E.6.1 General

The following text is a consolidation of Chapters 7 and 8 of Vol. 10A, "Load Rating Post-tensioned Concrete Segmental Bridges".

E.6.1.1 Rating Equation and Load Combinations

Six (6) features of concrete segmental bridges are to be load rated at both Inventory and Operating Levels. Three of these criteria are at the Service Limit State and three at the Strength Limit State, as follows:

At the Service Limit State:

- Longitudinal Box Girder Flexure
- Transverse Top Slab Flexure
- Principle Web Tension

At the Strength Limit State:

- Longitudinal Box Girder Flexure
- Transverse Top Slab Flexure
- Web Shear

E.6.1.2 General Load Rating Equation

In accordance with AASHTO LRFR Equation 6-1, the general Load Rating Factor, RF, shall be determined according to the formula:

$$RF = \frac{C - \gamma_{DC}DC - \gamma_{DW}DW \pm \gamma_{EL}(P + EL) - \gamma_{FR}FR - \gamma_{CR}(TU + CR + SH) - \gamma_{TG}TG}{\gamma_{L}(LL + IM)}$$

Where:

For Strength Limit States:

C = Capacity = (ϕ_c x ϕ_s x ϕ) R_n.
ϕ_c = Condition Factor per Article E.6.1.4.
ϕ_s = System Factor per Article E.6.1.5.
ϕ = Strength Reduction Factor per LRFD.
R_n = Nominal member resistance as inspected, measured and calculated according to formulae in LRFD - with the exception of shear, for which, capacity is calculated according to the AASHTO Guide Specification for Segmental Bridges.

For Service Limit States:

C = f_R = Allowable stress at the Service Limit State *(Table 1.5).*

Allowable stress levels have been established in order to limit cracking and protect the integrity of corrosion protection afforded post-tensioning tendons. This is particularly important for posting in order to limit the effects of excessive loads and rogue vehicles.

Load Effects and Nomenclature per LRFD / LRFR:

DC = Dead load of structural components (includes barriers if accurately known).
DW = Dead load of permanent superimposed loads such as wearing surface and utilities (applies to barriers when weight is not accurately known).
P = Permanent effects other than dead load (LRFR), including prestress.
EL = Permanent effects of erection forces (e.g. from erection equipment, changes in statical scheme) and includes secondary effects of post-tensioning.
FR = Forces from fixed bearings, bearing friction or frame action, otherwise zero.
TU = Uniform temperature effects from fixed bearings or frame action, otherwise zero.
CR = Creep.
SH = Shrinkage.
TG = Thermal gradient.
LL = Live load.
IM = Dynamic Load Allowance (Impact).
γ_{DC} = Load factor for structural components.
γ_{DW} = Load factor for permanent superimposed dead loads.
γ_{EL} = Load factor for secondary PT effects and locked-in erection loads.
γ_{FR} = Load factor for bearing friction or frame action.
γ_{CR} = Load factor for uniform temperature, creep and shrinkage.
γ_{TG} = Load factor for thermal gradient.
γ_{L} = Live load factor.

E.6.1.3 Capacity Factors

The LRFR Strength Limit States capacity factors to be used for load rating Florida concrete segmental bridges are discussed herein. Capacity factors are not used for Service Limit States. These capacity factors were developed by extending the concepts of “structural condition” and “structural redundancy” given in LRFR to the particulars of concrete segmental bridges

The Strength Limit State capacity factors to be used in LRFR load ratings are:

ϕ = LRFD Strength Reduction Factor as appropriate to type of load effect (flexure, shear, torsion) and structural configuration or detail.
ϕ_C = Condition Factor - takes a value from 0.85 to 1.10.
ϕ_S = System Factor - takes a value from 0.85 to 1.30.

Condition and System Factors apply to the Strength Limit State. In accordance with LRFR, the product of the Condition and System Factors (ϕ_C x ϕ_S) need not be taken less than 0.85 and in no case shall be greater than 1.30. One lower-bound value may be used or different values of these factors may be applied appropriately at different sections along the length of the bridge, if necessary.

E.6.1.4 Condition Factors, ϕ_c

For an existing bridge, the condition factor may be estimated from Table 1.1. These are the same condition factors indicated in LRFR Table 6.4.2.3-1.

E.6.1.5 System Factors, ϕ_s

The System Factor (ϕ_S) is related to the degree of redundancy in the total structural system. In LRFR, bridge redundancy is defined as the capability of a structural system to carry loads after damage or failure of one or more of its members. LRFR recognizes that structural members of a bridge do not behave independently, but interact with one another to form one structural system.

E.6.1.5.1 Longitudinal Flexure

System Factors for longitudinal flexure at the Strength Limit State should be taken from Table 1.2. System Factors in this table are given for different types of segmental construction, different degrees of longitudinal continuity expressed in terms of the number of plastic hinges required to create a mechanism, the number of webs (two and three or more) and number of tendons per web. For longitudinal flexure, System Factors range, for example from 0.85 for a simple span with only two tendons per web to 1.30 for a box with three or more webs each with four or more tendons per web.

