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Safety, Economy and Legal Aspects of Limit State Design - Experience in Eastern Europe

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Summary

The transition from the Allowable Stress (A.S.) design standards to the Limit States (L.S.) design method in Eastern Europe was accomplished a quarter of century ago. At that time it raised problems and disturbances, that are actual nowadays, too. This paper is a review of their results and proposals, which could be perceived now as a "background" for the present application of Structural Eurocodes in Western Europe and in the world over.

1. Introduction

The qualitative methodological differences between the deterministic A.S. and the probability based L.S. design methods cause considerable quantitative differences to the safety and economy of the bearing structures. Here we have in mind especially the "Partial Factors" of the "Actions on Structures". The safety of the structures depends not only on scientific/ technical "Design Rules" of the Structural Codes, but also (in many cases - first of all) on organisation/ procedure "Legal Rules". These two aspects - on one hand "Safety and Economy" and on the other hand "Legal" aspects - have a fundamental meaning to the application of the Structural Codes in every country.

2. The safety and Economy Aspects

2.1 The Point of the Matter

The safety and economy of the bearing structures are insured at two levels: **(1)** By structural modelling of the structural systems/ forms. In these cases it is possible that the more economical (involving less material) structures might be also more safe; **(2)** By structural dimensioning/ calculating of the separate cross sections/ elements. In theses cases the safety and economy are always in inverse interrelation - bigger cross sections are less economical (with more material) and more safe. Of course and vice versa.
The sparing of structural materials by dimensioning of the cross sections: **(1)** is independent of

the design and execution expenditures, insurance and interest of bank credits, etc, but it affects positively all of them, and **(2)** it is an important ecological problem - less steel plants, cement mills, energy, etc.

The advantages and disadvantages of the L.S. design - in comparison with the A.S. design - are manifested mainly by dimensioning of the cross sections. The advantages are mainly theoretical: **(1)** many individual Partial Factors (instead of one), revealing in this way economic reserves, and **(2)** methodological improvement of the structural codes by probabilistic approach. The disadvantages are mainly practical: **(1)** less economical (bigger cross sections, involving more structural material) in many dimensioning cases, and **(2)** the application of the theoretical probabilistic approach is used together with unsystematic deterministic interventions.

These disadvantages are treated in detail analytically and illustrated graphically in [6 - Part One], [1], [2], [3], [4], [5]. Here they are shown pointedly only on fig. 1, 2 and 3.

2.2 Safety - Economy Comparisons

The parametric studies reveal the following characteristics, shown on fig. 1 and fig. 2:

- The L.S. method is insignificantly more economical (respectively "less safe") than the A.S method only when the temporary design forces have the same sign (direction of action) with the permanent forces and exceed them a little. I.e. heavyweight structures - concrete and usually building structures.
- The L.S. method is less economical ("more safe") than the A.S. method in the cases when temporary design forces have the same sign as the permanent forces and are respectively bigger in absolute value. I.e. for lightweight structures - steel, timber and usually bridges, towers, masts etc.
- The L.S. method is less economical ("more safe") in all cases when the temporary forces have the reverse sign of permanent forces and have a bigger absolute value than them. I.e. for all structures - more in lightweight, less in heavyweight.

2.3. On the Initiations and Improvements of L.S. Design

The problem here is to eliminate the less economical cases of the L.S. method. It is possible by the parametric approach [6 - Part Two]:

- First way - in individual cases - by an algorithm for eliminating these individual cases which are less economical.
- Second way - for all cases - by increasing adequately the design resistance, so that to avoid less economical cases when the design forces have the sign of the permanent forces.
- Third way - especially for the cases with reverse sign ($\alpha < 0$) - by individual structural modelling in such a way that the design forces have the sign of the permanent forces.

The reason of these ways is based on the normative and objective position, that the safety of the previous A.S. design method is sufficient, based on practical experience.

2.4. To Conclude the Safety - Economy Aspects

The above mentioned comparisons really disturb the initiation of the L.S. design because it is less economical than the previous A.S. method - on account of needles higher safety than A.S.

method which is proved in practice to be sufficiently safe.

