EN 1991-2 « Traffic Loads on Bridges »

Traffic Loads on Road Bridges and Footbridges

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

EN 1991-2:2003 D	Ratifizierter Text der Europäischen Norm
EN 1991-2:2003 E	Ratified text of the European Standard
EN 1991-2:2003 F	Texte ratifié de la Norme européenne

ICS: 91.010.30; 93.040

Eurocode 1: Einwirkungen auf Tragwerke - Teil 2: Verkehrslasten auf Brücken

Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges

Eurocode 1: Actions sur les structures - Partie 2: Actions sur les ponts, dues au trafic

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GENERAL ORGANISATION FOR ROAD BRIDGES

Traffic load models

- Vertical forces : LM1, LM2, LM3, LM4
- Horizontal forces : braking and acceleration, centrifugal, transverse

Groups of loads

- gr1a, gr1b, gr2, gr3, gr4, gr5
- characteristic, frequent and quasi-permanent values

Combination with actions other than traffic actions

LOAD MODELS FOR LIMIT STATES OTHER THAN FATIGUE LIMIT STATES

Field of application : loaded lengths less than 200 m (maximum length taken into account for the calibration of the Eurocode – For very long loaded lengths, see National Annex)

Load Model Nr. 1
Concentrated and distributed loads (main model – general and local verifications)

Load Model Nr. 2
Single axle load (semi-local and local verifications)

Load Model Nr. 3
Set of special vehicles (general and local verifications)

Load Model Nr. 4
Crowd loading : 5 kN/m^2 (general verifications)

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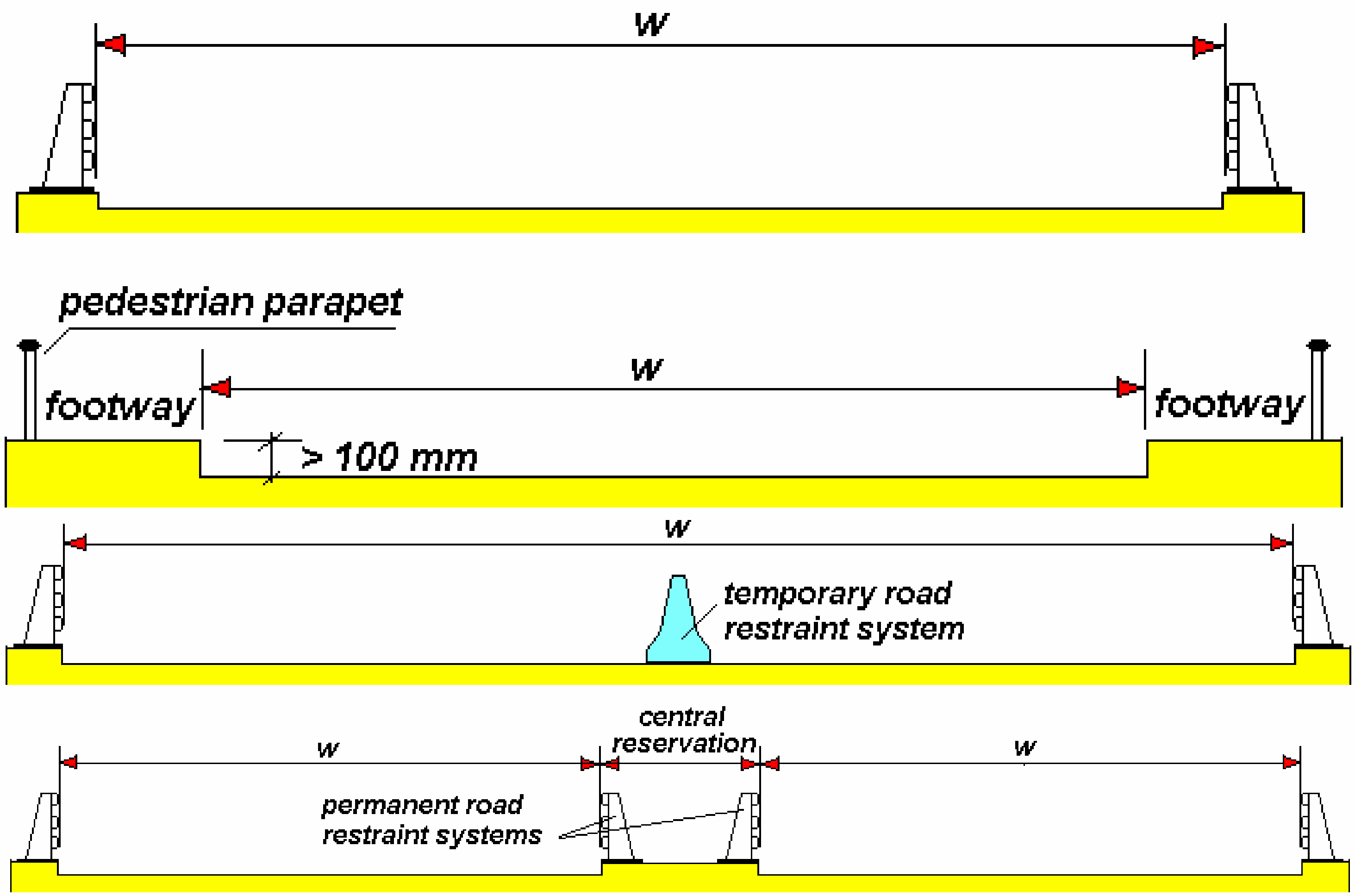
Traffic Load Models	Characteristic values	Frequent values	Quasi-permanent values
Road bridges			
LM1 (4.3.2)	1000 year return period (or probability of exceedance of 5% in 50 years) for traffic on the main roads in Europe (α factors equal to 1, see 4.3.2).	1 week return period for traffic on the main roads in Europe (α factors equal to 1, see 4.3.2).	Calibration in accordance with definition given in EN 1990.
LM2 (4.3.3)	1000 year return period (or probability of exceedance of 5% in 50 years) for traffic on the main roads in Europe (β factor equal to 1, see 4.3.3).	1 week return period for traffic on the main roads in Europe (β factor equal to 1, see 4.3.3).	Not relevant
LM3 (4.3.4)	Set of nominal values. Basic values defined in annex A are derived from a synthesis based on various national regulations.	Not relevant	Not relevant
LM4 (4.3.5)	Nominal value deemed to represent the effects of a crowd. Defined with reference to existing national standards.	Not relevant	Not relevant

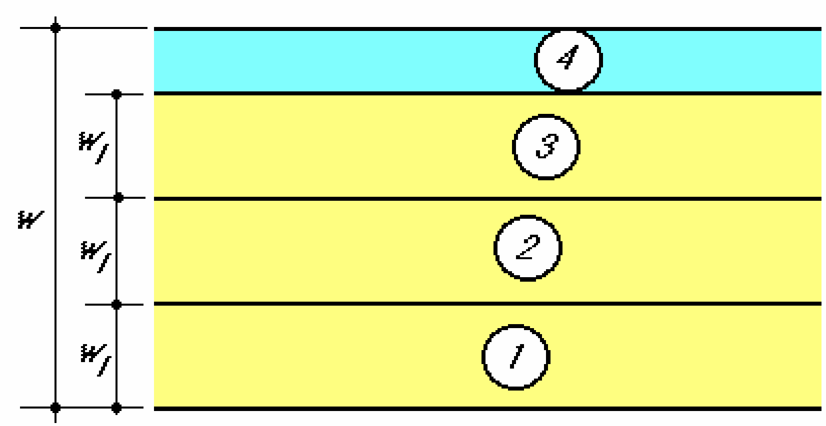
Carriageway width w

width measured between kerbs (height more than 100 mm – recommended value) or between the inner limits of vehicle restraint systems



Division of the carriageway into notional lanes

Carriageway width w	Number of notional lanes	Width of a notional lane w_l	Width of the remaining area
$w < 5{,}4\,m$	$n_1 = 1$	3 m	$w - 3m$
$5{,}4m \le w < 6m$	$n_1 = 2$	$\frac{w}{2}$	0
$6m \le w$	$n_1 = Int\left(\frac{w}{3}\right)$	3 m	$w - 3 \times n_l$
NOTE For example, for a carriageway width equal to 11m, $n_1 = Int\left(\frac{w}{3}\right) = 3$, and the width of the remaining area is 11 - 3×3 = 2m.			



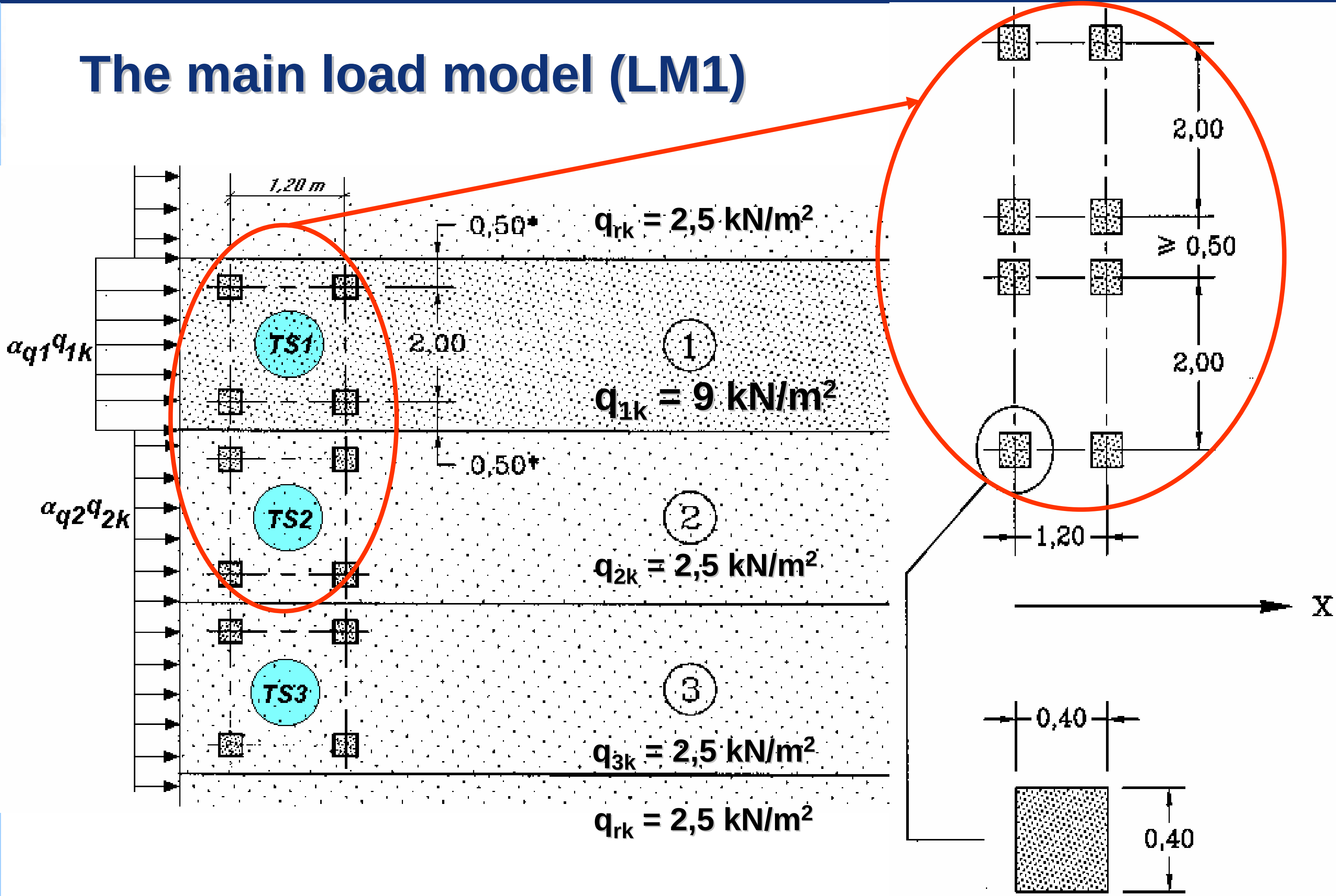
1 – Lane Nr. 1 (3m)