E.6.1.5.2 Shear and Torsion

System Factors for longitudinal shear or shear combined with torsion should be taken as a single value of $\phi_S = 1.00$.

E.6.1.5.3 Transverse Flexure

Where there is a closed box structure, the System Factor for transverse flexure should be $\phi_S = 1.00$.

E.6.1.5.4 Local Details

Local Details including dapped hinges within a span, diaphragms at interior and expansion joint piers, and deviators, are not part of the Load Rating procedure. These details should be reviewed, however, to ensure that the details can support the load ratings predicted for the major bridge elements.

In general, a System Factor (ϕ_S) depends upon the degree of redundancy provided by the local post-tensioning and reinforcing. System Factors for local details should be taken as 0.90 when only one post-tensioning tendon (or bar) contributes to or provides the main resistance of the detail. The System Factor of 1.00 may be used when two or more post-tensioning tendons or bars provide the resistance.

Structural Condition of Member	NBI Rating	Condition Factor (ϕ_c)
Good or Satisfactory	> 6	1.00
Fair	5	0.95
Poor	< 4	0.85
Bridges built to recommendations of "New Directions for Florida Post-Tensioned Bridges," FDOT, 2002	>> 6	1.10

(See LRFR Table 6.4.2.3-1 and Commentary)

Table 1.1 - Relationship Between NBI Rating and ϕ_c

			System Factors (ϕ_s)			
Bridge Type	Span Type	# of Hinges to Failure	No. of Tendons per Web 1/web	2/web	3/web	4/web
Precast Balanced Cantilever Type A Joints	Interior Span End or Hinge Span Statically Determinate	3 2 1	0.90 0.85 n/a	1.05 1.00 0.90	1.15 1.10 1.00	1.20 1.15 1.10
Precast Span-by-Span Type A Joints	Interior Span End or Hinge Span Statically Determinate	3 2 1	n/a n/a n/a	1.00 0.95 n/a	1.10 1.05 1.00	1.20 1.15 1.10
Precast Span-by-Span Type B Joints	Interior Span End or Hinge Span Statically Determinate	3 2 1	n/a n/a n/a	1.00 0.95 n/a	1.10 1.05 1.00	1.20 1.15 1.10
Cast-In-Place Balanced Cantilever	Interior Span End or Hinge Span Statically Determinate	3 2 1	0.90 0.85 n/a	1.05 1.00 0.90	1.15 1.10 1.00	1.20 1.15 1.10

(For box girder bridges with 3 or more webs, table values may be increased by 0.10).

Table 1.2 – System Factors for Longitudinal Flexure

E.6.1.6 Load Factors and Load Combinations

Load factors and load combinations for the Strength and Service Limit States shall be made in accordance with *Table1.3, "Load Factors for Segmental Bridges"* and *Table1.4, "Load Combinations for Segmental Bridges".* Tables 1.3 and 1.4 are separated horizontally into longitudinal and transverse requirements and vertically into Inventory or Operating conditions. Load factors for permanent (e.g. dead) loads and transient (e.g. temperature) loads are provided. Note: one-half thermal gradient (0.5TG) is used only for longitudinal Service Inventory conditions.

Altogether, load combinations (Table 1.4) are given for ten basic cases, labeled "#1" through "#10", which are necessary to satisfy FDOT and AASHTO LRFR. The first two (#1 and #2) are for Inventory (design) conditions. #3 and #4 are for Operating conditions using Design loads. #5 addresses FDOT Legal Loads. #6 and #7 address AASHTO limiting critical (legal) loads. For Permit vehicles in mixed traffic, two combinations must be added together: the permit is applied in one lane (#8) with HL93 in the remaining live load lanes (either #9 or #10) as appropriate.

STRENGTH I and II and SERVICE I and III conditions are used in the context of their definitions as given in Table 1.3 summarizing:

STRENGTH I - applies to Inventory and Operating conditions for Design and Legal loads.

STRENGTH II - applies only to Permit Loads.

SERVICE I - applies primarily for concrete in compression but is also to prevent yield of tension face reinforcement or prestress under overloads (permits). This condition is extended to concrete tension in transversely prestressed deck slabs, typical of most segmental bridges.

SERVICE III - applies to concrete in longitudinal tension and principal tension. Load factors for SERVICE III for Operating conditions have been selected to attain the benefits of reduced reliability when used in conjunction with either higher allowable tensile stress or, in the case of joints that cannot carry tension, use of the number of striped lanes. For consistency with the tension side, where the allowable stress cannot be augmented, use of the number of striped lanes is retained to achieve appropriate reductions in reliability for SERVICE I compression.

The following is a detailed checklist of the load applications, combinations and circumstances necessary to satisfy FDOT and AASHTO LRFR ratings.

E.6.1.6.1 Inventory Rating – Design Loads

Transverse:

- Apply HL93 Truck or Tandem *(Table 1.4, load combination #1).*
- Do not apply uniform lane load.
- Apply same axle loads in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Truck or Tandem.
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one lane, m =1.20; two lanes, m = 1.00; three, m = 0.85;

four or more, m = 0.65. (Maximum value of m = 1.20 is the appropriate AASHTO LRFD / LRFR current criteria to allow for rogue vehicles).

