ON THE CHOICE OF THE ACCEPTABLE SEISMIC RISK A NEW APPROACH

by

G. Grandori (°), D. Benedetti (°)

S U M M A R Y

The possibility of making a cost-benefit analysis for Earthquake Engineering was examined by the present authors in a previous study. They proposed a simplified method for calculating the monetary costs and the average yearly number of victims. They also presented and discussed a criterion that would lead to new principles for estimating the intangibles.

Here, a brief review will be made of results available in the literature on this topic. Then some developments of the above mentioned method will be illustrated. In particular, an attempt is made to compare two different seismic zones based on the "additional cost per life saved".

I N T R O D U C T I O N

Cost-benefit analyses in earthquake engineering require quantitative estimates for three essential elements:

1) additional construction costs due to seismic design;
2) the direct and indirect costs in money of damage from future earthquakes;
3) non monetary costs for future damage.

The additional construction costs depend on the severity of the codes in force for the zone in question. No systematic research results on additional construction costs are available in the literature. There is, however, a wide area of agreement, evidently based on the experience of designers.

It is generally thought that the costs for seismic design can vary between 2% and 6% of the total construction cost, depending on the type of building and the severity of the codes.

Anyway, analysing construction costs that depend on the severity of the codes is not particularly difficult.

As to the cost in money of future damage, the information available in the literature is not very helpful, being both limited and contradictory. An estimate of earthquake damage

(°) Civil engineering dept.,Politecnico di Milano - Italy.

suffered by the USA in the year 1933-67 leads to an average cost of 14.3 x 10^6 dollars per annum (1). For California the damage was about 1 dollar per inhabitant per annu . An estimate for the future, based on the present population and pro capita investments (2) gives the following figures: 320 x 10^6 dollars per annum over the entire country, 10 dollars per inhabitant per annum for California.

As to the non monetary costs (the "intagibles") there is obviously general agreement that most importance should be given to human life, the risk being measured in terms of expected yearly victims. The criteria that have been proposed in order to introduce quantitavely the intangibles in a cost-benefit analysis can be summarised as follows.

1) Some authors suggest assigning a value in monetary terms for each human life cost: roughly, the average expected contribution of an individual to the gross national product.For highly developed countries this leads to a figure of 100.000 to 150.000 dollars for each death.The same figure would be what the community is willing to spend to save one human life (3,4).

2) Other authors refuse to accept a comparison between money and the loss of human life. They suggest making a direct choice of the acceptable level for the specific risk in question, based only on the expected number of victims. The criteria for making this choice should depend on a comparison with those other inevitable risks to human condition.

Each risk, in this comparison, should be given a suitable weight to take into account those "qualities" of risk that cannot be represented simply by the expected number of yearly victims, e.g. voluntary or non voluntary risks, or the distribution in space and time of the expected number of victims(5).

3) Attemps have also been made to merge these two criteria,by making a comparison between different risks on the basis of particular indices that depend both on economic factors and on the number of victims. The best known of these attempts consists in considering the total output for a certain activity as a measure of the benefit derived by the community from that activity (6). Less well known, but really much closer to our problem, is the proposal to consider the ratio between the cost of preventing a given risk and its average number of yearly victims (7).

4) The present authors have recently proposed a new index, which they consider particularly significant. It may be defin-

ed as "the additional cost per life saved" and depends on the severity of the codes and, of course, the type of building and local seismicity (8). In that study they also put forward a highly simplified method for calculating the costs and the number of lives saved. This present work sets out some developments of that method, both for local seismicity and for calculating the costs. Then a comparison will be made between two zones of different seismicity.

S E I S M I C I T Y

Here the seismicity of a site is defined by means of the following set of hypotheses.

1) The site is in a zone with an uniform distribution of epicentres. The seismicity of the zone is expressed by a correlation between the Magnitude M and the return period T.

2) A correlation exists between the Magnitude and the maximum soil acceleration a_M in the epicentral zone.

3) The maximum ground acceleration in the site is equal to a_M if the distance from the epicentre is less than R, but is zero if the distance is greater than R.

4) R (in miles) = 10+2 (M-4). Earthquakes with $M < 4$ are not considered.

5) The shapes of the response spectra for all earthquakes in the site are the same as that of a normalised spectrum.

The response spectrum for each earthquake is thus constructed by amplifying the ordinates of the normalised spectrum, in order to take into account the value of a_M for each earthquake.

