Comparative Evaluation of Traffic Loads and Load Factors in the Design of Roadway Truss Bridges under International Standards

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Publication Date: 2025/09/17

Abstract: This study presents a comparative evaluation of traffic loads and load factors in the design of roadway bridges under three major international standards: AASHTO LRFD (2024), the Egyptian Code (2015), and Eurocode (EN 1991). The analysis highlights differences in lane width specifications, load model formulations, impact factor treatment, and fatigue assessment. AASHTO LRFD allows wider lanes (3.65 m) and employs independent impact factors, simplified fatigue models, and higher partial safety factors, emphasizing conservative yet straightforward design. The Egyptian Code adopts narrower lanes (3.0 m) with integrated impact effects and moderate safety factors, balancing serviceability and realism. Eurocode enforces stricter restrictions on loaded length and width, incorporates diverse load models including crowd and special vehicle loads and utilizes multiple fatigue models with moderate factors, providing high flexibility and accuracy. The study also compares tire contact areas, lane adjustment factors, and force application methods, revealing varying approaches to modeling braking and centrifugal forces. Overall, the findings illustrate the distinct philosophies of American, Egyptian, and European bridge design standards, offering insights for optimized and context-specific structural design.

Keywords: *Traffic Load Modeling, Load Combinations Factors, Lane Adjustment Factors, Fatigue Loads, Impact Factors, AASHTO LRFD, Egyptian Code, Eurocode.*

How to Cite: Mustafa K. Sadek; Nabil S. Mahmoud; Fikry A. Salem (2025) Comparative Evaluation of Traffic Loads and Load Factors in the Design of Roadway Truss Bridges under International Standards. *International Journal of Innovative Science and Research Technology,* 10(9)*,* 668-691. https://doi.org/10.38124/ijisrt/25sep468

I. INTRODUCTION

The ECP, or Egyptian Code of Practice[1] for Loads and Forces in Structural and Masonry Works (ECP-201:2012) [2] introduced major updates compared to the previous version ECP-201:2003. The addition of a new vehicle live load was one of the biggest modifications. (VLL) for roadway bridges, along with revised load factors and load combinations. These provisions were largely harmonized with the Eurocode EN 1991-2:2003 [3], resulting in closer alignment of Egyptian practice with European standards. Similar to the Eurocode, ECP-201:2012 is applicable to conventional bridges such as beam-slab, box, and truss bridges with spans up to 150 m, where small deflection theory is valid. Suspension and cable-stayed bridges, which require large-deflection theory, remain outside the scope of ECP-201:2012.

The American code AASHTO LRFD Bridge Design Specifications [4] provides a different design philosophy based on Load and Resistance Factor Design (LRFD). Unlike the Egyptian code, which only recently incorporated Eurocode-based VLL provisions, AASHTO has long adopted a system of load combinations that account for statistical variability of loads and resistances. The AASHTO live load model (HL-93) consists of a design truck or tandem combined with a uniform lane load and generally produces higher load effects compared to the former Egyptian ECP-201:2003, but comparable or slightly different values compared to ECP-201:2012 and Eurocode 1 (EN 1991-2:2003)[5].

Earlier comparative studies [6, 7]demonstrated that the live load internal forces calculated under ECP-201:2012 are nearly identical to those of EN 1991-2:2003, while generally exceeding those produced by the older ECP-201:2003. More recent investigations [8] extended the comparison to AASHTO LRFD, concluding that while the Eurocode and ECP-201:2012 share very similar basis for VLL and load combinations, the AASHTO HL-93 tends to be more conservative for longer spans and certain deck configurations[9]. However, differences depend strongly on girder spacing, cross-sectional stiffness, and span length[10].

Overall, ECP-201:2012 brought Egyptian practice closer to the Eurocode, while notable differences remain when

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

compared to AASHTO LRFD. These differences underline the importance of code-based calibration of live loads and combinations when evaluating the safety of existing bridges designed under earlier versions of ECP-201 or when adapting international design methodologies in local contexts.

II. THE AIM OF THIS STUDY

The aim of this study is to assess the main loads and their associated load factors in the design of pony truss girder roadway bridges according to three internationally recognized standards representing different continents: the Egyptian Code for Steel Bridges (ECP-207:2015), the Eurocode 3: Design of Steel Structures (EN 1993), and the AASHTO LRFD Bridge Design Specifications, 10th Edition. The study seeks to highlight the similarities and differences in the treatment of permanent loads among these codes, in order to establish a clearer understanding of their influence on the design process and to contribute towards achieving a more efficient and reliable structural design framework.

III. DESCRIPTION OF MODELS

Table1 summarizes the governing specifications, design method-ology, and key structural properties adopted for the investigated pony truss girder roadway bridge. The table presents the general layout, deck and girder properties, dead load weights, and live loading requirements according to the Egyptian Code (ECP 207:2015), Eurocode (EN 1993), and AASHTO LRFD Specific-ations (10th Edition, 2024). This overview provides the basis for the comparative assessment of design provisions among the three international standards. Fig.1 shows the dimensions of models.

Table 1 Assumption Used for the Suggested Model Shown Above.

Governing Specifications	- EGYPTION CODE FOR PLANNING, DESIGN & CONSTRUCTION OF BRIDGES AND ELEVATED INTERSECTIONS, No. 207 (2015) - EN 1993-2:2006: Eurocode 3: Design of Steel Structures - Part 2: Steel Bridges - AASHTO LRFD Bridge Design Specifications, 10th Edition (2024)
Design Methodology	- Load and Resistance Factor Design (LRFD)
General Layout	- Simple Roadway Through Bridge - Bridge Span = 61.0 m - Clear Roadway Width = 12.25 m
Deck Properties	- Deck Width = 16.75 m - Deck Thickness = 20 cm - Shoulder Width = 65.0 cm - Haunch Thickness = 5.0 cm - M.G. Side Clearance Width = 50.0 cm - Wearing Surface Thickness = 9.0 cm - Reinforcement Strength = 420 MPa - Concrete Strength = 35 MPa - Deck Reinforcement = MESH 6 Ø 18 /m (Top and Bottom) - Sidewalk Width = 1.75 m - Sidewalk Slab Thickness = 10 cm - Sidewalk Wearing Surface Thickness = 5.0 cm - Post Height = 1.20 m - Post Spacing = 5.0 m
Girder Properties	- Used Steel Grade 52 - Main Girder (Truss - Warren System) - Stringer Spacing = 1.75 m - Truss Girder Height = 6.10 m - Cross Girder Spacing = 5.0 m (Full Torsional Restraint) - Lower Bracing (K-System) - Vertical Bracing (U-Frame)
Dead Load Weights	- Stay-in-place Deck Form = 0.75 kN/m^2 - Wearing Surface = 1.55 kN/m^2
Live Loading Requirments	- Vehicular Live Load According to Egyptian Code No. 207 (2015) - Vehicular Live Load According to EUROCODE (EN 1991) - Vehicular Live Load (HL-93) According to AASHTO LRFD (2024)

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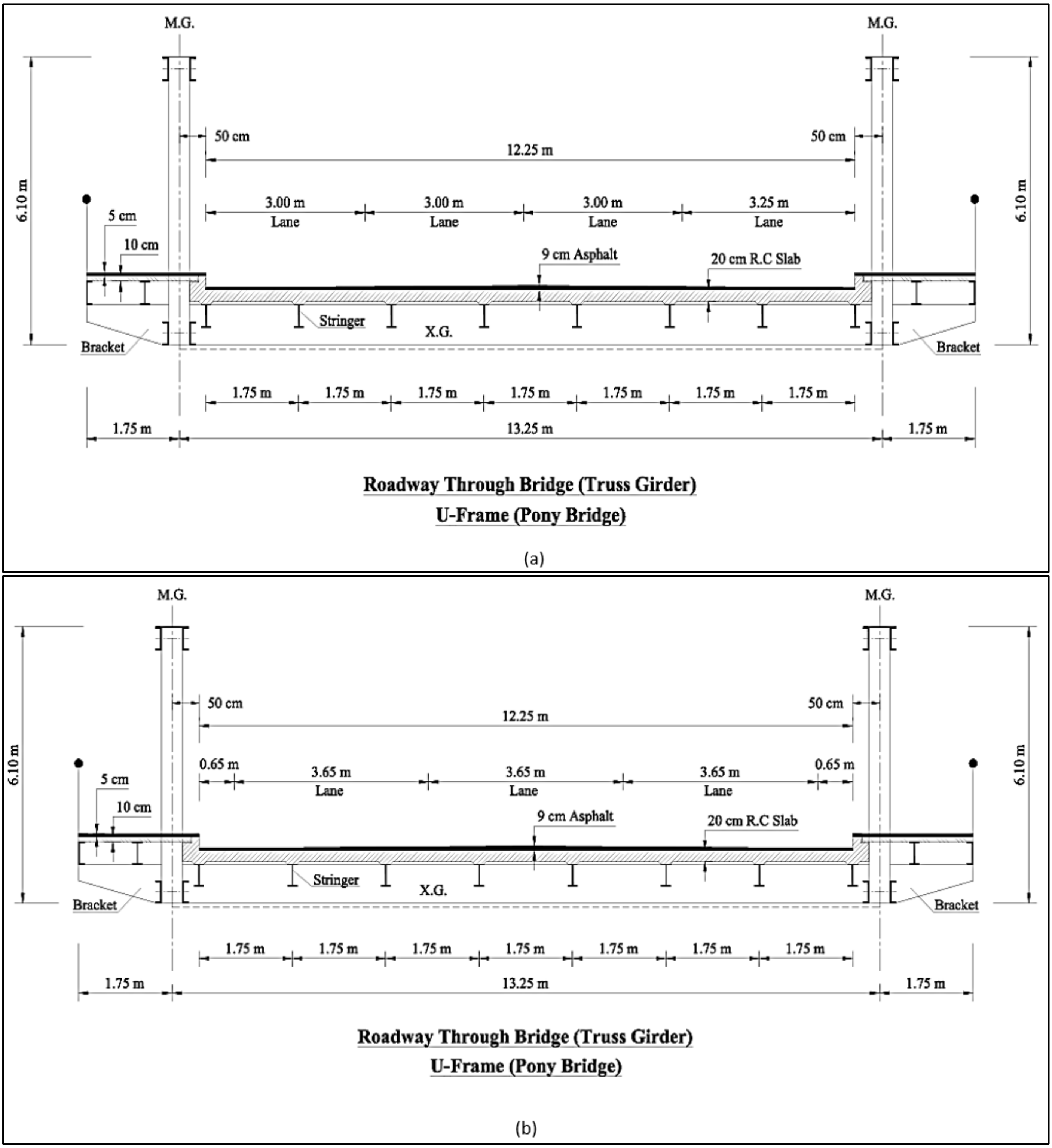

Fig 1 Show Dimensions of Models (a) Egyptian and Eurocode Specifications (b) AASHTO LRFD Specifications.

IV. LOADS ON ROADWAY BRIDGE

There are three types of loads found in roadway bridge superstructures: lateral, where the load axis is perpendicular to the longitudinal axis, longitudinal, where the load axis is parallel to the direction of traffic, and vertical, where the load axis is parallel to the direction of gravity. Gravity loads, which comprise dead, live, and impact loads, are the main loads to take into account when designing a roadway bridge. Because road live loads are applied restively quickly, the influence of live loads (dynamic effect) is included. However, when designing a roadway bridge, longitudinal and lateral forces should also be carefully considered.

There are two types of loads: transitory and permanent. The specifications' probabilistic character necessitates this classification. Loads may be greater than or less than the nominal value due to uncertainty. Lower values may be

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significant in the case of transient loads, but they have no bearing because permanent loads will always be there if the transient load is not placed on the structure at all. Both minimum and maximum load factors are stated for permanent loads.

This study emphasizes the two main loads—permanent loads and live loads—that are applied to roadway bridges., including traffic and pedestrian loads, and centrifugal forces, in addition to some secondary loads associated with traffic loads such as braking forces, as specified in the Egyptian, AASHTO and European specifications.

A. Permanent Loads

Dead loads and ground pressures are examples of permanent loads, which are loads that are constantly present in or on the structure and do not vary in size over the course of the bridge's life. Dead loads will be split into the following two categories:

➢ *Dead Load (DL, DC or G_1)*

Dead load is represented by its characteristic value DL, DC or G as defined in Egyptian, AASHTO and European specifications respectively, which is an own weight of all bridge components of superstructure and substructure, both structural or non-structural elements such as deck, girders, sidewalks, barriers, piers, abutments and foundation.

➢ *Superimposed Dead Load (SDL, DW or Gr)*

Superimposed dead load is represented by its characteristic value SDL, DW (Dead load of wearing surfaces) or G_1, as defined in Egyptian, AASHTO and European specifications respectively, which includes non-structural elements such as wearing surface on bridge deck, utilities, finishes and other appurtenances. The girder needs to be built to withstand the effects of dead load. Some dead loads are applied to the non-composite portion (just the structural steel framing) as part of the dead load components. Others are used in conjunction with the steel girders and are applied after the deck has solidified. Furthermore, the DC load factor is used to factor some dead loads, whereas the DW load factor is used to factor other dead loads. The different dead load elements that need to be incorporated into the steel girder design are compiled in Table 2 below.

Table 2 Dead Load Components.

	The Sort of Load Factor	
	DC	**DW**
Non-composite section	• Structural steel • Stay-in-place deck forms • A concrete porch and deck • Other dead load, such as that from stiffeners, cross frames, etc.	• Utilities and other appurtenances (sometimes)
Composite section	• Barriers (Parapets) • Sidewalks	• The surface for future wear • Utilities and other appurtenances (often)

By evaluating the provided materials' weights and volumes, permanent loads can be computed. Table 3 shows the unit weights for common material used in steel roadway bridges, as specified in the Egyptian, AASHTO and European specifications. This implies that it should be feasible to compute permanent loads with a reasonable level of accuracy in theory. The design of permanent loads, however, often far surpasses what is actually experienced in practice since structural engineers are sometimes conservative in their forecasts, allowing for a margin of error, avoiding probable deflections, and taking time changes into account.