- Place loads in full available width as necessary to create maximum effects.
- Apply pedestrian live load as necessary (counts as one lane for “m”).
- Apply no Thermal Gradient transversely.
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete transverse flexural stresses to values in Table 1.5. (Note: γ_L = 1.00 as AASHTO LRFR).
- For STRENGTH I Limit State use live load factor, γ_L = 1.75.

Longitudinal:

- Apply HL93 Truck or Tandem, including 0.64 kip/ft uniform lane load *(Table 1.4, load combination #1).*
- Apply same load in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Truck or Tandem only.
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one lane, m =1.2; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum value of m = 1.20 is the appropriate AASHTO LRFD / LRFR current criteria for notional loads and rogue vehicles).
- For negative moment regions: apply 90% of the effect of two Design Trucks of 72 kip GVW spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of uniform lane load *(Table 1.4, load combination #2).*
- Place loads in full available width as necessary to create maximum effects.
- Apply pedestrian live load as necessary (counts as one lane for “m”).
- For Thermal Gradient, apply 0.50TG with live load for Service but zero TG for Strength.
- Use SERVICE III Limit State with live load factor, γ_L = 0.80. (Note: use of γ_L = 0.80 is for load calibration as adopted by AASHTO LRFR).
- For SERVICE III Limit State, limit concrete Longitudinal Flexure Tensile Stress to values in Table 1.5 as appropriate.
- For SERVICE III Limit State, limit Principal Tensile Stress at the neutral axis to $3\sqrt{f'c}$ (psi) at Inventory. (During construction, a temporary overstress to $4.5\sqrt{f'c}$ (psi) may be allowed).
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural compressive stress to values in Table 1.5. (Note: γ_L = 1.00 as AASHTO LRFR).
- For STRENGTH I Limit State use live load factor, γ_L = 1.75.

E.6.1.6.2 Operating Rating – Design Load (HL93)

Transverse:

- Apply one HL93 Truck or Tandem per lane *(Table 1.4, load combination #3).*
- Do not apply uniform lane load.
- Apply same axle loads in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Truck or Tandem.
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one and two lanes, m =1.0; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because this is a rating for specific (defined) axle loads, not notional loads or rogue vehicles).
- Place loads in full available width as necessary to create maximum effects.
- Apply pedestrian live load as necessary (counts as one lane for “m”).
- Apply no Thermal Gradient transversely.

- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete transverse flexural stresses to values in Table 1.5 (Note: use of γ_L = 1.00 is necessary because loads are actual (defined) axle loads. Reduced reliability is obtained in this case by an increased allowable tensile stress - i.e. 6√f'c (psi) at Operating compared to 3√f'c (psi) at Inventory, Table1.5).
- For STRENGTH I Limit State use live load factor, γ_L = 1.35.

Longitudinal:

- Apply HL93 Truck or Tandem, including 0.64 kip/ft uniform lane load *(Table 1.4, load combination #3).*
- Apply same load in each lane.
- Apply Dynamic Load Allowance, IM = 1.33 on Truck or Tandem only.
- For the Strength Limit State, use number of load lanes per LRFD.
- For the Service Limit State use the number of striped lanes (this is to attain the benefits of reduced reliability).
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Multi-presence factor: HL93 Design Load (including uniform lane load) one lane, m =1.20; two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (The maximum value of 1.20 for one lane is necessary because the load is a notional load with a uniform lane load component).
- For negative moment regions, apply 90% of the effect of two Design Trucks of 72 kip GVW each spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of 0.64 kip/LF uniform lane load *(Table 1.4, load combination #4).*
- Apply pedestrian live load as necessary (counts as one lane for "m").
- Apply no Thermal Gradient.
- Use SERVICE III Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural tensile and principal tensile stresses to values in Table 1.5 as appropriate. (Note: use of γ_L = 1.00 is appropriate because reduced reliability for large boxes is attained through the use of the number of striped lanes. At Operating, although no increase in allowable tensile stress (i.e. zero) can be allowed in precast joints, an increase is allowed from 3 to 7.5√f'c (psi) in reinforced joints and the Principal Tensile Stress at the neutral axis is raised to 4√f'c (psi) to attain the benefit of reduced reliability per Table 1.5)
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural compressive stress to values in Table 1.5. (Note: γ_L = 1.00 AASHTO LRFR).
- For STRENGTH I Limit State use live load factor, γ_L = 1.35.

