EXPANSION JOINTS

NOTATIONS

θ = Skew angle.

α = Coefficient of thermal expansion
0.0000060/°F for concrete
0.0000065/°F for steel

β = Shrinkage Coefficient for reinforced concrete, 0.0003.

γ_{TU} = Load factor due to temperature, 1.20

μ = Factor accounting for the restraining effect imposed by superstructure elements installed before the concrete slab is cast.
1.0 for flat slabs
0.8 for cast-in-place box girders and t-beams
0.5 for prestressed girders
0.0 for steel girder bridges

T_c= Structure temperature during construction of joint opening.

L = Length of structure contributing to expansion or contraction of the joint (feet).

W = Nominal uncompressed width of expansion seal (inches)

A = Joint opening normal to joint at the time of deck placement (inches).

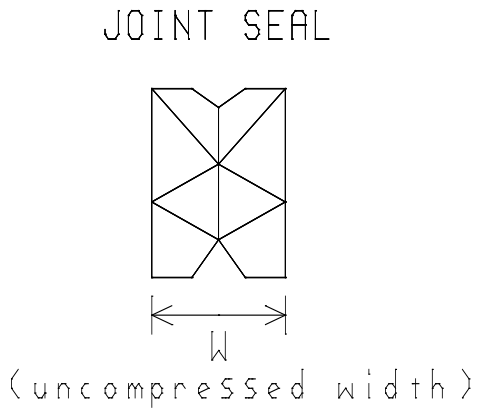
K = Temperature drop below the installation temperature divided by temperature range.
Assume installation temperature equals 60°F

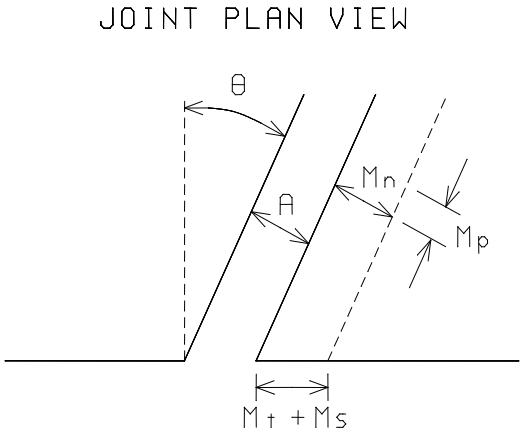
M_t= Movement due to temperature (inches).

M_s= Movement due to shrinkage after construction (inches)

M_p= Movement parallel to joint (inches).

M_n= Movement normal to joint (inches).





SELECTION CRITERIA FOR COMPRESSION SEALS

I. Design Limitations

A. Total anticipated movement of the expansion joint, $M_t + M_s$, should not exceed 2". When the nominal seal width computed by the following procedure exceeds 2", a joint system with greater movement capacity is required.

B. The maximum joint opening shall not be greater than 0.85W. The minimum joint opening shall not be less than 0.40W. The minimum joint opening at installation of the seal shall not be less than 0.60W.

C. The skew angle should not exceed 30°.

D. Temperature Range

Concrete structures.....… 0° to 80°F
Steel structures.....…….. -30° to 120°F

II. Design Procedure

A. Movement Calculations

1. $M_t = 12(L)(\alpha)(\text{temp. range})(\gamma_{TU})$
2. $M_s = 12(L)(\beta)(\mu)$
3. $M_p = (M_t + M_s) \sin\theta \leq 0.22W$
4. $M_n = (M_t + M_s) \cos\theta \leq 0.45W$

B. Selection of Seal Width

1. The maximum joint opening is equal to the minimum installation opening plus the movement due to temperature drop and shrinkage, therefore:
   $0.85W = 0.60W + (\cos\theta)(KM_t + M_s)$, or
   $W = 4(\cos\theta)(KM_t + M_s)$
2. The seal width to accommodate M_p:
   $W = M_p \div 0.22$
3. The seal width to accommodate M_n:
   $W = M_n \div 0.45$
4. The minimum seal width, W, shall be the largest of the values calculated in steps 1 thru 3 above.

C. Width of expansion joint opening at 60°F:

$A = (0.60)(W)$

D. Adjustment in joint opening for a 10°F change in temperature.

III. Design Example

Structure type, prestressed girder.
Total length, 300'.
Skew angle, 25°.
Expansion joints at both abutments.
Point of no movement for temperature and shrinkage is at the center of the bridge.