2 – Lane Nr. 2 (3m)

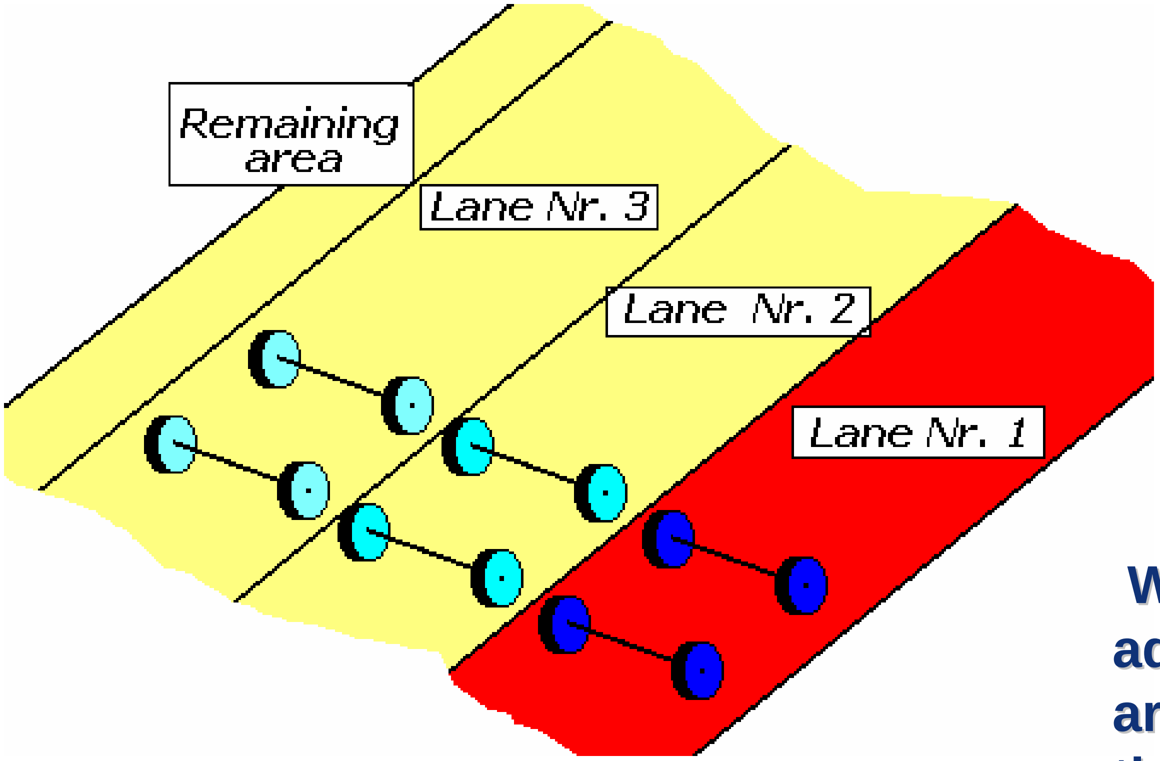
3 – Lane Nr. 3 (3m)

4 – Remaining area

The main load model (LM1)



The main load model for road bridges (LM1) : diagrammatic representation



For the determination of general effects, the tandems travel centrally along the axes of notional lanes

Where two tandems on adjacent notional lanes are taken into account, they may be brought closer, the distance between axles being not less than 0,50 m

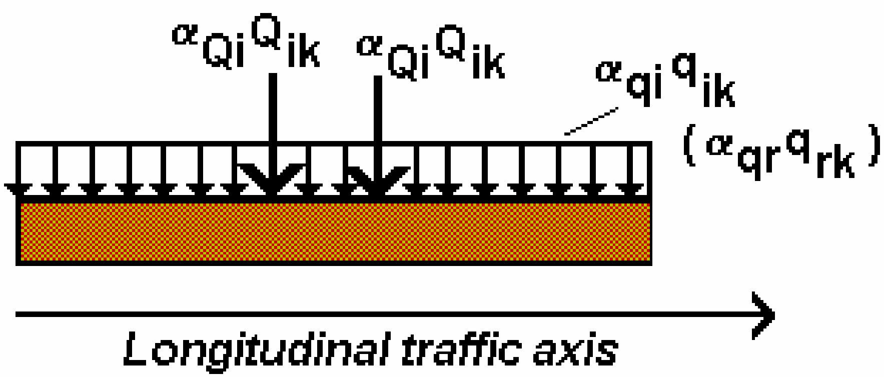
For local verifications, a tandem system should be applied at the most unfavourable location.

The main load model (LM1)

$Q_{1k} = 300$ kN

$Q_{2k} = 200$ kN

$Q_{3k} = 100$ kN



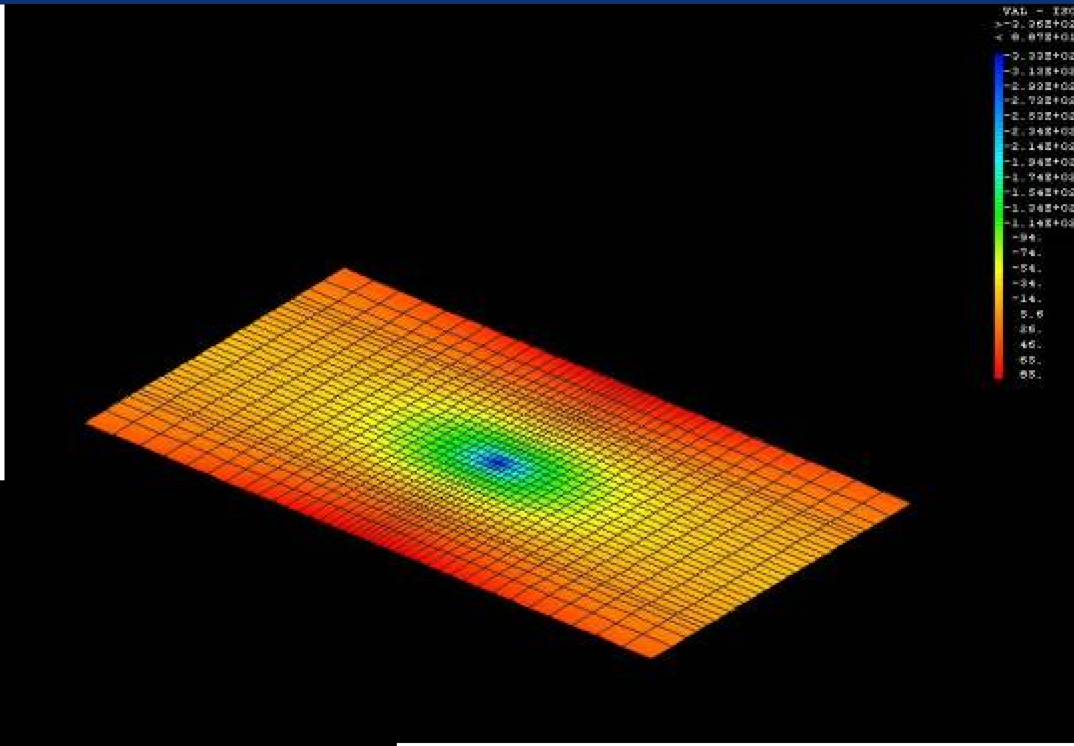
Example of values for α factors (National Annexes)