The correlation between M and T was first considered, shown in fig.1 (continuous line, marked SC). It is valid for Southern California and refers to an area of 1000 Km^2. The dashed line, marked EUR-19, will be discussed later.

Two correlations between a_M and M were obtained from the literature, shown in fig.2 with the numbers 1 and 2. They should include the real correlation, if it exists, for Southern California on rocky or firm ground. By hypotheses 3) and 4), the correlations between a_M and T shown in fig.3 were obtained from figures 1 and 2.

The normalised response spectrum used was that shown in fig.4, valid for a_M=0.1 g.

THE ADDITIONAL CONSTRUCTION COST AND THE DAMAGE COST.

Only one type of construction was considered, the same reinforced concrete building already used in the previous study (fig.5). The additional construction cost is shown in fig.6, curve a ,as a function of the lateral force design coefficient. The calculation details are given in Ref.8. The cost for C=0.01 (i.e. approximately the cost of wind design corresponding to the cost in the absence of seismic regulations) was substracted from the total cost. This gave curve b in fig.6. The same curve b is shown in fig.7 in terms of dollars per inhabitant per annum. The other curves in fig.7 are the total costs, taking damage into account, for the two different correlations between a_M and T. The damage cost was evaluated as follows.

The collapse accelerations a_M had already been calculated in the previous study as a function of the design coefficient C. The assumption was then made that damage would begin to show up when $a_M/g=0.05+C$ and would grow linearly with a_M until reaching 100% at which stage a_M equals the collapse value (fig.8). Basing on this assumption the damage in dollars per inhabitant per annun was evalutated. In order to take indirect costs into account, damage was increased by 50%. Total damage costs are shown in fig.9.

They show good agreement with the estimates given in the introduction.

ADDITIONAL COST PER SAVED LIFE.

Starting from the total costs of fig.7, the curves $\Delta D/\Delta L$ of fig.10 were obtained by proceeding as in the previous study. The incremental ratio $\Delta D/\Delta L$ represents the additional cost per life saved, and is a function of C. The dashed lines show the results obtained by only taking into account the additional construction costs, and neglecting the damage.

The curves at the top left of fig.10, marked EUR-19,were obtained in the same way, only changing the correlation between M and T. In fact they are derived from the seismicity defined by the dashed line of fig.1, valid for European zone number 19, which includes Central Italy.

These last results serve only to show up the sensibility of the index $\Delta D/\Delta L$ to the seismicity of the zone, and cannot in any way be referred to real conditions in Central Italy, for which there is neither an average response spectrum nor a known correlation between a_M and M.

C O N C L U S I O N S

As far as the quantitative aspect of this research is concerned the authors feel that more work has to be done before it becomes completely reliable. For the moment, only some generic comments can be attempted.

1) If the correlation between a_M and M is known along with the uncertainties shown by the two different curve in fig.2, the dispersion of the final results is not excessive.

2) Damage costs do not greatly influence final results, so that damages could be taken into account by means of more simplified schemes.

3) The correlation between magnitude and the return period T has proved to influence significantly the results, and this could permit an improvement in the differentiation between various seismic zones so far as the severity of design regulations are concerned.

4) The problem of the choice of the acceptable seismic risk is still,of course, very much open to discussion. It was not however the intention of the present authors to arrive at a solution. It is simply to be hoped that, in the future, the index $\Delta D/\Delta L$ may be of some help, together with others that have been or may be proposed, in making choices that become more and more satisfactory.

ACKNOLEDGEMENTS

The authors wish to express their gratitude to Prof.E. Rosenblueth for his encouragement and suggestions.

BIBLIOGRAPHY

1) J.D. CRUMLISH and G.F. WIRTH: A preliminary Study of Engineering Seismology Benefits.U.S. Department of Commerce, Rockville, Maryland, 1967.

2) "Earthquake Engineering Research" Nat.Academy of Sciences, Washington, 1969.

3) E. ROSENBLUETH: "Confiabilidad y utilidad en ingenieria", UNAM, MEXICO, 1970.

4) J.P. HOLLINGS:"The Economics of Earthquake Engineering" Bull. New Zealand Society for Earthquake Engineering,Vol.4 N.2, 1971.

5) J.H. WIGGINS and D.F. MORAN: "Earthquake Safety in the Ci-

ty of Long Beach Based on the Concept of Balanced Risk, Sept. 1971.

6) C.STARR: "Social Benefit Versus Technological Risk",Science, Vol.165, Sept.1969.

7) M. POTIER: "Energie et sécurité", Paris, Mouton 1969.

