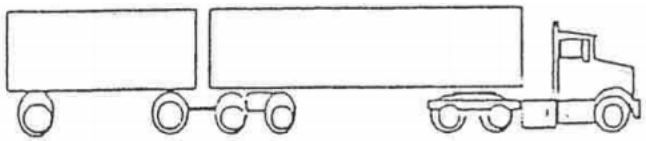
Lecture 3B – Key Messages

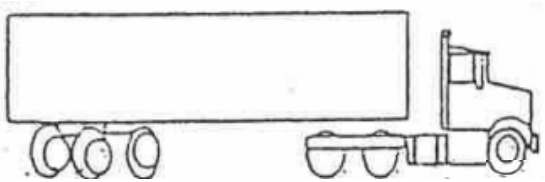
- Methods for load rating and posting of bridges in CSA S6 are reviewed.

Clause 14.9 – Transitory Loads

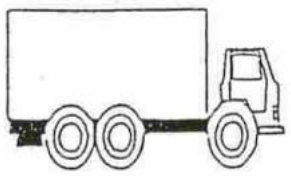
- Evaluation Level 1:
  - *Vehicle trains – i.e. vehicles with two or more trailers (in normal traffic)*



- Evaluation Level 2:
  - *Two-unit vehicles – i.e. vehicles with only one trailer (in normal traffic), when load restrictions are applied*

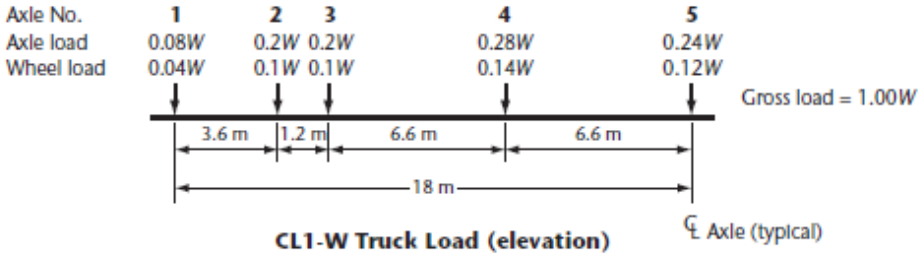


- Evaluation Level 3:
  - *Single-unit vehicles (in normal traffic), when load restrictions are applied*

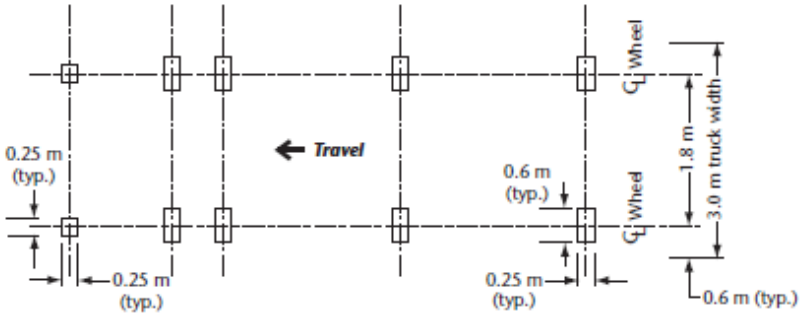


[CSA S6]

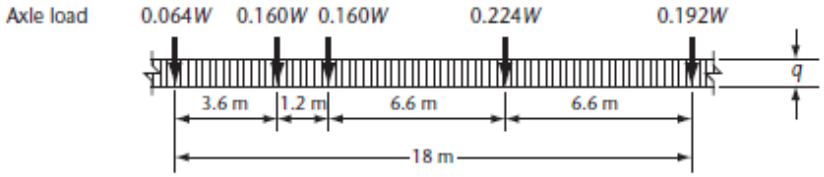
Clause 14.9 – Transitory Loads



CL1-W Truck Load (elevation)



CL1-W Truck Load (plan)



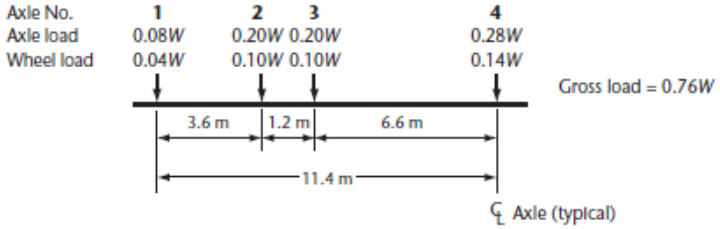
CL1-W Lane Load

Note: *The values of the uniformly distributed load, q, for each highway class (see Section 1) are as follows:*
(a) Class A: 9 kN/m;
(b) Class B: 8 kN/m; *and*
(c) Class C or D: 7 kN/m.