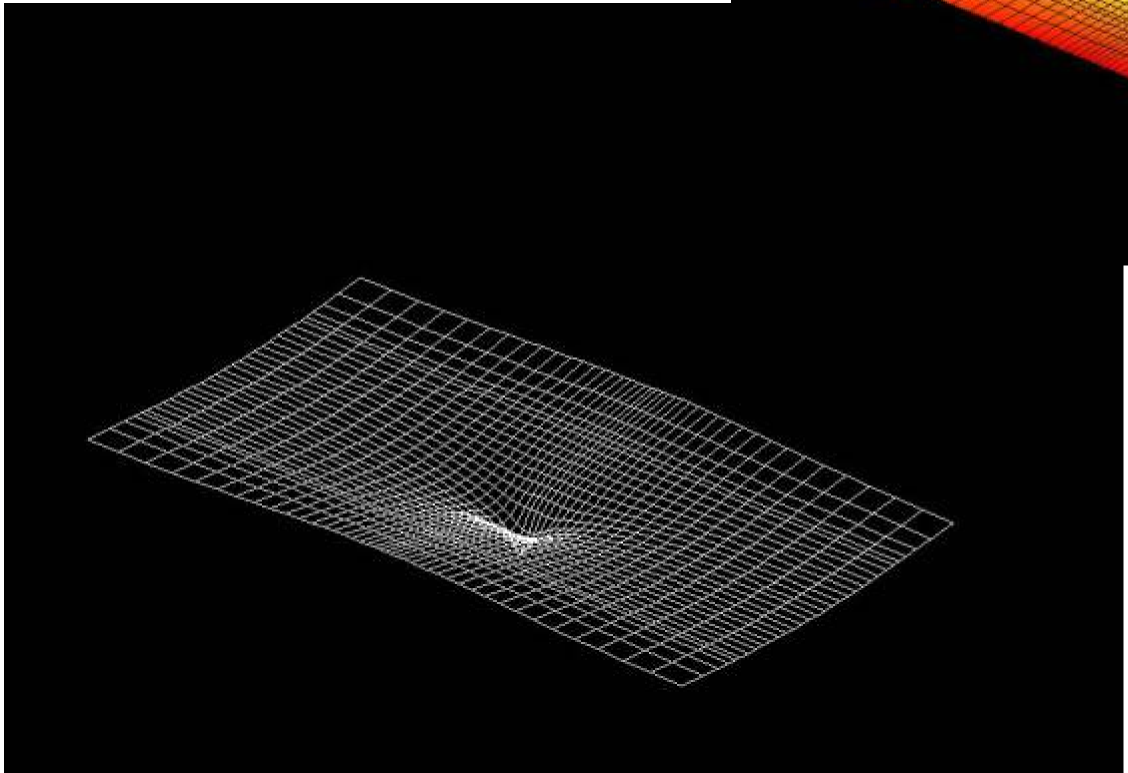
1st class : international heavy vehicle traffic

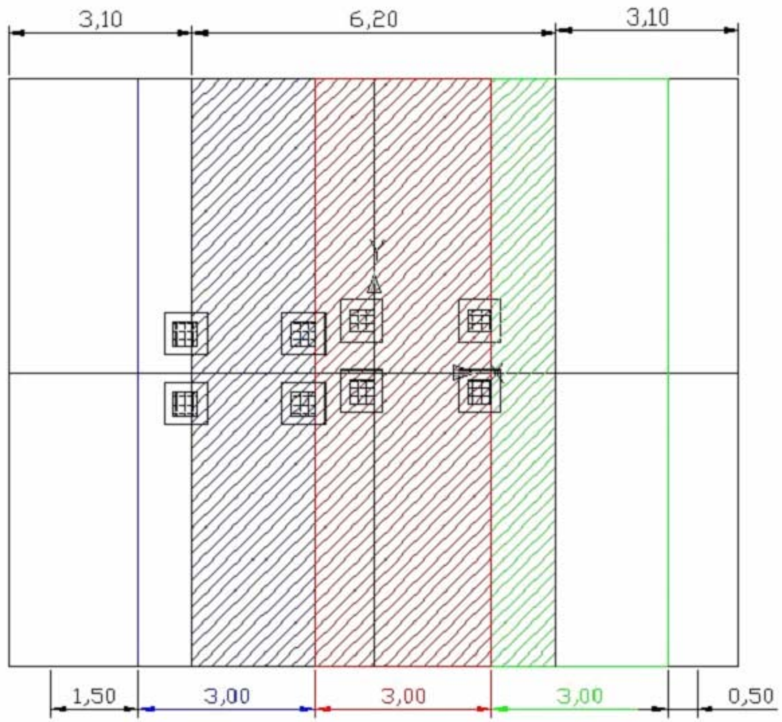
2nd class : « normal » heavy vehicle traffic

Classes	α_{Q1}	α_{Qi} $i \geq 2$	α_{q1}	α_{qi} $i \geq 2$	α_{qr}
1st class	1	1	1	1	1
2nd class	0,9	0,8	0,7	1	1

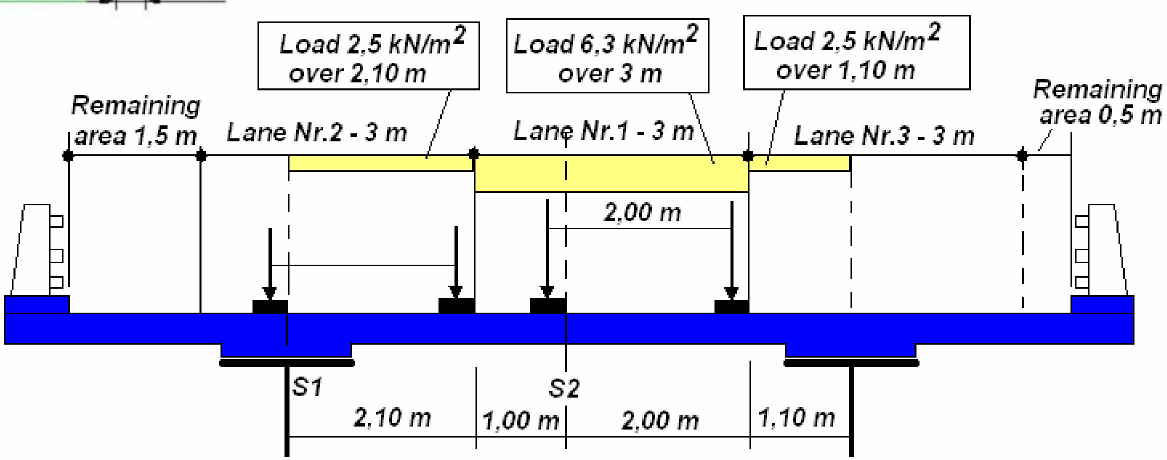
Examples of influence surfaces (transverse bending moment) for a deck slab



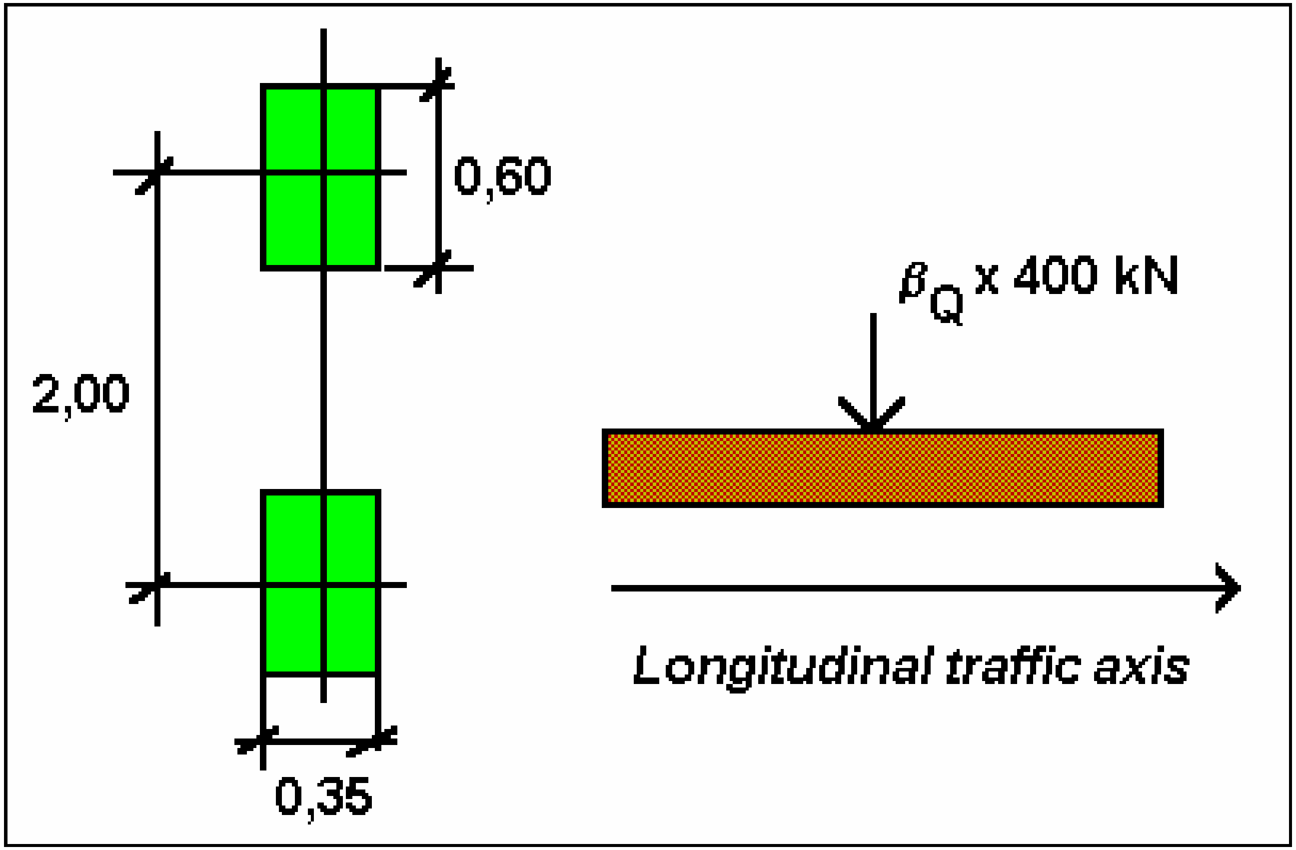




Example of application of LM1 to the concrete slab of a composite bridge

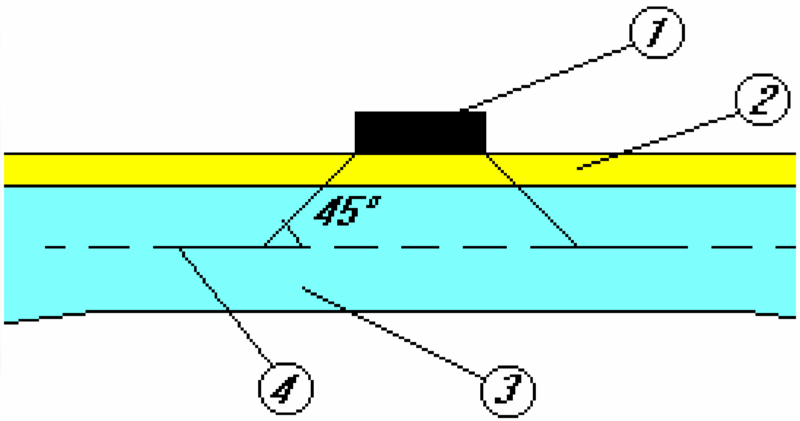


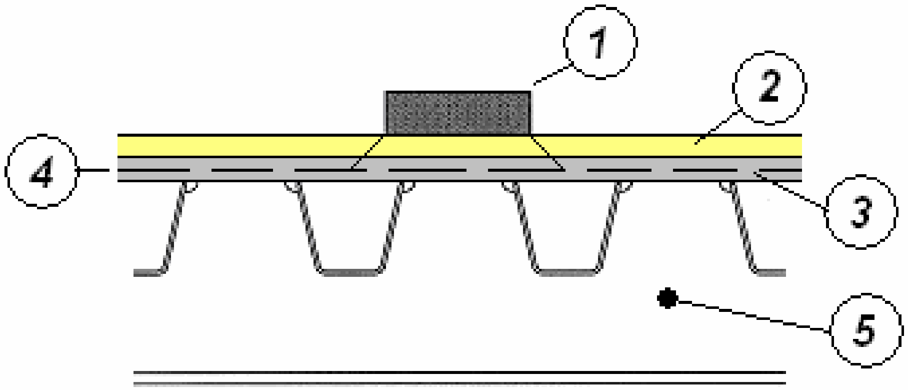
Load model Nr. 2 (LM2)



