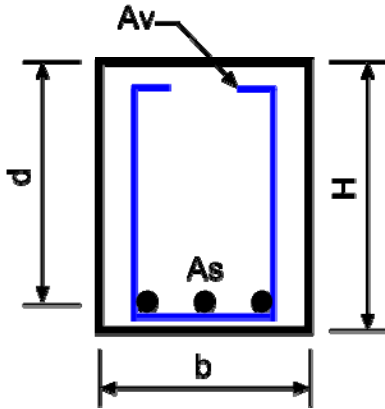
Shear reinf strength = 5.4182E+02
Ultimate shear capability = 6.5514E+02
Maximum shear capability = 7.5715E+02

MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 1.6520E+03

VERIFICATION PROBLEM NO. 12

Determine concrete shear strength using AASHTO LRFD code with shear stress less than minimum table values. This capability was added in version 5.10.



$f'_c = 4000$ psi (27.6 MPa)
 $f_y = 60000$ psi (414 MPa)

$b = 12''$ (305 mm)
 $H = 24''$ (610 mm)
 $D = 21''$ (533 mm)

$A_s = 5$ in² (3226 mm²)
 $A_v = 0.4$ in² (258 mm²) – for review
 $s = 5''$ (127 mm) – for review

$M_u = 100$ k-ft (136 kN-m)
 $V_u = 50$ kips (222 kN)

Shear strength of concrete

$$\phi V_c = \phi 0.0316 \beta \sqrt{f'_c} b d_v$$

AASHTO LRFD (2004) 5.8.3.3

$$\beta = f \left(\frac{v_f}{f'_c}, \varepsilon_x \right)$$

$$\varepsilon_x = \frac{\left[\frac{|M_f|}{d_v} + 0.5 |V_f| \cot \theta \right]}{2 E_s A_s} \leq 0.001$$

$$M_f > 100 \times 18.9 / 12 = 157.5$$

$$v_f / f'_c = 50 / (12 \times 18.9 \times 0.9 \times 4) = 0.061 < \text{minimum table value of } 0.075$$

For $v_f / f'_c < 0.075$, try 7th column theta = 30.5

$$\varepsilon = \frac{157.5 \times 12 / 18.9 + 0.5 \times 50 \times \cot(30.5)}{2 \times 29000 \times 5} = 0.000491$$

Since $0.00025 < 0.000491 < 0.0005$ falls in assumed range, then theta = 30.5, beta = 2.59.

$$V_c = 0.9 \times 0.0316 \times 2.59(4)^{1/2} \times 12 \times 18.9 = 33.4 \text{ kips (149 kN)}$$

STRUCTWARE

SHEET C12-2 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

AASHTO LRFD Shear review english

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* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
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(Version 5.1) 11/02/07, 3:08 pm

Output file = lrfd-vre-min.out

Shear review problem

D E S I G N C R I T E R I A

=====

Code = AASHTO LRFD (2004)

Units = English (pounds, inches - shear and moments in kip-ft)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 0.90
Shear reduction factor	= 0.90
Concrete resistance factor	= 1.00
Reinforcing resistance factor	= 1.00

STRESS BLOCK:

Ratio of average concrete strength	= 0.8500
Ratio of depth of compression block	= 0.8500
Maximum concrete strain	= 0.0030

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3.6400E+06
Concrete modulus of rupture	= 480
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9000E+07
Modular ratio	= 8
Maximum aggregate size	= 1.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5
Depth to tensile reinf	= 21
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C12-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Shear reinf area = 0.4
Shear reinf spacing = 5

D E S I G N L O A D S
=====

Factored (ultimate) moment = 100
Maximum service load moment = 0
Minimum service load moment = 0
Factored (ultimate) shear = 50

S E C T I O N P R O P E R T I E S
=====

RECTANGULAR SECTION:

Width = 12
Height = 24

PROPERTIES:

Gross moment of inertia = 1.3824E+04
Gross section modulus = 1.1520E+03
Distance to neutral axis = 1.2000E+01
Cracked moment of inertia = 8.6758E+03

S H E A R R E V I E W C A L C U L A T I O N S
=====

CONCRETE SHEAR CAPABILITY:

Effective shear depth = 1.8900E+01
Concrete shear strength = 3.3436E+01
Longitudinal strain = 3.6529E-04
Theta = 3.0500E+01
Beta = 2.5900E+00