Table 3 Unit Weights for Common Material Used in Superstructures of Steel Roadway Bridges as Mentioned in the Egyptian, AASHTO and European Specifications

Material	**Unit weights (kN/m²)**		
	ECP	**AASHTO**	**EUROCODE**
Steel	78.5	77.0	78.5
Reinforced Concrete	25.0	23.5	25.0
Plain Concrete	22.0	21.2	24.0
Bituminous Wearing Surfaces	23.0 to 24.0	22.0	24.0 to 25.0

B. Transient Loads - Live Loads

➢ *Live Loads Specified in ECP-LRFD*

• *Vertical Loads – Traffic and Pedestrian Loads*

The carriageway width, *w*, is the clear inner distance between kerbs or between barriers of the roadway. The notional lane width shall be taken as 3.0 m, and the number of design lanes shall be calculated as shown in Equation 1.

Number of design lanes = Carriageway width (w) / notional lane width (3.0 m) (1)

A center reservation physically divides the roadway on a bridge deck into two sections. As seen in Fig. 2 (a), if the sections are separated by a permanent road restraint system, each section—including all hard shoulders—must be divided into notional lanes independently. If a temporary road restraint system is used to split the carriageway, including the center reserve, as illustrated in Fig. 2(b), the entire carriageway will be divided into notional lanes.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

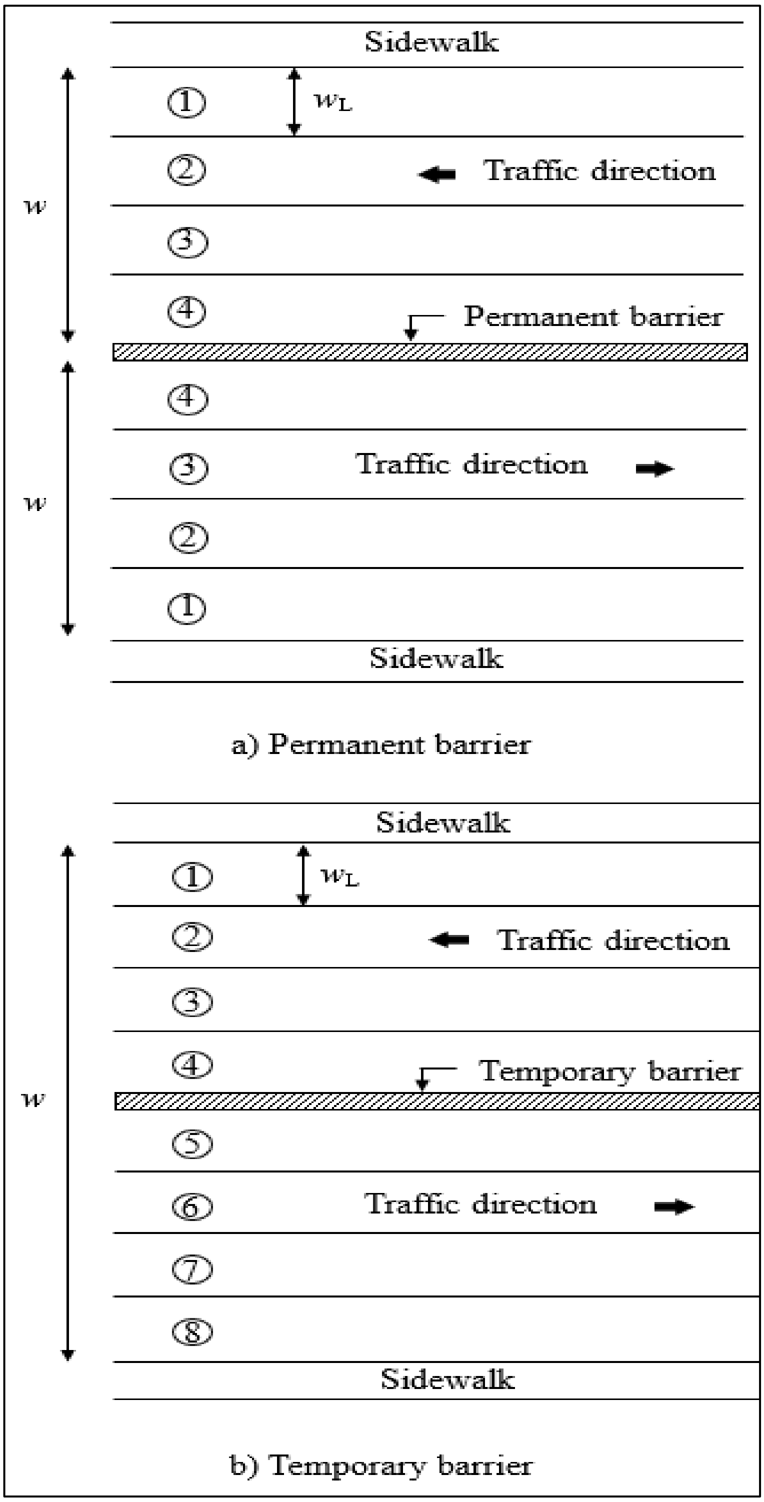

Fig 2 Numbering of the Lanes for Roadway Bridge.

✓ *Adjustment Factors of Live Load*

The adjustment factors of live load shall only be applied to Load Model 1, specifically lane 1 as specified in ECP-LRFD, these are not taken into account when figuring out the tiredness limit condition. The adjustment factors' recommended values are displayed in the following Table 4.

Table 4 Suggested Values Of Adjustment factors as Specified in ECP-LRFD.

Adjustment Factor, αi	First-Class International Travel for Large Vehicles	Second Class Regular Traffic with Large Vehicles	Third Class: Moderately High Traffic
α_1 (VEH1)	1.0	0.90	0.80
α_2 (UDL1)	1.0	0.90	0.80

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

✓ *Models of Traffic Loading*

Three models are used in ECP-LRFD to depict traffic loading on bridge highways. Each model includes either lane loads or a combination of vehicle loads. The bigger of the subsequent three models will be considered the extreme load effect.

- *Load Model 1 (LM1)* - *Concentrated and Distributed Loads (Main Model)*

Fig. 3 shows Load Model 1 and Table 5. shows its characteristic values as specified in ECP-LRFD.

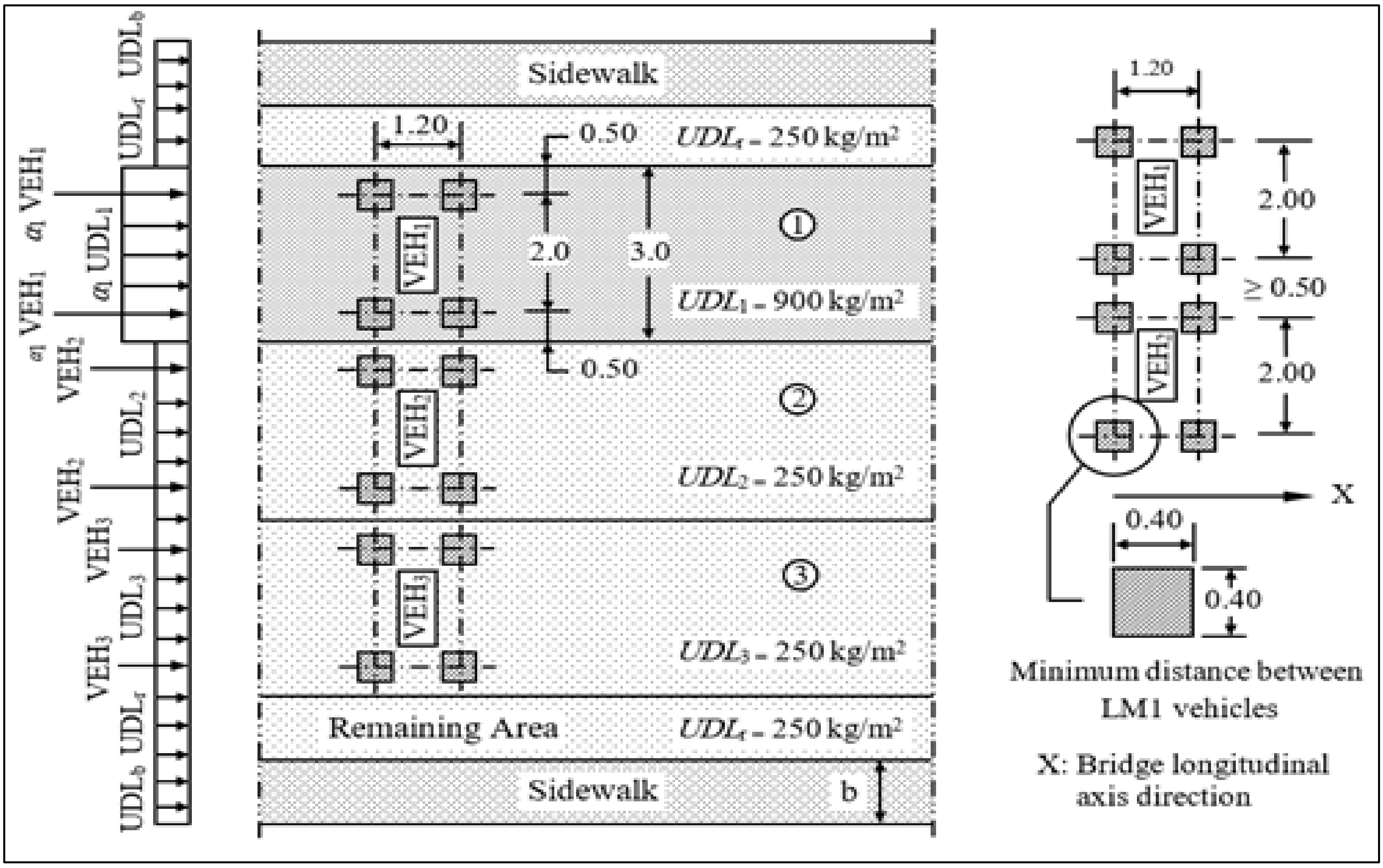

Fig 3 Details of the Load Model 1 (LM1) in ECP-LRFD.

Table 5 Characteristic Values of Load Model 1 (LM1) as Specified in ECP-LRFD.

Location		Vehicle Weight VEH_i (ton)	Wheel Load (ton)	Uniform Distributed Load UDL_i (kg/m²)
Lane Number 1		$(VEH_1) = 60$	15	$(UDL_1) = 900$
Lane Number 2		$(VEH_2) = 40$	10	$(UDL_2) = 250$
Lane Number 3		$(VEH_3) = 20$	5	$(UDL_3) = 250$
Other lanes		0	0	$(UDL_i) = 250$
Remaining areas		0	0	$(UDL_r) = 250$
Sidewalk	b < 1.5 m	0	0	$(UDL_b) = 250$
	b ≥ 1.5 m			$(UDL_b) = 500$

Where:

- International heavy vehicle traffic is classified as first class, regular heavy vehicle traffic is classified as second class, and light heavy vehicle traffic is classified as third class.
- The dynamic amplification of the VEH and UNI characteristic values included.
- For each hypothetical lane, there should only be one tandem system taken into consideration. The only tandem systems that should be considered are complete ones.
- To assess the total effects, it is necessary to suppose that each tandem system travels centrally along the axes of the imaginary lanes.
- The loads on lane 1 only are reduced by (α_1), according to the class of the road.
- • Each wheel's contact surface should be regarded as square and having a side of 0.40 meters.
- Only the unfavorable areas of the influence surface should be subjected to concentrated loads and uniformly dispersed loads.
- When designing concrete slabs for bridges, the minimum distance between the wheel axles for any two vehicles in two adjacent notional lanes is taken 0.5 m. Otherwise, the distance shall not be less than 1.0 m.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

- It is not necessary that the three vehicles of load model 1 be adjacent or in the same cross section of the bridge, as long as it achieves the maximum or minimum stress of the structural element required to be studied**.**

- *Load Model 2 (LM2) - Single Axle Load*

Fig. 4 shows Load Model 2 and Table 6. shows its characteristic values as specified in ECP-LRFD.

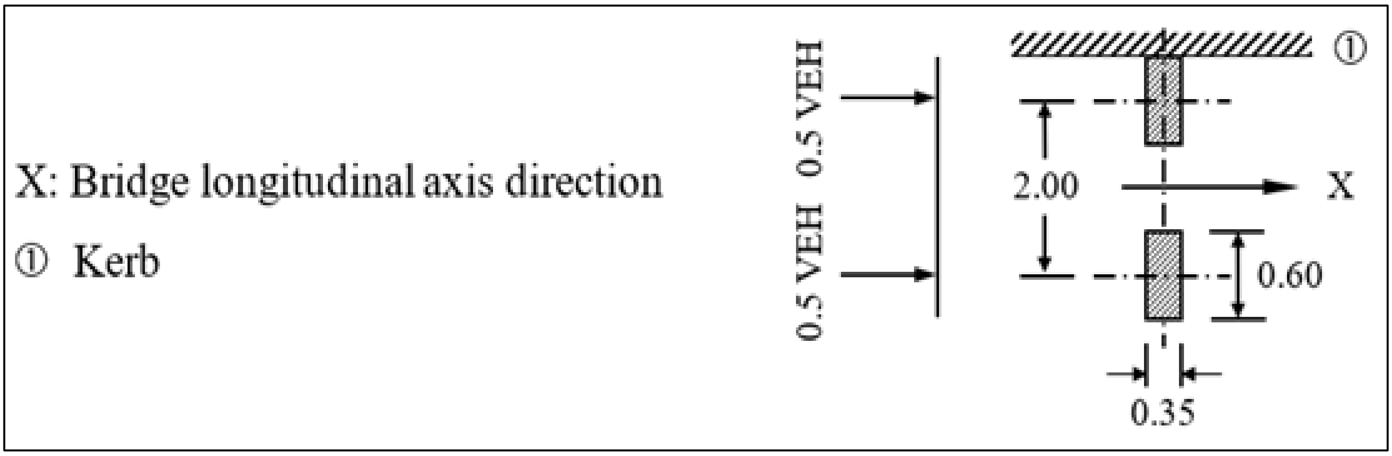

Fig. 4 Load Model 2 (LM2) specified in ECP-LRFD.