8) G. GRANDORI and D. BENEDETTI: "On the Choice of the Acceptable Seismic Risk" 4th European Symposium on Earthquake Engineering, London, Sept. 1972.

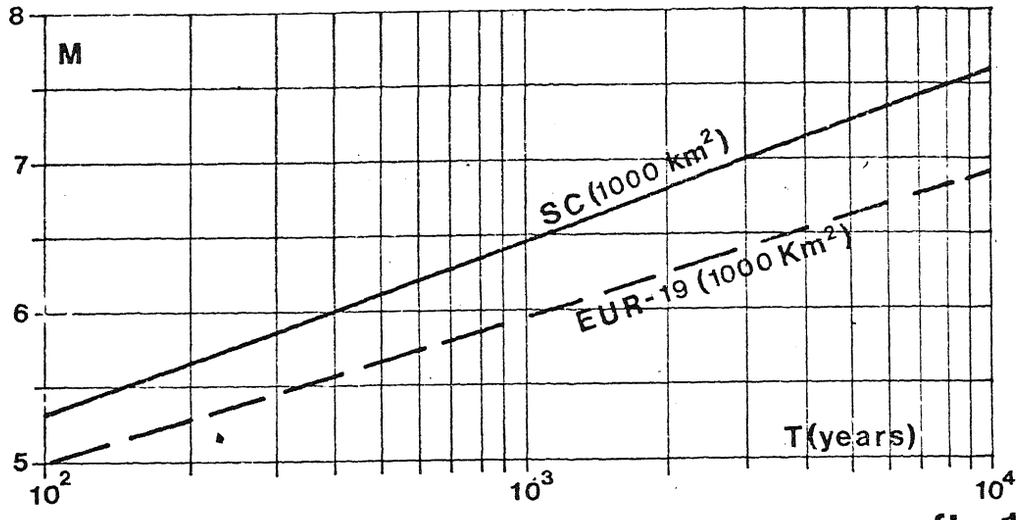

fig.1