E.6.1.6.3 Operating Rating – Florida Legal Loads

Transverse:

- Apply FDOT Legal Load Trucks *SU4, C5 and ST5 (Table 1.4, load combination #5).*
- *Also, apply HL93 Truck or Tandem only (load combination #5). This is to facilitate comparison and posting decisions.*
- Do not apply any uniform lane load.
- Apply same axle loads in each lane using only one truck per lane (i.e. do not mix Trucks).
- Apply Dynamic Load Allowance, IM = 1.33 on Legal, HL93 Truck or Tandem (see

Volume 10A, Chapter 9, “Posting Avoidance”).
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one and two lanes, m =1.0; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because this is a rating for specific (defined) axle loads, not notional loads or rogue vehicles).
- Place loads in full available width as necessary to create maximum effects.
- Apply no pedestrian live load (unless very specifically necessary for the site - in which case it counts as one lane for establishing “m”).
- Apply no Thermal Gradient transversely.
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete transverse flexural stresses to values in Table 1.5. (Note: use of γ_L = 1.00 is necessary because this is a rating for specific (defined) axle loads. Reduced reliability is obtained in this case by an increased allowable tensile stress - i.e. 6√f’c (psi) at Operating compared to 3√f’c (psi) at Inventory, Table1.5).
- For STRENGTH I Limit State use live load factor, γ_L = 1.35.

Longitudinal:
- Apply FDOT Legal Load Trucks *SU4, C5 and ST5 (Table 1.4, load combination #5).*
- *Also, apply HL93 Truck only - i.e. 72 kip GVW (load combination #5). This is to facilitate comparison and posting decisions.*
- Apply same Truck load in each lane using only one truck per lane (i.e. do not mix Trucks).
- Apply no uniform lane load.
- Apply Dynamic Load Allowance, IM = 1.33 on Legal, HL93 Truck or Tandem (see Volume 10A, Chapter 9, “Posting Avoidance”).
- For the Strength Limit State, use number of load lanes per LRFD.
- For Service Limit States, use number of striped lanes (this is to attain the benefits of reduced reliability).
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Use multi-presence factor: one and two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because loads are specific (defined) truck loads, not notional loads or rogue vehicles).
- Apply no pedestrian live load (unless very specifically necessary for the site - in which case it counts as one lane for establishing “m”).
- Apply no Thermal Gradient.
- Use SERVICE III Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural tensile and principal tensile stresses to values in Table 1.5 as appropriate. (Note: use of γ_L = 1.00 is appropriate because reduced reliability for large boxes is attained through the use of the number of striped lanes. At Operating, although no increase in allowable tensile stress (i.e. zero) can be allowed in precast joints, an increase is allowed from 3 to 7.5√f’c (psi) in reinforced joints and the Principal Tensile Stress at the neutral axis is raised to 4√f’c (psi) to attain the benefit of reduced reliability per Table1.5)
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural compressive stress to values in Table 1.5. (Note: γ_L = 1.00 AASHTO LRFR).
- For STRENGTH I Limit State, use live load factor, γ_L = 1.35.
- Negative moments load ratings may be limited by AASHTO LRFR 6.4.4.2.1, as follows. Determine the AASHTO Limiting Critical Load effects from a lane load of 0.20 K/LF combined with 0.75 times the effect of two AASHTO Type 3-3 Trucks in the same lane,

heading in the same direction and separated by 30ft. *(Table 1.4, load combination #6).* If the value of the Rating Factor for the AASHTO Limiting Critical Load is less than 1.00, then the basic rating factor for all FDOT Legal Loads shall be reduced by multiplying by this value.

- In addition, load rating may be limited by AASHTO LRFR 6.4.4.2.1. For spans less than 200 feet, determine AASHTO Limiting Critical Load effects for one AASHTO Type 3-3. For spans over 200 feet, determine effects for one AASHTO Type 3-3 multiplied by 0.75 combined with a lane load of 0.20 K/LF *(Table 1.4, load combination #7).* If the value of the Rating Factor for the AASHTO Limiting Critical Load is less than 1.00, then the basic rating factor for all FDOT Legal Loads shall be reduced by multiplying by this value.

E.6.1.6.6 Operating Rating – Florida Permit Loads

Transverse, annual blanket permits, mixed traffic:

- Apply ONE Permit Vehicle in one load lane. Use T160 vehicle with its triple axle units of 3 axles of 22 kips each *(Table1.4, load combination #8 or #9).*
- Apply HL93 Truck or Tandem axles only in each of the other load lanes as necessary to create maximum effects *(Table 1.4, load combination #8 or #9).*
- Do not apply any uniform lane load.
- Apply Dynamic Load Allowance, IM = 1.33 on Permit, HL93 Truck or Tandem (See Volume 10A, Chapter 9 “Posting Avoidance”).
- Do not mix Permit Load with Legal Load.
- For both Strength and Service Limit States, use number of load lanes per LRFD.
- Apply multi-presence factor: one and two lanes, m =1.0; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because this is a rating for specific (defined) axle loads, not notional loads or rogue vehicles).
- Place loads in full available width as necessary to create maximum effects.
- Apply no pedestrian live load (unless very specifically necessary for the site - in which case it counts as one lane for establishing “m”).
- Apply no Thermal Gradient transversely.
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete transverse flexural stresses to values in Table 1.5. (Note: use of γ_L = 1.00 is necessary because this is a rating for specific (defined) axle loads. Reduced reliability is obtained in this case by an increased allowable tensile stress - i.e. 6√f’c (psi) at Operating compared to 3√f’c (psi) at Inventory, Table 1.5).
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 if it is necessary to evaluate the rating according to the maximum allowable tensile stress (i.e. 90% yield) in reinforcing or prestressing steel closest to the tension fiber (AASHTO LRFR).
- For STRENGTH II Limit State, use live load factor, γ_L = 1.35.
- Reduced Dynamic Load Allowance (IM) or live load factor (γ_L) may be considered only to avoid restrictions .