Table 6 Characteristic Values of Load Model 2 (LM2) as Specified in ECP-LRFD

Location	Vehicle weight VEH (ton)	Wheel load (ton)	Uniform distributed load UDL (kg/m^2)
Lane Number 1	40	20	0

Where:

- Q's characteristic values, including dynamic amplification.
- The contact surface of each wheel should be viewed as a rectangle with sides of 0.35 and 0.60 meters.
- An additional dynamic amplification factor (I) should be added to all loads in the region of expansion joints, as indicated by Equation 2.

$$I = 0.30\ (1- (D/6)); \qquad (2)$$

I: An extra factor of amplification

D: The separation between the expansion joint and the cross section (m), where D ≤ 6 m.

- When designing expansion joints (D= 0), additional amplification factor (I = 30%).
- Bridge slabs are designed using this concept. In designing slabs, the unfavorable effect of (LM1 and LM2) should be considered especially, in steel bridges with orthotropic decks.

✓ *Load Model 3 (LM3) - Crowd Loading*

Fig. 5 shows Load Model 3 and Table 7. shows its characteristic values as specified in ECP-LRFD.

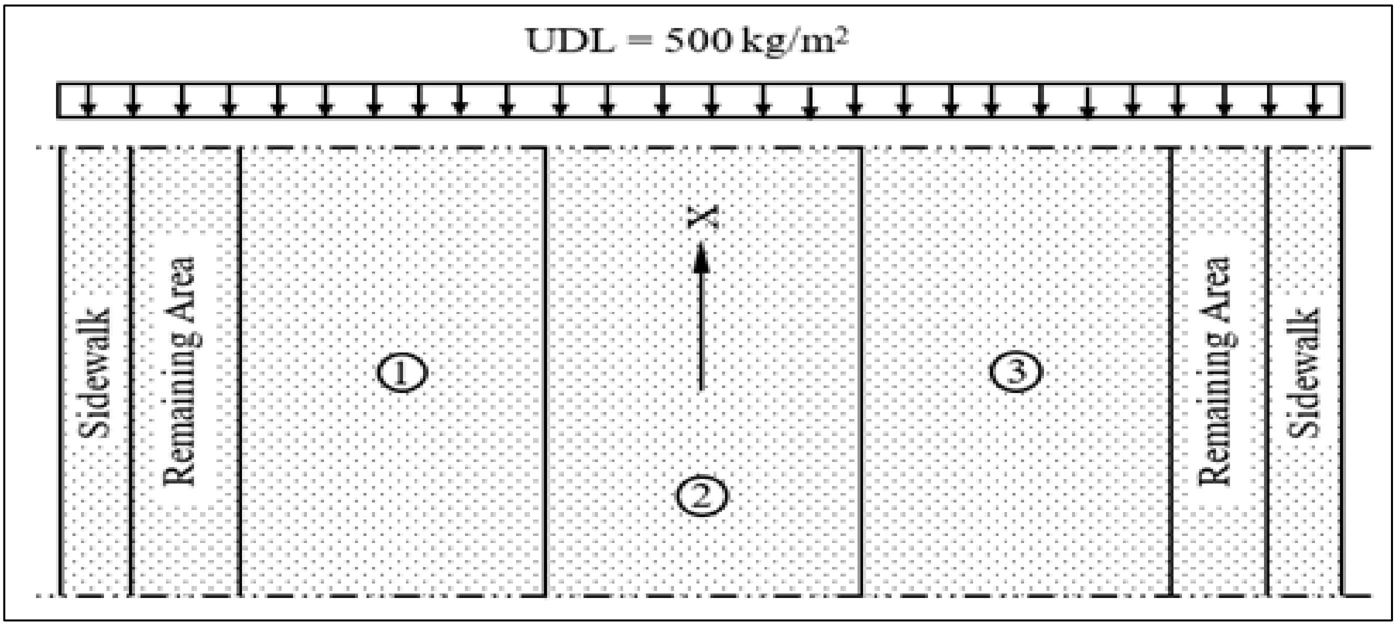

Fig 5 Load Model 3 (LM3) Specified in ECP-LRFD.

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Table 7 Properties of the Load Model 3 (LM3) as Specified in ECP-LRFD

Location	Vehicle weight (ton)	Wheel load (ton)	Uniform distributed load UDL (kg/m²)
All Lanes	—	—	500

A load model that incorporates dynamic amplification and has an evenly distributed load of 5 kN/m² should be used to reflect crowd loading, if applicable. The center reservation should be incorporated when appropriate, and load model 3 should be applied to the pertinent sections of the road bridge deck's length and width.

✓ *Fatigue Load Model – Single Vehicle Model*

Four axles, each with two identical wheels, make up this type. Each axle weighs 120 kN, and each wheel's contact surface is square in side 0.40 m as shown in Fig. 6 and Table 8. shows its characteristic values as specified in ECP-LRFD.

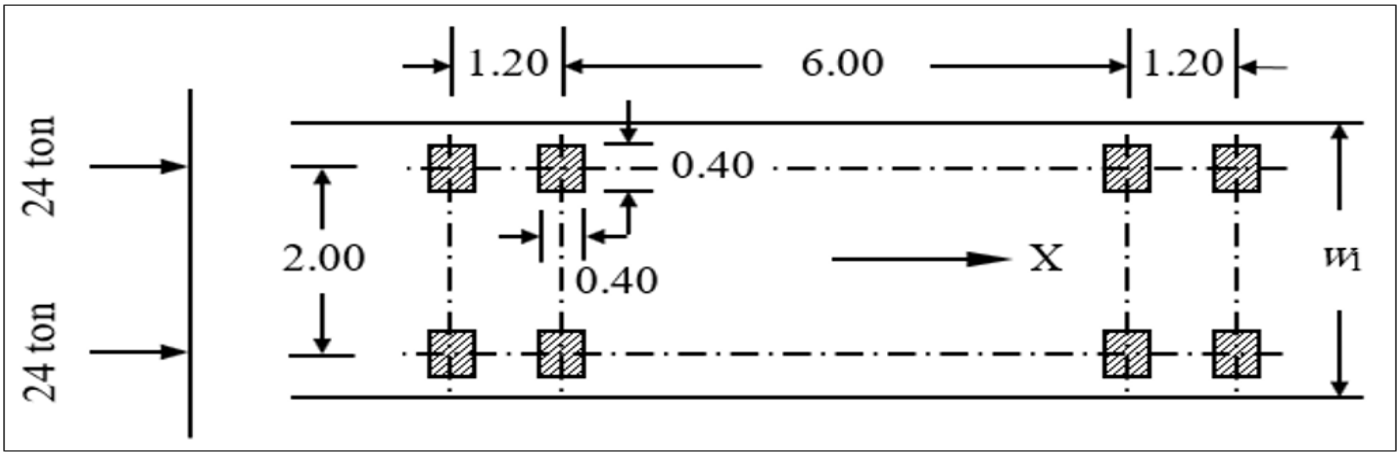

Fig 6 Fatigue Load Model - Single Vehicle Model.

Table 8 Characteristic Values of Fatigue Load Model as Specified in ECP-LRFD

Location	Vehicle Weight (ton)	Wheel Load (ton)	Axles Distances (m)
Any Lane	48	6	1.20/6.0/1.20

Two cars in the same lane should be considered when appropriate. The second vehicle has the above-described geometry, each axle weighs 36 kN (rather than 120 kN), and the distance between the two cars, measured from center to center, is at least 40 m.

✓ *Pedestrian Loads*

For sidewalks that are more than 1.5 meters wide, a pedestrian load of 500 kg/m² must be applied; for sidewalks that are less than 1.5 meters wide, the load must be 250 kg/m². In the vehicle lane, the pedestrian load and the vehicle design live load are taken into account at the same time.

- *Horizontal Forces - Characteristic Values*

✓ *Braking Forces (Q_L)*

Equation 3 is used to calculate the braking force, Q_L, which is defined as a longitudinal force operating at the carriageway's surface level.

$$Q_L = 360 + 2.7\,L\ (kN);\ Q_L \leq 900\ kN \quad (3)$$

Where (L) is loaded length of the bridge (m)

Braking forces are projected along the axis of any notional loading lane and distributed uniformly along the loaded length of axle. Expansion joints are designed to transmit horizontal Braking force equal to 180 kN divided into two forces, the distance between them 2 m. A transverse braking force (due to inclined braking or sliding), equal to 25% of the longitudinal braking, in a direction perpendicular to the direction of longitudinal braking.

✓ *Centrifugal Forces (Q_t)*

A centrifugal force, Q_t, is defined as a transverse force operating radially to the carriageway's axis and at the level of the completed highway. Table 8. shows its characteristic values as specified in ECP-LRFD.

Table 8 Characteristic Values of Centrifugal Forces as Specified in ECP-LRFD.

Centrifugal force, Q_t (kN)	Horizontal radius (m)
$Q_t = 0.2\,Q_v$	If $r < 200$
$Q_t = 40\,Q_v / r$	If $200 \leq r \leq 1500$
$Q_t = 0$	If $r > 1500$

Where (Q_v) is the total maximum weight of the vertically concentrated loads of LM1 vehicles and (r) is the horizontal radius of the carriageway centerline (m). Together with Q_t's characteristic value, which incorporates dynamic effects.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

➢ *Live Loads Specified in AASHTO*

- *Vertical Loads – Traffic and Pedestrian Loads*

The unobstructed road space between curbs, barriers, or both is known as the carriageway width, or w. The typical lane width will be assumed to be 3.65 m (12.0 ft) unless otherwise specified, and the number of design lanes shall be calculated as shown in Equation 4.

Number of design lanes = Carriageway width (w) / standard lane width (3.65 m) (4)

Future modifications to the bridge's functional or physical clear highway width should be taken into account. When the width of the traffic lanes is less than 12.0 feet, the number of design lanes must correlate with the number of traffic lanes. The width of the design lane must be the same as the width of the traffic lane. Two design lanes, each equal to half the roadway width, are required for roads between 20.0 and 24.0 feet in width.

✓ *Multiple Presence of Live Load*

Notwithstanding the number of design lanes, the multiple presence factors of live load must be applied to all loading scenarios as outlined by AASHTO; however, they are not taken into account when determining the fatigue limit condition for which a single design truck is utilized. The recommended values of multiple presence factors are shown in the following Table 9.

Table 9 Recommended Values of Multiple Presence Factors as Specified in AASHTO.

Number of Loaded Lanes	Multiple Presence Factor, m
One lane	1.20
Two lanes	1.00
Three lanes	0.85
More than three lanes	0.65

When loading conditions include pedestrian loads in addition to when determining the number of lanes, pedestrian loads may be treated as one loaded lane, even while there are one or more lanes with a vehicle live load. Pedestrian loads are exempt from the single lane multiple presence factor of 1.20. m = 0.85 when there are two lanes with live vehicle loads and pedestrian loads.

✓ *Models of Traffic Loading*

Three different situations that combine the design truck or design tandem with the design lane load, depicting vehicular loads on bridge or incidental structure highways (marked HL-93) in AASHTO. Unless otherwise noted, the bigger of the following three scenarios will be considered the extreme load effect.

▪ *Case I – Design Truck Combined with Design Lane Load*

Fig. 7 shows Case I – Design lane load in conjunction with a design truck and Table 10 shows its characteristic values on a multi-lane bridge as specified in AASHTO.