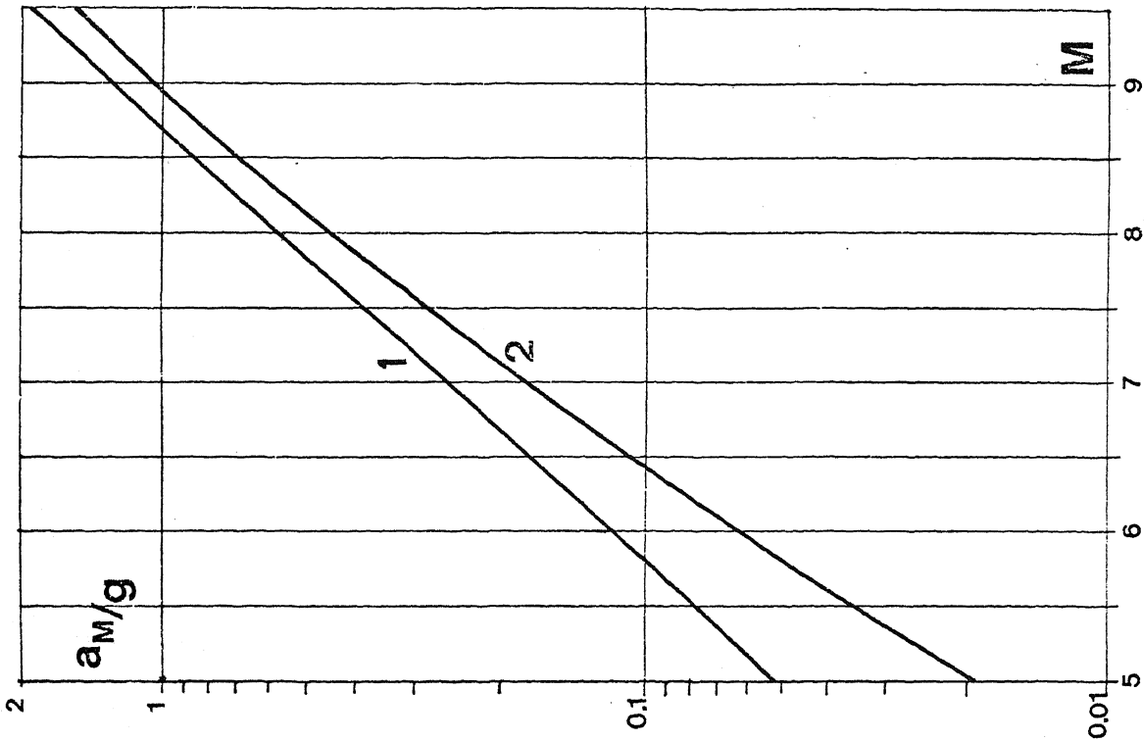

fig. 2

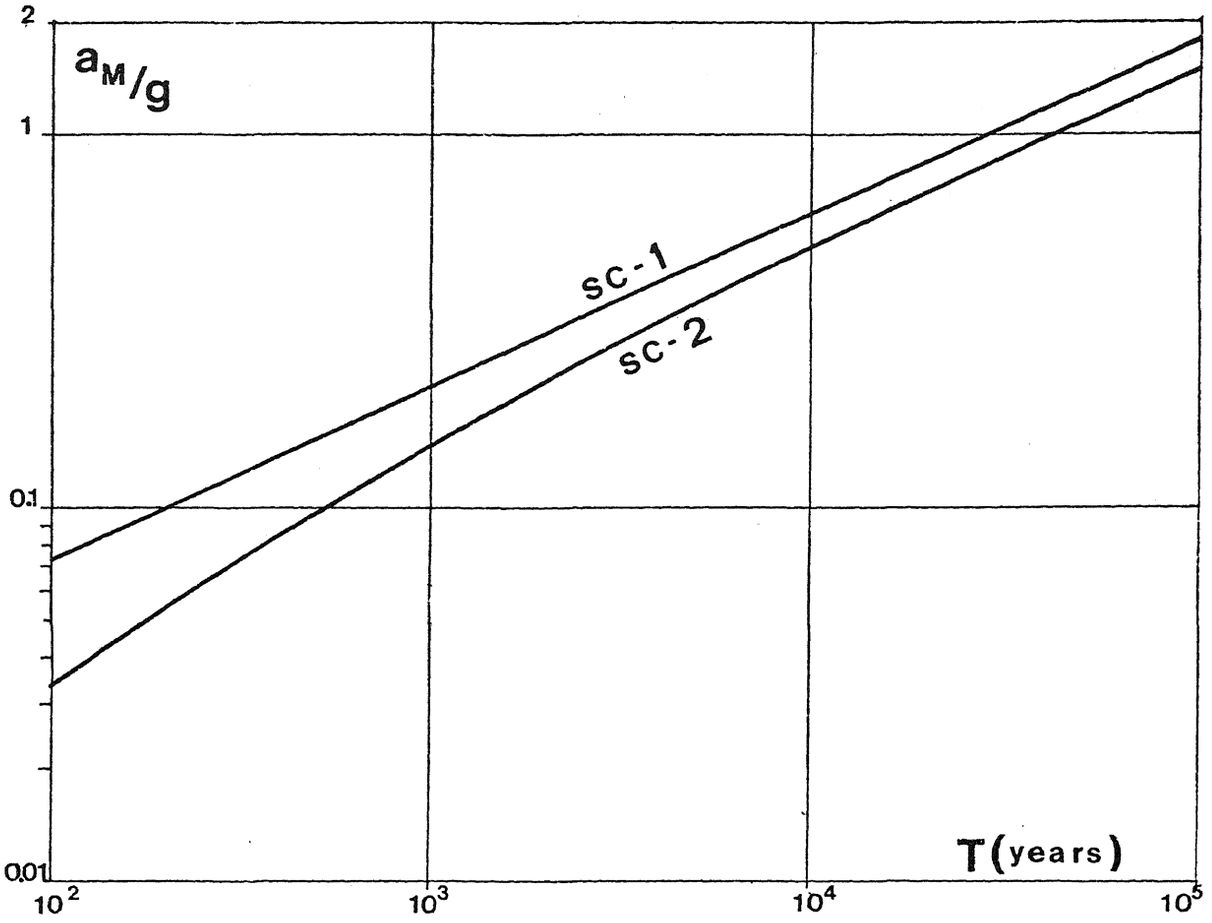

fig.3

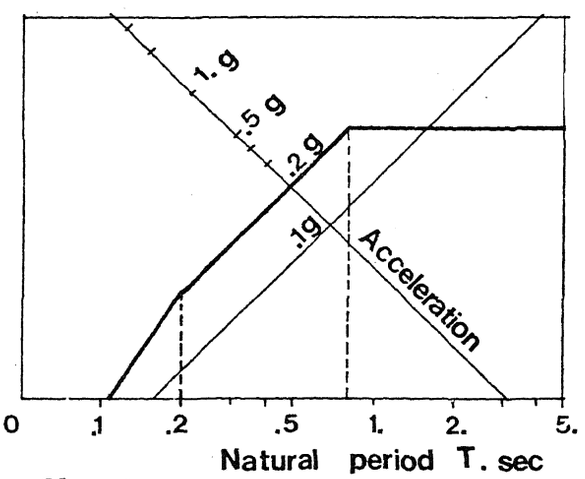

fig.4

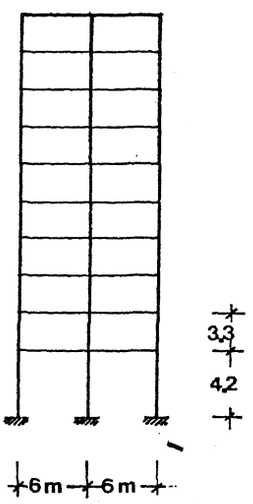

fig.5

