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EC 1: Traffic Loads on Road Bridges

EC 1: Charges dues au trafic sur les ponts-routes

EC 1: Verkehrslastmodell für Strassenbrücken

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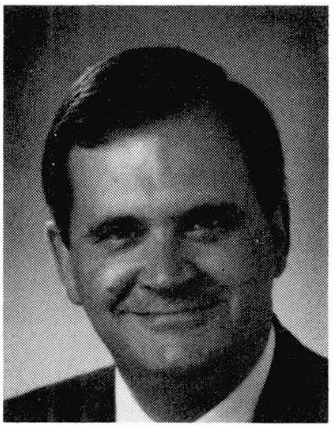

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SUMMARY

After describing the situation at the beginning of the work the procedure adopted for the development of a new European harmonized traffic load model for road bridges is presented. Some features of the first proposal for the model are given. As an example the actions due to this model are compared with those due to national bridge loading standards.

RESUME

Après un rappel de la situation lors du démarrage des travaux, la démarche adoptée pour l'élaboration d'un nouveau modèle européen harmonisé de charges dues au trafic sur les ponts-routes est présentée. Quelques caractéristiques de la première proposition de modèle sont détaillées. A titre d'exemple, les effets de ce modèle sont comparés à ceux de codes nationaux actuels.

ZUSAMMENFASSUNG

Nach Darlegung der Situation bei Beginn der Arbeiten wird auf die Vorgehensweise bei der Entwicklung des neuen Europäischen Verkehrslastmodells für Strassenbrücken eingegangen. Zu dem ersten bereits fertiggestellten Entwurf werden einige Angaben gemacht. An einem Beispiel werden die Schnittgrössen infolge des vorgeschlagenen Modells mit den Ergebnissen der derzeitigen nationalen Belastungsvorschriften verglichen.

1. INTRODUCTION

- In 1987 a working group has been formed by the Eurocode Steering committee chaired by the Commission to prepare a draft for a European loading code for actions on road bridges to be used together with the design rules for concrete, steel and composite structures as being worked out for the Eurocodes 2, 3 and 4.
- Whereas in the field of railway bridges the national railway authorities had already organized their international cooperation for harmonizing technical specifications in UIC and hence were in a position to present an agreed UIC loading model, such cooperation of the ministries concerned with road bridges did not yet exist. So it had to be established by inviting delegates from the ministries to join the working group and to give the necessary input to the works from the users side.
- Under the chairmanship of Mr Mathieu (SETRA, France) the works were planned and executed in the following way:

  1. In 1987 a feasibility study [1] was carried out to clarify the state of the art and define the objectives, namely:
     - The load model should consist of a normal traffic load model calibrated on the effects of measured traffic data and a classified abnormal traffic load model that may be chosen in case exceptional vehicles not covered by the normal traffic load model have to be foreseen.
     - The normal load model should be composed of concentrated loads and uniformly distributed loads in such a way that it is both suitable for global verifications and local verifications of the bridge and of parts thereof in both the longitudinal and transverse direction of the bridge. That includes its applicability to a great variety of influence surfaces for action effects.
     - The normal load model should be suitable for ULS, SLS and Fatigue verifications and also allow for horizontal traffic effects and for accidental situations.
     - The load model should be defined with characteristic numerical values and include vehicle, pedestrian and crowding effects.
  2. In 1988 subgroups were formed with experts that laid the ground for the further drafting works by performing prenormative research in those fields where according to the feasibility study so far no agreement could be achieved. The results of these works were documented in background reports, fig. 1.