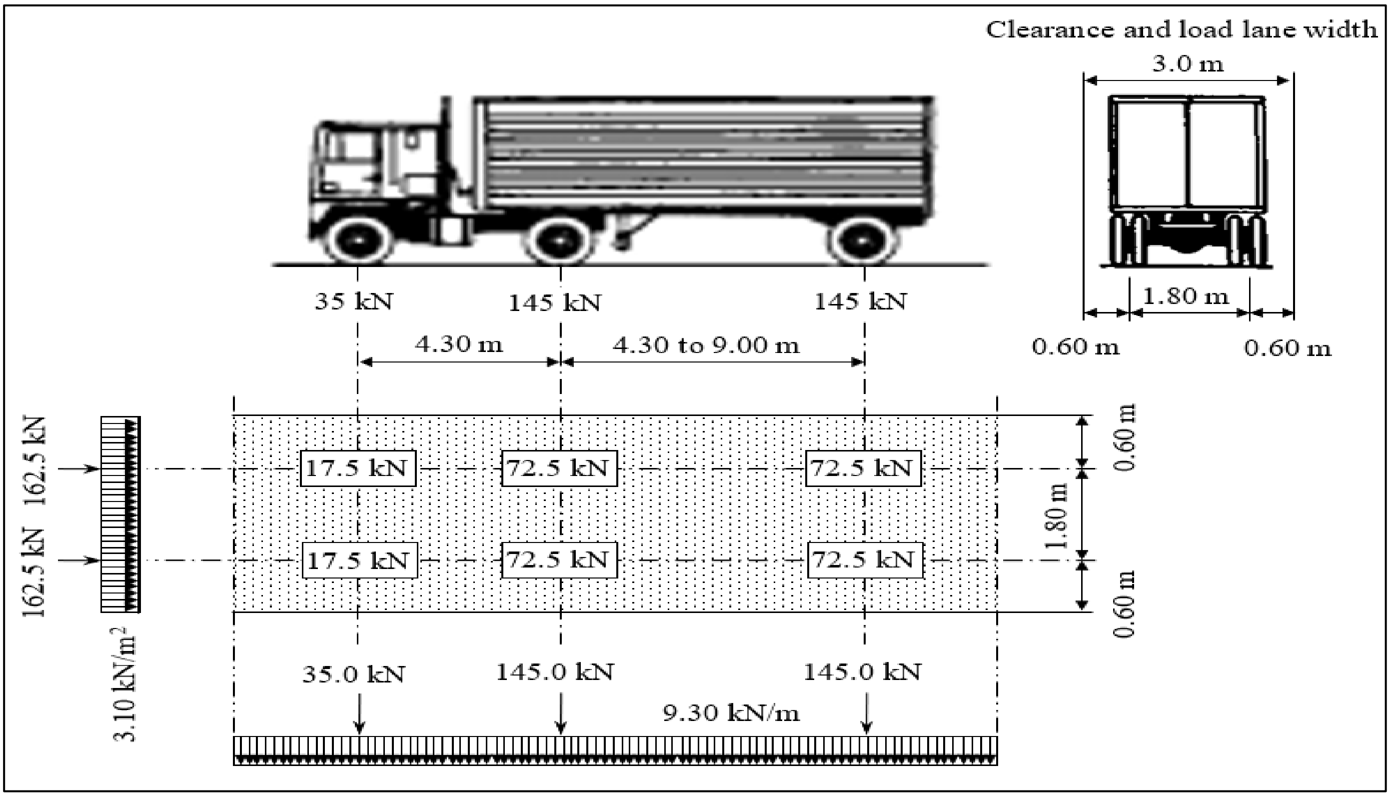

Fig 7 Case I – (Design Lane Load in Conjunction with a Design Truck)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

Table 10 Characteristic Values of Case I on a Multi-Lane Bridge According to AASHTO

Location	Truck weight (kN)	Axle load (kN)	Uniform distributed load (kN/m^2)
Lane Number 1	325	35/145/145	3.10
Lane Number 2	325	35/145/145	3.10
Lane Number 3	325	35/145/145	3.10
Other lanes	325	35/145/145	3.10
Remaining areas	0	0	3.60
Sidewalk	0	0	3.60

- *Case II – Design Tandem Combined With Design Lane Load*

Fig. 8 shows Case II – Design tandem combined with design lane load and Table 11. shows its characteristic values on a multi-lane bridge as specified in AASHTO.

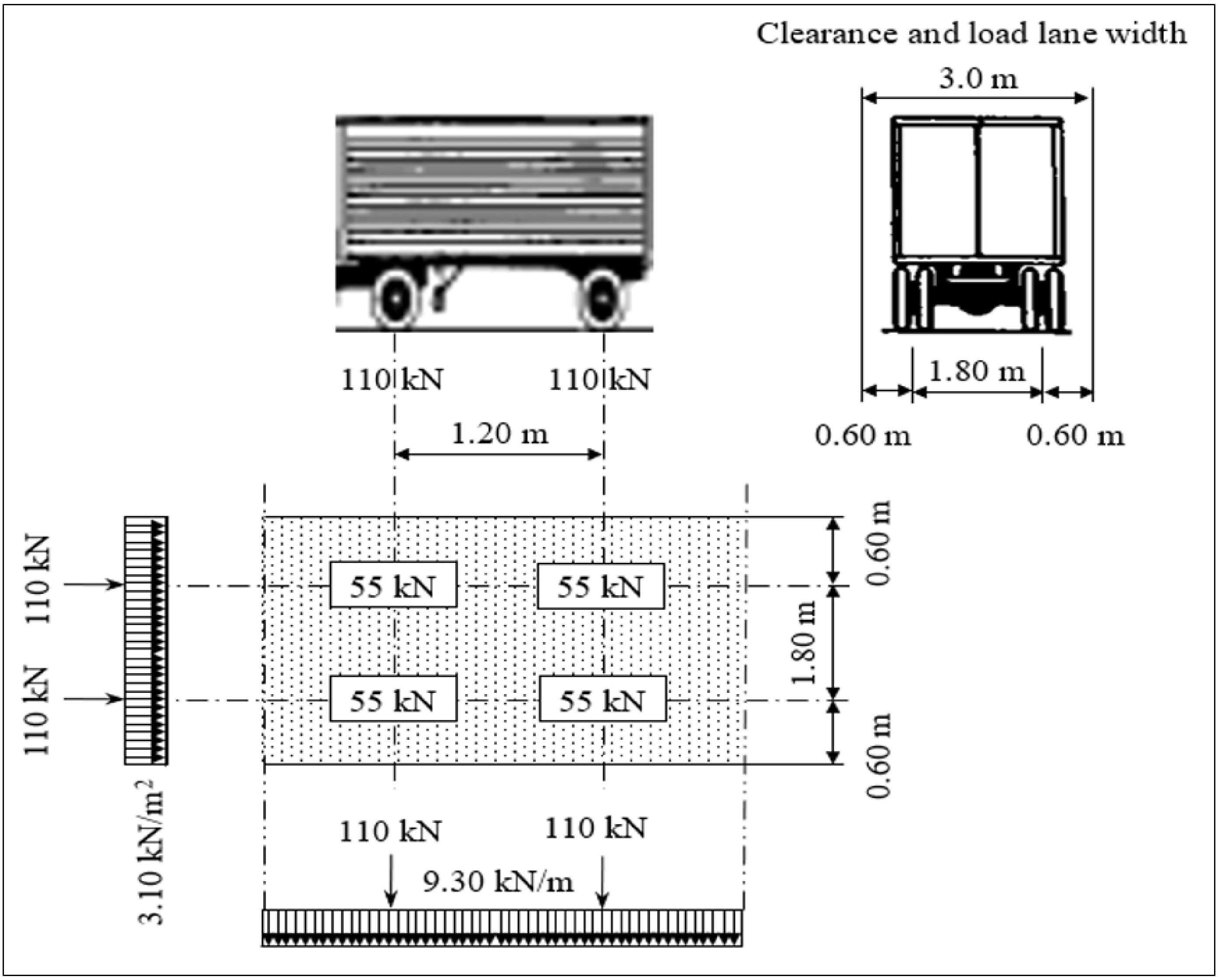

Fig 8 Case II – (Design Tandem Combined with Design Lane Load)

Table 11 Characteristic Values of Case II on a Multi-Lane Bridge According to AASHTO.

Location	Tandem weight (kN)	Axle load (kN)	Uniform distributed load (kN/m^2)
Lane Number 1	220	110/110	3.10
Lane Number 2	220	110/110	3.10
Lane Number 3	220	110/110	3.10
Other lanes	220	110/110	3.10
Remaining areas	0	0	3.60
Sidewalk	0	0	3.60

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

- *Case III – Two Design Truck Combined With Design Lane Load*

90 percent of the impact of the design lane load and two design trucks placed at least 15.0 meters (50.0 feet) apart between the lead axle of one vehicle and the rear axle of the other truck, as shown in Fig. 9, are necessary to provide a negative moment between contraflexure points under a constant load on all spans and to react exclusively at the interior piers.

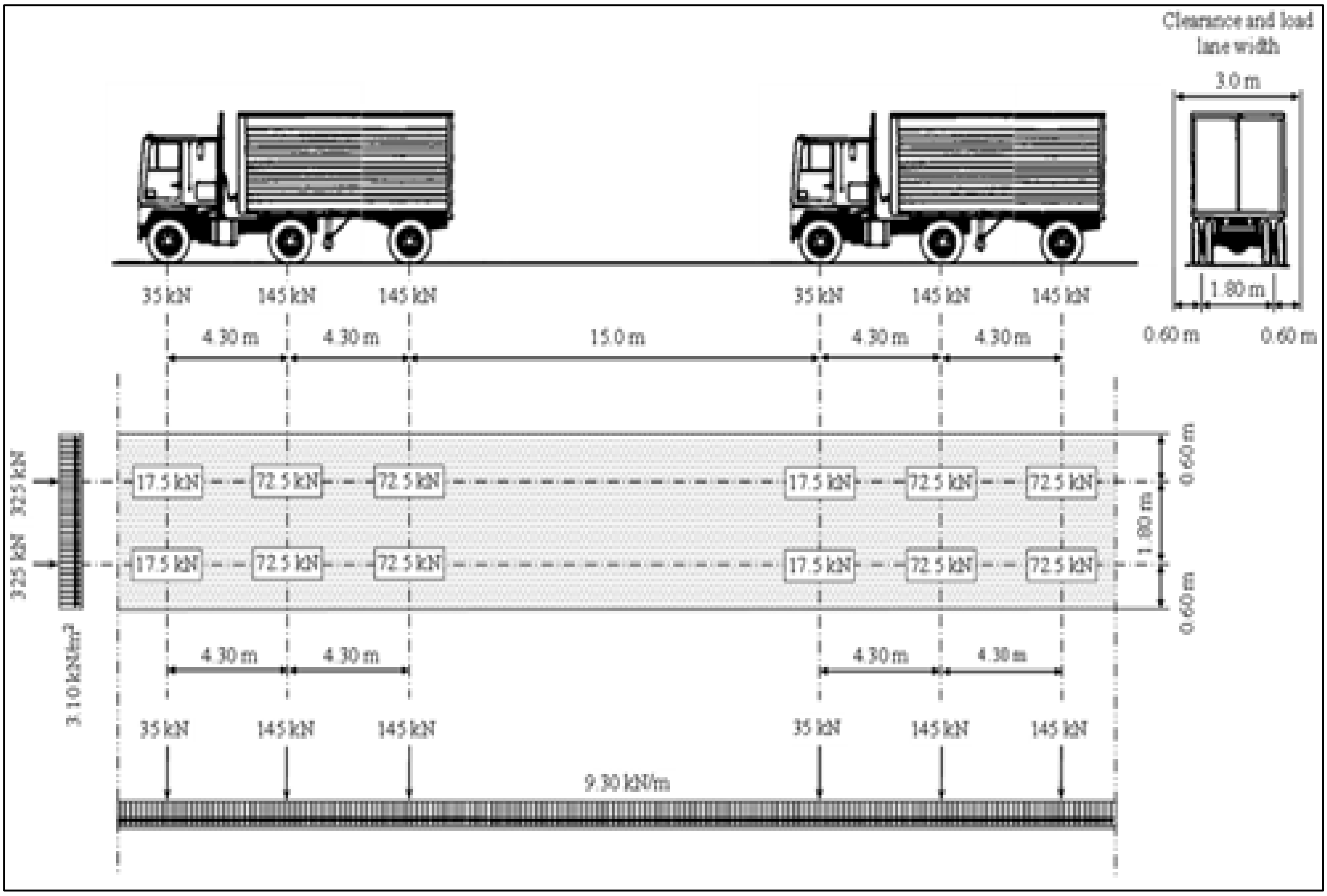

Fig 9 Case III – Two Design Truck Combined with Design Lane Load

- *Fatigue Load Model*

As stated in Case I, the fatigue load must be one design truck or axles, but the 145.0 kN (32.0-kip) axles must be spaced 9.0 m (30.0 ft) apart. The fatigue load (IM = 15%) will be subject to the dynamic load allowance. Orthotropic decks and their wearing surfaces must be designed using the loading pattern depicted in Fig. 10. To produce the greatest stress or deflection, as appropriate, this pressure should be placed on the bridge deck both longitudinally and transversely, ignoring the striped lanes. Table 12 shows its characteristic values as specified in AASHTO.

Table 12 Characteristic Values of Fatigue Load as Specified in AASHTO.

Location	Truck weight (kN)	Axle loads (kN)	Axles distances (m)
Any Lane	325	35/145/145	4.30/9.0

International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165
https://doi.org/10.38124/ijisrt/25sep468

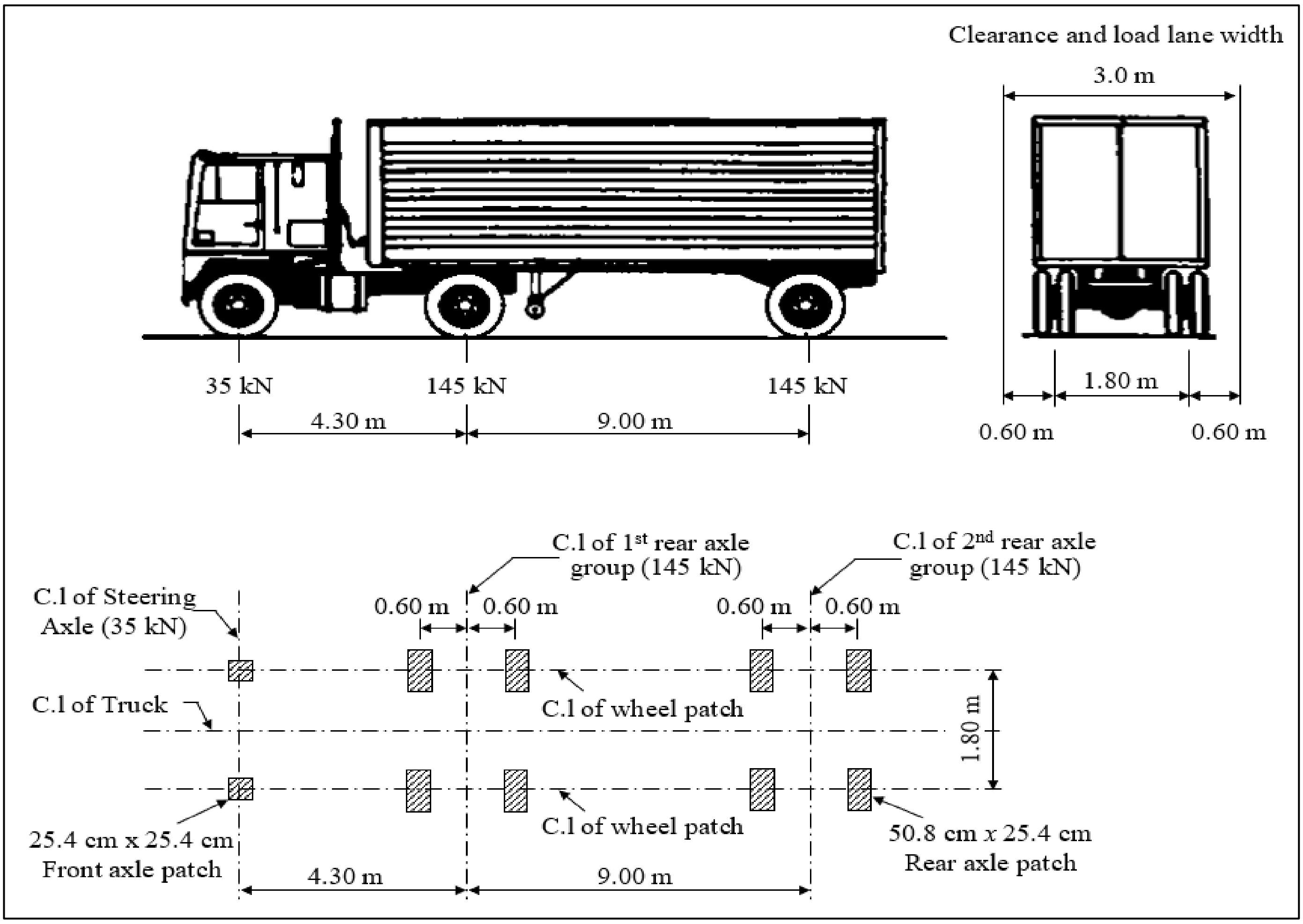

Fig 10 Refined Design Truck Footprint for Fatigue Design of Orthotropic Decks.