Recommended value : $\beta_Q = \alpha_{Q1}$ **(National Annex)**

Dispersal of concentrated loads





a) Pavement and concrete slab

1 Wheel contact pressure

2 Pavement

3 Concrete slab

4 Middle surface of concrete slab

b) Pavement and orthotropic deck

1 Wheel contact pressure

2 Pavement

3 Bridge floor

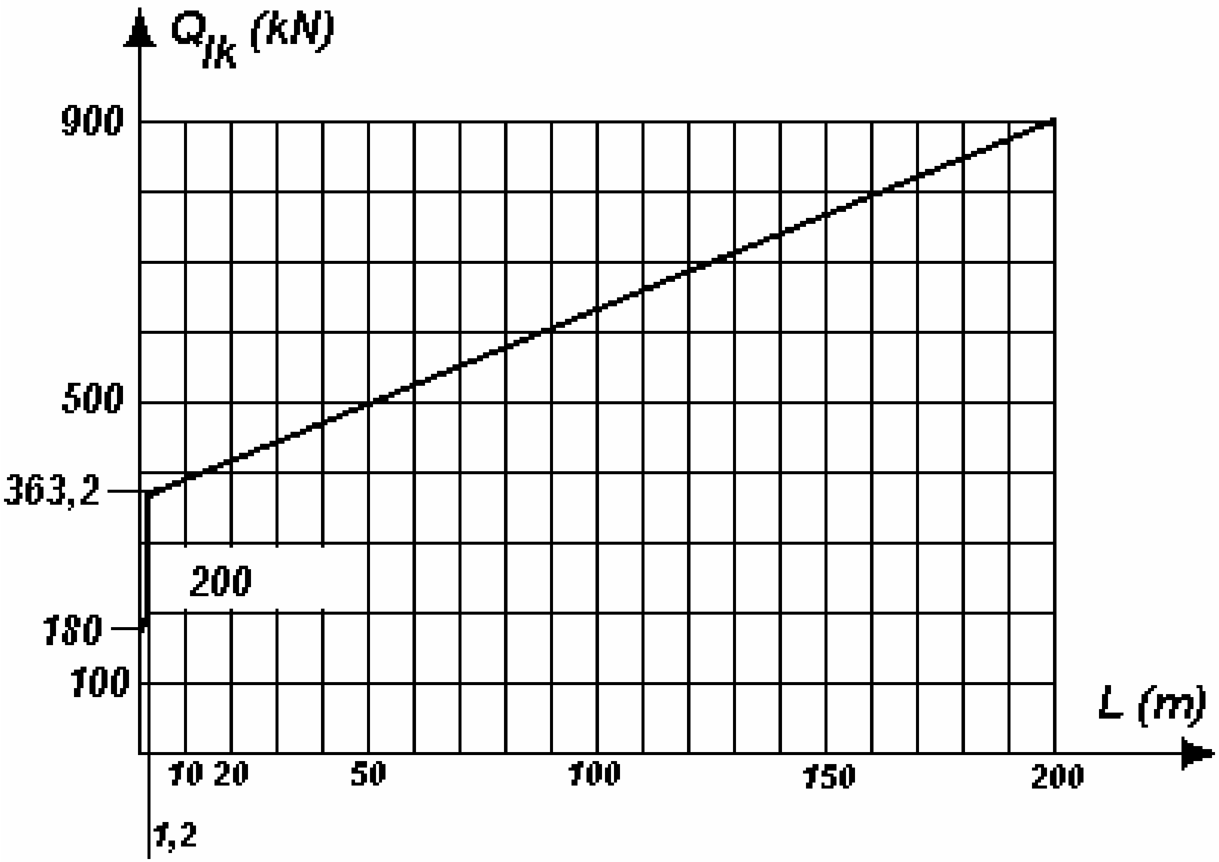
4 Middle surface of the bridge floor

5 Transverse member

HORIZONTAL FORCES : Braking and acceleration (Lane Nr. 1)

$$Q_{\ell k} = 0{,}6\alpha_{Q1}(2Q_{1k}) + 0{,}10\alpha_{q1}q_{1k}w_1 L$$

$$180\alpha_{Q1} kN \leq Q_{\ell k} \leq 900\, kN$$



$\alpha_{Q1} = \alpha_{q1} = 1$

$Q_{lk} = 180 + 2{,}7L$

For $0 \leq L \leq 1{,}2$ m

$Q_{lk} = 360 + 2{,}7L$

For $L > 1{,}2$ m

HORIZONTAL FORCES : Centrifugal forces

$Q_{tk} = 0{,}2Q_v$ (kN)	if r < 200 m
$Q_{tk} = 40Q_v / r$ (kN)	if 200 ≤ r ≤ 1500 m
$Q_{tk} = 0$	if r > 1500 m

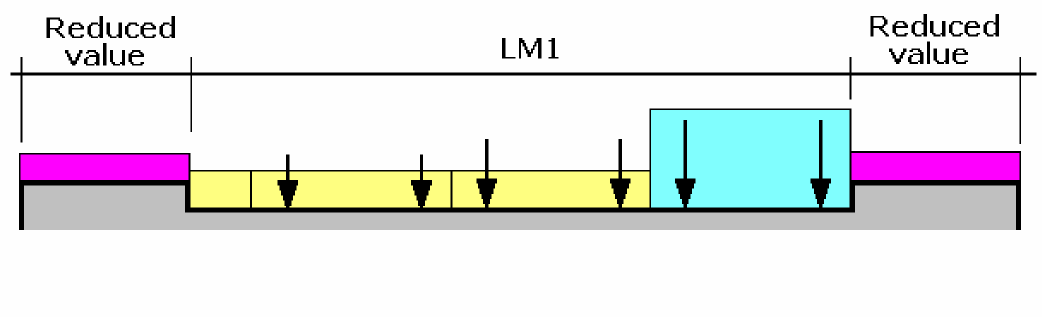
r : horizontal radius of curvature of the carriageway centreline [m]

Q_v : total maximum weight of vertical concentrated loads of the tandem systems of LM1

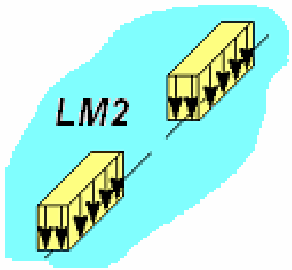
$$\sum_i \alpha_{Qi}(2Q_{ik})$$

Groups of loads

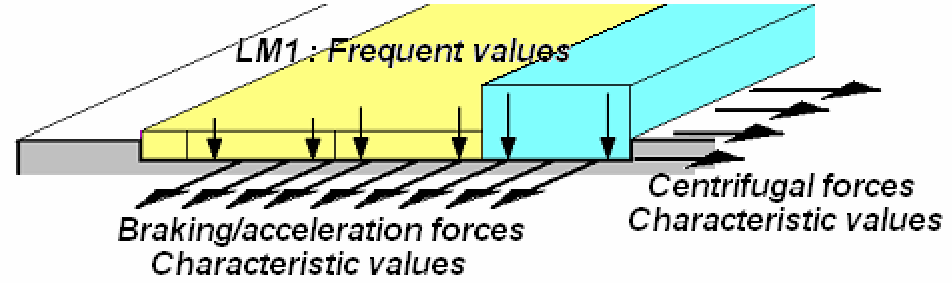
Group of loads gr1a : LM1 + « reduced » value of pedestrian load on footways or cycle tracks (3 kN/m²)



Group of loads gr1b : LM2 (single axle load)



Group of loads gr2 : characteristic values of horizontal forces, frequent values of LM1



Group of loads gr3 : loads on footways and cycle tracks

Group of loads gr4 : crowd loading

Group of loads gr5 : special vehicles (+ special conditions for normal traffic)

Table 4.4b – Assessment of groups of traffic loads (frequent values of the multi-component action)

		CARRIAGEWAY		FOOTWAYS AND CYCLE TRACKS
Load type		Vertical forces		
Reference EN 1991-2		4.3.2	4.3.3	5.3.2(1)
Load system		LM1 (TS and UDL systems)	LM2 (single axle)	Uniformly distributed load
Groups of loads	gr1a	Frequent values		
	gr1b		Frequent values	
	gr3			Frequent value [a)]

a) See 5.3.2.1(3). One footway only should be considered to be loaded if the effect is more unfavourable than the effect of two loaded footways.