Longitudinal, annual “blanket” permits, mixed traffic:

- Apply ONE T160 Permit Vehicle in one load lane (*Table 1.4, load #8*).
- Apply HL93 Truck of 72 kips GVW in each of the other load lanes as necessary to create maximum effects, including 0.64 kip / LF uniform lane load (*Table 1.4, load #9*). Combine #8 with #9.

- Alternatively, for negative moment regions: in conjunction with the Permit vehicle in its lane, apply to the other lanes 90% of the effect of two Design Trucks of 72 kip GVW each spaced a minimum of 50 feet apart between the leading axle of one and the trailing axle of the other, plus 90% of 0.64 kip/LF uniform lane load *(Table 1.4, load #10).* Combine #8 with #10.
- For spans over 200 feet, apply a uniform lane load of 0.20 kip / LF in the lane with the permit vehicle. This uniform lane load should be applied beyond the footprint of the vehicle to create the maximum effects. However, for convenience, it may be applied coincident with the vehicle.
- For the Strength Limit State, use number of load lanes per LRFD.
- For Service Limit States, use number of striped lanes (this is to attain the benefits of reduced reliability).
- Place loads in full available width as necessary to create maximum effects (for example, in shoulders).
- Use multi-presence factor: one and two lanes, m = 1.00; three, m = 0.85; four or more, m = 0.65. (Maximum limit of 1.0 applies because loads are specific (defined) Permit loads, not notional loads or rogue vehicles).
- Do not mix Permit Load with Legal Loads.
- Dynamic Load Allowance, IM = 1.33 on Permit and HL93 Trucks (see Volume 10A, Chapter 9, "Posting Avoidance").
- Apply no pedestrian live load (unless very specifically necessary for the site - in which case it counts as one lane for establishing "m").
- Apply no Thermal Gradient.
- Use SERVICE III Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural tensile and principal tensile stresses to values in Table 1.5 as appropriate. (Note: use of γ_L = 1.00 is appropriate because reduced reliability for large boxes is attained through the use of the number of striped lanes. At Operating, although no increase in allowable tensile stress (i.e. zero) can be allowed in precast joints, an increase is allowed from 3 to 7.5$\sqrt{f'c}$ (psi) in reinforced joints and the Principal Tensile Stress at the neutral axis is raised to 4$\sqrt{f'c}$ (psi) to attain the benefit of reduced reliability per Table 1.5)
- Use SERVICE I Limit State with live load factor, γ_L = 1.00 and limit concrete longitudinal flexural compressive stress to values in Table 1.5. (Note: γ_L = 1.00 AASHTO LRFR).
- For STRENGTH II Limit State, use live load factor, γ_L = 1.35.
- Reduced Dynamic Load Allowance (IM) or live load factor (γ_L) may be considered only to avoid restrictions.

E.6.1.7 Capacity – Strength Limit State

The capacity of a section in transverse and longitudinal flexure may be determined using any of the relevant formulae or methods in the LRFD Code, or AASHTO Guide Specification for Segmental Bridges dated 1999, including more rigorous analysis techniques involving strain compatibility. The latter should be used in particular where the capacity depends upon a combination of both internal (bonded) and external (unbonded) tendons.

For Load Rating, the capacity should be determined based upon actual rather than specified or assumed material strengths and characteristics. Concrete strength should be found from records or verified by suitable tests. If no data is available, the specified design strength may be assumed, appropriately increased for maturity. All new designs will assume the plan specified concrete properties. Post construction will include updated concrete properties.

In particular, for shear or combined shear with torsion, the capacity at the Strength Limit State for segmental bridges should be calculated according to the AASHTO Guide Specification for Segmental Bridges. The “Modified Compression Field Theory” (MCFT) of LRFD may be used as an alternative, but only for structures with continuously bonded reinforcement (e.g. large boxes cast-in-place in cantilever or on falsework).

E.6.1.8 Allowable Stress Limits – Service Limit State

Allowable stresses for the Service Limit State are given in *Table 1.5.* The intent is to ensure a minimum level of durability for FDOT bridges that avoids the development or propagation of cracks or the potential breach of corrosion protection afforded to post-tensioning tendons. Also, these are recommended for the purpose of designing new bridges.

E.6.1.8.1 Longitudinal Tension in Joints

Type “A” Joints with Minimum Bonded Reinforcement

The Service level tensile stress is limited to $3\sqrt{f'c}$ (psi) for cast-in-place joints with continuous longitudinal mild steel reinforcing for both Inventory and Operating Ratings. (Reference: AASHTO Guide Specification for Segmental Bridges and LRFD Table 5.9.4.2.2-1). Reduced reliability at Operating conditions is attained by using the number of striped lanes and by allowing an increase in tensile stress to $7.5\sqrt{f'c}$ (psi) (Table 1.5).