It is necessary to include the percentage in Table 13 in the static impacts of the design truck or tandem. It is prohibited to apply the dynamic load allowance to pedestrian loads, centrifugal and braking forces, and the design lane load. The static load's factor should be calculated as follows: (1+IM/100).

Table 13 Dynamic Load Allowance (IM) as Specified in AASHTO

Component	**Dynamic load allowance (IM)**
Deck Joints – All Limit States	75%
All Other Components:	
• Fatigue and Fracture Limit State	15%
• All Other Limit State	33%

✓ *Pedestrian Loads*

All sidewalks wider than 60 cm (2.0 ft) must have a pedestrian load of 3.60 kN/m^2, which must be taken into account concurrently with the vehicle design live load in the vehicle lane. Bridges intended solely for bicycle and/or pedestrian traffic must be built to support a live load of 4.10 kN/m^2. Vehicle live loads must be applied 30 cm (1.0 ft) from the deck edge for the overhang design and 60 cm (2.0 ft) from the deck edge for the design of all other bridge components if the sidewalk is ever removed.

- *Horizontal Forces – Braking and Centrifugal Forces*

✓ *Braking Forces (BR)*

It is expected that the braking force, BR, will act horizontally in all loaded design lanes at a distance of 6.0 feet (1.80 meters) above the roadway surface in a longitudinal orientation. Equations 5 and 6 will be used to get the braking force.

- Twenty-five percent of the design truck or design tandem's axle weights.

$$\mathbf{BR_1} = 25\% \; x \text{ Design truck or tandem } x \text{ N } x \text{ m} \quad (5)$$

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- Five percent of the design truck plus lane load or five percent of the design tandem plus lane load.

BR_2 = 5% *x* [(Design truck or tandem *x* N *x* m) + (Lane load *x* L *x* N *x* m)] (6)

Where:

N: Number of lanes

L: Length of bridge (m)

m: Multiple presence factor (adjustment factor)

✓ *Centrifugal Forces (CE)*

A horizontal centrifugal force, CE, must be delivered 1.80 meters (6.0 feet) above the surface of the road. It happens because to the bridge's curve and the speed of the cars. Equation 7 shows that the centrifugal effect on live load is determined by multiplying the design truck or tandem axle weights by factor C, which is used to compute the radial force or overturning effect on wheel loads.

CE = C *x* Design truck or tandem *x* N *x* m, C = f (v^2/gR) (7)

Where:

N : Number of lanes

m : Multiple presence factor (adjustment factor)

f : 4/3 for load combination other than fatigue (1.0 for fatigue)

v : Highway design speed (ft/s) or (m/s)

g : Gravitational acceleration (32.2 ft/s^2) or (9.80 m/s^2)

R : Radius of curvature of traffic lane (ft)

➢ *Live Loads Specified in Eurocode*

- *Vertical Loads – Traffic and Pedestrian Loads*

The carriageway width, w, should be measured between curbs or between the inner boundaries of vehicle restraint systems; it shouldn't consist of the widths of these systems or the distance between fixed vehicle restraint systems and a central reservation's curbs. The number of design lanes will be determined using the following Equation 8, with the notional lane width set at 3.0 m.

Number of design lanes = Carriageway width (*w*) / notional lane width (3.0 m) (8)

The definition of the number of notional lanes for varied carriageway widths must follow the guidelines in Table 14.

Table 14 The Number of Lanes and their Width

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
5.4 m $\leq w <$ 6 m	$n_1 = 2$	*w*/2	0
6 m $\leq w$	$n_1 = Int(w/3)$	3 m	*w* - 3 *x* n_1

The lane giving the most unfavorable effect is numbered Lane 1, the lane giving the second most unfavorable effect is numbered Lane 2, etc. as shown in Fig. 11.

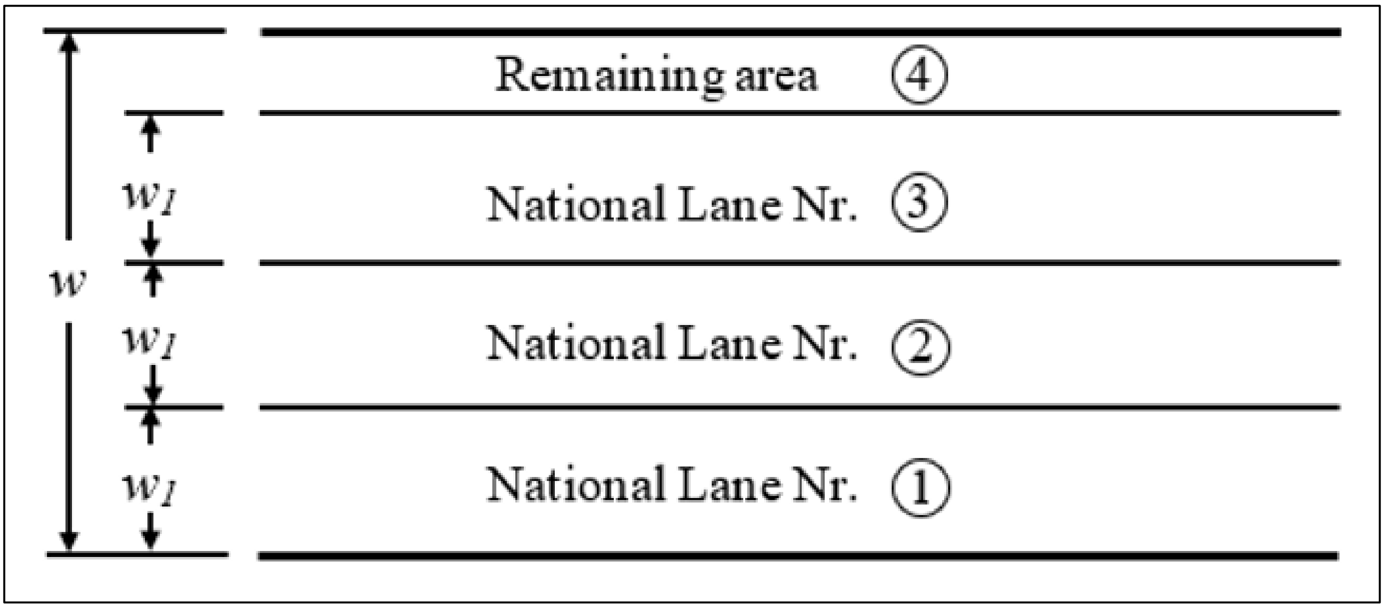

Fig 11 Example of the Lane Numbering in the Most General Case

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✓ *Adjustment Factors of Live Load*

The adjustment factors of live load shall only be applied to Load Model 1 and 2 and are not taken into account with the fatigue limit state. The recommended values of adjustment factors are shown in the following Table 15.

Table 15 Recommended Values of Adjustment Factors as Specified in ECP-LRFD.

Adjustment factor, α_i	First-class international travel for large vehicles	Second Class Regular traffic with large vehicles	Third Class: Moderately high traffic
$\alpha_{Q1} = \beta_Q$	1.0	0.9	0.8
α_{Qi}, $i \geq 2$	1.0	0.8	0.5
α_{q1}	1.0	0.7	0.5
α_{qi}, $i \geq 2$	1.0	1.0	1.0
αq_r	1.0	1.0	1.0

✓ *Models of Traffic Loading*

Four types are used in Eurocode to indicate traffic loading on bridge roadways; each model includes either lane loads or a combination of vehicle loads. The biggest of the following four models will be considered the extreme load effect.

- *Load Model 1 (LM1) - Concentrated and Distributed Loads (Main Model)*

Fig. 12 shows Load Model 1 and Table 16. shows its characteristic values as specified in Eurocode.

Table 16 Characteristic values of Load Model 1 (LM1) as specified in Eurocode

Location	Tandem system TS (kN)	Axle loads Q_{ik} (kN)	UDL system q_{ik} (kN/m^2)
Lane Number 1	$(TS_1) = 600$	$(Q_{1k}) = 300$	$(q_{1k}) = 9.0$
Lane Number 2	$(TS_2) = 400$	$(Q_{2k}) = 200$	$(q_{2k}) = 2.5$
Lane Number 3	$(TS_3) = 200$	$(Q_{3k}) = 100$	$(q_{3k}) = 2.5$
Other lanes	0	0	$(q_{ik}) = 2.5$
Remaining areas	0	0	$(q_{rk}) = 2.5$

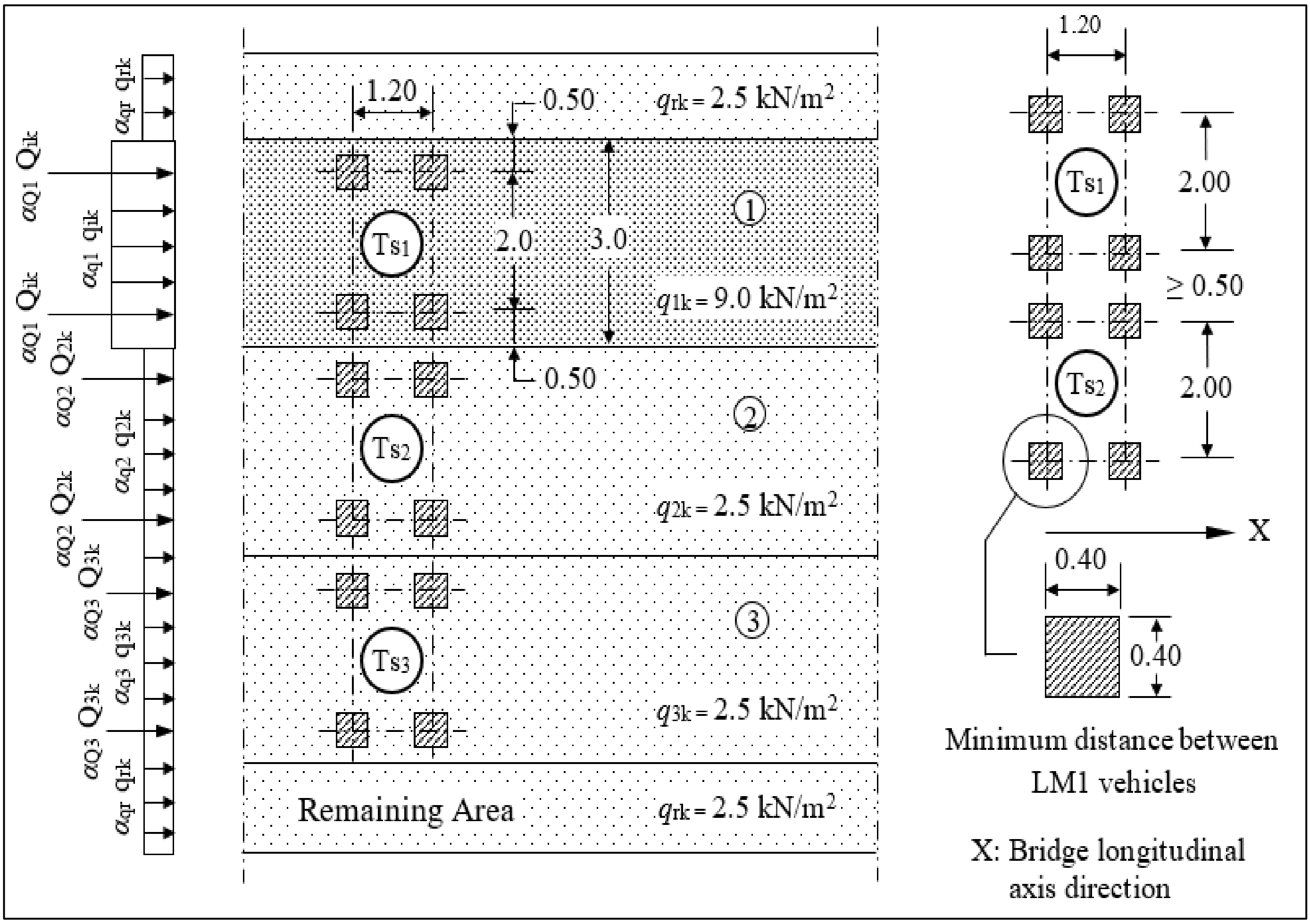

Fig 12 Load Model 1 (LM1) specified in Eurocode.

