PROPOSAL FOR A VALUATION PROCESS FOR THE ASSESSMENT FOR BIOMECHANICAL EXPERIMENTS

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INTRODUCTION

Despite the great number of biomechanical experimentel results available, it is difficult to provide valid loading limits. There is too much variation in the test conditions, in the material examined, and in the type of evaluation. In addition, the loading values determined for one particular accident type can only under certain conditions be applied to another type of accident.

In this study, proposal is made of a process by which the quality of conclusions reached in a biomechanical investigation may be numerically designated. This method has up to now been tested on 30 investigations. Determination of the qualitiy ranking has been presented using 10 selected investigations. The investigations selected vary according to material investigated, loading limit investigated, and test conditions.

Furthermore, demonstration is made of combination of various experimental results for better determination of a loading limit. By means of the previously determined quality of the experiments, the degree of safety of loading limit can be arrived at. The procedure is presented using the example of serial rib fractures, and the results are discussed.

THE STRUCTURE OF THE VALUATION SYSTEM

The following basic requirements must be fulfilled in the design of the valuation structure:

- Applicability to a broad range of investigations
- Differentiated valuation of differing standpoints
- Clear-cut and capable of verification
- Guarantee of identical results for comparable investigations
- Extensive objectivity of the evaluation, i.e., independent of the evaluator.

The standard of the results of an investigation is determined by three influencing factors:

" P " : the type of test object for experimentation
(e.g., human shin)

" G " : expression of the loading limit (e.g., mean value and distribuation range of a breaking load)

" V " : circumstances of the test conditions (e.g., pendulum impact test)

The combined individual valuation of the three valuation components " P ", " G ", and " V " results in the specific quality $Z_{(N)}$ of a single investigation, see Fig. 1. The value of $Z_{(N)}$ can lie between 0 and 100 %. The specific quality alone does not take into account the number of the tests conducted.

The number of tests conducted leads through the weighting function $F_{(N)}$ in conjunction with the specific quality $Z_{(N)}$ to the total quality Z_N, see Fig. 2.

$$Z_N = Z_{(N)} \cdot F_{(N)}$$

The valuation function $F_{(N)}$, Fig. 3, must satisfy the following requirements:

- The increase in Z_N must be greater for a small number of tests than for a larger nuber of tests
- $F_{(N)}$ must asymtotically approach a finite limit value (max 1)
- The smaller the specific quality $Z_{(N)}$, the greater the required number of the tests for reaching the same value of Z_N
- For $Z_{(N)}$ = 100 %, 40 tests should suffice to arrive at a total quality of 95 %.

The function $Z_N = Z_{(N)} \cdot F_{(N)}$ is depicted in Fig.4.

The valuation components " P ", " G ", and " V " are further broken down into valuation units. The valuation component " P " (test object) includes the following units: The age P_A, the condition P_K, and the suitability P_T. The breakdown of " P " and the further breakdown of P_A and P_T can be seen in Fig.5.

The units of the valuation component loading limit " G " are simultaneously valuation criteria, see Fig. 6. The breakdown of the valuation of the test conditions " V " can be taken from Fig. 7. Fig. 8 shows the complete combination of the valuation criteria to form the total quality Z_N.

Valuation scales have been developed for the individual criteria which have been closely oriented to the goal of biomechanical experiments.

Without going into a detailed description of the valuation scales at this point, the following principles serving as orientation for the valuation components " P ", " G ", and " V " can be listed:

Valuation component " P " :

- Comparison of the age spectrum of the experimental material with the accident type considered
- Comparison of the mean age of the experimental material with the accident type
- Relation of the condition of the experimental material to normal condition. Equally less suitable is material in too good or too bad condition.
- Valuation of the experiments for a individual bodily part, for function groups, or for the entire body
- Valuation of the experiments for volunteer persons, cadavers, or animals.

Valuation component " G " :

- Thethreshold of injury (loading limit) must be clearly recognizable
- The mean loading limit has been reached when just as many test subjects are injuered as remain uninjuried
- Valuation of the distribuation range of the loading limit. It is determinded on the one hand by specific characteristics or on the other by unsuitable selection of the physical measured quantity.

Valuation component " V " :

- Valuation of the similarity to the real accident type
- Comparison of the loading relationships
- Consideration of form and stiffness of the loading body.

In order to arrive at a meaningful total quality, the valuation criteria must be combined, and must be weighted and calibrated according to their importance. In this process of combination, basic differentation must be made between those critera which can compensate for each other (e.g. age and condition), and those criteria which cannot be compensated, (e.g. use of animals instead of humans). The criteria or units which can compensate for each other are combined by addition after weighting. Criteria or units which cannot compensate for each other are combined by multiplication in such a way that the total valuation always depends on the worst valuation.