FATIGUE LOAD MODELS

Load Model Nr. 1 (FLM1) : Similar to characteristic Load Model Nr. 1

$$0{,}7 \times Q_{ik} - 0{,}3 \times q_{ik} - 0{,}3 \times q_{rk}$$

Load Model Nr. 2 (FLM2) : Set of « fequent » lorries

Load Model Nr. 3 (FLM3) : Single vehicle

Load Model Nr. 4 (FLM4) : Set of « equivalent » lorries

Load Model Nr. 5 (FLM5) : Recorded traffic

Table 4.5 - Indicative number of heavy vehicles expected per year and per slow lane

(FLM3 and FLM4 Models)

Traffic categories		N_{obs} per year and per slow lane
1	Roads and motorways with 2 or more lanes per direction with high flow rates of lorries	$2{,}0 \times 10^6$
2	Roads and motorways with medium flow rates of lorries	$0{,}5 \times 10^6$
3	Main roads with low flow rates of lorries	$0{,}125 \times 10^6$
4	Local roads with low flow rates of lorries	$0{,}05 \times 10^6$

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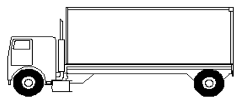
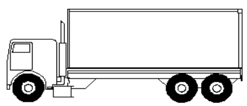
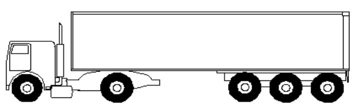
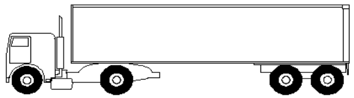
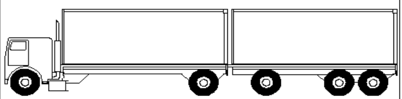
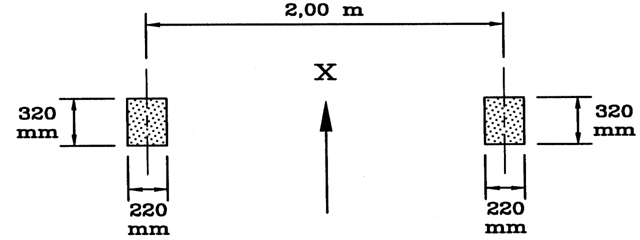
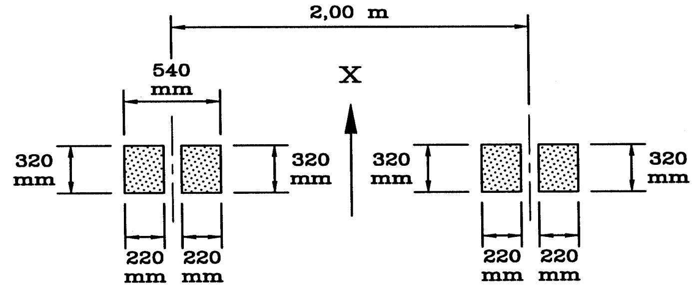
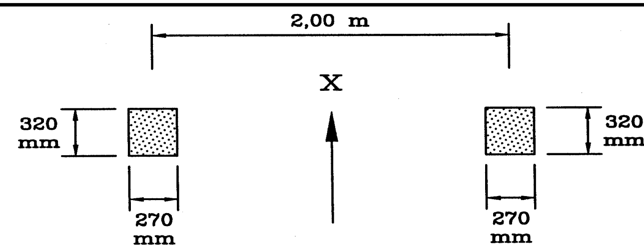
1	2	3	4
LORRY SILHOUETTE	Axle spacing (m)	Frequent axle loads (kN)	Wheel type (see Table 4.8)
	4,5	90 190	A B
	4,20 1,30	80 140 140	A B B
	3,20 5,20 1,30 1,30	90 180 120 120 120	A B C C C
	3,40 6,00 1,80	90 190 140 140	A B B B
	4,80 3,60 4,40 1,30	90 180 120 110 110	A B C C C

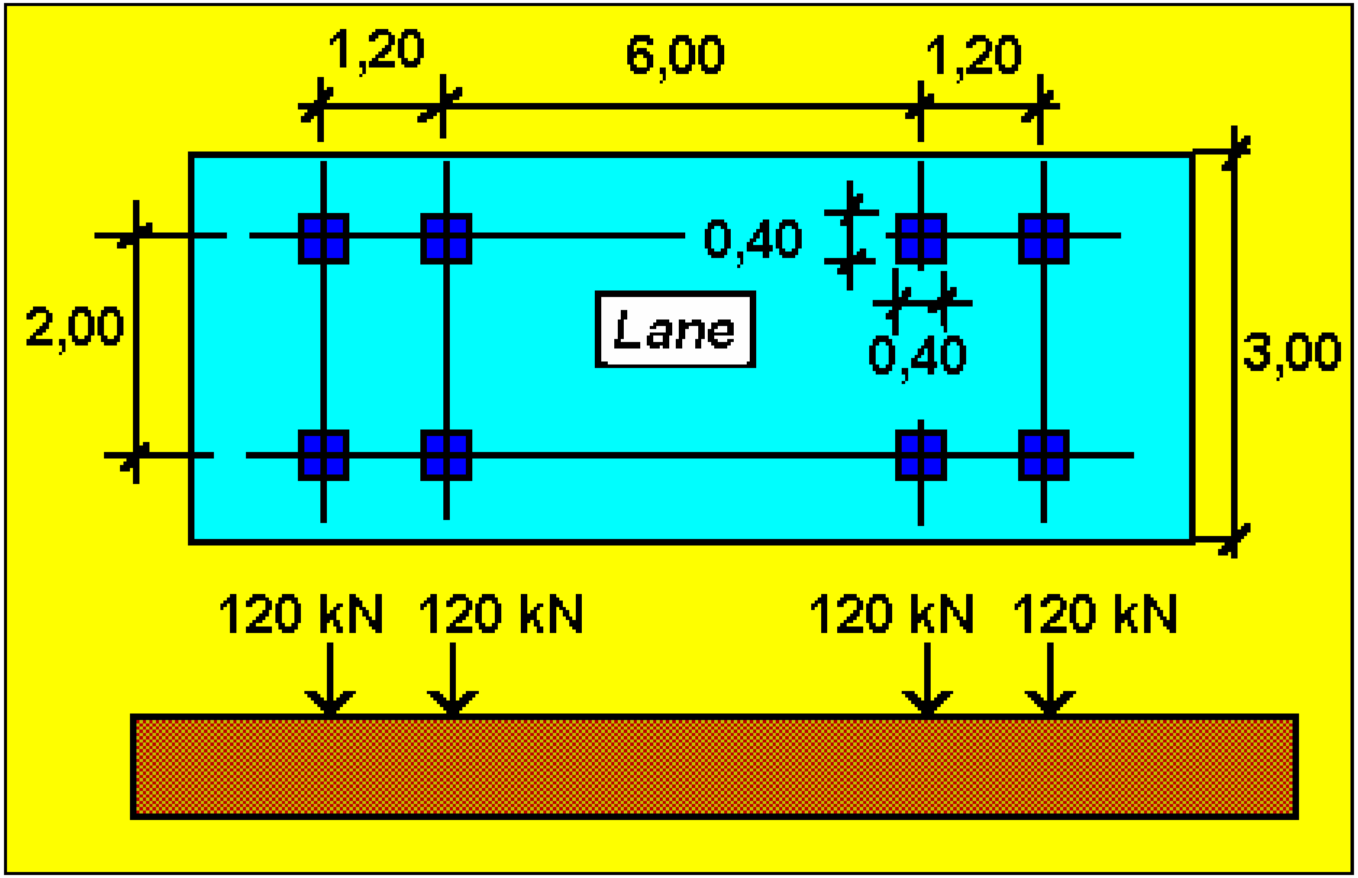
FLM2

Set of « frequent » lorries

FLM2 : Definition of wheels and axles (Table 4.8)

AXLE/WHEEL TYPES	GEOMETRICAL DEFINITION
A	
B	
C	

Fatigue Load Model Nr.3 (FLM3)



A second vehicle may be taken into account :
Recommended axle load value Q = 36 kN
Minimum distance between vehicles : 40 m

Verification procedure with Load Model FLM 3

Determination of the maximum and minimum stresses resulting from the transit of the model along the bridge

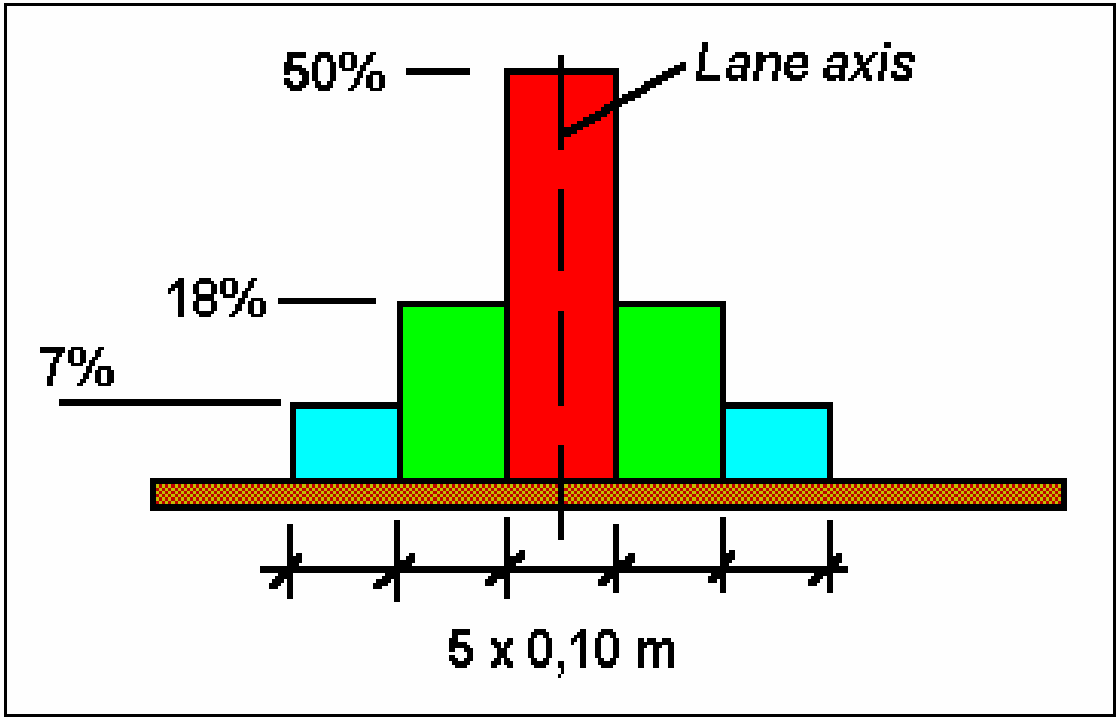
$$\Delta\sigma_{LM} = \left| Max\,\sigma_{LM} - Min\,\sigma_{LM} \right|$$