SHEAR REINFORCING:

Min shear reinf area = 6.3246E-02
Max shear reinf spacing = 1.5120E+01

Shear reinf strength = 1.3861E+02
Ultimate shear capability = 1.7205E+02
Maximum shear capability = 2.0412E+02

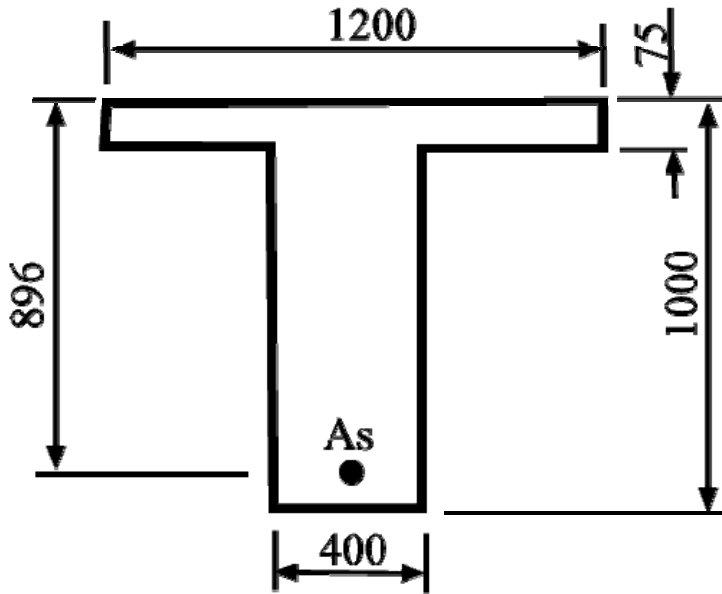
MINIMUM LONGITUDINAL TENSILE REINFORCING:

Minimum reinf area = 1.9617E+00

VERIFICATION PROBLEM NO. 13

CAN/CSA S6 code

Ref. CPCA, "Concrete Design Handbook", 2nd edition, Example 2.7



Same beam as used in verification problem no. 7

$f'_c = 30 \text{ MPa}$
 $f_y = 400 \text{ MPa}$

$A_s = 5600 \text{ mm}^2 \Rightarrow (8) \text{ 30M bars}$
 $M_f = 1500 \text{ kN-m}$
 $M_{\max} = 1000 \text{ kN-m}$

STRUCTWARE

SHEET C13-2 OF _____JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

$$\alpha_1 = 0.85 - 0.0015 \times 30 = 0.805$$

$$\beta_1 = 0.97 - 0.0025 \times 30 = 0.895$$

$$E_c = (3000(30)^{1/2} + 6900)(2450/2300)^{1.5} = 25650 \text{ MPa}$$

$$y_{cg} = (800 \times 75 \times 37.5 + 400 \times 1000 \times 500) / 460000 = 440 \text{ mm}$$

$$I_g = 800(75)^3/12 + 400(1000)^3/12 + 60000(402.5)^2 + 400000(60)^2$$

$$I_g = 4.452E+10 \text{ mm}^4$$

$$1.2M_{cr} = 1.2 \times 0.4(30)^{1/2} \times 4.452E+10 / [(1000 - 440) \times 1000000] = 209 \text{ kN-m}$$

$$400y^2/2 + 60000(y - 37.5) = 8 \times 5600(896 - y)$$

$$200y^2 + 104800y - 42390800 = 0$$

$$y = 268 \text{ mm}$$

$$I_{cr} = 400(268)^3/3 + 800(75)^3/12 + 60000(230.5)^2 + 8 \times 5600(628)^2$$

$$I_{cr} = 2.345E+10 \text{ mm}^4$$

$$S_c = I_{cr} / y = 87500000$$

$$S_s = I_{cr} / ((896 - 268) \times 8) = 4667596$$

$$f_{cmax} = 1000 \times 1000000 / 87500000 = 11.43 \text{ MPa}$$

$$f_{smax} = 1000 \times 1000000 / 4667596 = 214 \text{ MPa}$$

Crack width = w

$$w = 1.0 \times 1.7 \times s_{rm} \times \epsilon_{sm}$$

Bar diameter $d_b = 30$

$$A_{ct} = 400 \times (1000 - 268) / 3 = 97600$$

$$\rho_c = 5600 / 97600 = 0.0574$$

$$s_{rm} = 50 + 0.25 \times 0.5 \times 30 / 0.0574 = 115$$

$$M_w = 209 / 1.2 = 174 \text{ kN-m}$$

$$f_w = 174 \times 1000000 / 4667596 = 37.3 \text{ MPa}$$

$$\epsilon_{sm} = (214 / 200000) \times [1 - (37.3/214)^2] = 0.00104$$

$$w = 1.0 \times 1.7 \times 115 \times 0.00104 = 0.20 \text{ mm} < 0.35 \text{ mm Okay}$$