- **Reference Bridges and Influence Lines** (report of Subgroup 1)
  (Calgaro, König/Sedlacek, Malakatas, Eggermont)
- **Traffic Data of the European Countries** (report of Subgroup 2)
  (König/Sedlacek, Bruls, Jacob, Page, Sanpaolesi)
- **Definition and Treatment of Abnormal Loads** (report of Subgroup 3)
  (DeBuck,Kanellaidis,Eggermont,Hayter,Merzenich)
- **Definition of Dynamic Impact Factors** (report of Subgroup 5)
  (Sanpaolesi, König/Sedlacek, Astudillo, Bruls, Jacob)
- **Other Action Components** (pedestrians, braking etc) (report of Subgroup 6)
  (Gilland, Pfohl, Mehue, O'Connor)
- **Guidelines for the Definition of Fatigue Loading** (report of Subgroup 7)
  (Bruls, König/Sedlacek, Jacob, Flint, Sanpaolesi)
- **Methods for the Prediction of Extreme Vehicular Loads and Load Effects on Bridges**
  (report of Subgroup 8) (Jacob, Flint, König/Sedlacek, Bruls)
- **Reliability Aspects** (report of Subgroup 9) (Flint, König/Sedlacek, Bruls, Jacob, Sanpaolesi)

Figure 1 : List of reports from prenormative research

3. In 1991, when the works on the Eurocodes had been transferred from the Commission to CEN and the background works came to an end the drafting work on Part 3 (traffic loads on bridges) of Eurocode 1 (Basis of Design and Actions on Structures) started. In early 1992 the first completed draft was sent to the CEN-member organisations for comments and discussions were opened with other Project Teams that for other Eurocodes prepare the design rules for concrete, steel and composite bridges. These comments and discussions shall help to finalize the draft and to achieve an European loading model fitting to the requests of the bridge authorities, industry and consulting engineers.

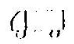
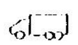
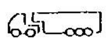
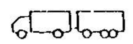
- In the following some features of the first draft and some background informations are given.

2. GENERAL PROCEDURE FOR THE DETERMINATION OF THE TRAFFIC LOAD MODEL FOR ROAD BRIDGES

- From a comparison of the data from traffic measurements carried out at different bridge sites in Europe the Auxerre traffic (highway Paris - Lyon) recorded by the LCPC was chosen for defining the European traffic load model for road bridges for the following reasons:

  1. the data were obtained only recently and represent an homogeneous traffic sample (comprising 1st and 2nd lane data)

  2. the composition of the traffic was considered as representing already a future trend in the traffic development on other roads in view of the percentage of articulated heavy vehicles, the loading rates and the weights, fig. 2.

		LANE 1	LANE 2
Vehicle Flow	[veh/24 hrs]	8158	1664
Lorry Flow	[veh/24 hrs]	2650 (=32.3%)	153 (=9.2%)
Percentage of lorries in the lorry flow : (lorry flow = 100%)			
	[%]	22.7	27.6
	[%]	1.3	3.5
	[%]	65.2	58.4
	[%]	10.8	10.5

GROSS WEIGHT OF ALL LORRIES OF LANE 1

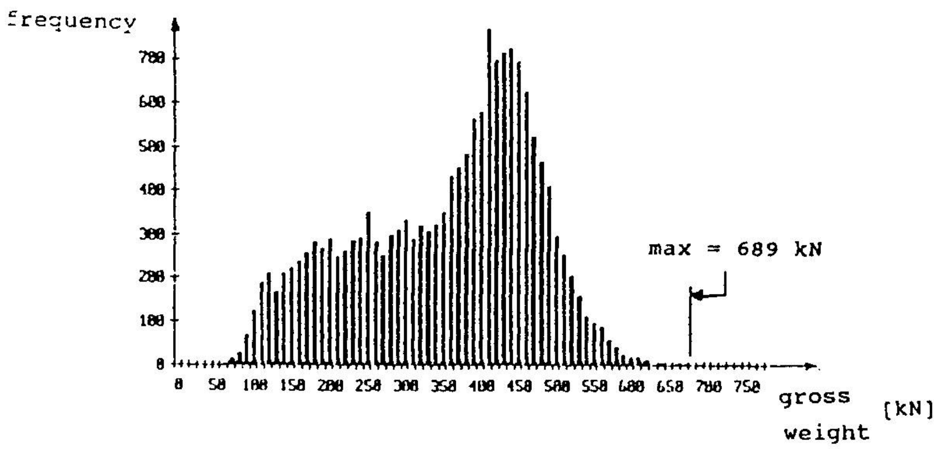


Figure 2 : Characteristics of the Auxerre traffic

- In order to evaluate the traffic data and to simulate the dynamic traffic effects on bridges numerically simulation programmes for timestep analysis have been developed, that allow to take account of
  1. the dynamic behavior of the bridges (FE modelling of stiffness, mass distribution and damping)
  2. the dynamic characteristics of the vehicles, fig. 3, taking account of the non linear hysteretical behavior of the suspensions including friction effects.