Type “A” Epoxy Joints with Discontinuous Reinforcement

The Service level tensile stress is limited to zero tension for epoxy joints for both inventory and operating ratings. (Reference: AASHTO Guide Specification for Segmental Bridges and LRFD Table 5.9.4.2.2-1). Reduced reliability at operating conditions is attained by using the number of striped lanes.

Type “B” Dry Joints

Early precast segmental bridges with external tendons and non-epoxy filled, Type-B (dry) joints were designed to zero longitudinal tensile stress. In 1989, a requirement for 200 psi residual compression was introduced with the first edition of the AASHTO Guide Specification for Segmental Bridges. This was subsequently revised in 1998 to 100 psi compression. Service level Inventory Ratings shall be based on a residual compression of 100 psi for dry joints. For Operating Ratings, the limit is zero tension. (Reference: AASHTO Guide Specification for Segmental Bridges and LRFD Table 5.9.4.2.2-1). Reduced reliability at operating conditions is attained by using the number of striped lanes.

E.6.1.8.2 Transverse Tensile Stress

For a transversely prestressed deck slab, the allowable flexural stresses for concrete tension are provided in Table 1.5: namely, for Inventory $3\sqrt{f'c}$ (psi) and for Operating $6\sqrt{f'c}$ (psi). For Florida, no distinction is made for different environmental conditions. This is deliberate. It is intended to provide a degree of confidence in the durability of the deck.

E.6.1.8.3 Principal Tensile Stress – Service Limit State

A check of the principal tensile stress has been introduced to verify the adequacy of webs for longitudinal shear at service. This is to be applied to both for the design of new bridges and Load Rating. The verification, made at the neutral axis, is the recommended minimum prescribed procedure, as follows:

Sections should be considered only at locations greater than “H/2” from the edge of the bearing surface or face of diaphragm, where classical beam theory applies: i.e. away from discontinuity regions. In general, verification at the elevation of the neutral axis may be made without regard to any local transverse flexural stress in the web itself given that in most large, well proportioned boxes the maximum web shear force and local web flexure are mutually exclusive load cases. This is a convenient simplification. However, should the neutral axis lie in a part of the web locally thickened by fillets, then the check should be made at the most critical elevation, taking into account any coexistent longitudinal flexural stress. Also, if the neutral axis (or critical elevation) lies within 1 duct diameter of the top or bottom of an internal, grouted duct, the web width for calculating stresses should be reduced by half the duct diameter.

All stresses at the elevation of the neutral axis due to thermal gradient at Inventory conditions may be disregarded for principal tension checks.

Classical beam theory and Mohr’s circle for stress should be used to determine shear and principal tensile stresses. At the Service Limit State, the shear stress and Principal Tensile Stress should be determined at the neutral axis (or critical elevation) under the long-term residual axial force, maximum shear and/or maximum shear force combined with shear from torsion in the highest loaded web, using a live load factor, γ_L = 1.00. The live load should then be increased in magnitude so that the shear stress in the highest loaded web increases until the Principal Tensile Stress reaches its allowable maximum value (Table 1.5).

The Rating Factor at the Service Limit State is the ratio between the live load shear stress required to induce the maximum Principal Tensile Stress to that induced by a live load factor of 1.00.

E.6.1.9 Local Details

Local Details (i.e. diaphragms, anchorage zones, blisters, deviation saddles, etc.) in concrete segmental bridges are discussed in Chapter 4 of Volume 10A Load Rating Post-tensioned Concrete Segmental Bridges. If a detail shows signs of distress (cracks), a structural evaluation should be performed for the Strength Limit State. The influence of anchorage zones shall be checked for principal tension in accordance with Structure Design Guidelines Section 4.5.11, Principal Tensile Stresses.

Table 1.3 - Load Factors for Segmental Bridges

			LRFD Dead and Permanent Loads			LRFD Transient Loads					Inventory				Operating		
	Nomenclature per LRFD:		DC	DW	EL including PT sec	FR	TU (B) CR SH	TG (B) Inv.	TG (B) Oper.		Design Load LC #1, #2	No. of Ld. Lanes = No. of Design Lanes per LRFD	No. of Ld. Lanes = No. of Design Lanes per LRFD	No. of Ld. Lanes = No. of Striped Lanes placed for max. effects (A)	Design Load LC #3, #4	Legal Loads LC #5, #6, #	FDOT Permit Loads LC #8, #9, #10
LONGITUDINAL	**STRENGTH I**	γ =	1.25	1.50	1.00	1.00	0.50	0.00	0.00	γ_L =	1.75	X	X		1.35	1.35	-
	STRENGTH II	γ =	1.25	1.50	1.00	1.00	0.50	0.00	0.00	γ_L =	-	-	X		-	-	1.35
	SERVICE I	γ =	1.00	1.00	1.00	1.00	1.00	0.50	0.00	γ_L =	1.00	X		X	1.00	1.00	1.00
	SERVICE III	γ =	1.00	1.00	1.00	1.00	1.00	0.50	0.00	γ_L =	0.80	X		X	1.00	1.00	1.00
TRANSVERSE OR LOCAL DETAILS	**STRENGTH I**	γ =	1.25	1.50	1.00	n/a	n/a	n/a		γ_L =	1.75	X	X		1.35	1.35	-
	STRENGTH II	γ =	1.25	1.50	1.00	n/a	n/a	n/a		γ_L =	-	-	X		-	-	1.35
	SERVICE I	γ =	1.00	1.00	1.00	n/a	n/a	n/a		γ_L =	1.00	X	X		1.00	1.00	1.00