Value of Constants:

$\theta = 25°$
$\alpha = 0.000006/°F$
$\beta = 0.0003$
$\mu = 0.5$
$L = 300' \div 2 = 150'$
$K = (60\text{-}0) \div 80 = 0.75$

A. Movement Calculations

1. $M_t = (12)(150)(0.000006)(80)(1.20) = 1.04"$
2. $M_s = (12)(150)(0.0003)(0.5) = 0.270"$
3. $M_p = (1.04 + 0.27) \sin 25° = 0.55"$
4. $M_n = (1.04 + 0.27) \cos 25° = 1.19"$

B. Selection of Seal Width

1. $W = 4(\cos 25°)[(0.75)(1.04) + 0.27] = 3.80"$
2. $W = 0.55 \div 0.22 = 2.51"$
3. $W = 1.19 \div 0.45 = 2.63"$
4. Therefore use W = 3.80"

WA-400	W = 4.00”
CV-4000	W = 4.00”

SELECTION CRITERIA FOR COMPRESSION SEALS

C. Width of expansion joint opening at 60°F:
A =(0.60)(4.00) = 2.40”

D. Adjustment for 10°F temperature change
Δ = (12)(150)(0.000006)(10°)(cos 25°) = 0.098”

SELECTION CRITERIA FOR SILICONE SEALS

I. Design Limitations

A. Sealant designed to accommodate 100% tension and 50% compression.
B. Use on rehabilitation projects.
C. Temperature Range

Concrete structures.....… 0° to 80°F
Steel structures.....……. -30° to 120°F

II. Design Procedure

A. Movement Calculations
1. $M_t = 12(L)(\alpha)(\text{temp range})\ (\gamma_{TU})$

2. $M_s = 0$
3. $M_{normal} = (M_t + M_s)(\cos\theta)$
4. $M_{10F} = 12(L)(\alpha)(10°F)$

B. Expansion gap widths at assumed extreme installation temperatures
1. $G_{min} = G_{exist} + (T_{normal}\text{-}Install_{min})/10(M_{10F})$
2. $G_{max} = G_{exist} - Install_{max}\text{-}T_{normal})/10(_{M10F})$

C. Check sealant capacity if installed at assumed minimum temperature
1. Closing movement
$M_c = (T_{max}\text{-}Install_{min})/10(M_{10F})$
2. Check 50% compression
$Mc/Gmin < 0.50$
3. Opening Movement
$M_o = (Install_{min} - T_{min})/10(M_{10F})$
4. Check 100% tension
$M_o/G_{min} < 1.00$

D. Check sealant capacity if installed at assumed maximum temperature
1. Closing movement
$M_c = (T_{max}\text{-}Install_{max})/10(M_{10F})$
2. Check 50% compression
$Mc/G_{max} < 0.50$
3. Opening Movement
$M_o = (Install_{max} - T_{min})/10(M_{10F})$
4. Check 100% tension
$M_o/G_{max} < 1.00$

III. Design Example

Existing 25 year old concrete bridge with 1" expansion gaps at each abutment at 60°F
160' total length
Skew angle = 15°

Value of constants

$\Theta = 15°$
$\alpha = 0.0000060$
$L = 160/2 = 80'$
$T_{min} = 0°$
$T_{max} = 80°$
$T_{normal} = 60°$
$G_{exist} = 1"$
$Install_{min} = 40°$
$Install_{max} = 80°$

A. Movement Calculations
1. $M_t = (12)(80')(0.0000060)(80°\text{-}0°)(1.20) = 0.53"$

SELECTION CRITERIA FOR SILICONE SEALS

2. $M_s = 0$
3. $M_{normal} = (0.553" + 0)(\cos 15°) = 0.534"$
4. $M_{10F} = (12)(80')(0.0000060)(10°)(\cos 15°) = 0.0556"$

B. Expansion gaps at assumed extreme installation temperatures
   1. $G_{min} = 1" + (60°-40°)/10(0.0556) = 1.111"$
   2. $G_{max} = 1" - (80°-60°)/10(0.0556) = 0.89"$

C. Check Sealant Capacity at minimum installation temperature
   1. $M_c = (80°-40°)/10(0.0556) = 0.224"$
   2. $0.224/1.111 = 0.20 < 0.50$ OK
   3. $M_o = (40°-0°)/10(0.0556) = 0.224"$
   4. $0.224/1.111 = 0.20 < 1.00$ OK

D. Check Sealant Capacity at maximum installation temperature
   1. $M_c = (80°-80°)/10(0.0556) = 0.0"$
   2. $0.0/0.89 = 0.\ 0 < 0.50$ OK
   3. $M_o = (80°-0°)/10(0.0556) = 0.445"$
   4. $0.445/0.89 = 0.50 < 1.00$ OK

SELECTION CRITERIA FOR STRIP SEALS

I. Design Limitations

A. Total anticipated movement of the expansion joint should not exceed 4". When the nominal seal width computed by the following procedure exceeds 4", a joint system with greater movement capacity is required. The movement is measured along centerline of bridge.