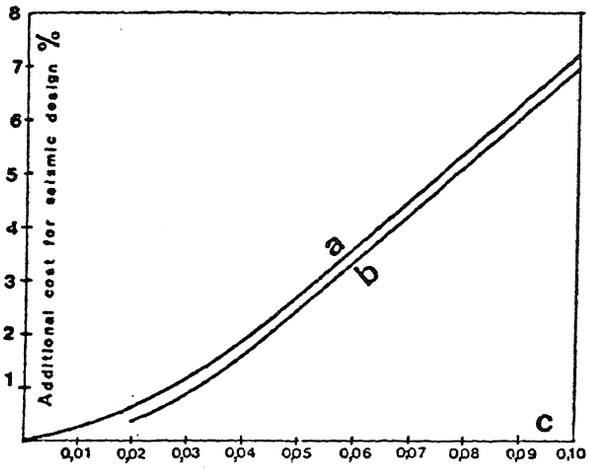

fig.6

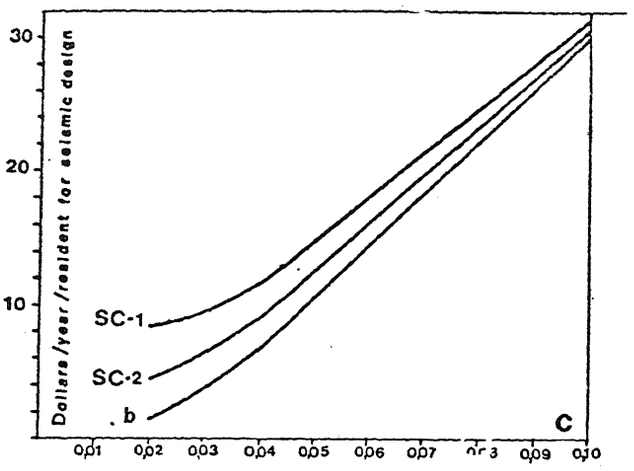

fig.7

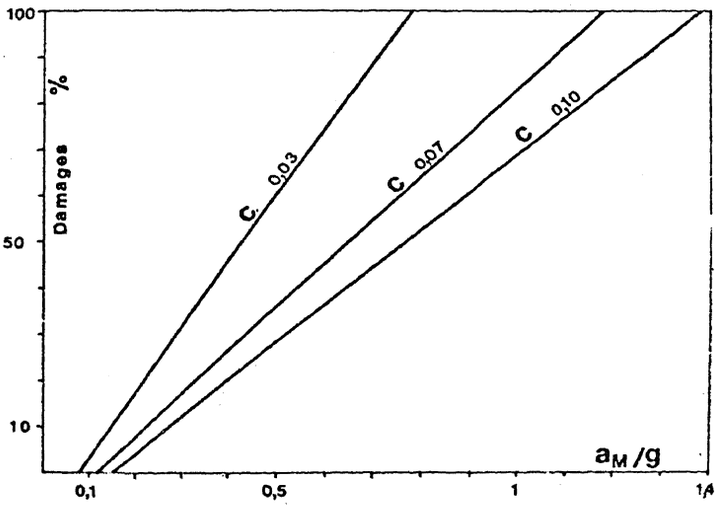

fig.8

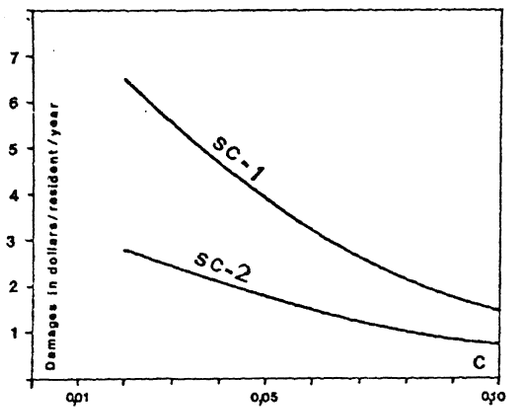

fig.9