The stress variation is multiplied by a local dynamic amplification factor in the vicinity of expansion joints

$$\Delta\varphi_{fat}$$

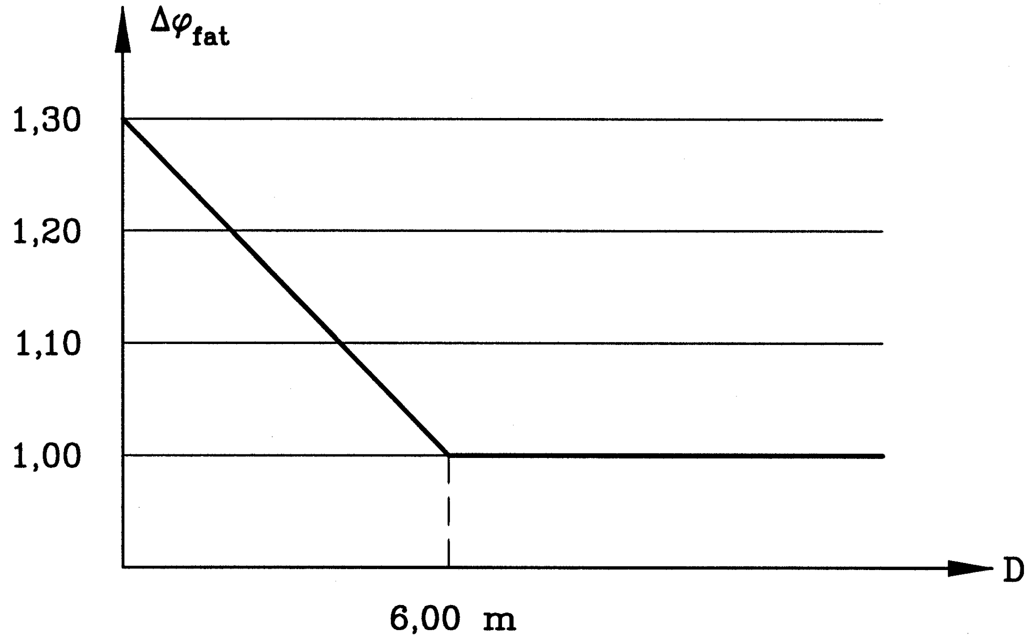
The model is normally centered in every slow lane defined in the project specification. But where the transverse position is important, a statistical distribution of this position should be taken into account.

Finally : $\Delta\sigma_{fat} = \lambda\Delta\varphi_{fat}\Delta\sigma_{LM}$



Frequency distribution of transverse location of a vehicle (Models 3 to 5)

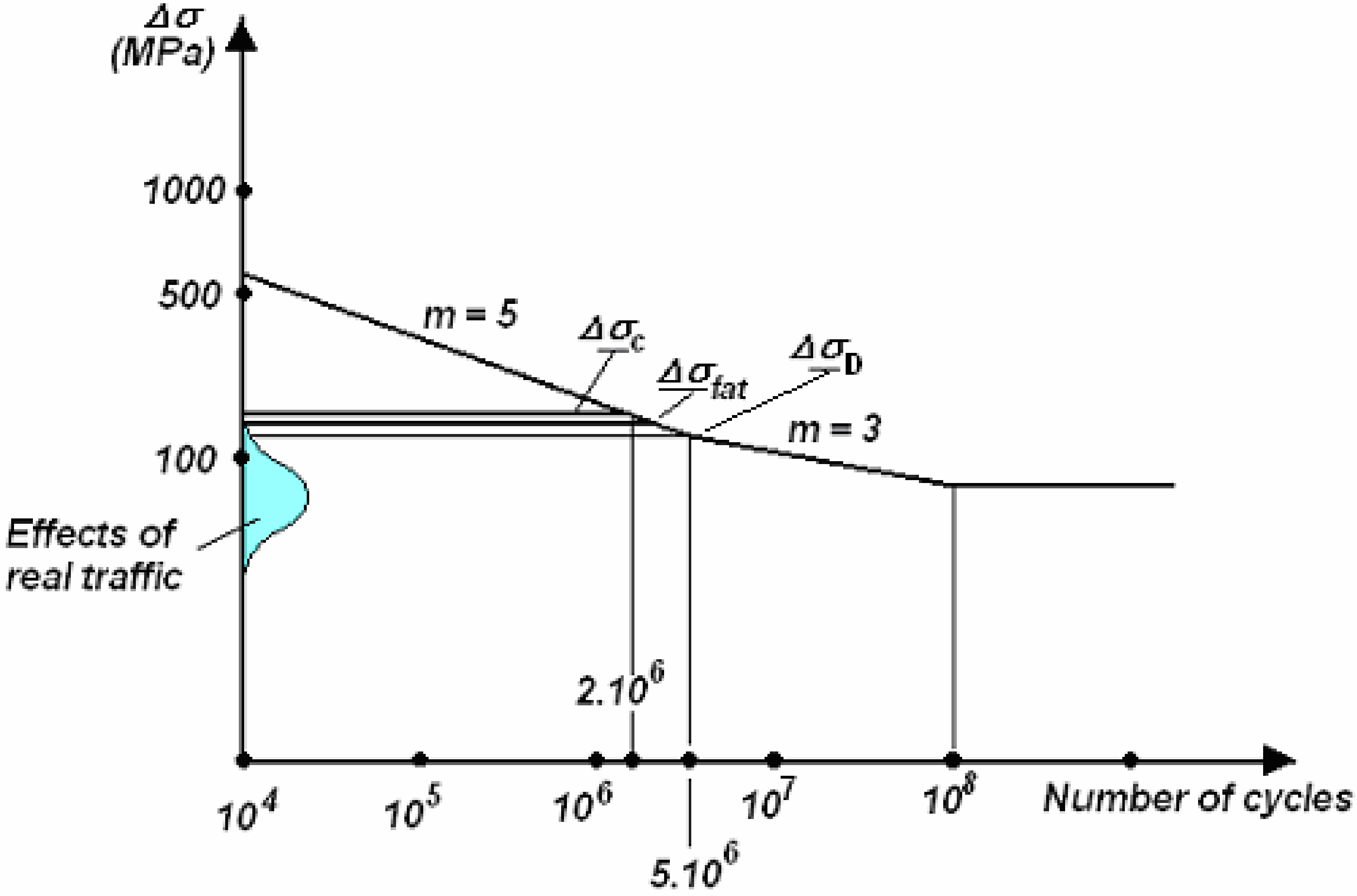
Fatigue Load Models for road bridges
Representation of the additional amplification factor



$\Delta\varphi_{fat}$: Additional amplification factor

D : Distance of the cross-section under consideration from the expansion joint

Principle of the fatigue verification with FLM 3



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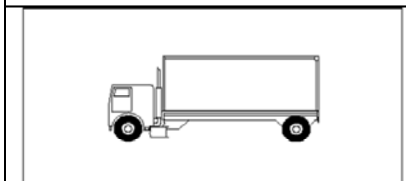
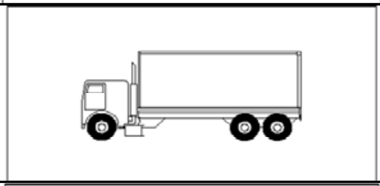
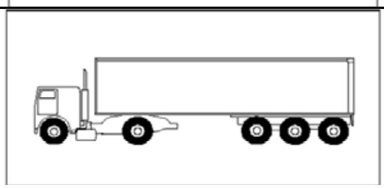
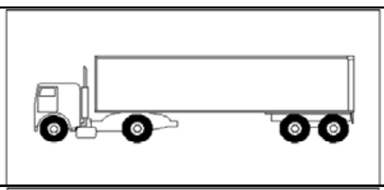
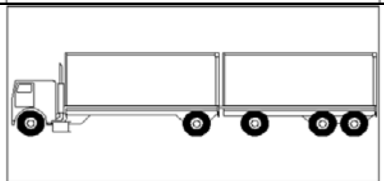
VEHICLE TYPE			TRAFFIC TYPE			
1	2	3	4	5	6	7
			Long distance	Medium distance	Local traffic	
LORRY	Axle spacing (m)	Equivalent axle loads (kN)	Lorry persentage	Lorry percentage	Lorry percentage	Wheel type
	4,5	70 130	20,0	40,0	80,0	A B
	4,20 1,30	70 120 120	5,0	10,0	5,0	A B B
	3,20 5,20 1,30 1,30	70 150 90 90 90	50,0	30,0	5,0	A B C C C
	3,40 6,00 1,80	70 140 90 90	15,0	15,0	5,0	A B B B
	4,80 3,60 4,40 1,30	70 130 90 80 80	10,0	5,0	5,0	A B C C C

FLM4

Set of « equivalent» lorries.