INDIVIDUAL VALUATION RESULTS

Ten experiments showing considerable variation have been chosen for purposes of discussion of the valuation process. Volunteer persons, cadavers, and animals are represented in the valuation component " P "; the test conditions in " V " vary between sled tests, fall tests, and static loading; and the type of loading is with reference to skull, brain, chest, liver and kneecap.

An order of ranking results among the individuel valuation components, based on logical and reasonable principles. This ranking allows an arrangement based on verry good, good, average, poor, and very poor. The ranking is clear and understandable for the specific quality $Z_{(N)}$ and for the total quality as well. The ranking of the individuel valuation components as well as for the specific quality and the total quality is shown in Fig.9.

For improvement of the applicability of the method, the influence of the valuator's subjectvity must in particular be examined. For this reason, a further experiment is planned in which a large number of valuators performs the valuation using the same system. Should this result in comparable outcomes, then the method could be applied for the evaluation of most of the exiting biomechanical experimental results.

CERTAINTY OF LOADING LIMIT

Several experiments, frequently with varying distribuations ranges, were available for almost every one of the loading cases. It appeared useful to combine several experiments in order to obtain a standard for determining the certainty of a loading limit.

For purposes of the project, 8 exemplary experiments on the loading limit for rib serial fractures of a car passenger were selected. Differentiation has been made between the three following loading cases:

- " G " : thorax loading by belt forces for belted passengers
- " T " : thorax loading for unbelted passengers
- " L " : lateral thorax loading.

Fig. 10 shows the distribuation of the nonweighted experiments, broken down to the subgroups " T ", " G ", and " L ".

A simple valuation is possible by indicating the loading values which have been assured by the also indicated number of experiments, See Fig. 11. An absolute maximum of 580 to 600 daN results. Six experiments support this value. A relative maximum lies at 423 to 431 daN.

The conclusions can be drawn from this diagram:

- Rib serial fractures are to be expected between 177 to 1020 daN (belt or thorax force), regardless of the direction of impact.
- Rib serial fractures are to be expected between 177 and 681 daN for frontal intodruction of force and occupant not using seat belts.
- Rib serial fractures are to be expected between 315 and 681 daN for frontal loading caused by belt forces.

A value for the certainty of the conclusions may be determined by consideration of the quality of the individuel investigation.

Fig. 12 shows the Quality of the experiments, and Fig. 13 shows the combined quality for the respective loading values, broken down once again according to the three loading cases. If one chooses only the loading case " G ", it is shown here that the value between 450 and 600 daN can be regarded with very good certainty for rib serial fractures from frontal belt loading.

CONLUSIONS

It has been shown that it is possible to determine the quality of the results of one biomechanical investigation in comparison to others. It was further demonstrated that it is possible to combine the results of several experiments in such a way that the certainty of a loading limit can be considerably more sharply defined than was possible until now. The following advantages would result upon application of this method to a large number of experiments - perhaps with some modifications or improvements:

- Poorly qualified experiments would no longer lead to an unnecessary increase in the distribution range.
- Minimum requirements could be placed on the quality for the execution of biomechanical experiments.
- Only those experiments would then have to be conducted which could contribute to a significant improvement of the certainty of a loading limit.

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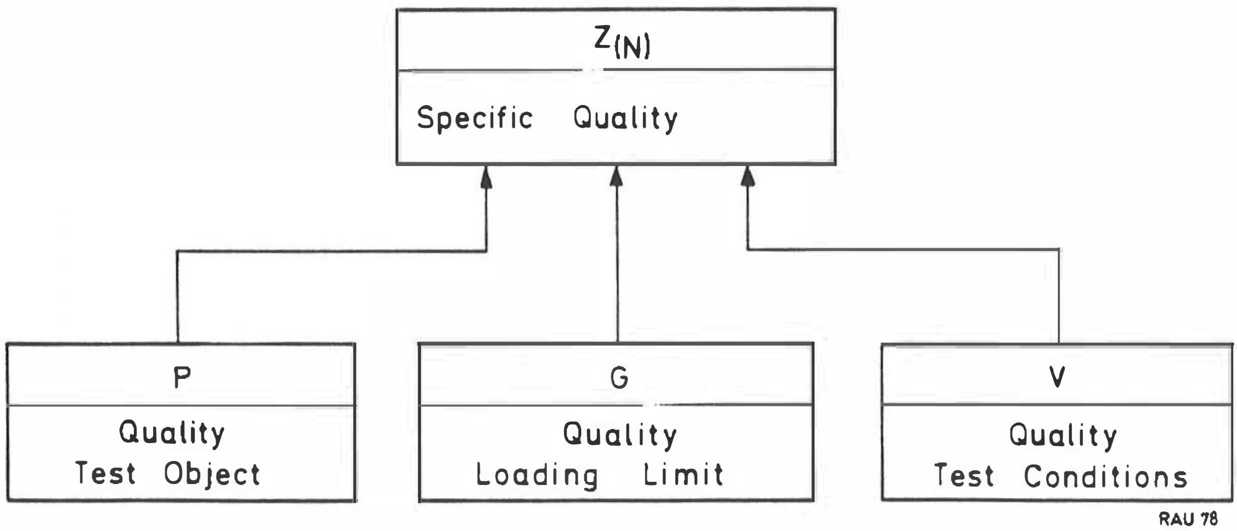