Tension steel is assumed to yield.

with $a = 128.3 \text{ mm}$

$$T = 0.9 \times 400 \times 5600 = 2016000 \text{ N}$$

$$C_{web} = 0.75 \times 0.805 \times 30 \times 128.3 \times 400 = 929534 \text{ N}$$

$$C_{flange} = 0.75 \times 0.805 \times 30 \times 800 \times 75 = 1086750 \text{ N}$$

$$M_r = 929.534 \times (0.896 - 0.1283 / 2) + 1086.75 \times (0.896 - 0.075 / 2) = 1706 \text{ kN-m}$$

STRUCTWARE

SHEET C13-3 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Verification problem 13 review

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* * * * *
*
*           P R O G R A M   R E B E A M
*
*           O U T P U T   D A T A
*
* * * * *
(Version 5.1)                               11/02/07, 7:49 pm
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Output file = v13.out

Moment review problem

D E S I G N C R I T E R I A

=====

Code = CAN/CSA-S6 (2006)

Units = Metric (Newtons, millimeters - shear and moments in kN-m)

STRENGTH REDUCTION AND RESISTANCE FACTORS:

Flexure reduction factor	= 1.00
Shear reduction factor	= 1.00
Concrete resistance factor	= 0.75
Reinforcing resistance factor	= 0.90

STRESS BLOCK:

Ratio of average concrete strength	= 0.8050
Ratio of depth of compression block	= 0.8950
Maximum concrete strain	= 0.0035

M A T E R I A L P R O P E R T I E S

=====

Concrete compressive strength	= 30
Concrete modulus of elasticity	= 2.5650E+04
Concrete modulus of rupture	= 2.191
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 2.0000E+05
Modular ratio	= 8
Maximum aggregate size	= 20.000

R E I N F O R C I N G S T E E L

=====

Tensile reinf area	= 5600
Depth to tensile reinf	= 896
Compressive reinf area	= 0
Depth to compressive reinf	= 0

STRUCTWARE

SHEET C13-4 OF

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. CALCULATION No. REVIEWER DATE

Shear reinf area	= 0
Shear reinf spacing	= 0
DESIGN LOADS	
=====	
Factored (ultimate) moment	= 1500
Maximum service load moment	= 1000
Minimum service load moment	= 0
Factored (ultimate) shear	= 0
SECTION PROPERTIES	
=====	
TEE SECTION:	
Height	= 1000
Top flange width	= 1200
Top flange thickness	= 75
Total web thickness	= 400
PROPERTIES:	
Gross moment of inertia	= 4.4522E+10
Gross section modulus	= 7.9457E+07
Distance to neutral axis	= 4.3967E+02
Cracked moment of inertia	= 2.3451E+10
Effective moment of inertia	= 2.3562E+10
MOMENT REVIEW CALCULATIONS	
=====	
MINIMUM REINFORCING:	
1.2 * Cracking moment	= 2.0891E+02
Design moment	= 1.5000E+03
MAXIMUM REINFORCING:	
c/d	= 1.5994E-01
Maximum c/d	= 5.0000E-01
MOMENT CAPABILITY:	
Ultimate moment capability	= 1.7060E+03
Stress block depth	= 1.2826E+02

STRUCTWARE

SHEET C13-5 OF _____

JOB TITLE Rebeam Program Documentation ORIGINATOR RM DATE 11/2/2007

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

SERVICE LOAD STRESS:

Maximum steel stress = 2.1433E+02
Minimum steel stress = 0.0000E+00
Maximum concrete stress = 1.1416E+01
Minimum concrete stress = 0.0000E+00

CRACK CONTROL:

Rebar x load type factor = 1.7
Rebar diameter = 30
Average crack spacing = 1.1538E+02
Average rebar strain = 1.0392E-03
Computed crack width = 2.0384E-01
Maximum crack width = 3.5000E-01