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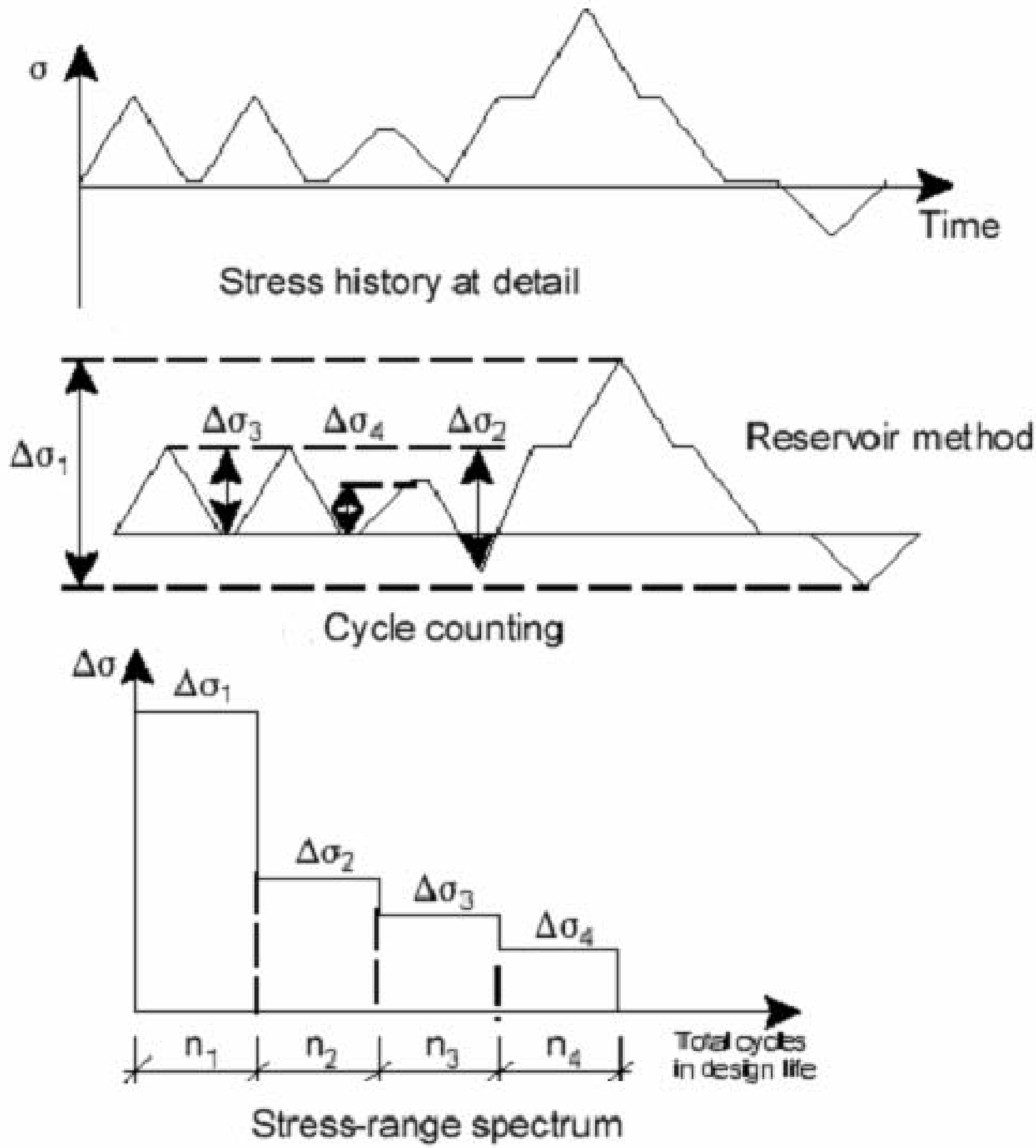

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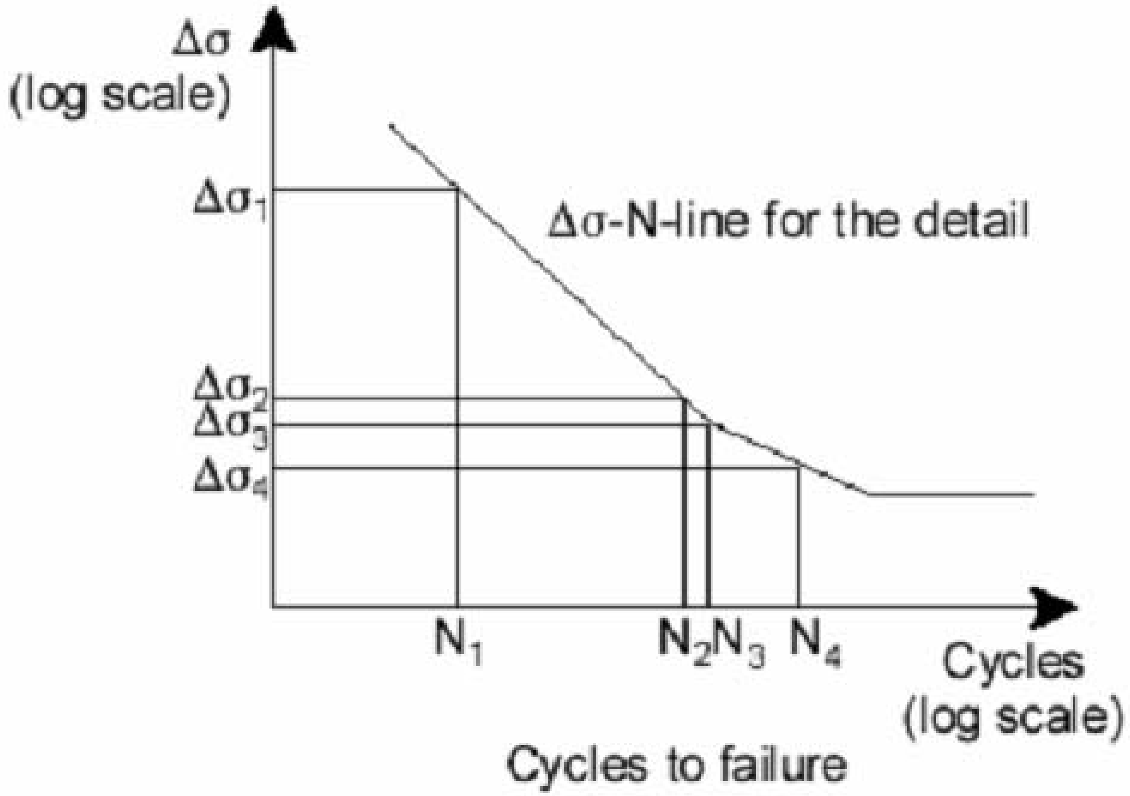
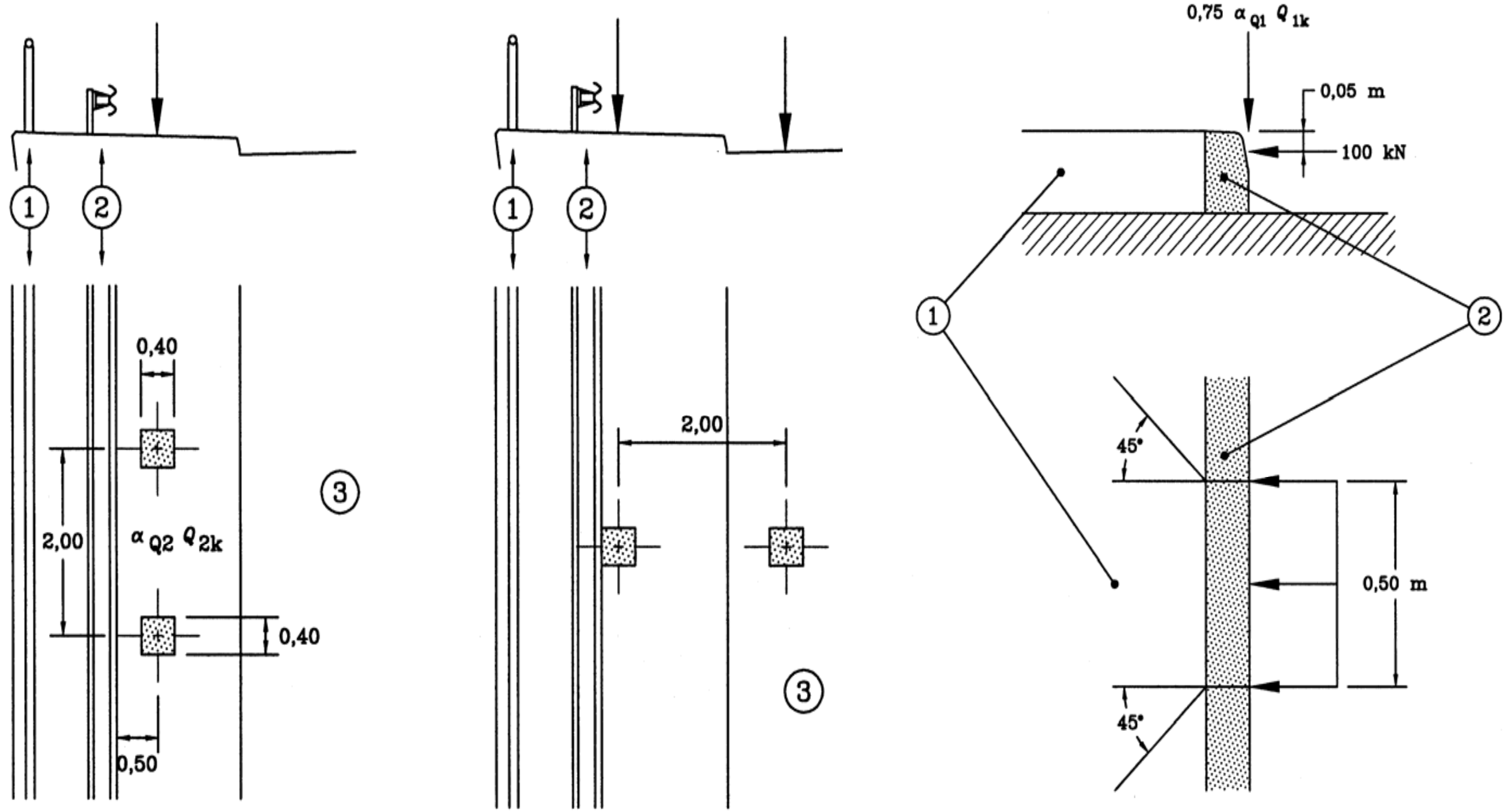


$$\sum \frac{n_i}{N_i} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \frac{n_4}{N_4} \leq D_L$$

Damage summation
(Palmgren-Miner rule)

ACTIONS FROM VEHICLES ON THE BRIDGE

- Vehicles on footways and cycle tracks
- Impact forces on kerbs
- Impact forces on safety barriers