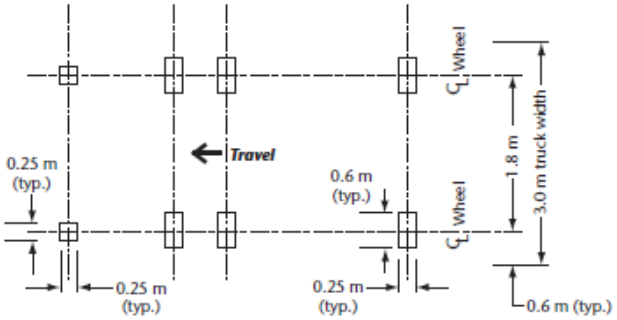
Figure 14.1
Level 1 evaluation loads with CL1-W Truck
(See Clauses 14.9.1.2 and 14.9.1.7.)

[CSA S6]

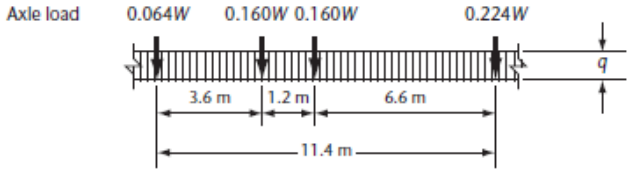
Clause 14.9 – Transitory Loads



CL2-W Truck Load (elevation)



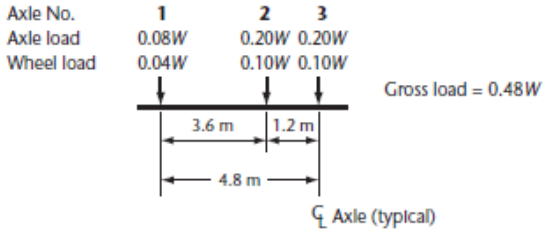
CL2-W Truck Load (plan)



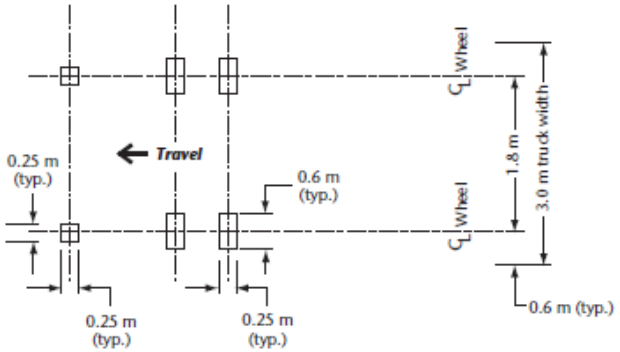
CL2-W Lane Load

Note: *The values of the uniformly distributed load, q, for each highway class (see Section 1) are as follows:*
(a) Class A: 9 kN/m;
(b) Class B: 8 kN/m; and
(c) Class C or D: 7 kN/m.

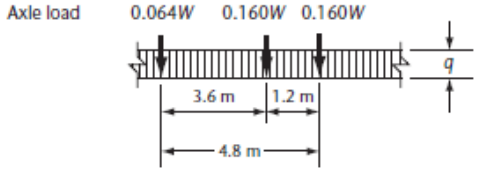
Figure 14.2
Level 2 evaluation loads with CL2-W Truck
(See Clauses 14.9.1.3 and 14.9.1.7.)



CL3-W Truck Load (elevation)



CL3-W Truck Load (plan)



CL3-W Lane Load

Note: *The values of the uniformly distributed load, q, for each highway class (see Section 1) are as follows:*
(a) Class A: 9 kN/m;
(b) Class B: 8 kN/m; and
(c) Class C or D: 7 kN/m.

Figure 14.3
Level 3 evaluation loads with CL3-W Truck
(See Clauses 14.9.1.4 and 14.9.1.7.)

[CSA S6]

Clause 14.9 – Transitory Loads

- Permit — Annual or project (PA):
  - *vehicles authorized by permit on an annual basis or for the duration of a specific project to carry an indivisible load, mixed with other traffic without supervision*
- Permit — Bulk haul (PB):
  - *includes bulk haul divisible load traffic authorized by permit programs for many trips, mixed with other traffic*

[CSA S6]

Clause 14.9 – Transitory Loads

- Permit — Controlled (PC):
  - *vehicles authorized by permit to carry an indivisible load on a specified route under supervision and specified conditions*
- Permit — Single trip (PS):
  - *vehicles authorized by permit for a single trip to carry an indivisible load, mixed with other traffic without supervision*

[CSA S6]

Clause 14.9 – Transitory Loads

For a permit vehicle crossing the bridge at a restricted speed, the dynamic load allowance so calculated shall be multiplied by

- 0.30 for a vehicle speed of 10 km/h or less
- 0.50 for a vehicle speed greater than 10 km/h and less than or equal to 25 km/h
- 0.75 for a vehicle speed greater than 25 km/h and less than or equal to 40 km/h
- 1.00 for a vehicle speed greater than 40 km/h

In other words, design load for permit vehicle can be reduced by limiting permit vehicle speed.