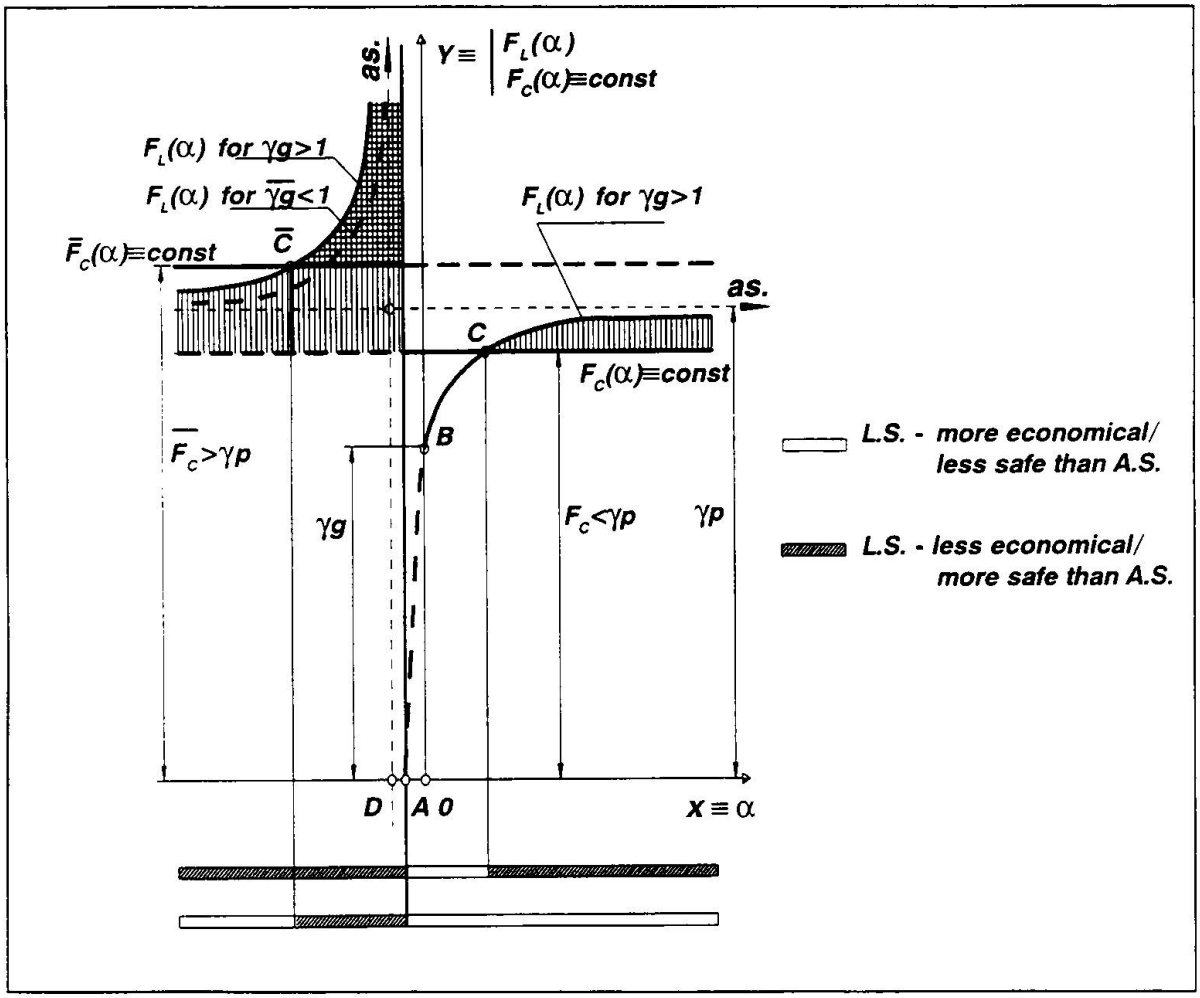

Fig. 1 Characteristic feature of the "Safety and Economy Reciprocity" between L.S. and A.S. design by dimensioning of particular cross sections/ elements in parametric study: α -Ratio of normative (without partial factors) dimensioning the temporary to the permanent forces; F_L - ratio of the acting forces (with partial factors) after L.S. to the forces after A.S.; F_C - ratio of the bearing capacities after L.S. to the capacities after A.S.; γ -partial factors.

The comparisons made for different dimensioning cases - actions, structural materials, types of buildings and structures - give the following practical possibilities: **(1)** for safety/ economy evaluations of existing structures (cross-sections/ elements designed in the past by A.S. method) - to reveal the cases where they are not safe according to the new legitimate L.S. method, and **(2)** for improvements of the L.S. design - by elimination/ reduction of the zones/ cases where it is less economical than the past A.S. method. This comparison (in text, graphics and formulas) would be helpful by the application of the Structural Eurocodes in the individual countries as a "Structural Codes Background". They could be placed in Eurocode 1 - as an **addendum "Recommendations for Evaluation of the L.S. Design Regarding the Compatibility of the Previous A.S. Design Practice".**

3. The Legal Aspects

3.1 The Point of the Matter

For one and the same earthquake impact the differences in different countries are very indicative: in one country were killed 3 persons, in another - 3 000, and in a third - 30 000 (well known cases). The reason for these extremely great differences is not in the lack of "Design Rules" in Structural Eurocodes, but the lack of "Legal Rules"(lows in force).
For example: **(1)** first of all - the role of the central, regional and local state administrations for safety and reliability of the bearing structures of all buildings, etc, **(2)** no construction - without special structural design/ project, **(3)** types and degrees of structural engineers - consultants, designers, controllers, experts, builders, operators, **(4)** certification of the qualification of structural engineers, **(5)** regulation of structural engineering design activities,