Where:

- Q_{ik}'s characteristic values, including dynamic amplification.
- No more than one tandem system should be taken into account per notional lane.
- It should be assumed that each tandem system moves centrally along the axes of the hypothetical lanes in order to evaluate the overall effects.
- The load per wheel should be equal to 0.50 α_Q Q_k since each axle of the tandem system should be considered with two identical wheels.
- Each wheel's contact surface should be regarded as square and have a 0.40 m side.
- Only the unfavorable longitudinal and transverse portions of the influence surface should receive the uniformly distributed loads.
- The heaviest tandem should be used at the least advantageous location for local verifications. When two tandem systems on neighboring hypothetical lanes are taken into consideration, they could be brought closer together, with wheel axles separated by no less than 0.5 meters.

- *Load Model 2 (LM2) – Single Axle Load*

Fig. 13 shows Load Model 2 and Table 17. shows its characteristic values as specified in Eurocode.

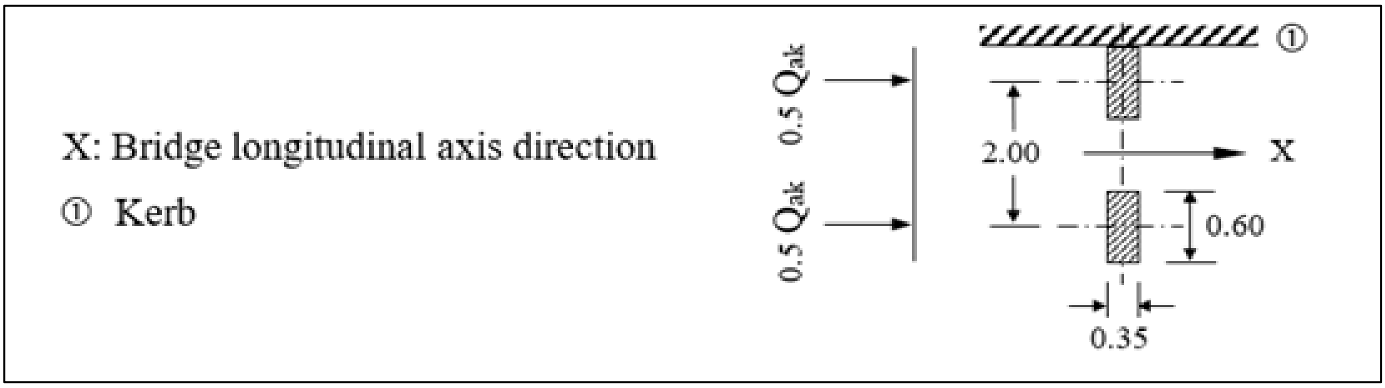

Fig 13 Load Model 2 (LM2) Specified in Eurocode.

Table 17 Characteristic Values of Load Model 2 (LM2) as Specified in Eurocode

Location	Axle load Q_{ak} (kN)	Wheel load (kN)	UDL system (kN/m^2)
Lane Number 1	Q_{ak} = 400	200	0

Where:

- Among the dynamic amplification's typical values for Qak.
- It is recommended to consider each wheel's contact surface as a rectangle with sides of 0.35 and 0.6 meters.
- In the vicinity of expansion joints, an additional dynamic amplification factor ($\Delta\varphi_{fat}$) shall be considered near expansion joints and applied to all loads as shown in Equation 9.

$$\Delta\varphi_{fat} = 1.30\ (1- (D/26));\ \Delta\varphi_{fat} \geq 1 \quad (9)$$

I : Additional amplification factor

D : Distance of the cross section from the expansion joint (m), where D ≤ 6 m

- When designing expansion joints (D= 0), additional amplification factor ($\Delta\varphi_{fat}$ = 1.30).

- *Load Model 3 (LM3) – Special Vehicles*

Load Model 3 consists of a set of special vehicles that can be used for the design of roadway bridges, defined in Tables 18 and 19, and in Figures 14, 15 and 16.

Table 18 Classes of Special Vehicles as Specified in Eurocode

Total weight	**Composition**	**Notation**
600 kN	4 axle-lines of 150 kN	600/150
900 kN	6 axle-lines of 150 kN	900/150
1200 kN	8 axle-lines of 150 kN	1200/150
	6 axle-lines of 200 kN	1200/200
1500 kN	10 axle-lines of 150 kN	1500/150
	7 axle-lines of 200 kN + 1 axle-lines of 100 kN	1500/200
1800 kN	12 axle-lines of 150 kN	1800/150
	9 axle-lines of 200 kN	1800/200
2400 kN	12 axle-lines of 200 kN	2400/200
	10 axle-lines of 240 kN	2400/240
	6 axle-lines of 200 kN (Spacing 12 m) + 6 axle-lines of 200 kN	2400/200/200
3000 kN	15 axle-lines of 200 kN	3000/200

	12 axle-lines of 240 kN + 1 axle-lines of 120 kN	3000/240
	8 axle-lines of 200 kN (Spacing 12 m) + 7 axle-lines of 200 kN	3000/200/200
3600 kN	18 axle-lines of 200 kN	3600/200
	15 axle-lines of 240 kN	3600/240
	9 axle-lines of 200 kN (Spacing 12 m) + 9 axle-lines of 200 kN	3600/200/200

Table 19 Description of Special Vehicles as Specified in Eurocode

Total weight (kN)	**Axle-lines of 150 kN**		**Axle-lines of 200 kN**		**Axle-lines of 240 kN**	
	n	***e* (m)**	***n***	***e* (m)**	***n***	***e* (m)**
600	4x150	1.5	—			
900	6x150	1.5			—	
1200	7x150	1.5	6x200	1.5		
1500	10x150	1.5	1x100 + 7x200	1.5		
1800	12x150	1.5	9x200	1.5		
2400	—		12x200	1.5	10x240	1.5
			n = 6x200 + 6x200 *e* = 5x1.5 + 12 + 5x1.5			
3000	—		15x200	1.5	1x120 + 12x240	1.5
			n = 8x200 + 7x200 *e* = 7x1.5 + 12 + 6x1.5			
3600	—		18x200	1.5	15x240	1.5
			n = 9x200 + 9x200 *e* = 8x1.5 + 12 + 8x1.5			

Where:

n : number of axles multiplied by the weight (kN) of each axle in each group.

e : axle spacing (m) within and between each group.

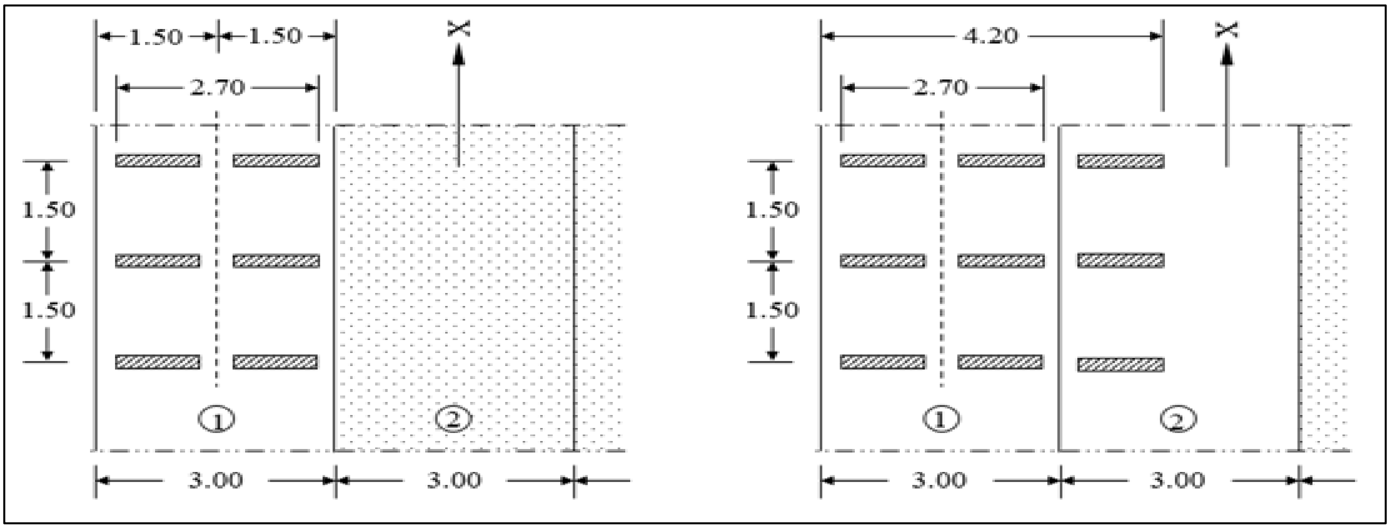

Fig 14 Application of special vehicles on notional lanes.

Fig 15 Arrangement of Axle-Lines and Definition of Wheel Contact Areas

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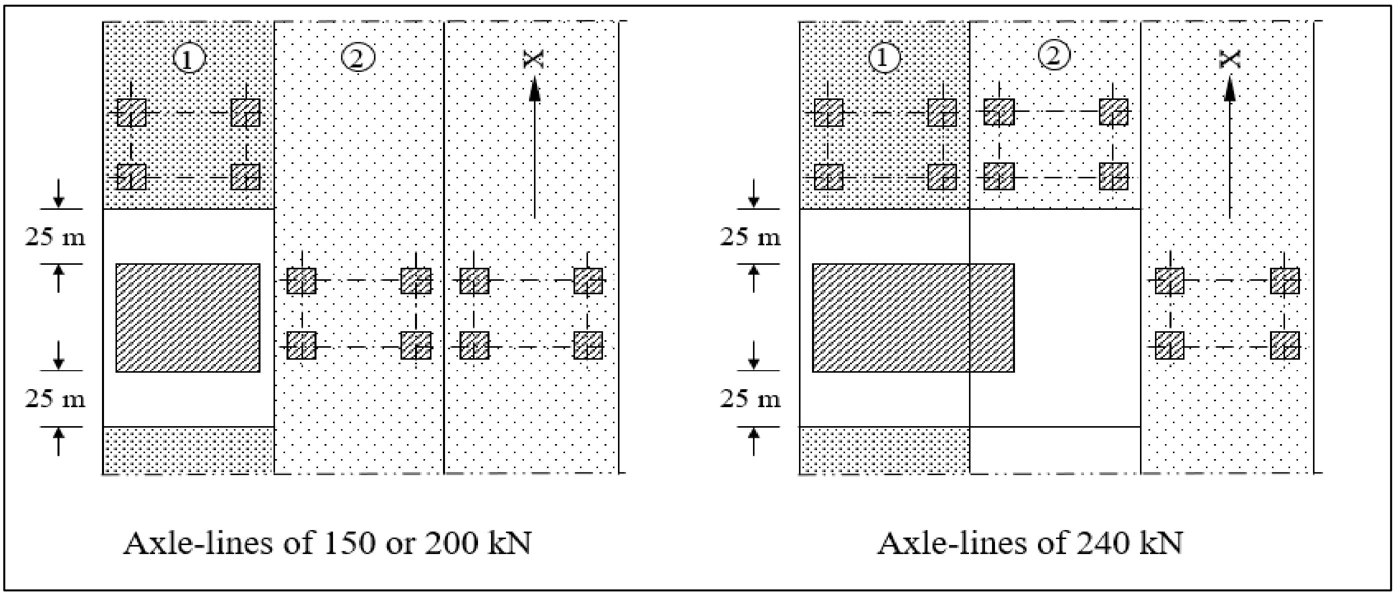


Fig 16 Simultaneity of Load Model 1 and Special Vehicles.

Where:

- The models in question may be expected to travel at a regular pace of 70 km/h or at a low speed of no more than 5 km/h.
- Since it is anticipated that the models move slowly, only vertical loads devoid of dynamic amplification should be taken into account.
- Since it is expected that the models move at their typical speed, a dynamic amplification should be taken into account, as seen in Equation 10:

$$\varphi = 1.40 - (L/500);\ \varphi \geq 1 \quad (10)$$

φ: Dynamic amplification

L: influence length (m)

- *Load Model 4 (LM4) – Crowd loading*

A load model with a uniformly distributed load of 5 kN/m^2 and a combination value of 3 kN/m^2 (including dynamic amplification) should be used to approximate crowd loading, if applicable. The center reservation should be incorporated when appropriate, and load model 4 should be applied to the pertinent portions of the road bridge deck's length and width. Fig. 17 shows Load Model 4 and Table 20. shows its characteristic values as specified in Eurocode.