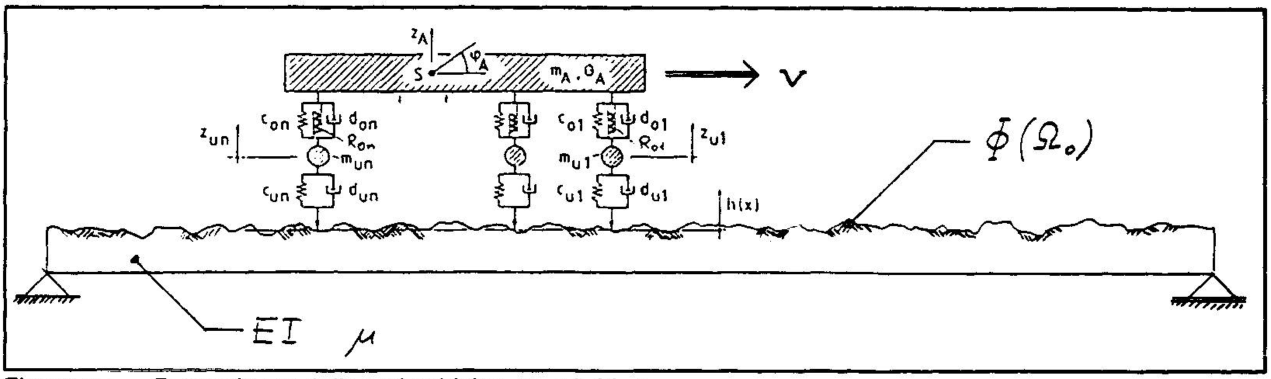


Figure 3 : Dynamic modeling of vehicles on a bridge

  3. the roadway roughness on the bridge taking account of the definition $\Phi(\Omega_0)$ in ISO-TC 208 or discrete irregulations e.g. at the transition joints.
  4. the different speeds of the vehicles.

These dynamic simulation programmes [2], [3], [4], [5] were calibrated with dynamic bridge measurements undertaken at the EMPA Dübendorf [6], [7], fig. 4 and proved to be rather accurate.