[CSA S6]

Clause 14.12 – Target Reliability Index, β

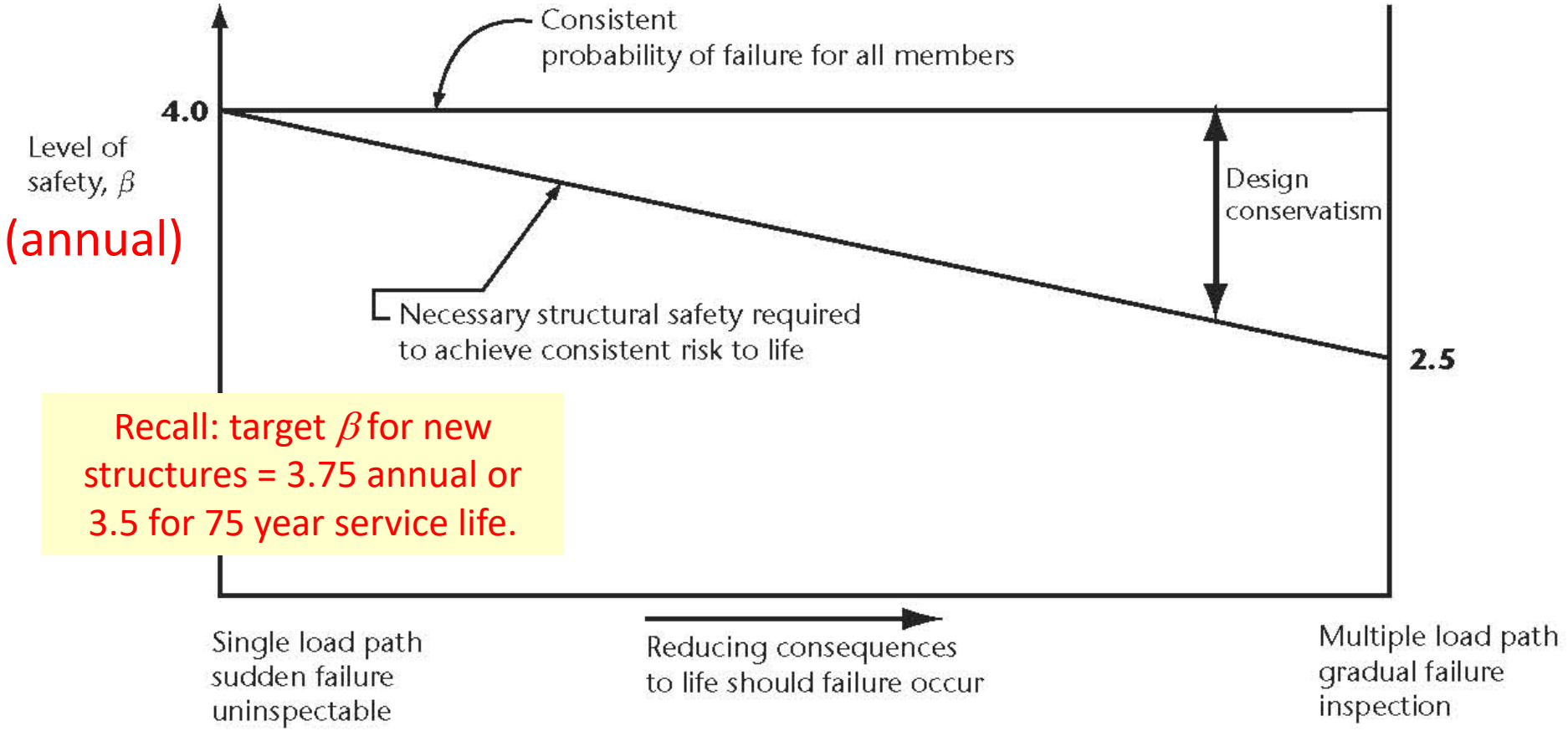


Figure C14.1
Relationship between risk and probability of failure
(See Clause C14.12.1.)

[CSA S6]

Clause 14.12 – Target Reliability Index, β

14.12.2 System behaviour

System behaviour shall take into consideration the effect of any existing deterioration and shall be classified into one of the following categories:

(a) Category S1, where element failure leads to total collapse. This includes failure of main members with no benefit from continuity or multiple-load paths, e.g., a simply supported girder in a two-girder system.

(b) Category S2, where element failure probably will not lead to total collapse. This includes main load-carrying members in a multi-girder system or continuous main members in bending.

(c) Category S3, where element failure leads to local failure only. This includes deck slabs, stringers, and bearings in compression.