SERVICE I:
Load combination relating to the normal operational use of the bridge with a 55 MPH wind and all loads taken at their nominal values.
In the context of concrete segmental bridges, SERVICE I is extended to apply to transverse analysis relating to flexural tension and compression in transversely prestressed (pre- and post-tensioned) deck slabs.
In accordance with AASHTO LRFR 6.5.4.2.2.2, the following SERVICE I check of Permit load combinations for reinforced and prestressed concrete components is considered optional. During Permit Load Rating, the stress in reinforcing bars or prestressing steel nearest the extreme tension fiber should not exceed 0.90 of the yield point stress for unfactored loads (i.e. cracked). Absent well defined yield stress for prestressing steels, the following may be assumed:

Low Relaxation Strand 0.90 fpu
Stress Relieved Strand and Type 1 High-Strength Bar 0.85 fpu
Type 2 High Strength Bar 0.80 fpu

SERVICE III:
Load combination for longitudinal analysis relating to tension in prestressed concrete superstructures with the objective of crack control and to principal tension in prestressed concrete webs under normal, unlimited number of, repeat loads (i.e. durability at inventory level). This is attained by limits on tensile stress in Table 1.5.

STRENGTH I:
Basic load combination relating to the normal vehicular use of the bridge without wind.

STRENGTH II:
Load combination relating to the use of the bridge by Owner-specified special design vehicles, evaluation permit vehicles, or both without wind.

(A) Reduced reliability is attained by using only the no. of striped lanes, with a live load factor of 1.00, for Operating SERVICE conditions.
(B) Temperature (TU & TG) is considered for SERVICE I & III, Inventory Rating.

No. of Live Load Lanes, n		Multiple Presence Factor, m			
		Inventory	**Operating**		
		Design	Design	Legal	Permit
1	Long. (L)	1.20	1.20	1.00	1.00
	Trans. (T)	1.20	1.00	1.00	1.00
2	L or T	1.00			
3	L or T	0.85			
$\geq$ 4	L or T	0.65			

Table 1.4 - Load Combinations for Segmental Bridges

				Inventory		Operating							
				Design Loads (A)		Design Loads (A)		Legal Loads (A)			FDOT Permit Loads (A)		
											Annual Permits, Mixed Traffic (C)		Permit Only
		LOAD COMBINATION (LC) NO.:		#1	#2	#3	#4	#5	#6 (B)	#7 (B)	#8	#9	#10
LONGITUDINAL	All regions, All spans	HL93 Truck or Tandem *plus* 0.64 k/lf uniform lane load in All Load Lanes (except Permit Lane for LC #9)	LRFD 3.6.1.2 LRFR 6.4.3	X		X						X	
LONGITUDINAL	All regions, All spans	FDOT Legal Loads - one SU4, C5 or ST5 in each load lane. For comparison and posting decisions, one HL93 Truck Only per load lane.	FDOT					X					
LONGITUDINAL	All regions, All spans	One FDOT T160 Permit Vehicle in One Load Lane (For Spans >200', apply 0.2 k/lf uniform lane load in same lane, beyond fooprint of permit vehicle for max. effects, or coincident with vehicle for convenience).	FDOT LRFR 6.4.5.4								X		
LONGITUDINAL	Negative moment regions, All spans	90% of Two HL93 Trucks in same lane spaced at 50 ft minimum *plus* 90% of 0.64 k/lf uniform lane load	LRFD 3.6.1.3.1		X		X						X
LONGITUDINAL	Negative moment regions, All spans	Two Type 3-3 Vehicles in same lane times 0.75 separated by 30 ft *plus* 100% of 0.2 k/lf uniform load	LRFR 6.4.4.2.1						X				
LONGITUDINAL	Pos. mom. & shear, For spans ≤ 200' For spans > 200'	One Type 3-3 Vehicle One Type 3-3 Vehicle times 0.75 *plus* 100% of 0.2 k/lf uniform load	LRFR 6.4.4.2.1							X			
TRANSVERSE OR LOCAL DETAILS	All regions, All spans	HL93 Truck or Tandem Only (one per lane) (no uniform lane load) in All Load Lanes (except Permit Lane for LC #9)	LRFD 3.6.1.2 LRFR 6.4.3	X		X						X	
TRANSVERSE OR LOCAL DETAILS	All regions, All spans	FDOT Legal Loads - one SU4, C5 or ST5 in each load lane. For comparison and posting decisions, one HL93 Truck or Tandem Only per load lane.	FDOT					X					
TRANSVERSE OR LOCAL DETAILS	All regions, All spans	One FDOT T160 Permit Vehicle in One Load Lane (Triple axle, 3 at 22 kips)	FDOT LRFR 6.4.5.4								X		

(A) Apply added Dynamic Load Allowance, IM, of 33% to Vehicle or Axle Loads only.
Pedestrian Load per LRFD may be included as necessary. Pedestrian load counts as ONE LANE for determining "m".
(B) In negative moment regions for all span lengths and in positive moment regions in spans over 200 ft, if the value of the Rating Factor for the AASHTO Limiting Critical Load is less than 1.0, then the basic Rating Factors for all FDOT Legal Loads shall be reduced by multiplying by this value.
(C) FDOT Permit Load Rating for annual permits and mixed traffic is LC (#8 + #9) or (#8 + #10).