Fig. 1 Breakdown of the valuation of the specific quality

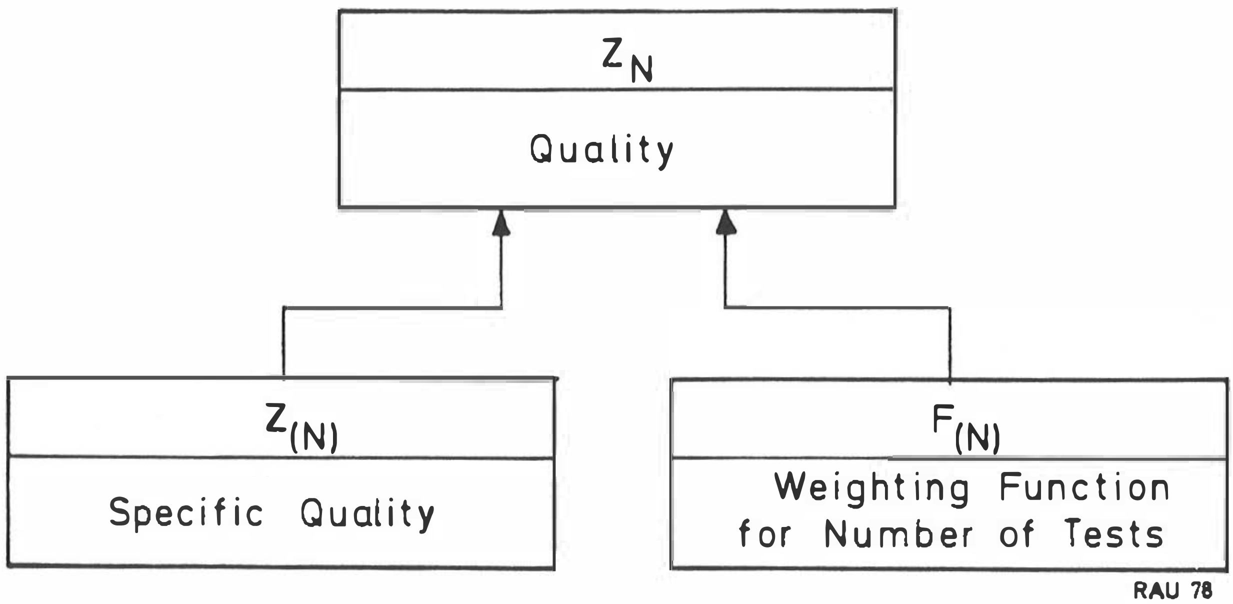

Fig. 2 Combination of the specific quality and number of tests

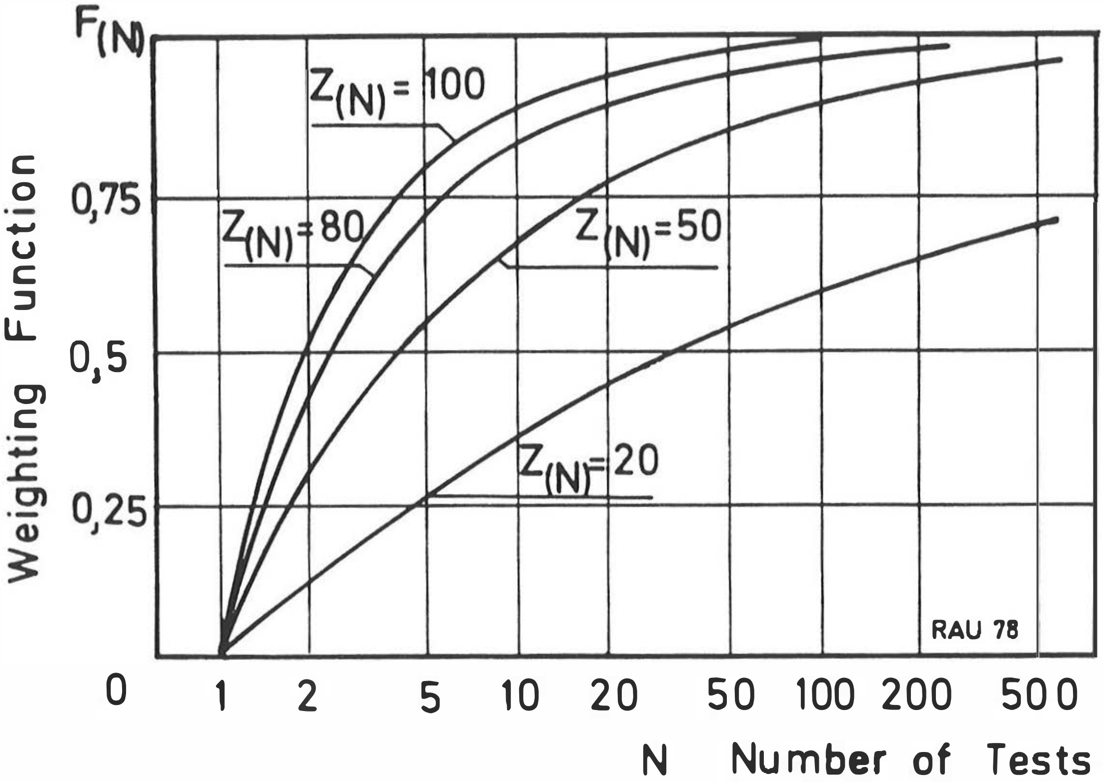