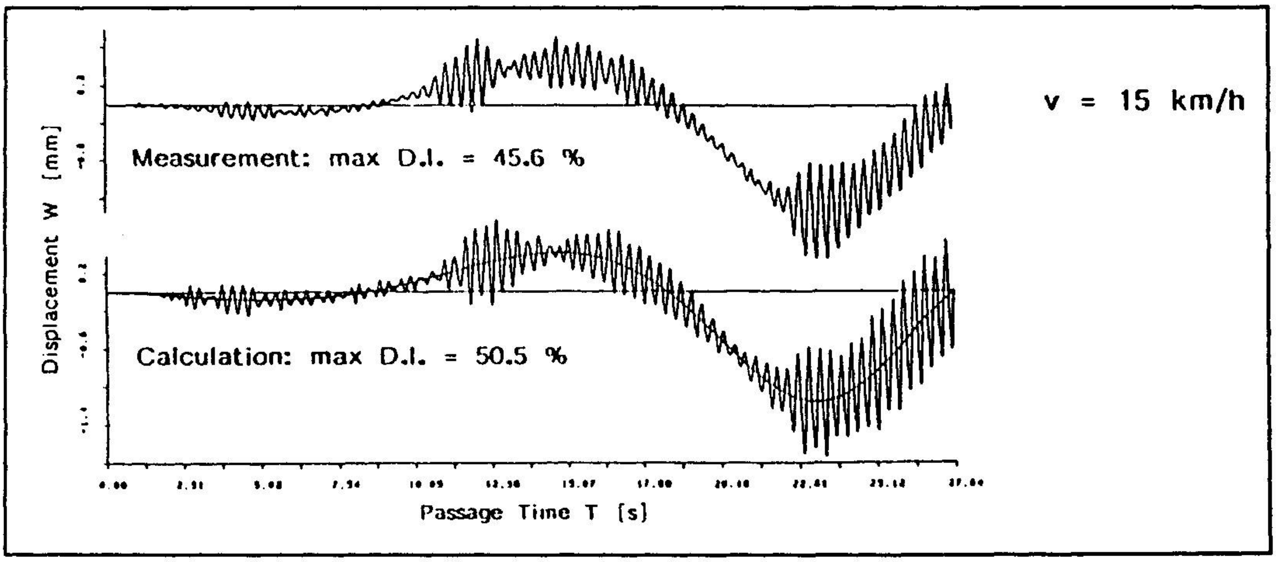


Figure 4 : Comparison of measured and calculated bridge responses

- In a first step the simulation programmes were used for filtering the dynamic effects from the statistical distributions of the Auxerre traffic data and to obtain purely statical data, fig. 5, from which random vehicles sequences could be formed by Monte Carlo methods in order to take account of the variability of the traffic effects.
- In a second step loading scenarios for flowing (at different speeds) and jammed (slowly moving) traffic situations for a great variety of simply supported and continuous bridges with different systems (open cross section and box girders), different widths (number of lanes) and different span length were identified for which the dynamic simulation programme served to calculate the maximum action effects (e.g. bending

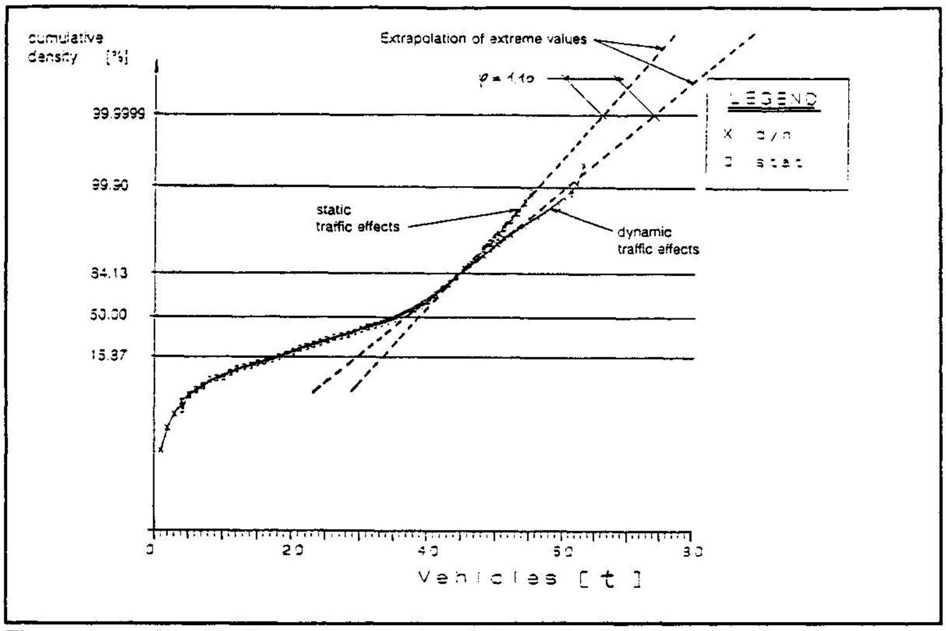


Figure 5 : Distributions of statical and dynamic data from the Auxerre measurements

