2.4. Load factors and Load Combinations

The total factored load effect shall be taken as:

$$Q = \sum \eta_i \gamma_i Q_i$$

Where:

Q: total factored force effect.

Q_i: force effect.

η_i: load modifier

γ_i: load factor; a statistically based multiplier applied to force effects.

The values of load factor (γ_i), which defined before, depend on the case of design or analysis the bridge system (global) or bridges components (local) and taken according to the intended load combination. ASSHTO specifications adopted these values as tabulated herein for all the limit states.

Table 2-1: Load Combinations and Load Factors
[AASHTO LRFD Table 3.4.1-1]

Load Combination Limit State	DC DD DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	WL	FR	TU CR SH	TG	SE	Use One of These at a Time				
										EQ	BL	IC	CT	CV
Strength I (unless noted)	γ_p	1.75	1.00	–	–	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Strength II	γ_p	1.35	1.00	–	–	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Strength III	γ_p	–	1.00	1.00	–	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Strength IV	γ_p	–	1.00	–	–	1.00	0.50/1.20	–	–	–	–	–	–	–
Strength V	γ_p	1.35	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Extreme Event I	1.00	γ_{EQ}	1.00	–	–	1.00	–	–	–	1.00	–	–	–	–
Extreme Event II	1.00	0.50	1.00	–	–	1.00	–	–	–	–	1.00	1.00	1.00	1.00
Service I	1.00	1.00	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Service II	1.00	1.30	1.00	–	–	1.00	0.50/1.20	–	–	–	–	–	–	–
Service III	1.00	γ_{LL}	1.00	–	–	1.00	0.50/1.20	γ_{TG}	γ_{SE}	–	–	–	–	–
Service IV	1.00	–	1.00	1.00	–	1.00	0.50/1.20	–	1.00	–	–	–	–	–
Fatigue I LL, IM & CE only	–	1.75	–	–	–	–	–	–	–	–	–	–	–	–
Fatigue II LL, IM & CE only	–	0.80	–	–	–	–	–	–	–	–	–	–	–	–

Table 2-2: Load Factors for Permanent Loads [AASHTO LRFD Table 3.4.1-2]

Type of Load, Foundation Type and Method Used to Calculate Downdrag				Load Factor (γ_P)	
				Maximum	Minimum
DC	Component and Attachments			1.25	0.90
	Strength IV only			1.50	0.90
DD	Downdrag	Piles, α Tomlinson Method		1.40	0.25
		Piles, λ Method		1.05	0.30
		Drilled shafts, O'Neill and Reese (2010) Method		1.25	0.35
DW	Wearing Surfaces and Utilities			1.50	0.65
EH	Horizontal Earth Pressure	Active		1.50	0.90
		At-Rest		1.35	0.90
		AEP for anchored walls		1.35	N/A
EL	Locked-in Construction Stresses			1.00	1.00
EV	Vertical Earth Pressure	Overall and Compound Stability		1.00	N/A
		Retaining Walls and Abutments		1.35	1.00
		MSE wall internal stability soil reinforcement loads	Reinforcement and connection rupture	1.35	N/A
			Soil failure – geosynthetics (Service I)	1.25	N/A
			Coherent Gravity Method	1.35	N/A
		Rigid Buried Structure		1.30	0.90
		Rigid Frames		1.35	0.90
		Flexible Buried Structures	Metal Box Culverts, Structural Plate Culverts with Deep Corrugations, and Fiberglass Culverts	1.50	0.90
			Thermoplastic Culverts	1.30	0.90
			All others	1.95	0.90
		Internal and Compound Stability for Soil Failure in Soil Nail Walls		1.00	N/A
ES	Earth Surcharge			1.50	0.75

Table 2-3: Load Factors for Permanent Loads Due to Superimposed Deformation [AASHTO LRFD Table 3.4.1-3]

Bridge Component		Load Factor (γ_P)	
		PS	CR , SH
Segmental Superstructures Supported by Concrete Substructures		1.00	γ_P for DC
Non-Segmental Concrete Superstructures		1.00	1.00
Substructures Supporting Non-Segmental Superstructures	Using I_g	0.50	0.50
	Using I_e	1.00	1.00
Steel Substructures		1.00	1.00

Table 2-4: Load Factors for Service III Load Combination [AASHTO LRFD Table 3.4.1-4]

Bridge Component	Load Factor (γ_{LL})
Prestressed Concrete Components Designed Using the Refined Estimates of Time-Dependent Losses in Conjunction with Taking Advantage of the Elastic gain	1.00
All Other Prestressed Concrete Components	0.80

Table 2-5: Load Factors for Permanent Loads Due to Foundation Movements [AASHTO LRFD Table 3.4.1-5]

Foundation Movement and Movement Estimation Method		Load Factor (γ_{SE})
Immediate Settlement	Hough method	1.00
	Schmertmann method	1.40
	Local owner approved method	*
Consolidation settlement		1.00
Lateral Movement	Soil-structure interaction method (P-y or Strain Wedge)	1.00
	Local owner approved method	*

* To be determined by the owner based on local geologic conditions.