Fig. 3 Weighting function depending on number of tests and specific quality

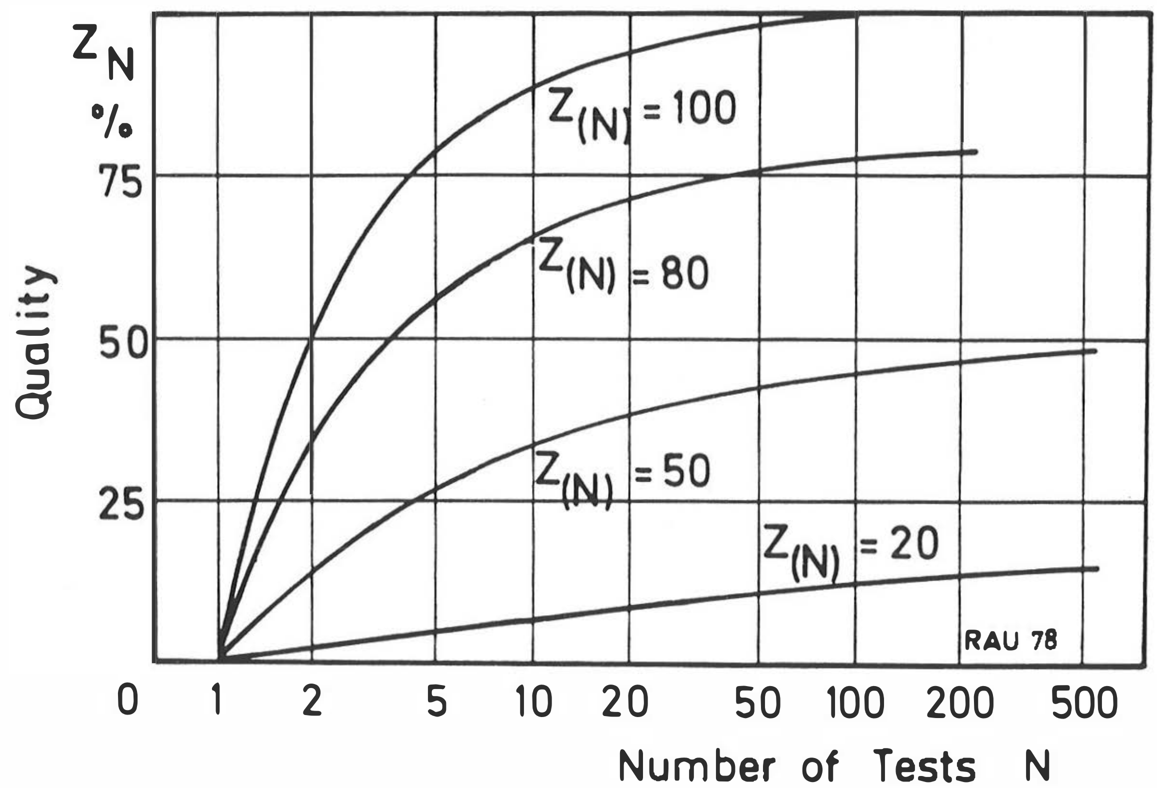

Fig. 4 Total quality depending on $Z_{(N)}$ and number of tests