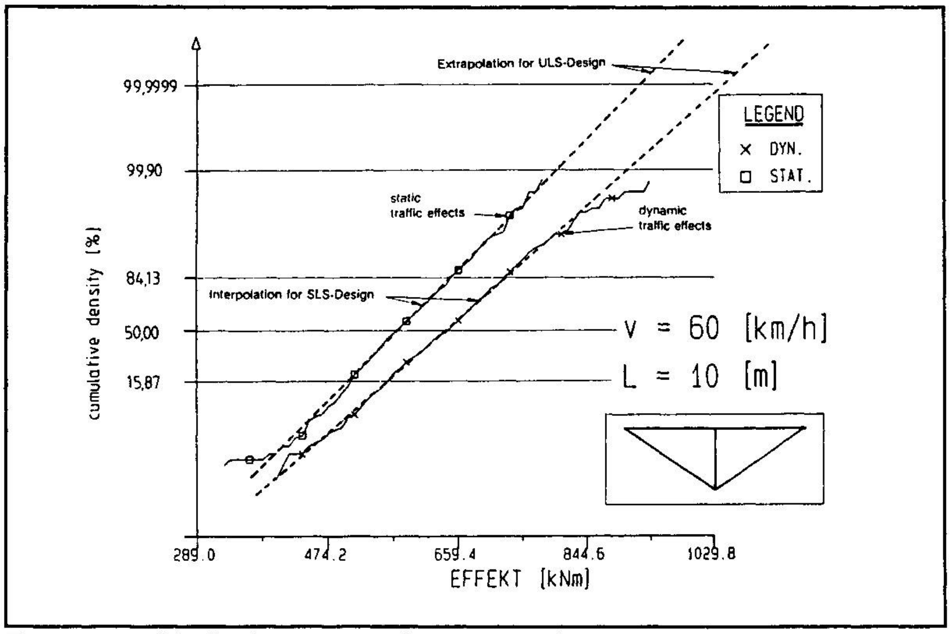


Figure 6 : Distribution curves of maximum effects

moments at midspan or at the supports or shear forces) in order to establish distribution curves of these maximum effects, fig. 6.

- The maximum dynamic action effects representing the 95 % fractiles for a reference period of 50 years were considered as the characteristic target values the traffic load model should cover, fig. 7. From comparing the characteristic values of the dynamic action effects with those yielding from distribution curves for statical action effects only (where the dynamic influence of the vehicles and the bridge were neglected), fig.6, "effective impact factors" were defined that could be applied to target values determined by simple statical calculations only without using the dynamic simulation programmes.

- Several proposals for loading scenarios were developed in order to obtain target values for 1-4 loaded lanes. A synthesis of these proposals permitted to define a set of harmonized target values on the basis of which the main model was calibrated.

- In the last step the traffic load model was synthesized by optimizing its free parameters for the geometrical load pattern and the numerical values such, that for given weighting factors for the types of influence areas, number of lanes and span lengths a minimum of the square of the deviation of the characteristic target values from the effects of the load model was achieved, fig. 7.

- The works in each step were carried out redundantly by independent groups to avoid systematic and incident mistakes and ensure reliable results.

3. SOME FEATURES OF THE FIRST DRAFT OF THE TRAFFIC LOAD MODEL ON ROAD BRIDGES

- The normal traffic load model is given in fig. 8. It consists of tandem axle loads in lane 1, 2 and 3, superimposed to uniformly distributed loads. The contact area of the tyres was chosen in accordance with the actual trends for the conception of lorries and tyres [8].