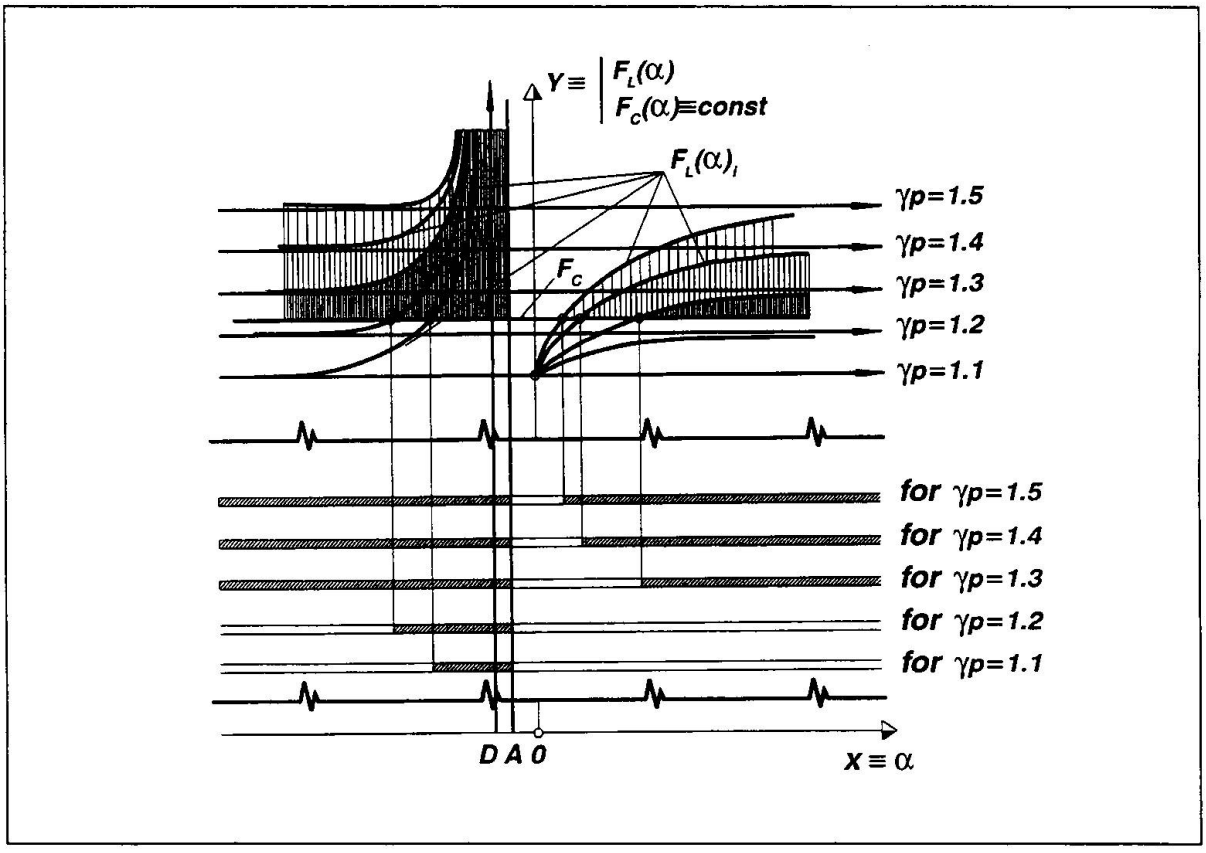

Fig. 2 Safety - Economic Relations between L.S. and A.S. design by cases with different F_L, but one F_C (see fig. 1)

(6) qualitative and quantitative criteria - system and priorities, **(7)** conjuncture factors - specificity and significance, **(8)** design parts of the structural projects - kinds and contents, **(9)** design process - functions and responsibilities of the designers, controllers and experts, **(10)** design teams - interaction and responsibilities, **(11)** role and responsibility of CAD and licenses, **(12)** control by the state - central, regional and local - structural engineering administrations, **(13)** collaboration with structural engineering societies, associations, unions, chambers, **(14)** structural project as an intellectual product - authorship, rights, **(15)** expert appraisal of the

structures of buildings, etc. for the purpose of insurance, leasing, purchase, etc. We have prepared Legal Rules, available at any interest.