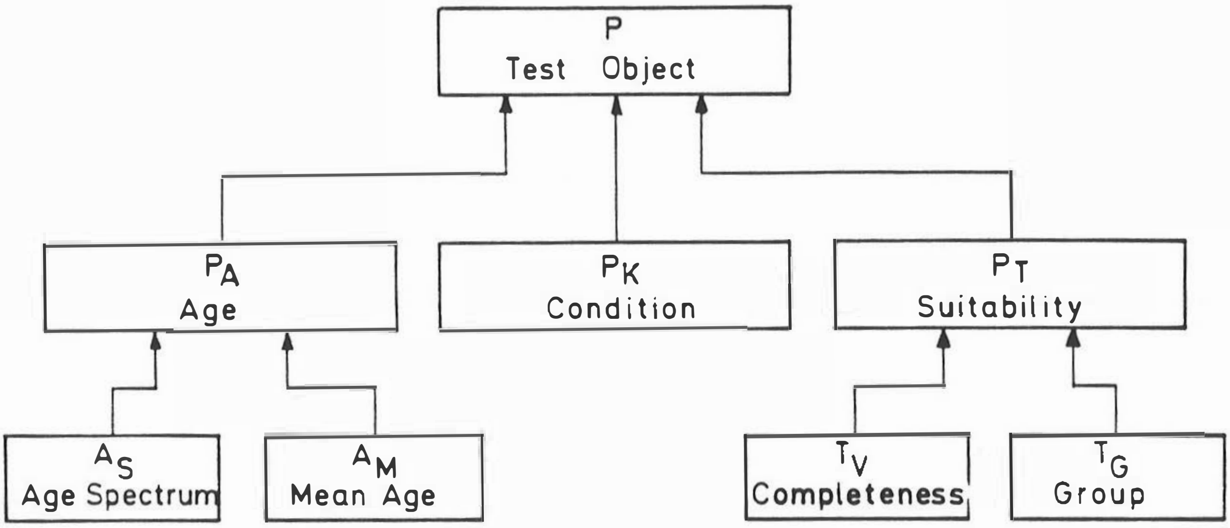

Fig. 5 Breakdown of the valuation of the test object

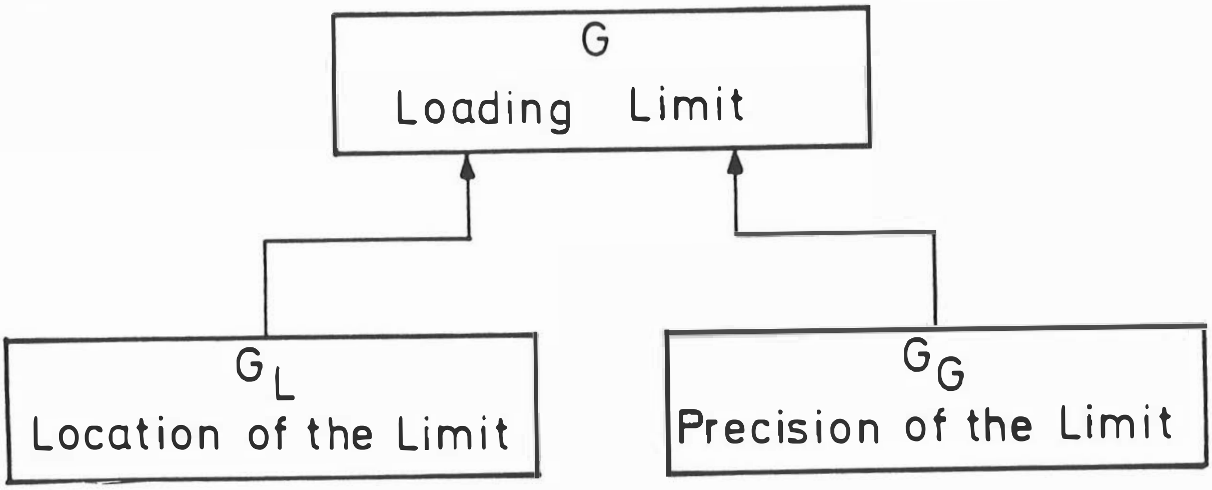

Fig. 6 Breakdown of the valuation of the loading limit