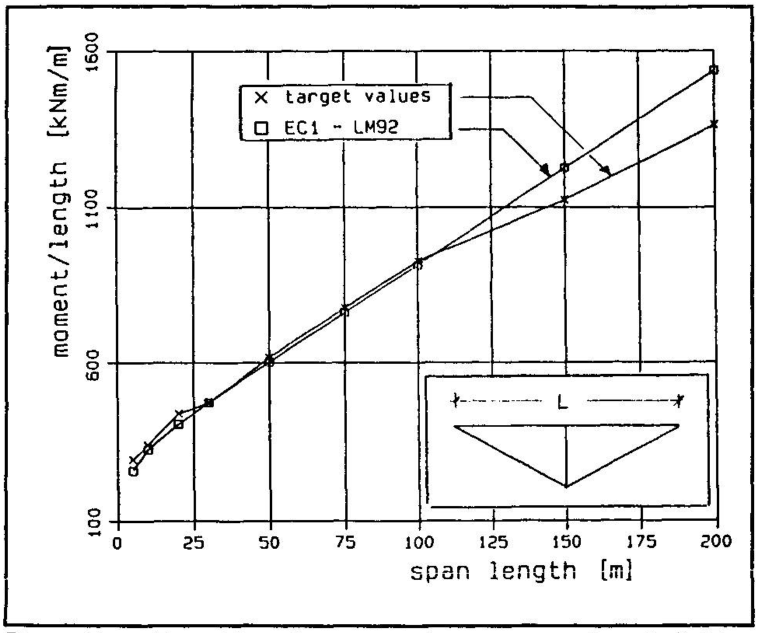


Figure 7 : Target bending moments versus span length (bridge width corresponds to 4 loaded lanes)

- Fatigue verifications may be carried out on different levels. A detailed method is envisaged on the basis of a set of realistic fatigue vehicles according to fig. 9. A conservative approach is also envisaged by using a unique fatigue equivalent vehicle according to fig. 10.

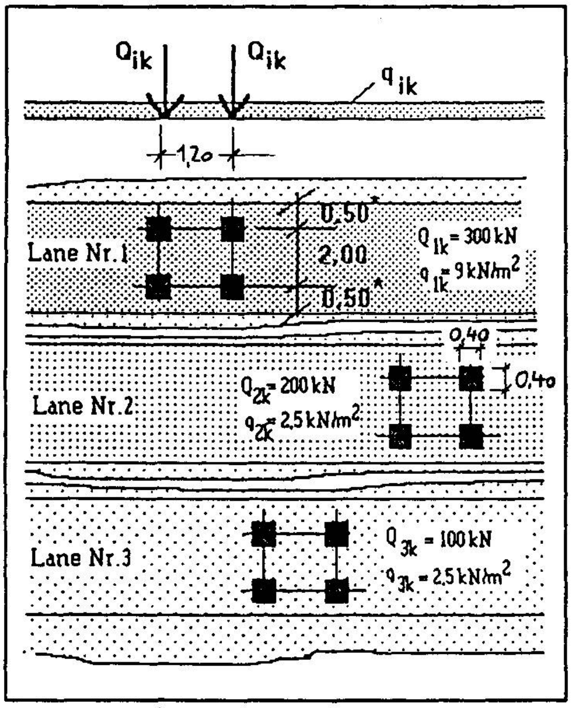


Figure 8 : Normal traffic load model

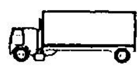
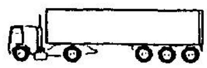
VEHICLE Silhouette	AXLE SPACING (m)	AXLE LOAD (kN)	Vehicle percentage
	4,50	75 120	25%
	4,20 1,30	70 90 90	2%
	3,20 5,20 1,30 1,30	70 120 85 85 70	37%
	3,20 5,50 1,30	70 120 90 90	23%
	4,20 1,30 3,50 4,50	70 90 90 100 100	13%