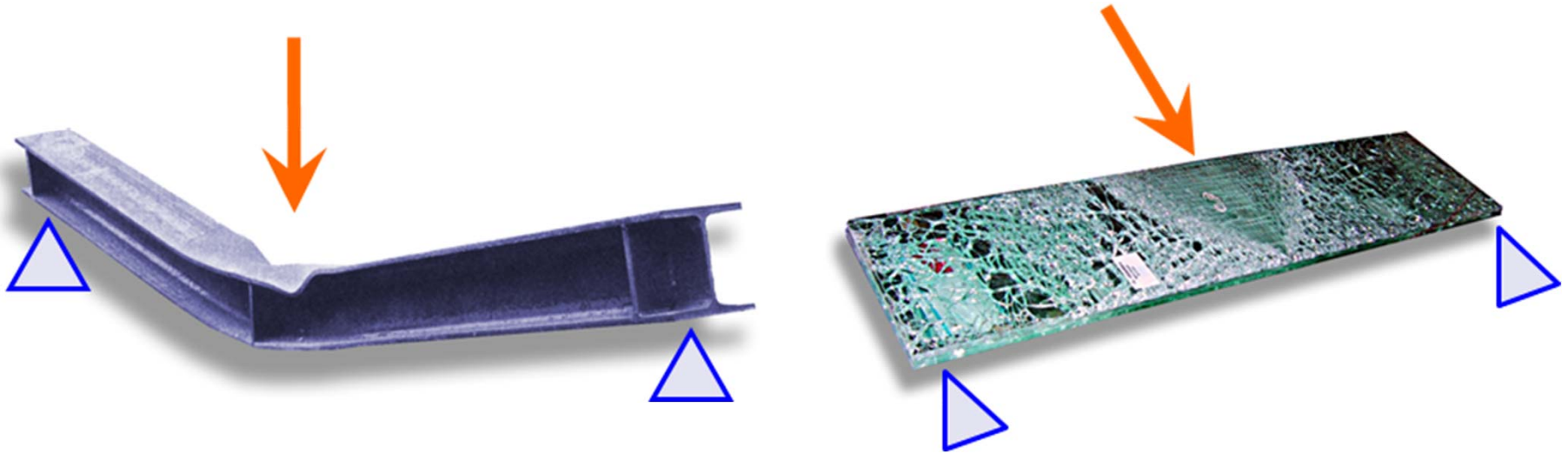
[CSA S6]

Clause 14.12 – Target Reliability Index, β

14.12.3 Element behaviour

Element behaviour shall take into consideration the effect of any existing deterioration and shall be classified into one of the following categories:

(a) Category E1, where the element being considered is subject to sudden loss of capacity with little or no warning. This can include failure by buckling, concrete in shear and/or torsion with less than the minimum reinforcement required by Clause 14.14.1.6.2(a), bond (pullout) failure, suspension cables, eyebars, bearing stiffeners, over-reinforced concrete beams, connections, concrete beam-column compression failure, and steel in tension at net section.



[CSA S6, Haldimann 2005 (Photos)]

Clause 14.12 – Target Reliability Index, β

(b) Category E2, where the element being considered is subject to sudden failure with little or no warning but will retain post-failure capacity. This can include concrete in shear and/or torsion with at least the minimum reinforcement required by Clause 14.14.1.6.2(a), and steel plates in compression with post-buckling capacity.

(c) Category E3, where the element being considered is subject to gradual failure with warning of probable failure. This can include steel beams in bending or shear, under-reinforced concrete in bending, decks, and steel in tension at gross section.

14.12.4 Inspection level

Evaluation shall not be undertaken without inspection. Inspection levels shall be classified as follows:

(a) Inspection Level INSP1, where a component is not inspectable. This can include hidden members not accessible for inspection, e.g., interior webs of adjacent box beams.

(b) Inspection Level INSP2, where inspection is to the satisfaction of the evaluator, with the results of each inspection recorded and available to the evaluator.

(c) Inspection Level INSP3, where the evaluator has directed the inspection of all critical and substandard components and final evaluation calculations account for all information obtained during this inspection.

14.12.5 Important structures

For structures that can affect the life or safety of people under or near a bridge, are essential to the local economy, or are designated as emergency route bridges (in accordance with Clause 4.4.2), a value of β greater than that specified in Table 14.5 or 14.6 shall be used if directed by the Regulatory Authority.

[CSA S6]

Table 14.5
Target reliability index, β, for normal traffic and for PA, PB, and PS traffic

(See Clauses 14.12.1 and 14.12.5.)

(annual)

System behaviour category	Element behaviour category	Inspection level		
		INSP1	INSP2	INSP3
S1	E1	4.00	3.75	3.75
	E2	3.75	3.50	3.25
	E3	3.50	3.25	3.00
S2	E1	3.75	3.50	3.50
	E2	3.50	3.25	3.00
	E3	3.25	3.00	2.75
S3	E1	3.50	3.25	3.25
	E2	3.25	3.00	2.75
	E3	3.00	2.75	2.50

[CSA S6]

Table 14.6
Target reliability index, β, for PC traffic

(See Clauses 14.12.1 and 14.12.5.)

(annual)

System behaviour category	Element behaviour category	Inspection level		
		INSP1	INSP2	INSP3
S1	E1	3.50	3.25	3.25
	E2	3.25	3.00	2.75
	E3	3.00	2.75	2.50
S2	E1	3.25	3.00	3.00
	E2	3.00	2.75	2.50
	E3	2.75	2.50	2.25
S3	E1	3.00	2.75	2.75
	E2	2.75	2.50	2.25
	E3	2.50	2.25	2.00

[CSA S6]

Clause 14.13 – Load Factors

Table 14.7
Maximum dead load factors, α_D
(See Clause 14.13.2.1.)

new bridge

Dead load category	Target Reliability Index, β								
	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00
D1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11
D2	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
D3	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55

D1: dead load of factory-produced components and cast-in-place concrete, excluding decks;

D2: cast-in-place concrete decks (including deck overlays), wood, field-measured bituminous surfacing, and non-structural components;

D3: bituminous surfacing where the nominal thickness is assumed to be 90 mm for the evaluation.