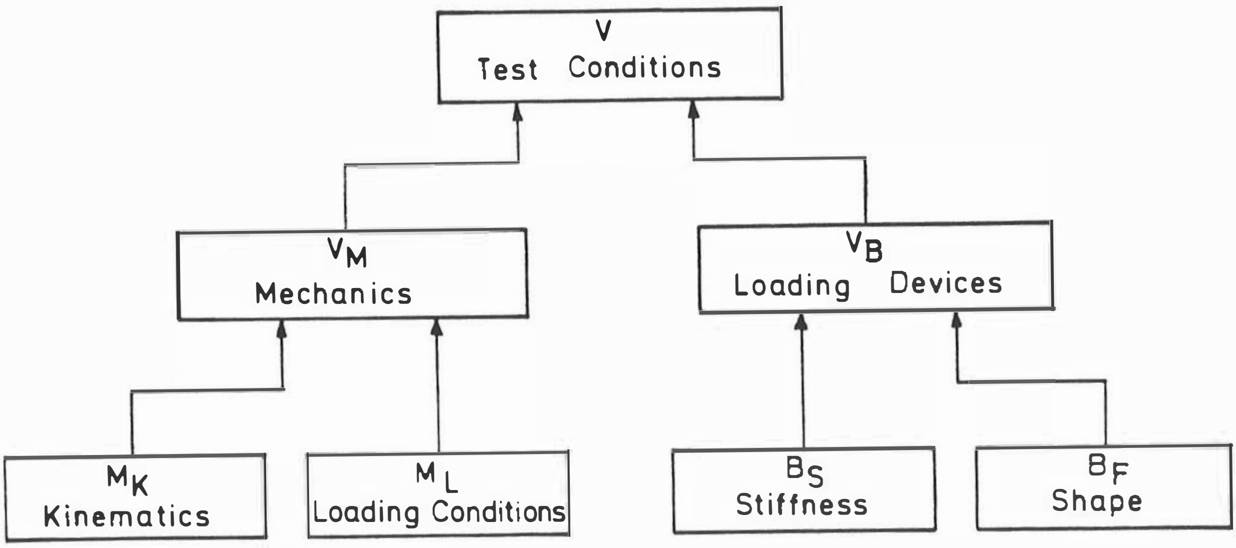

Fig. 7 Breakdown of the valuation of the test conditions

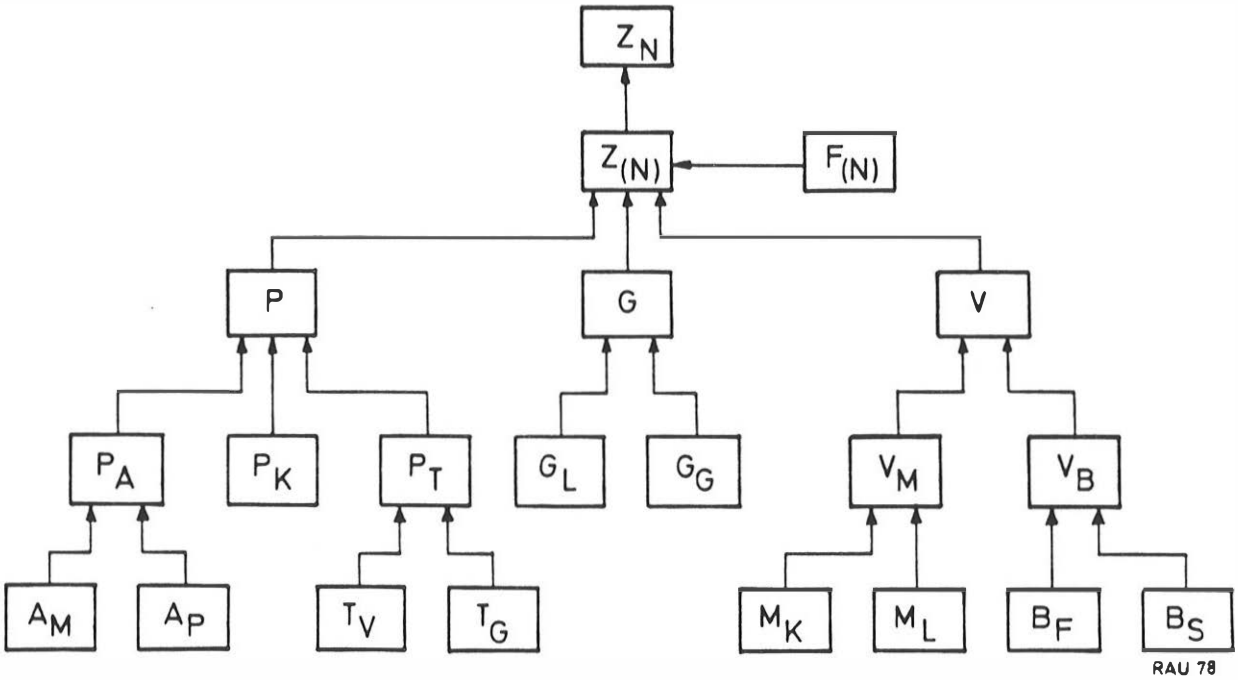

Fig. 8 Criteria combination for the total quality

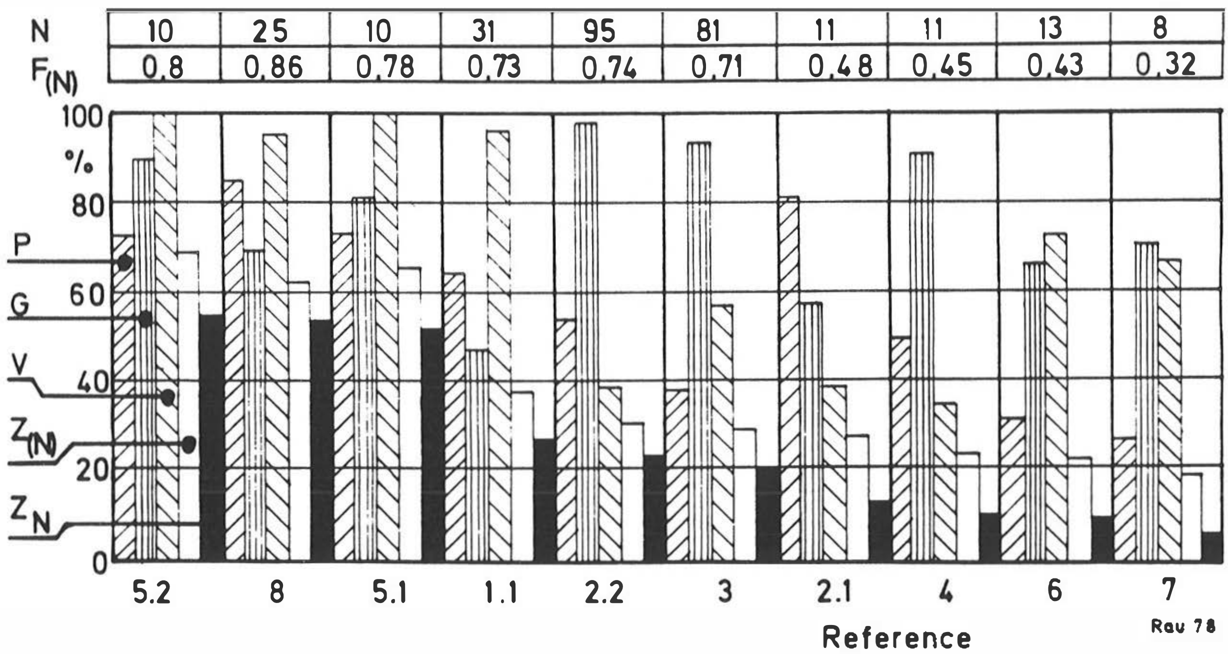