Figure 9 : Set of fatigue vehicles

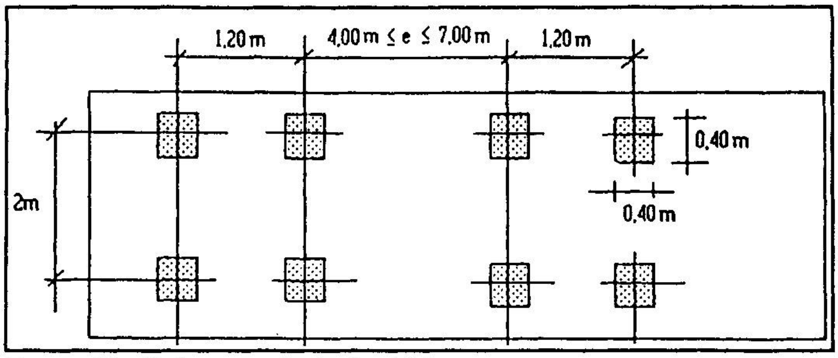


Figure 10 : Fatigue equivalent vehicle

4. COMPARISON OF THE PROPOSED TRAFFIC LOAD MODEL WITH NATIONAL CODES

- The load scaling factors $\lambda_p = \dfrac{M_{Nat.Code}}{M_{EC\ Load}}$ representing the ratio between the bending moments due to national bridge loading codes and to the Eurocode loading model as presently proposed for the example of the midspan moments of a continuous bridge may be taken from fig. 11.
- The differences are enormous due to the fact that the national design rules for the bridges differ as well. A better comparison will be possible as soon as both the action and the resistance side will be harmonized and the design results (e.g. in terms of quantities built in) can be compared.

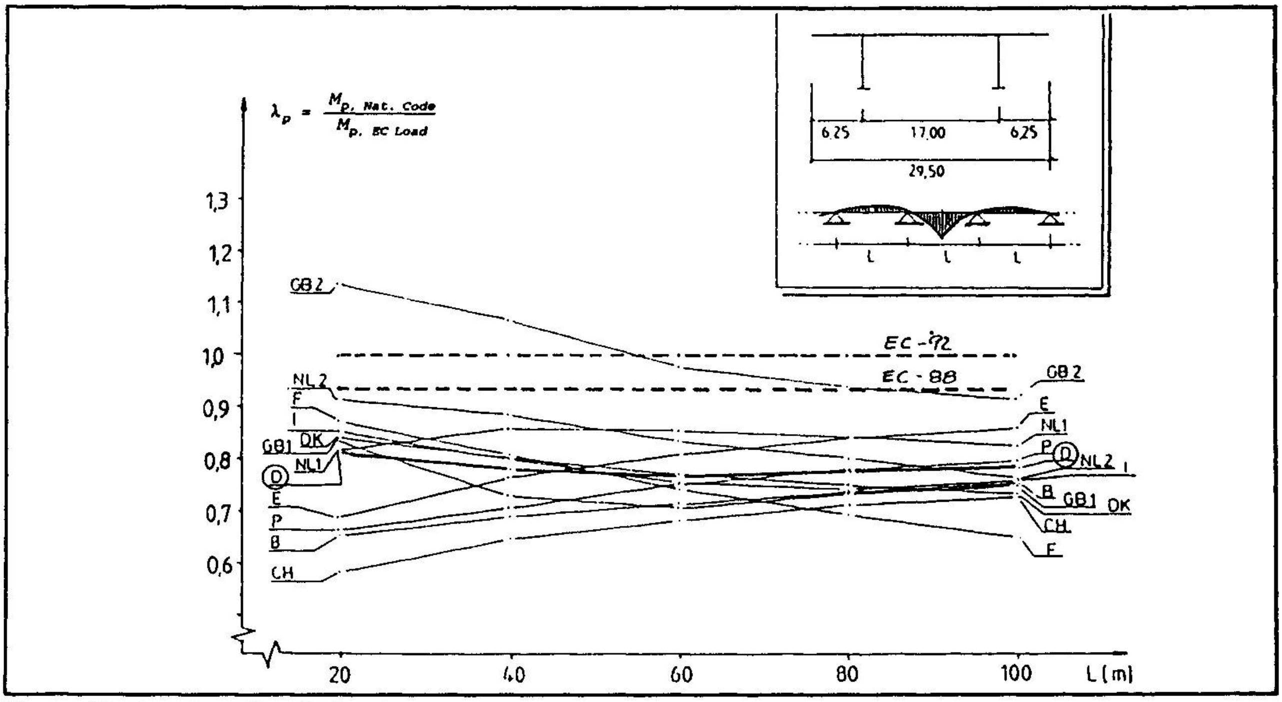


Figure 11 : Load scaling factor λ_p

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