[CSA S6]

Clause 14.13 – Load Factors

Table 14.8
Live load factors, α_L, for normal traffic (Evaluation Levels 1, 2, and 3) for all types of analysis
(See Clause 14.13.3.1.)

	Target reliability index, β						
Spans	2.50	2.75	3.00	3.25	3.50	3.75	4.00
All Spans	1.35	1.42	1.49	1.56	1.63	1.70	1.77

new bridge

[CSA S6]

Table 14.8
Live load factors, α_L, for PS, PA, PB, and PC traffic
(See Clause 14.13.3.2.)

Traffic type	Type of analysis	Target reliability index, β								
		2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00
PS traffic	Statically determinate	x	x	1.20	1.24	1.29	1.34	1.39	1.44	1.50
	Sophisticated	x	x	1.21	1.26	1.31	1.36	1.42	1.48	1.54
	Simplified (Section 5)	x	x	1.20	1.26	1.32	1.38	1.44	1.51	1.57
PA traffic	Statically determinate	x	x	1.27	1.32	1.37	1.42	1.48	1.53	1.59
	Sophisticated	x	x	1.29	1.34	1.39	1.45	1.51	1.57	1.63
	Simplified (Section 5)	x	x	1.28	1.34	1.40	1.47	1.53	1.60	1.67
PB traffic	Statically determinate	x	x	1.10	1.12	1.16	1.21	1.26	1.30	1.36
	Sophisticated	x	x	1.10	1.13	1.18	1.23	1.28	1.33	1.39
	Simplified (Section 5)	x	x	1.10	1.13	1.19	1.24	1.30	1.36	1.42
PC traffic	Statically determinate	1.10	1.10	1.10	1.13	1.18	1.23	1.28	1.33	1.38
	Sophisticated	1.10	1.10	1.10	1.14	1.19	1.24	1.30	1.35	1.40
	Simplified (Section 5)	1.10	1.10	1.10	1.13	1.19	1.25	1.31	1.37	1.43

[CSA S6]

Clause 14.14 – Resistance Calculation

"The purpose of resistance adjustment factors, U, is to fine-tune the resistance factors used in the rest of the Code. While approximations made to the resistance factors in the interests of simplicity are appropriate for the design of new bridges, in the evaluation of existing bridges their use may lead to unnecessary bridge postings or strengthenings."

Table 14.15
Resistance adjustment factor, *U*
(See Clause 14.14.2.)

Resistance category	Resistance adjustment factor, *U*
Structural Steel (ϕ per Clause 10.5.7)	
Plastic moment	1.00
Yield moment	1.06
Inelastic lateral torsional buckling moment	1.04
Elastic lateral torsional buckling moment	0.96
Compression or tension on gross section	1.01
Tension on net section	1.18
Shear (stocky web)	1.02
Shear (tension field)	1.03
Bolts	1.20
Welds	1.32
Rivets	1.81
Composite — Slab on steel girder (ϕ per Clauses 8.4.6 and 10.5.7)	
Bending moment	0.96
Shear connectors	0.94
Reinforced concrete (ϕ per Clause 8.4.6)	
Bending moment	
$\rho \le 0.4\rho_b$	1.02
$0.4\rho_b < \rho \le 0.7\rho_b$	0.95
Axial compression	1.06
Shear (> min. stirrups)	1.05
Prestressed concrete (ϕ per Clause 8.4.6)	
Bending moment	
$\omega_p \le 0.15$	1.01
$0.15 < \omega_p \le 0.30$	0.94

[CSA S6]

Clause 14.15 – Live Load Capacity Factor

For ultimate limit states, the live load capacity factor, *F*, is calculated as follows:

$$F = \frac{UR_r - \Sigma\alpha_D D - \Sigma\alpha_A A}{\alpha_L L(1 + I_D)}$$

I_D = dynamic load allowance (DLA)

- For normal traffic, *F* based on CL1-W loading.
- If $F < 1.0$ and load posting is an option, then *F* is also calculated for CL2-W and CL3-W loading.
- For permit traffic, *F* is calculated for the type of vehicle(s) for which a permit is sought.