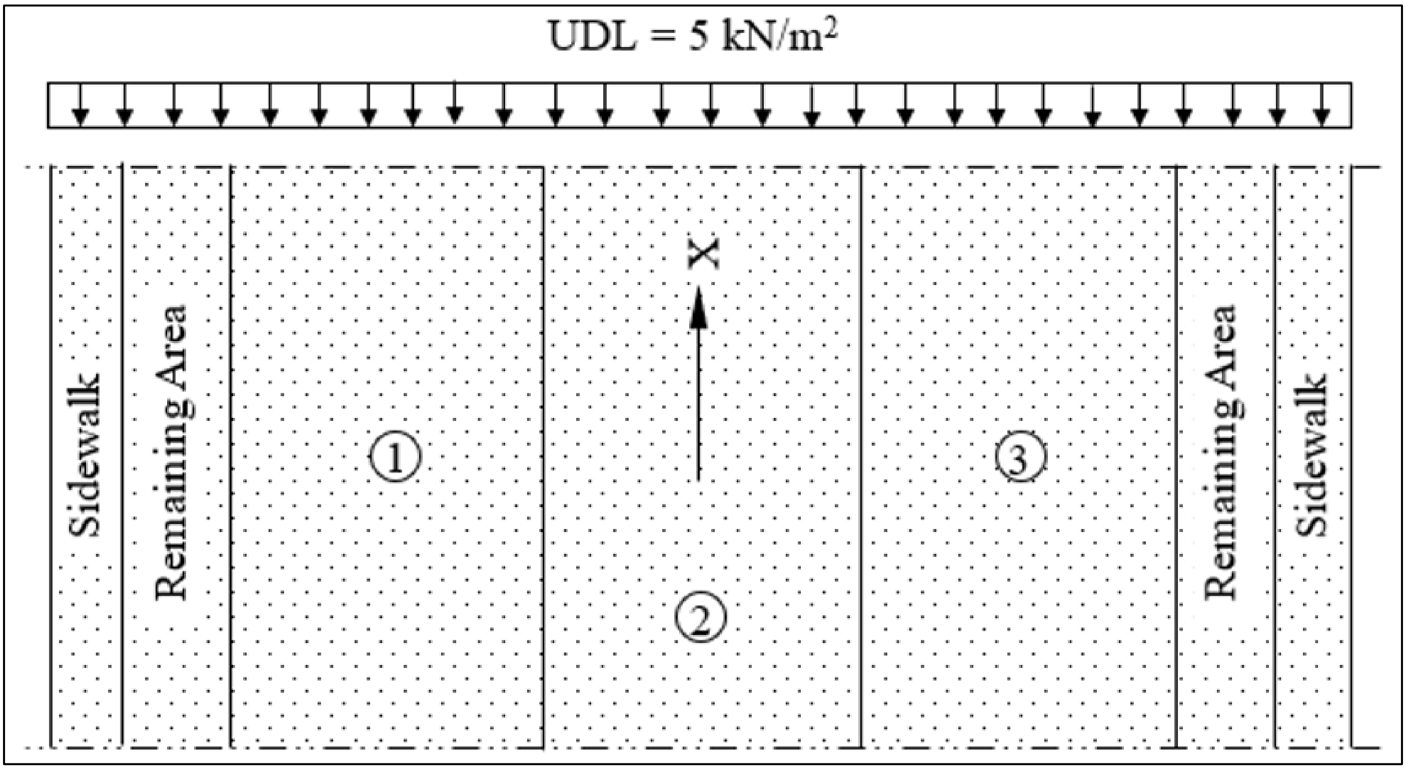


Fig 17 Load Model 4 (LM4) specified in Eurocode

Volume 10, Issue 9, September– 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

Table 20 Characteristic Values of Load Model 4 (LM4) as Specified in Eurocode

Location	Tandem system (kN)	Axle loads (kN)	UDL system (kN/m^2)
All Lanes	—	—	5

- *Fatigue Load Models*

Fatigue loads of vertical loads on roadway bridges are represented by five models as follows:

Fatigue Load Model 1 – Similar To LM1

With axle loads equal to 0.7 Q_{ik} and uniformly distributed loads equal to 0.3 Q_{ik} and (unless otherwise noted) 0.3 Q_{rk}, Fatigue Load Model 1 has the configuration of the characteristic Load Model 1. The Frequent Load Model's load levels are similar to those for Fatigue Load Model 1. In contrast to the other models, the Frequent Load Model would have been overly conservative if it had been adopted without modification, particularly for big, loaded areas. Q_R work could be overlooked for individual projects. Fig. 18 shows Fatigue Load Model 1 and Table 21. shows its characteristic values as specified in Eurocode.

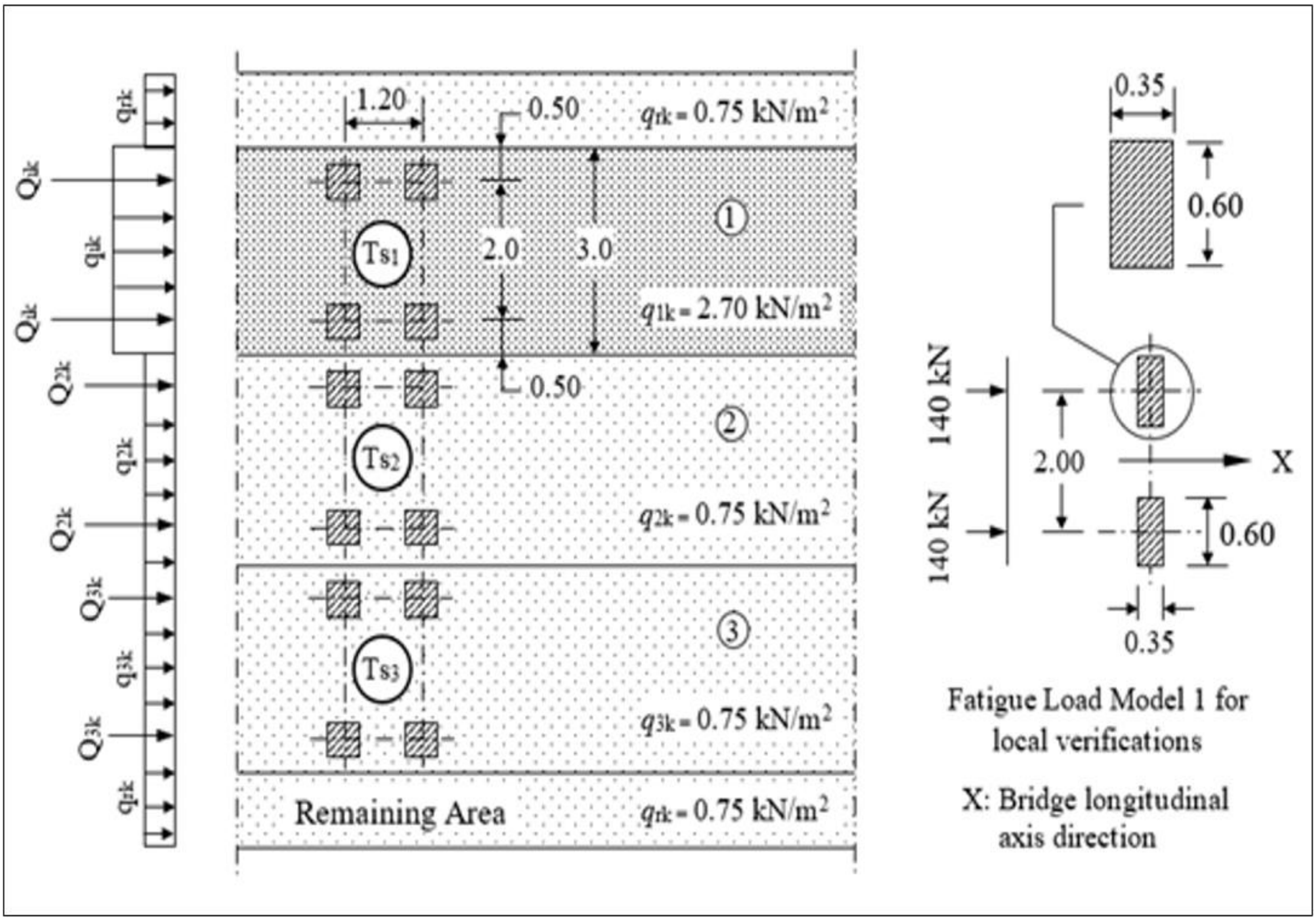


Fig 18 Fatigue Load Model 1 Specified in Eurocode

Table 21 Characteristic values of Fatigue Load Model 1 as Specified in Eurocode

Location	**Tandem system TS (kN)**	**Axle loads Q_{ik} (kN)**	**UDL system q_{ik} (kN/m^2)**
Lane Number 1	(TS_1) = 420	(Q_{1k}) = 210	(q_{1k}) = 2.70
Lane Number 2	(TS_2) = 280	(Q_{2k}) = 140	(q_{2k}) = 0.75
Lane Number 3	(TS_3) = 140	(Q_{3k}) = 70	(q_{3k}) = 0.75
Other lanes	0	0	(q_{ik}) = 0.75
Remaining areas	0	0	(q_{rk}) = 0.75

Fatigue Load Model 2 – Set of **"***Frequent***"** *Lorries*

Fatigue Load Model 2 consists of a set of idealized lorries, called "frequent" lorries, each "frequent lorry" is defined in the following Tables 22 and 23.

Table 22 Set of "Frequent" Lorries as Specified in Eurocode

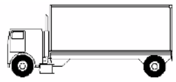
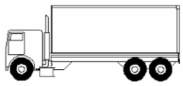
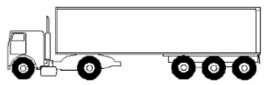
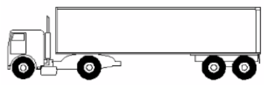
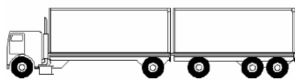
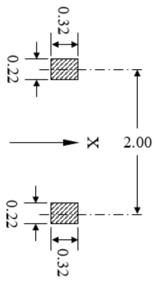
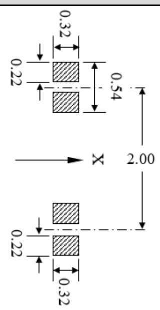
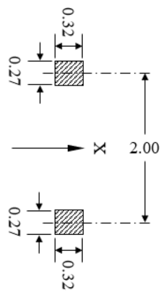
LORRY SILHOUETTE	**Axle spacing (m)**	**Frequent axle loads (kN)**	**Wheel type**
	4.5	90 190	A B
LORRY SILHOUETTE	Axle spacing (m)	Frequent axle loads (kN)	Wheel type
	4.20 1.30	80 140 140	A B B
	3.20 5.20 1.30 1.30	90 180 120 120 120	A B C C C
	3.40 6.00 1.80	90 190 140 140	A B B B
	4.80 3.60 4.40 1.30	90 180 120 110 110	A B C C C

Table 23 Definition of Wheels and Axels as Specified in Eurocode

	Wheel/Axle Type		
	A	**B**	**C**
WHEEL/AXLE TYPE			

The most severe effects of various lorries, taken into consideration separately, traveling alone along the proper lane, will be used to calculate the maximum and lowest strains.

- *Fatigue Load Model 3 – Single Vehicle Model*

There are four axles in this type, and each axle has two identical wheels, each wheel's contact surface is square with a side of 0.40 meters, and each axle weighs 120 kN, as seen in Fig. 19 and Table 24. shows its characteristic values as specified in Eurocode.

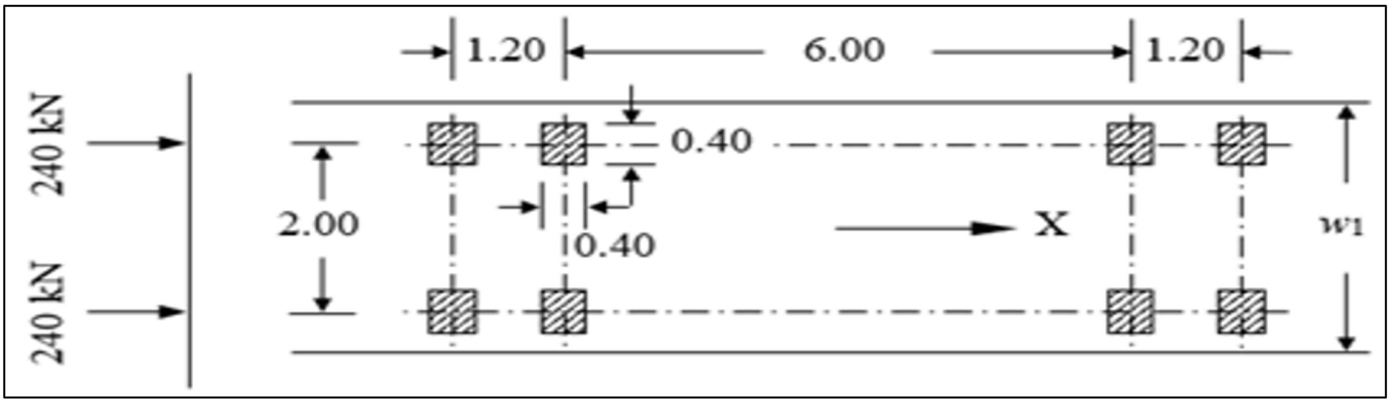


Fig 19 Fatigue Load Model 3 specified in Eurocode.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

Table 24 Characteristic Values of Fatigue Load Model 3 as Specified in Eurocode.

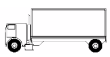
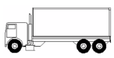
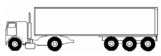
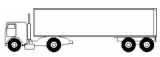
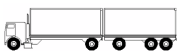
Location	Vehicle weight (kN)	Wheel load (kN)	Axles distances (m)
Any Lane	480	120	1.20/6.0/1.20

It is important to consider two vehicles in the same lane when it is appropriate. The geometry of the second vehicle is as follows: each axle weighs 36 kN instead of 120 kN, and the two automobiles are at least 40 meters apart from center to center.

- *Fatigue Load Model 4 – Set of* **"***Standard***"** *Lorries*

Sets of regular lorries make up Fatigue Load Model 4, which simulates the impact of normal traffic on European highways. Based on five typical trucks, this model replicates traffic, which is thought to cause fatigue damage comparable to that caused by real traffic. A set of lorries appropriate to the traffic mixes predicted for the route should be considered as defined in Table 25.

Table 25 Set of "Frequent" Lorries as Specified in Eurocode

VEHICLE TYPE			TRAFFIC TYPE			Wheel type
			Lorry percentage			
LORRY	Axle spacing (m)	Axle loads (kN)	Long distance	Medium distance	Local Traffic	
	4.5	70 130	20	40	80	A B
	4.20 1.30	70 120 120	5	10	5	A B B
	3.20 5.20 1.30 1.30	70 150 90 90 90	50	30	5	A B C C C
	3.40 6.00 1.80	70 140 90 90	15	15	5	A B B B
	4.80 3.60 4.40 1.30	70 130 90 80 80	10	5	5	A B C C C

When individual trucks are passing over the bridge, the stress range spectrum and the number of cycles from each stress variation should be ascertained using the rain flow or reservoir counting method. Hundreds of kilometers are considered long distance, fifty to one hundred kilometers are considered medium distance, and fewer than fifty kilometers are considered local traffic.