In current academic course (HTE403), only gravity loads are considered to design the decking components; thus, load combinations used which normally have only (DC), (DC) and $(LL + IM)$ with $(\eta_i = 1.00)$. So that the load effect (Q) is given in the following equations relating to various limit states:

$Q = 1.25DC + 1.50DW + 1.75(LL + IM)$ [Strength I]

$Q = 1.25DC + 1.50DW + 1.40(LL + IM)$ [Strength III]

$Q = 1.50DC + 1.50DW$ [Strength IV]

$Q = 1.00DC + 1.00DW + 1.00(LL + IM)$ [Service I]

$Q = 1.00DC + 1.00DW + 1.30(LL + IM)$ [Service II]

$Q = 1.00DC + 1.00DW + 0.80(LL + IM)$ [Service III]

$Q = 1.75(LL + IM)$ [Fatigue I]

By the same way, moment and shear demands for **Strength I Limit State** shall be:

$$M_u = \eta[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$$
$$V_u = \eta[1.25V_{DC} + 1.50V_{DW} + 1.75V_{LL+IM}]$$

2.5. Resistance Factors

The strength limit state issues are considered for strength and stability. Factored resistance shall be the product of nominal resistance determined according to AASHTO specifications.

$$R_r = \phi R_n$$

The values of resistance factor (ϕ) for **strength limit state** shall be taken regardless of concrete density (normal weight or lightweight) as:

- $\phi = 0.90$ [tension-controlled RC sections]
  - $= 1.00$ [tension-controlled PC sections with bonded strand or tendons]
  - $= 0.90$ [tension-controlled PTC sections with unbonded strand or tendons]
  - $= 0.90$ [shear and torsion in RC sections]
  - $= 0.90$ [shear and torsion in PC sections with bonded strand or tendons]
  - $= 0.85$ [shear and torsion in PC sections with unbonded strand or tendons]
  - $= 0.75$ [compression-controlled sections with spirals or ties]
  - $= 0.70$ [bearing on concrete]
  - $= 0.70$ [compression in strut-and-tie models]
  - $= 0.90$ [tension in strut-and-tie models RC]
  - $= 1.00$ [tension in strut-and-tie models PC]
  - $= 0.70$ [compression in strut-and-tie models]
  - $= 0.80$ [compression in anchorage zones]
  - $= 1.00$ [resistance during pile driving]
  - $= 1.00$ [tension in steel in anchorage zones]
  - $= 1.00$ [flexure in structural steel]
  - $= 1.00$ [shear in structural steel]
  - $= 0.90$ [axial compression in structural steel]
  - $= 0.95$ [tension yielding in steel gross section]

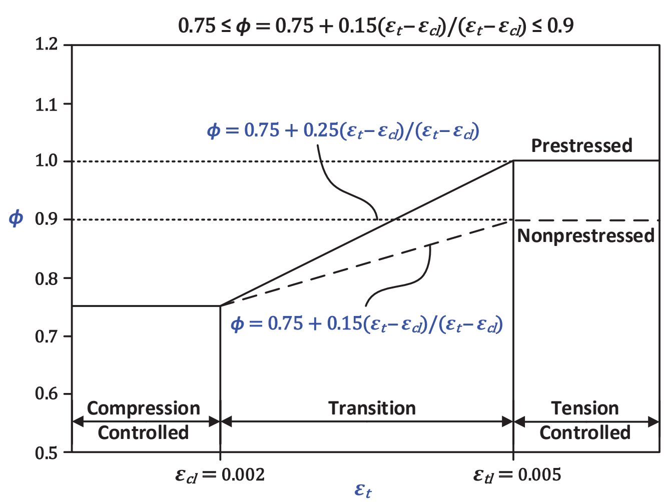

Figure 2-1: Variation of Resistance Factor with Net Tensile Strain at Extreme Fibers for Reinforced and Prestressed Concrete [AASHTO LRFD Figure C5.5.4.2-1]

Concrete sections are classified as tension controlled, transition or compression controlled, depending on the strain at extreme tension fibers (ε_t) as follows:

- $\varepsilon_t \geq 0.005$ [tension-controlled section]
- $0.005 > \varepsilon_t \geq 0.002$ [transition section]
- $0.002 > \varepsilon_t$ [compression-controlled section]

So, the (ϕ) value in transition zone shall be obtained by linear interpolation from:

- $0.75 \leq \phi = 0.75 + 0.25(\varepsilon_t - \varepsilon_{cl})/(\varepsilon_{tl} - \varepsilon_{cl}) \leq 1.00$ [prestressed members]
- $0.75 \leq \phi = 0.75 + 0.15(\varepsilon_t - \varepsilon_{cl})/(\varepsilon_{tl} - \varepsilon_{cl}) \leq 0.90$ [nonprestressed members]

Where:

R_r: factored resistance.

R_n: nominal resistance.

ϕ: resistance factor.

RC: reinforced concrete.

PC: prestressed Concrete.

PTC: post-tensioned concrete.

ε_t: net tensile strain in the extreme tension steel at nominal resistance.

ε_{cl}: compression-controlled strain limit in the extreme tension steel.

ε_{tl}: tension-controlled strain limit in the extreme tension steel.

- For **all other limit states**:
  - $\phi = 1.0$