B. The minimum joint opening at installation of the seal shall not be less than 1.5" normal to the joint.

C. Skewed joints are classified as follows:

TYPE	SKEW ANGLE
1	≤30°
2	>30° ≤ 45°
3	>45°

For skews greater than 45° also contact the manufacturer's representative for help in selecting both the joint type and size.

D. Temperature Range

Concrete structures.....… 0° to 80°F
Steel structures.....……. -30° to 120°F

II. Design Procedure

A. Movement Calculations

1. Calculate the joint opening movement due to temperature drop from the installation temperature and shrinkage.

2. a. Calculate the total closing movement due to temperature rise from the installation temperature.

b. Convert the 1.5" minimum installation width normal to the joint to a length along centerline of bridge.

c. Use the larger value obtained from (a) or (b).

3. The total movement along the centerline of bridge is equal to (1) + (2).

B. Joint Size

1. Type 1 Joints: The joint size required equals the total movement along the centerline of bridge.

2. Type 2 Joints: The joint size required equals the larger of:
   - The total movement along the centerline of bridge,
   - The movement parallel to the joint centerline divided by 0.60.

3. Type 3 Joints: The joint size required equals the larger of:
   - The total movement along the centerline of bridge,
   - The movement parallel to the joint centerline divided by 0.50.

C. Calculate the width of expansion joint opening at 60°F. The width along centerline of bridge equals the total closing movement plus the gap at full closure.

D. Calculate the adjustment in joint opening for a 10°F change in temperature.

SELECTION CRITERIA FOR STRIP SEALS

III. Design Example 1

Structure type, prestressed girder
Total length, 400'.
Skew angle, 30°.
Expansion joints at both abutments.
Point of no movement for temperature and shrinkage is at the center of the bridge.
Value of Constants:

$\theta = 30°$
$\alpha = 0.000006/°F$
$\beta = 0.0003$
$\mu = 0.5$
$L = 400' \div 2 = 200'$

A. Movement Calculations

1. Opening Movement

$M_t = (12)(200)(0.000006)(60\text{-}0)\,)(\,1.20) = 1.04"$
$M_s = (12)(200)(0.0003)(0.5) = 0.36"$
Total opening movement = 1.40"

2. Closing Movement

a. $M_t = (12)(200)(0.000006)(80\text{-}60)\ (1.20) = 0.35"$
b. Assume 0" min. gap (1.5-0)/cos 30° = 1.732"
c. Total closing movement = 1.732"

3. Total Movement = 1.40 + 1.732 = 3.13”

B. Joint Size

Type 1 joint
Total = 3.13"
SE-400: total movement = 4.00” min. gap = 0”
A2R-400: total movement = 4.00” min. gap = 0.5”

C. Joint width at 60°

(1.5)/cos 30° = 1.732"
(0.5)/cos 30° = 0.577"
Total = 2.309"

D. Adjustment in joint opening for a 10°F change in temperature:

$\Delta = (12)(200)(0.000006)(10°)(\cos 30°) = 0.125”$

SELECTION CRITERIA FOR STRIP SEALS

III. Design Example 2

Structure type, concrete box girder
Total length, 600'.
Skew angle, 35°.
Expansion joints at both abutments.
Point of no movement for temperature and shrinkage is at the center of the bridge.
Value of Constants:

$\theta = 35°$
$\alpha = 0.000006/°F$
$\beta = 0.0003$
$\mu = 0.8$
$L = 600' \div 2 = 300'$

A. Movement Calculations

1. Opening Movement

$M_t = (12)(300)(0.000006)(60-0)\ (1.20) = 1.56"$
$M_s = (12)(300)(0.0003)(0.8) = 0.864"$
Total opening movement = 2.42"

2. Closing Movement

a. $M_t = (12)(300)(0.000006)(80-60)\ (1.20) = 0.52"$
b. Assume 0" min. gap $(1.5-0)/\cos 35° = 1.831"$
c. Total closing movement = 1.831"

3. Total Movement = 2.42 + 1.831 = 4.25”

B. Joint Size

2a. Type 2 joint Total = 4.25"

2b. $M_p = (4.25)(\sin 35°) = 2.44"$
$2.44/0.6 = 4.07"$
SE-400: total movement = 4.00” min. gap = 0”
A2R-400: total movement = 4.00” min. gap = 0.5”