- *Fatigue Load Model 5 - (Based on Recorded Traffic Data)*

Recorded traffic data is directly applied in Fatigue Load Model 5, with pertinent statical and prospective extrapolations added if necessary.

✓ *Pedestrian Loads*

Every sidewalk must have a pedestrian load of 5.0 kN/m^2 and a combination value of 3 kN/m^2 (including dynamic amplification). In the vehicle lane, the pedestrian load is taken into account concurrently with the vehicle design live load.

- *Horizontal Forces – Braking and Centrifugal Forces*

✓ *Braking Forces (Q_{lk})*

A characteristic braking force, Q_{lk}, shall be taken as a longitudinal force acting at the surface level of the carriageway. Q_{lk}, which is restricted to 900 kN for the bridge's overall width, shall be computed using Equation 11 as a percentage of the total maximum vertical loads that correspond to the Load Model 1 that is most likely to be imposed on Lane Number 1.

$$Q_{lk} = 0.6\,\alpha_{Q1}\,(2Q_{1k}) + 0.1\,\alpha_{q1}\,q_{1k}\,w_l\,L\,,\quad 180\,\alpha_{Q1}\,(\text{kN}) \le Q_{lk} \le 900\,(\text{kN}) \qquad (11)$$

Where:

L : Length of the deck or of the part of it under consideration (m)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

By substituting in the previous equation with Q_{1k} = 300 kN, q_{1k} = 9 kN/m^2, w_l = 3 m wide lane and $\alpha_{Q1} = \alpha_{q1}$ = 1.0 then, the equation will become as the following Equation 12.

$$Q_{lk} = 360 + 2.7\ L\ (kN);\ Q_{lk} \leq 900\ kN \quad (12)$$

Where:

L : Loaded length of the bridge (m), L > 1.2 m.

Since the acceleration forces are equal to the braking forces but acting in the opposite direction, Q_{1k} can be both positive and negative. At the finished road level, a transverse braking force, Q_{trk}, which is equivalent to 25% of the longitudinal braking Q_{lk}, should be regarded as acting concurrently with Q_{lk}. $Q_{lk} = 0.6\ \alpha_{Q1}\ Q_{1k}$ should be used to determine the horizontal force imparted to structural members that can be loaded by a single axle or transmitted by expansion joints.

✓ *Centrifugal Forces (Q_{tk})*

Q_{tk}, a typical centrifugal force, is defined as a transverse force acting at the level of the completed highway and radially to the carriageway's axis. Table 26. shows its characteristic values as specified in Eurocode.

Table 26 Characteristic Values of Centrifugal Forces as Specified in Eurocode

Centrifugal force, Q_{tk} (kN)	**Horizontal radius (m)**
$Q_{tk} = 0.2\ Q_v$	If $r < 200$
$Q_{tk} = 40\ Q_v / r$	If $200 \leq r \leq 1500$
$Q_{tk} = 0$	If $r > 1500$

Where *(r)* is horizontal radius of the carriageway centerline (m) and (Q_v) is total maximum weight of vertical concentrated loads of the tandem system of LM1. Q_{tk}'s characteristic value, which takes dynamic effects into account. Additionally, it is reasonable to suppose that Q_{tk} acts as a point load at any deck cross section.

V. LOAD COMBINATIONS AND LOAD FACTORS

To identify the worst-case loading that causes the greatest straining actions and, as a result, stresses at crucial bridge sections, the various loads acting on steel bridges must be aggregated and stacked. Load combinations are a common way to group the various loads acting on the bridges. The methods used to design the bridge's components—such as acceptable stress design, limit state design, plastic design, and load and resistance factored design—determine the load combinations.

Multiplying nominal or characteristic load values by partial safety factors yields the load's design value, which is the basis for the idea of grouping various loads acting on the bridge. In order to achieve the same likelihood of occurrence for the combination as for the individual loads, the partial safety factors for the individual application of the loads should be decreased when multiple loads are to be grouped or combined.

A. Groups of Traffic Loads Specified in ECP-LRFD

According to the Egyptian code for loads and forces on bridges, the groups of loads listed in Table 27 should be taken into consideration while evaluating the simultaneity of the loading systems Load Model 1 (LM1), Load Model 2 (LM2), and Load Model 3 (LM3) as well as horizontal forces. While Table 28 shows load combinations and load factors for these groups

Table 27 Assessment of Groups of Traffic Loads (Characteristic Values of Multi-Component Action) According to ECP-LRFD.

Load type	**Carriageway**				
	Vertical forces			**Horizontal forces**	
Load system	**LM1 (TS and UDL systems)**	**LM2 (Single axle)**	**LM4 (Crowd loading)**	**Braking and acceleration forces**	**Centrifugal and transverse forces**
Comb 1	C. values			C. value	C. value
Comb 2		C. value			
Comb 3			C. value		
Where (C.) refers to Characteristic Dominant component action (designated as component associated with the group).					

Table 28 Load Combinations and Load Factors According to ECP-LRFD

Combination Type	Load Factors								
	Permanent Actions		LL (Traffic Actions)						
			Vertical					Horizontal	
	DL	SDL	LM1		LM2	LM3	FM	BR	CENT
			VEH	UDL					
Ultimate	1.35	1.35	1.35	1.35				1.35	1.35
	1.35	1.35			1.35				
	1.35	1.35				1.35			
Service	1.00	1.00	1.00	1.00				1.00	1.00
	1.00	1.00			1.00				
	1.00	1.00				1.00			
Fatigue							1.00		

B. Groups of Traffic Loads Specified in AASHTO

AASHTO recommends that the simultaneity of the three loading cases and horizontal forces should be considered by considering the groups of loads defined in Table 29. While Table 30 shows load combinations and load factors for these groups.

Table 29 Assessment of Groups of Traffic Loads (Characteristic Values of Multi-Component Action) According to AASHTO.

Load type	Carriageway				
	Vertical forces			Horizontal forces	
Load system	Case 1 (Truck and UDL systems)	Case 2 (Tandem and UDL systems)	Case 3 (2 Truck and UDL systems)	Braking and acceleration forces	Centrifugal and transverse forces
Comb 1	C. values			C. value	C. value
Comb 2		C. value		C. value	C. value
Comb 3			C. value	C. value	C. value
Where (C.) refers to Characteristic Dominant component action (designated as component associated with the group).					

Table 30 Load Combinations and Load Factors According to AASHTO

Comb Type	Load Factors											
	Permanent Actions		LL (Traffic Actions)									
			Vertical								Horizontal	
	DC	DW	Case 1		Case 2		Case 3		IM	FL	BR	CE
			TR	UDL	TS	UDL	TR	UDL				
Ultimate	1.25	1.50	1.75	1.75					1.75		1.75	1.75
	1.35	1.00			1.75	1.75			1.75		1.75	1.75
	1.35	1.00					1.75	1.75	1.75		1.75	1.75
Service	1.00	1.00	1.30	1.30					1.30		1.30	1.30
	1.00	1.00			1.30	1.30			1.30		1.30	1.30
	1.00	1.00					1.30	1.30	1.30		1.30	1.30
Fatigue									0.80	0.80		0.80

C. Groups of Traffic Loads Specified in Eurocode

According to Eurocode 1, the loads of footways and the loading systems (Load Model 1, Load Model 2, Load Model 3, and horizontal forces) should be considered simultaneously by taking into account the groupings of loads listed in Table 31.

When combined with non-traffic loads, each of these mutually exclusive load groups will be regarded as constituting a distinctive activity. Only the frequent values of LM1 or LM2, as indicated in Table 32, should be included in the frequent action. While Table 33 shows load combinations and load factors for these groups.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

Table 31 Assessment of Groups of Traffic Loads (Characteristic Values of Multi-Component Action) According to Eurocode.

		Carriageway						**Footways and Cycle track**
Load type		**Vertical forces**				**Horizontal forces**		**Vertical forces only**
Load system		**LM1 (TS and UDL systems)**	**LM2 (Single axle)**	**LM3 (Special vehicles)**	**LM4 (Crowd loading)**	**Braking and acceleration forces**	**Centrifugal and transverse forces**	**Uniformly distributed load**
Groups of Loads	gr1a	C. values						CO. value [b)]
	gr1b		C. value					
	gr2	F. values [b)]				C. value	C. value	
	gr3							C. value [a)]
	gr4				C. value			C. value [b)]
	gr5	Annex A		C. value				
Dominant component action (designated as component associated with the group)								

Table 32 Assessment of Groups of Traffic Loads (Frequent Values of Multi-Component Action) According to Eurocode.

		Carriageway		**Footways and Cycle track**
Load type		**Vertical forces**		
Load system		**LM1 (TS and UDL systems)**	**LM2 (Single axle)**	**Uniformly distributed load**
Groups of Loads	gr1a	Frequent values		
	gr1b		Frequent value	
	gr3			Frequent value [(a)]

Where (C.) refers to Characteristic, (CO.) refers to Combination and (F.) refers to Frequent. ([a]) one footway only should be loaded if the effect is more unfavorable than the effect of two loaded footways. ([b]) is defined in the National Annex. Recommended value is 3 kN/m^2. (gr3) group is irrelevant if (gr4) is considered.

Table 33 Load Combinations and Load Factors According to Eurocode.

Comb Type	**Load Factors**										
	Permanent Actions		**LL (Traffic Actions)**								
			Vertical							**Horizontal**	
	$G_{kj,sup}$	**$G_{kj,inf}$**	**LM1 TS**	**LM1 UDL**	**LM2**	**LM3**	**LM4**	**F & CT**	**FMs**	**BR**	**CEN**
Ultimate	1.35	1.00	1.35	1.35				1.35			
	1.35	1.00			1.35						
	1.35	1.00	1.35	1.35						1.35	1.35
	1.35	1.00						1.35			
	1.35	1.00					1.35	1.35			
	1.35	1.00	1.35	1.35		1.35					
Service	1.00	1.00	1.00	1.00				1.00			
	1.00	1.00			1.00						
	1.00	1.00	1.00	1.00						1.00	1.00
	1.00	1.00						1.00			
	1.00	1.00					1.00	1.00			
	1.00	1.00	1.00	1.00		1.00					
Fatigue									1.00		

VI. SUMMARY AND CONCLUSION

- The comparison shows that AASHTO LRFD (2024) allows the widest flexibility with a larger lane width (3.65 m) and no limits on loaded length or width. The Egyptian Code (2015) adopts a narrower lane width (3.0 m) but similarly applies no restrictions. In contrast, the Eurocode (EN 1991) uses the same 3.0 m lane width but imposes strict limits on loaded length (200 m) and width (42 m), reflecting a more conservative design approach.
- In AASHTO LRFD (2024), impact is treated independently and not embedded in the initial load models, with explicit factors of 15% for fatigue and fracture limit states and 33% for other limit states. By contrast, the Egyptian Code (2015) and the Eurocode (EN 1991) incorporate impact effects directly into their load models, eliminating the need for

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep468

separate factors. This illustrates two distinct approaches: the American standard isolates impact for clearer evaluation, while the Egyptian and European standards adopt an integrated representation.

- AASHTO LRFD (2024) applies three loading cases, mainly combining concentrated and distributed loads, with Case III limited to continuous bridges. The Egyptian Code (2015) and Eurocode (EN 1991) provide more diversified load models, including axle loads and crowd/special vehicle loading, showing a broader consideration of traffic scenarios.
- The Eurocode is the most comprehensive, introducing four distinct load models, with LM4 specifically addressing crowd loading and LM3 accounting for special vehicles. The Egyptian Code partially aligns with this by including crowd loading (LM3), while AASHTO does not explicitly consider such cases.
- AASHTO LRFD (2024) applies lane adjustment factors across all loading cases, decreasing progressively as the number of lanes increases (1.2 to 0.65). The Egyptian Code (2015) and Eurocode (EN 1991) apply lane adjustment factors only to certain load models (LM1 in Egyptian Code; LM1 and LM2 in Eurocode), and their reduction is linked to lane classification rather than number of lanes.
- AASHTO LRFD (2024) and the Egyptian Code (2015) use a single vehicle model for fatigue, reflecting a simplified approach. The Eurocode (EN 1991) introduces five fatigue models, ranging from single vehicles to traffic data–based models, offering greater realism and adaptability.
- AASHTO LRFD (2024) defines smaller tire contact areas with square and rectangular patches for front and rear axles. The Egyptian Code (2015) and Eurocode (EN 1991) adopt larger and nearly identical tire dimensions for their main load models (40×40 cm^2 and 60×35 cm^2). Additionally, the Eurocode introduces a third rectangular patch (120×15 cm^2), reflecting a broader consideration of loading conditions.
- The calculation equations for braking and centrifugal forces in the Egyptian Code (2015) and Eurocode (EN 1991) are similar, while AASHTO LRFD (2024) applies different formulations. In terms of application, AASHTO prescribes both braking and centrifugal forces to act horizontally at 1.80 m above the roadway surface, whereas the Egyptian and European standards apply these forces directly at the finished carriageway level.
- AASHTO LRFD (2024) adopts the limit states design approach, applying relatively high partial safety factors for instance, 1.75 for live loads in Strength I across fewer but conservative load combinations, emphasizing simplicity and safety margins. In contrast, Eurocode (EN 1991) uses a semi-probabilistic method with moderate factors (typically 1.35–1.5 for live loads) applied to multiple realistic combinations, including frequent and quasi-permanent cases, providing greater flexibility and accu racy. The Egyptian Code (2015) aligns closely with Eurocode, adopting similar moderate factors and combination rules, balancing realism, serviceability, and moderate conservatism.

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