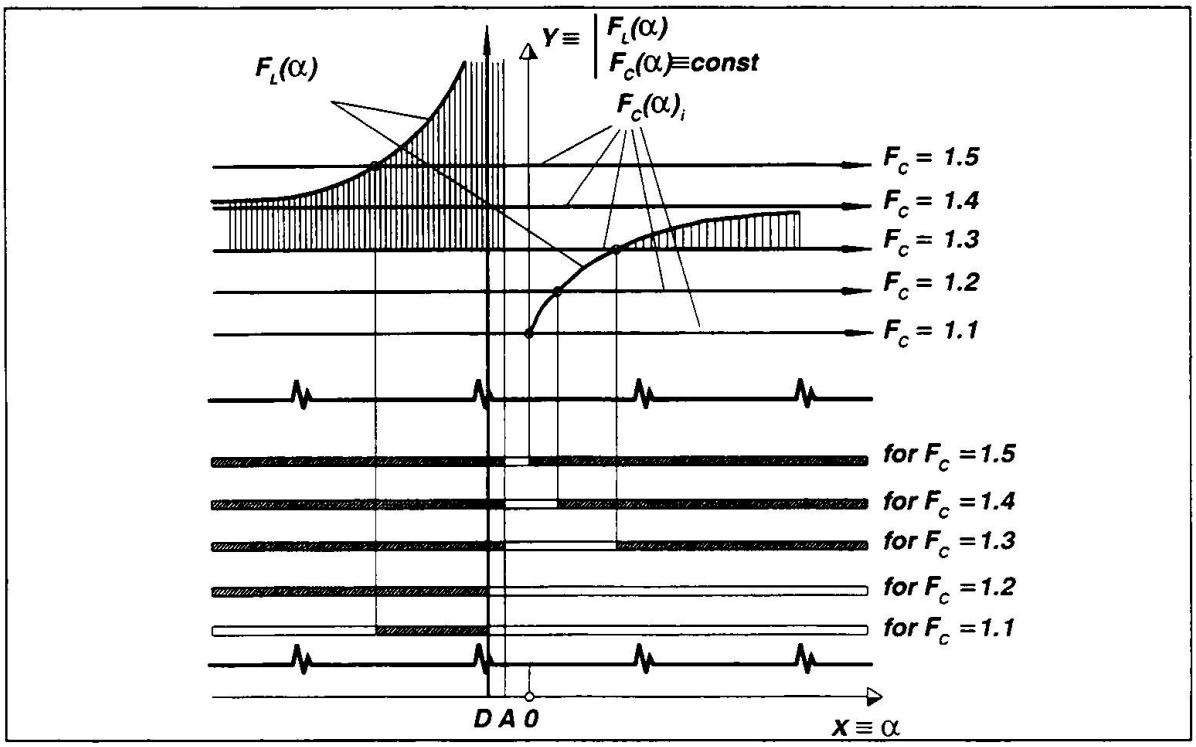

Fig. 3 Safety - Economic Relations between L.S. and A.S. design by cases with different F_C, but one F_L (see fig. 1)

3.2 To Conclude the Legal Aspects

The Legal Aspects concern "Procedure Rules": **(1)** for structural design processes and activities, and **(2)** for structural engineering administration and control. Through them only the Structural Eurocodes could run throughout all the investment activities (planning, design, construction, etc) to achieve their **final economical social goals - Safety and Economy, etc of buildings and all civil engineering works as basic conditions for a qualitative life and work of the people, for a sustainable function and development of the society**. This will mainly manifests the necessary common interest of the structural/ civil engineers and the society/ government administration. These "Legal Rules" could be placed also in Eurocode 1 as another **addendum "General Recommendation for the National Legal Acts to Compulsory Complete Application of the Structural Eurocodes"**.

After the legal acceptation of L.S. Design, respectively of the Structural Eurocodes, almost all of the existing structures (buildings, bridges, etc.), designed according to the A.S. method will turn out to be insufficiently safe from legal point of view. In this case it will be necessary: **in the above mentioned addendum to include a closing mark to legalise the existing bearing structures**. The legal alternative - analyse all of them, to close them for operation or their strengthening - is not acceptable.

4. The Structural Eurocodes and Eastern Europe

The technical standardisation system of the former socialist block, including the structural standards (codes) does not exist any more. For association and integration of these countries into the European Community the basic prerequisite is the harmonisation of the standards, and particularly of the Structural Eurocodes.

The only organised system in the world now for the development and harmonisation of the Structural Eurocodes is TC 250 at CEN. The Countries in Eastern Europe have to join this system as a matter of necessity. But on the other hand their knowledge and experience in this field could be of great use for the western countries as well.

The safety, economy and legal aspects of the bearing structures are of great importance for all countries in the world over. The protection of the society against the subjective errors and administrative negligence, concerning the safety and reliability, serviceability and durability, effectiveness and economy, natural disasters, technological accidents, etc. of the buildings, bridges and all other civil engineering works (by means of Structural Codes - for Structural Design Rules, and Legal Norms - for Structural Engineering Guidance and Control) is professional mission of the structural engineers and social duty of the state administration.

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