C. Joint width at 60°

$(1.5)/\cos 35° = 1.831"$
$(0.5)/\cos 35° = 0.610"$
Total = 2.441"

D. Adjustment in joint opening for a 10°F change in temperature:

$\Delta = (12)(300)(0.000006)(10°)(\cos 35°) = 0.177”$

SELECTION CRITERIA FOR MODULAR JOINTS

I. Design Limitations

A. Maximum movement of 3" per each seal element.
B. Maximum gap between adjacent center beams should be limited to 3½".
C. Temperature movements should be increased for the load factor of 1.20.
D. Temperature Range
   Concrete structures.....… 0° to 80°F
   Steel structures.....……. -30° to 120°F

II. Design Procedure

A. Movement Calculations
   1. Calculate the joint opening movement due to temperature drop from the installation temperature and shrinkage.
   2. Calculate the joint closing movement due to temperature rise from the installation temperature.
   3. Total movement (M_t) along centerline of bridge is the sum of (1) & (2).
   4. Total movement normal to joint is $M_t(\cos\theta)$.

B. Joint Size
   1. Total movement range (MR) should be a multiple of 3" based upon A3,

C. Installation Gaps
   1. Compute the minimum distance face-face of edge beams (G_{min}).
      Number of seals (n) = MR/3
      Number of center beams = (n-1)
      w = Center beam top flange width
      g = Minimum gap per seal at full closure
      $G_{min} = (n-1)(w) + (n-1)(g)$
   2. Compute the maximum distance face-face of edge beams (G_{max}).
      $G_{max} = G_{min} + MR$
   3. Compute gaps at different temperatures.

D. Center Beam Spacing
   1. Check spacing between center beams at minimum temperature.
      $G_{0F} = G_{60F}$ + total opening movement
      Spacing = $[G_{0F} – (n-1)(w)]/n$
   2. Check spacing between center beams at 60°F for seal replacement.
      Spacing = $[G_{60F} – (n-1)(w)]/n$

III. Design Example

Structure type - box girder
Total length – 1200'
Skew Angle - 15°
Expansion joints at both abutments
Point of no movement for temperature and shrinkage is at the center of the bridge
Value of Constants:
$\Theta = 0°$
$\alpha = 0.0000060$
$\beta = 0.0003$
$\mu = 0.8$
L = 1200/2 = 600'

SELECTION CRITERIA FOR MODULAR JOINTS

A. Movement Calculations

1. Opening Movement

M_{temp} = (12)(600)(0.0000060)(60-0)(1.20)= 3.11”

M_{shrink} = (12)(600)(0.0003)(0.8) = 1.728”

Total = 4.84”

2. Closing Movement

M_{temp} = (12)(6300)(0.0000060)(80-60)(1.20) = 1.04”

3. Total Movement along centerline of bridge

M_{total} = (4.84+1.04) = 5.88”

4. Total movement normal to joint

M_{normal} = 5.88”(cos15) = 5.68”

B. Joint Size

1. MR = 5.68” Use a 6” movement rating joint.

C. Installation Gaps

1. Assume center beam top flange width =2½”

Number of seals = 6/3 = 2

Number of center beams = (2-1) = 1

Minimum gap per seal at full closure = 0”

G_{min} = (1)(2.50”) + (1)(0”) = 2.50”

2. G_{max} = 2.5” + 6” = 8.5”

3. G_{60F} = G_{min} + total closing movement = 2.5” + (1.04”)(cos15) = 3.50”

Adjustment in opening for a 10°F change in temperature = (12)(600)(0.0000060)(10)(cos15)= 0.417”

G_{40F} = 3.50” + (60-40)/10(0.417) = 4.33”

G_{80F} = 3.50” – (80-60)/10(0.417) = 2.67”

D. Center Beam Spacing

1. Spacing at minimum temperature

G_{0F} = 3.50” + (4.84)(cos15) = 8.18”

Spacing = [8.18 – (1)(2.50”)]/2 = 2.84” < 3.50” OK

2. Spacing at 60°F

Spacing = [3.50” – (1)(2.50”)]/2 = 0.50” Minimum recommended installation width = 1.5”. Center beam must be mechanically separated in order to replace strip seal elements.

Revisions:

July 2009	Added definition of μ on Page 1 and revised 0.8 factor to include c-i-p box girders & t-beams
	Added Selection Criteria for modular Joints
	Added Selection Criteria for silicone sealant joints
March 2011	Changed coefficient of shrinkage for concrete β to 0.0003 to agree with the value used for bearing design. 0.0003 is the average of the values in Article 5.4.3.2.1.
	Added temperature load factor of 1.20
	Deleted the 15% modular joint size increase due to adding the temperature load factor