Fig. 9 Ranking of " P ", " G ", " V ", $Z_{(N)}$, and quality Z_N

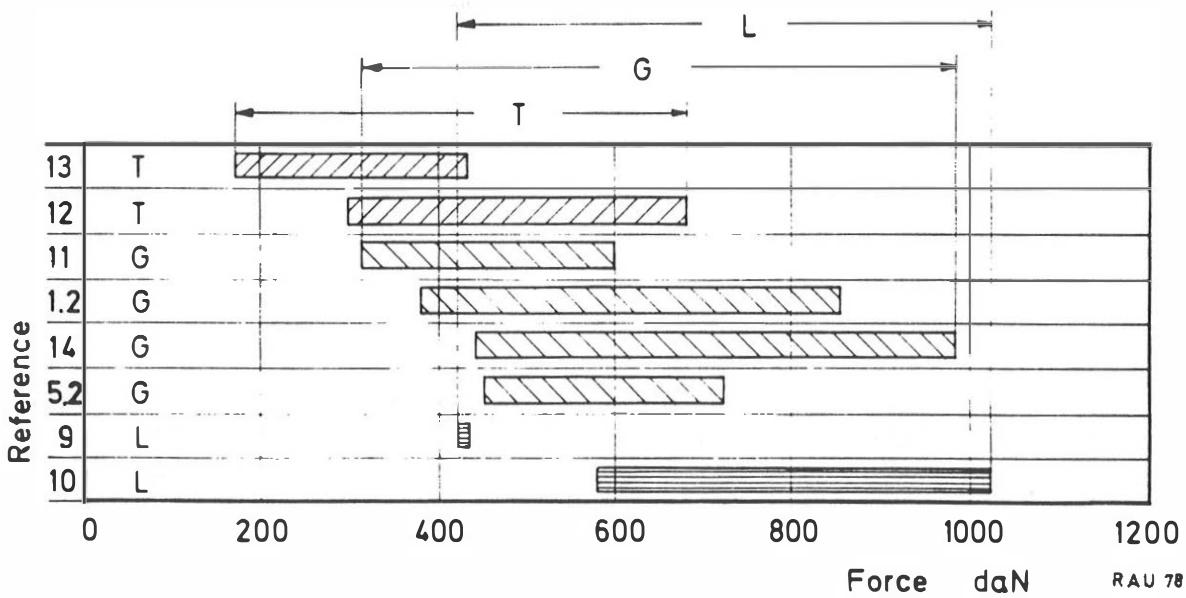

Fig. 10 Unweighted loading spectrum for rib serial fractures