Table 1.5 - Allowable Streses for Concrete Bridges

At the Service Limit State after losses	Stress Limit INVENTORY Rating	Stress Limit OPERATING Rating	Source of Criteria
Compression (Longitudinal or Transverse):			
• Compressive stress under effective prestress, permanent loads, and transient loads	0.60f'c	0.60f'c	LRFD Table 5.9.4.2.1-1 Seg Guide Spec 9.2.2.1
• Allowable compressive stress shall be reduced according to AASHTO Guide Specification for Segmental Bridges when slenderness of flange or web is greater than 15 (For both New Design and Load Rating purposes)			Seg Guide Spec 9.2.2.1
Longitudinal Tensile Stress in Precompressed Tensile Zone: (Intended for Pre and Post-Tensioned Beams and similar construction) For components with bonded pretressing tendons or reinforcement that are subject to not worse than: For (a) an aggressive corrosion environment and (b) moderately aggressive corrosion environment	3√f'c psi tension	7.5√f'c psi tension	LRFD Table 5.9.4.2.2-1 and FDOT FDOT no distinction for Environ't
For components with unbonded prestressing tendons	No Tension	No Tension	LRFD Table 5.9.4.2.2-1
Longitudinal Tensile Stress through Joints in Precompressed Tensile Zone: (Intended for Segmental and similar construction)			
• Type A joints with minumum bonded auxiliary longitudinal reinforcement sufficient to carry the calculated longitudinal tensile force at a stress of 0.5fy; for internal and/or external PT (e.g.cast-in-place construction) For (a) an aggressive corrosion environment and (b) moderately aggressive corrosion environment	3√f'c psi tension	7.5√f'c psi tension	LRFD Table 5.9.4.2.2-1 Seg Guide Spec 9.2.2.2 FDOT no distinction for Environ't
• Type A joints without the minimum bonded auxiliary longitudinal reinforcement through the joints; internal and/or external PT (e.g. match-cast epoxy joints or unreinforced cast-in-place closures between precast segments or between spliced girders or similar components.)	No Tension	No Tension	Ditto and FDOT Seg. Rating Criteria
• Type B joints (dry joints - no epoxy, existing only); external tendons:	100 psi min comp	No Tension	Seg Guide Spec 9.2.2.2 FDOT Seg. Rating Criteria
Transverse Tension, Bonded PT:			
• Tension in the transverse direction in precompressed tensile zone calculated on basis of uncracked section (i.e. top prestressed slab) For (a) an aggressive corrosion environment and (b) moderately aggressive corrosion environment	3√f'c psi tension	6√f'c psi tension	Seg Guide Spec 9.2.2.3 LRFD Table 5.9.4.2.2-1 FDOT no distinction for Environ't FDOT Seg. Rating Criteria
Tensile Stress in Other Areas:			
• Areas without bonded reinforcement	No tension	No tension	Seg Guide Spec 9.2.2.4 LRFD Table 5.9.4.2.2-1
• Areas with bonded reinforcement sufficient to carry the tensile force in the concrete calculated on the assumption of an uncracked section is provided at a stress of 0.5fy (< 30 ksi)	6√f'c psi tension	6√f'c psi tension	Seg Guide Spec 9.2.2.4 LRFD Table 5.9.4.2.2-1
Principal Tensile Stress at Neutral Axis in Webs (Service III):			
• All types of segmental or beam construction with internal and/or external tendons.*	3√f'c psi tension	4√f'c psi tension	FDOT LRFR Rating Criteria

* Principal tensile stress is calculated for longitudinal stress and maximum shear stress due to shear or combination of shear and torsion, whichever is the greater. For segmental box, check neutral axis. For composite beam, check at neutral axis of beam only and at neutral axis of composite section and take the maximum value. Web width is measured perpendicular to plane of web. For segmental box, it is not necessary to consider coexistent web flexure. Account should be taken of vertical compressive stress from vertical PT bars provided in the web, if any, but not including vertical component of longitudinal draped post-tensioning - the latter should be deducted from shear force due to applied loads.
Check section at H/2 from edge of bearing or face of diaphragm, or at end of anchor block transition, whichever is more critical.
For the design of a new bridge, a temporary principal tensile stress of 4.5√f'c may be allowed during construction - per AASHTO Seg. Guide Spec.

Initial load ratings for new design should be based upon specified concrete strength.
Load rating of an existing bridge should be based upon actual concrete strength from construction or subsequent test data.