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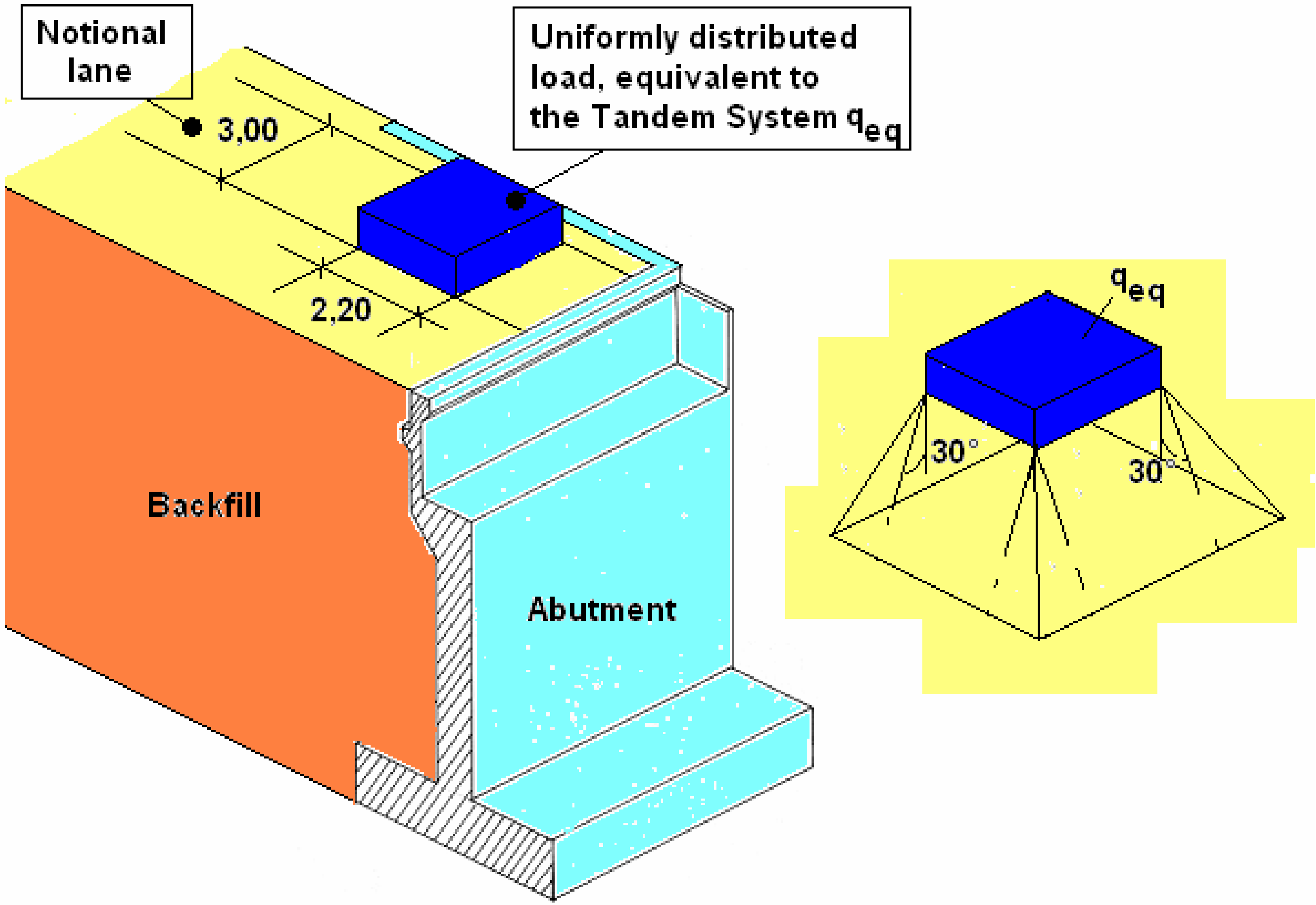
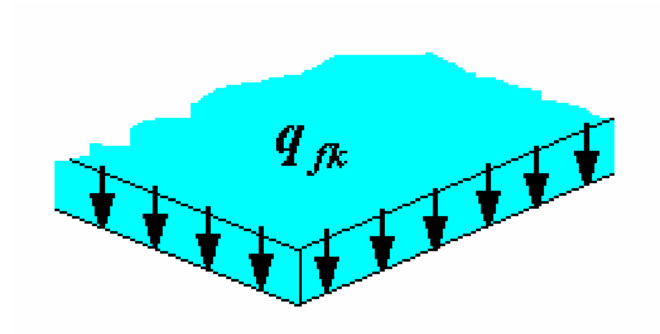


LOAD MODELS FOR FOOTWAYS AND FOOTBRIDGES (Section 5)

LOAD MODEL Nr.1

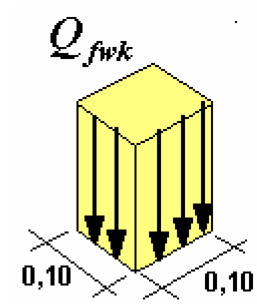
Uniformly distributed load q_{fk}



LOAD MODEL Nr.2

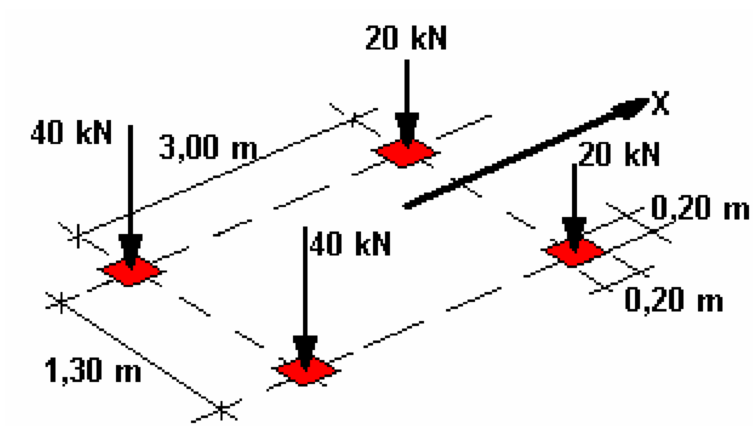
Concentrated load Q_{fwk}

(10 kN recommended)



LOAD MODEL Nr.3

Service vehicle Q_{serv}



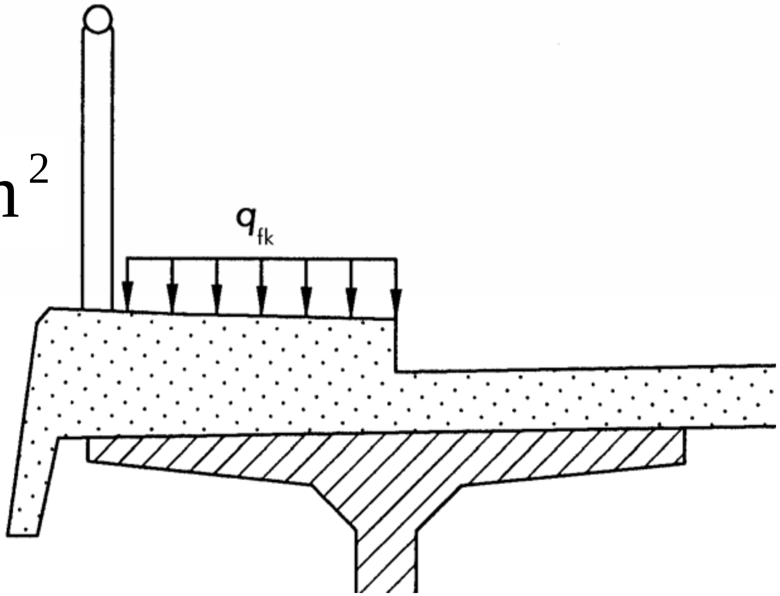
Recommended characteristic value for :
- **footways and cycle tracks on road bridges,**
- **short or medium span length footbridges :**

$$q_{fk} = 5{,}0 \ \text{kN/m}^2$$

Recommended expression for long span length footbridges :

$$q_{fk} = 2{,}0 + \frac{120}{L+30} \quad \text{kN/m}^2$$

$$q_{fk} \geq 2{,}5 \ \text{kN/m}^2 \qquad q_{fk} \leq 5{,}0 \ \text{kN/m}^2$$



***L* is the loaded length [m]**

For footbridges only, a horizontal force should be taken into account, to be applied along the deck axis at the surfacing level Q_{flk}.

Its characteristic value, which may be altered in the National Annex, is equal to the higher of the two following values :

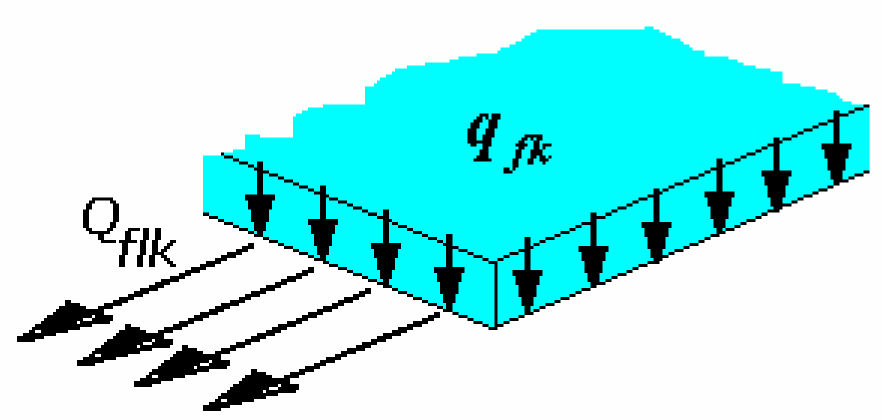
• 10% of the total uniformly distributed load as defined in 5.3.2.1,

• 60% of the total service vehicle load where relevant (5.3.2.3-(1)P).

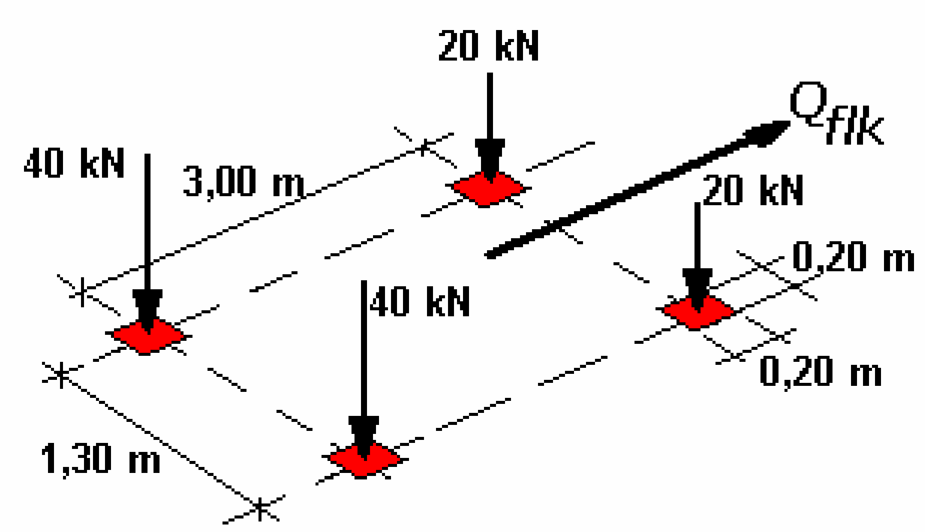
The horizontal force is applied simultaneously with the vertical load, but not with the concentrated load.

Groups of loads for footbridges

Group of loads gr1



Group of loads gr2



Thank you for your attention