[CSA S6]

Dynamic Load Allowance

- The DLA is a factor by which the live load is increased to account for addition load effects due to vibration and the dynamic response of the structure.
- = 0.50 (i.e. 50%) for deck joints
- = 0.40 where only one axle load is used
- = 0.30 where two axle or axles 1-3 loads
- = 0.25 otherwise

[CSA S6]

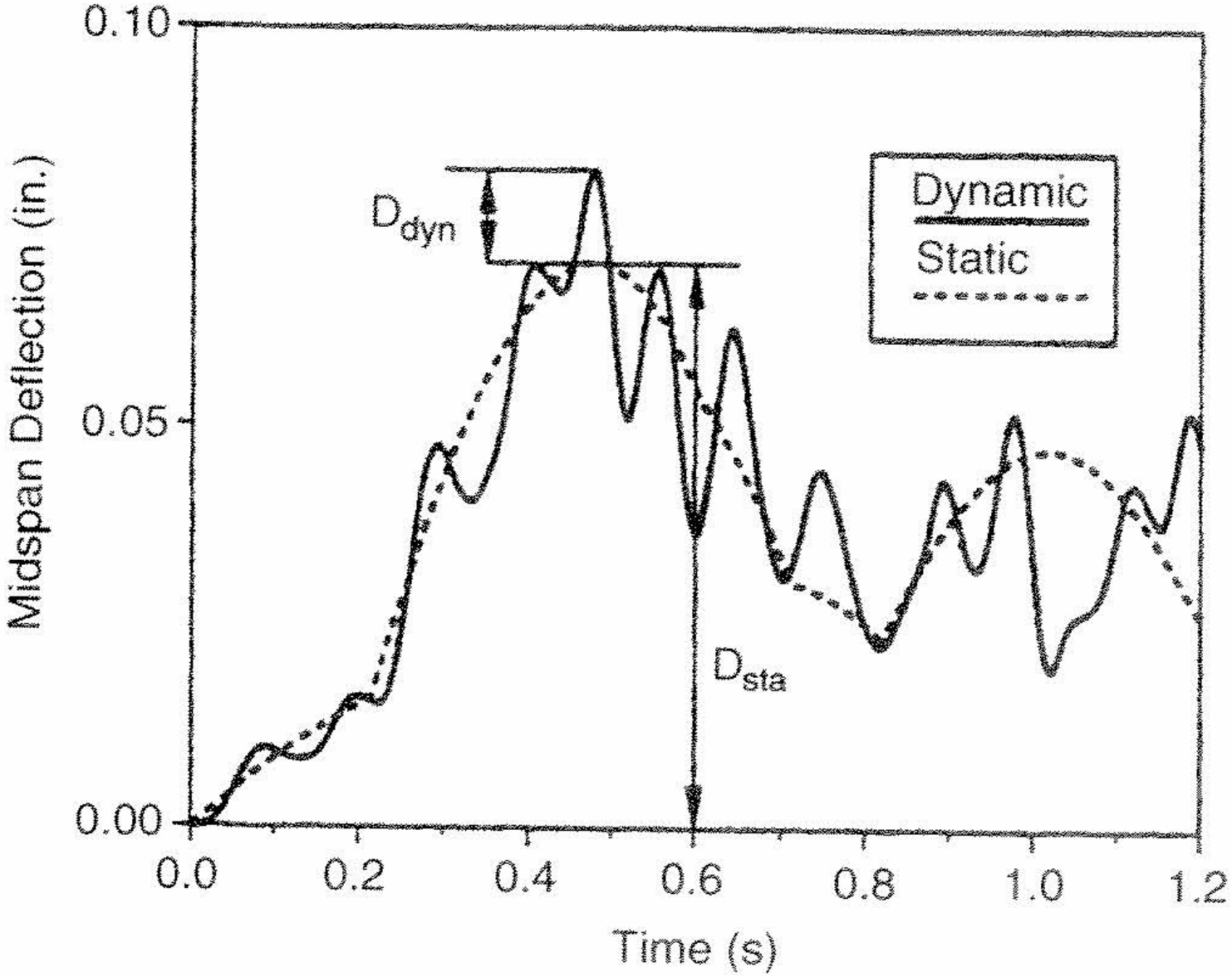


Fig. 4.12
Typical live-load response (Hwang and Nowak, 1991a).

[Barker & Puckett]