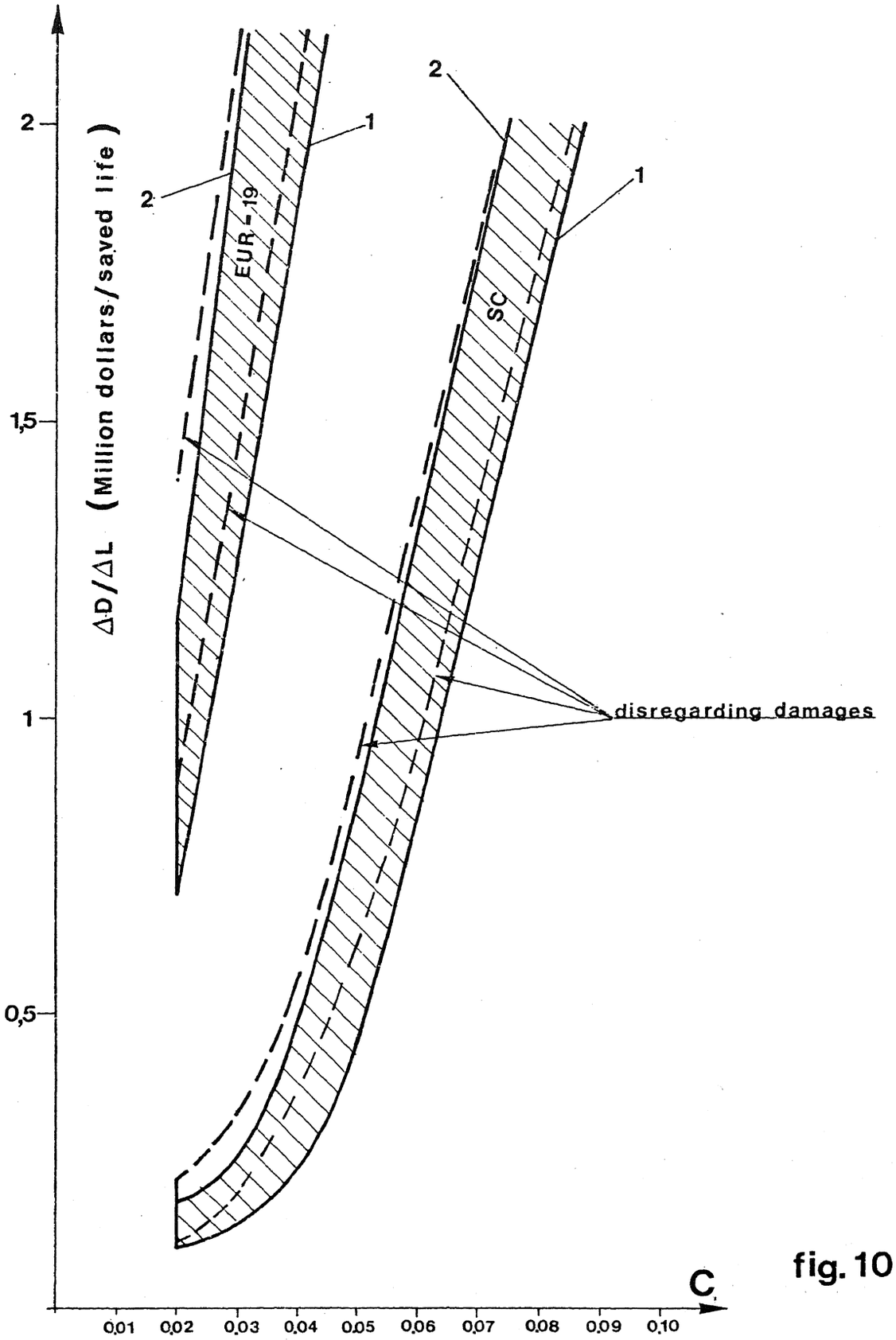
ΔD/ΔL (Million dollars/saved life)
2
1,5
1
0,5
EUR - 19
SC
1
2
disregarding damages
C
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,08
0,09
0,10

fig. 10