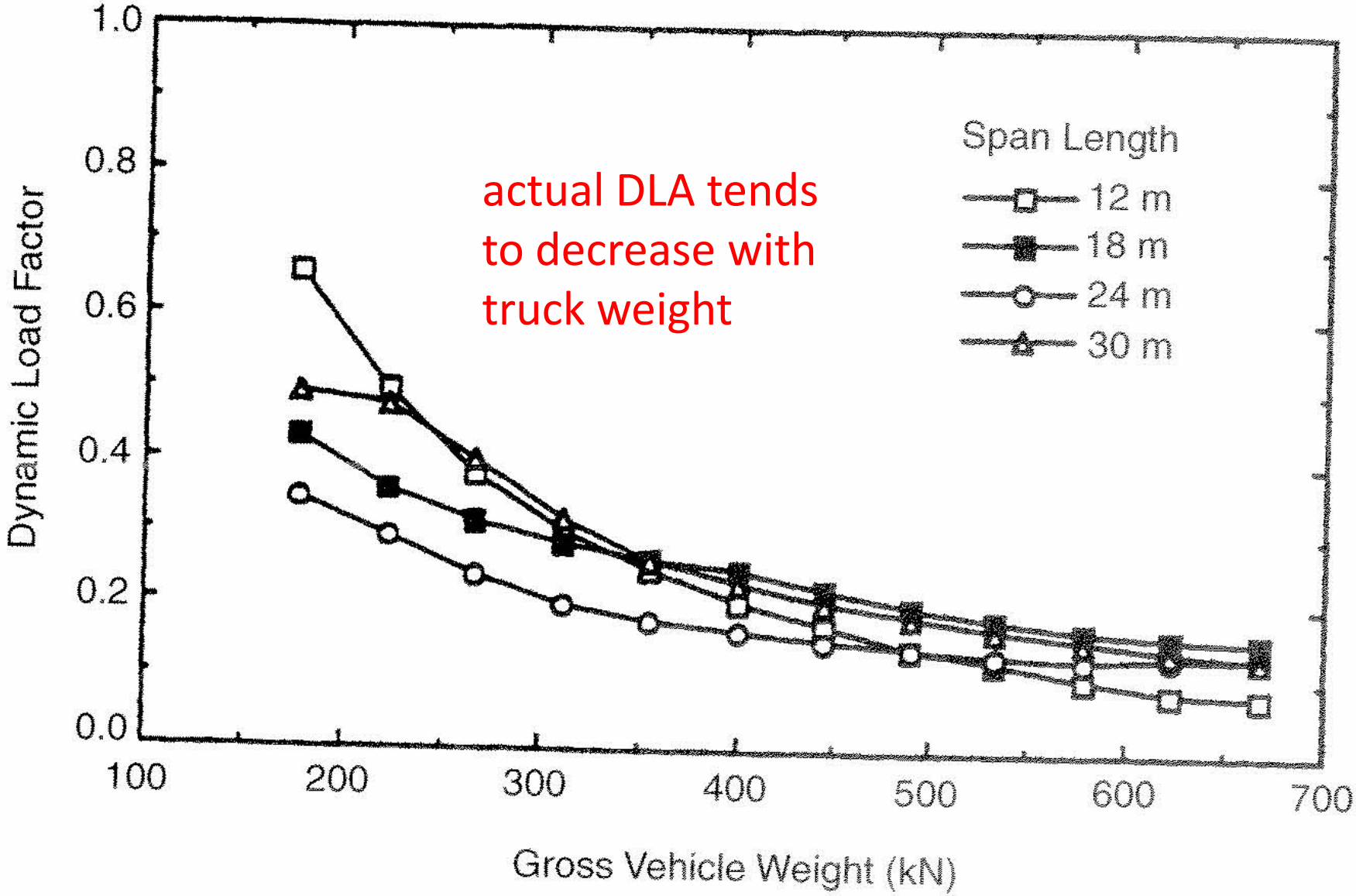


Fig. 4.15
Dynamic load allowance (Hwang and Nowak, 1991a).

[Barker & Puckett]

Dynamic Load Allowance

- The DLA is not applied to centrifugal, braking, collision, or pedestrian loads.
- The DLA is applied to single truck load model only – not to lane loads.

- Structural components down to the top of the foundation should be designed considering the DLA. Below this, the ground dampens the vibrations, reducing dynamic effects.
- The single axle case is applicable to slabs, steel decking, and short span supporting elements.

Example

$M_p = 1053$ kNm

$M_D = 357$ kNm

$M_L = 286$ kNm

$DLA\ (1_D) = 0.25$

given

* assume steel beam supporting factory-produced components only & normal traffic

1) check as new design

2) find F for following case:

S3 system
E3 element
} behaviour

Insp 3 inspection

1) $M_r \geq M_f$

$M_r = \phi M_p = 0.95 \cdot 1053 = 1000 \text{ kNm}$

$M_f = \alpha_L M_L (1 + DLA) + \alpha_D M_D$

$= 1.7 \times 286 (1 + 0.25) + 1.1 \times 357$

$= 1000 \text{ kNm}$

$M_r = M_f \rightarrow$ ok !

2) S3, E3, Insp 3 $\longrightarrow \beta = 2.5$

plastic moment $\longrightarrow U = 1.0$

$$F = \frac{\phi \cdot M_r - \alpha_D M_D}{\alpha_L \cdot M_L (1 + DLA)}$$

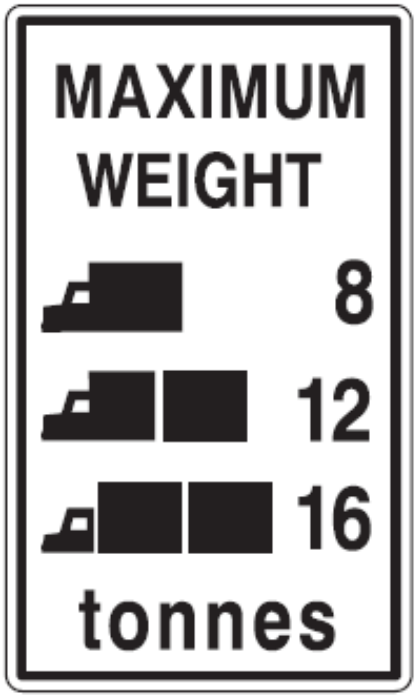
$$= \frac{1 \times 1000 - 1.05 \times 357}{1.35 \times 286 (1 + 0.25)}$$

$$= \boxed{1.30}$$

→ beam could support a truck 30% heavier than truck used for new design ($w = 625$ kN)

Clause 14.17 – Load Posting

(a) Single posting



(b) Triple posting

Figure C14.2
Typical posting signs in use in Ontario
(See Clause C14.17.3.)

[CSA S6]

Clause 14.17 – Load Posting

When Evaluation Levels 1, 2, and 3 are used as a basis for posting, the smallest value of *F* shall be calculated and applied as follows:

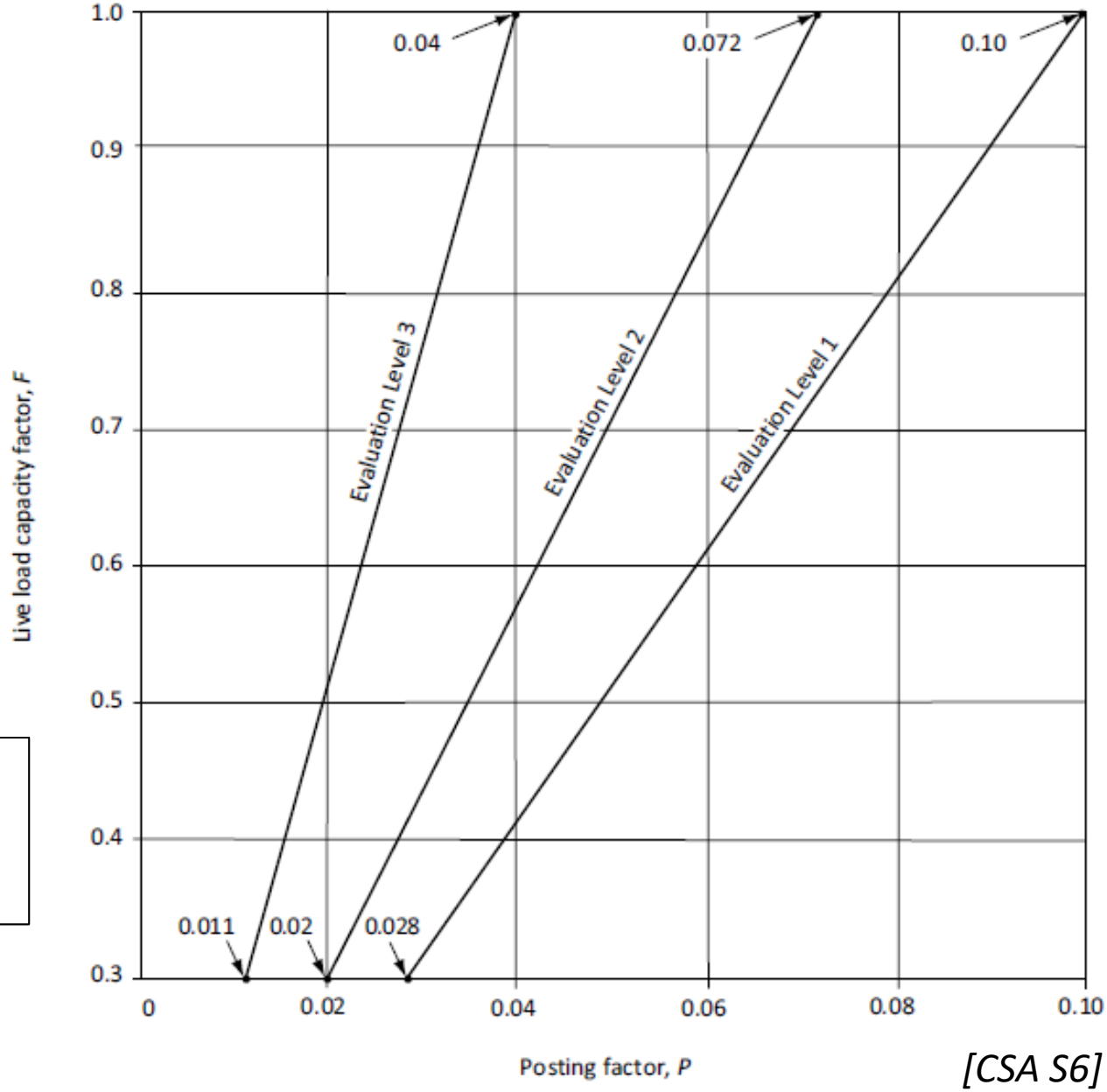
- when $F \geq 1.0$ for Level 1, posting not required;
- when $1.0 > F \geq 0.3$ for Level 1, triple posting req'd.;
- when $F < 0.3$ for Level 1 and $F \geq 0.3$ for Level 3, single posting for Level 3 only required;
- when $F < 0.3$ for Level 3, consider closing bridge.

[CSA S6]

Posting load (in tonnes) = Code truck gross vehicle weight, W (in kN) · P

Recall: ~10 kN per tonne

Figure 14.6
Posting loads for gross vehicle weight
(See Clause 14.17.2.1.)



[CSA S6]