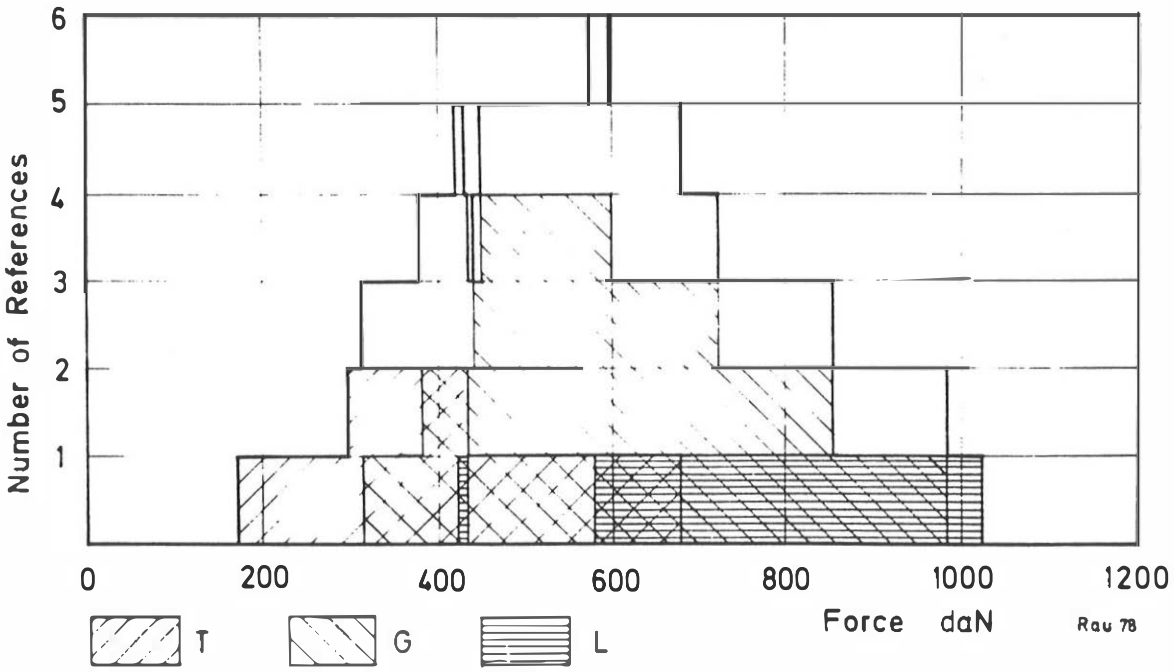

Fig.11 Superimposed unweighted loading spectrum for rib serial fractures

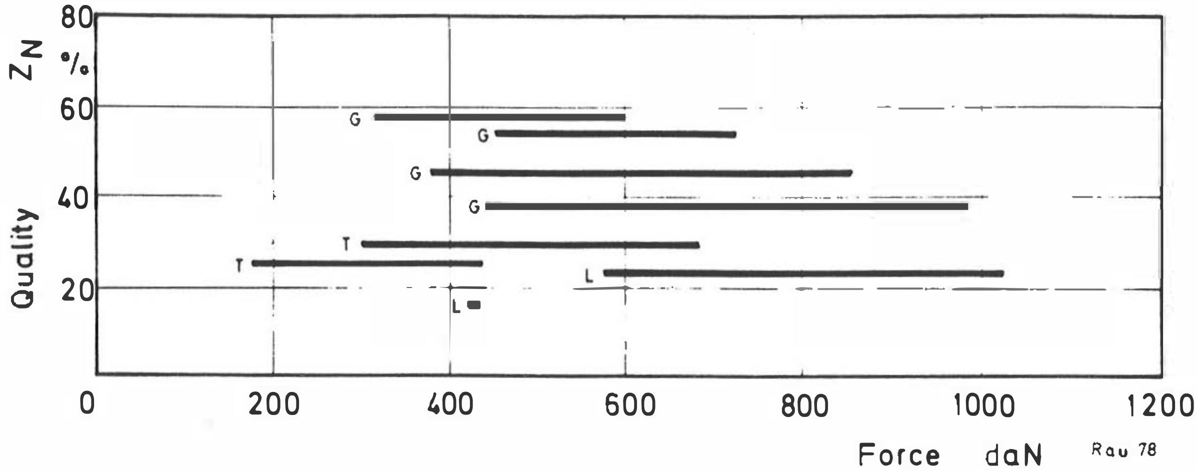

Fig. 12 Weighted loading spectrum for rib serial fractures

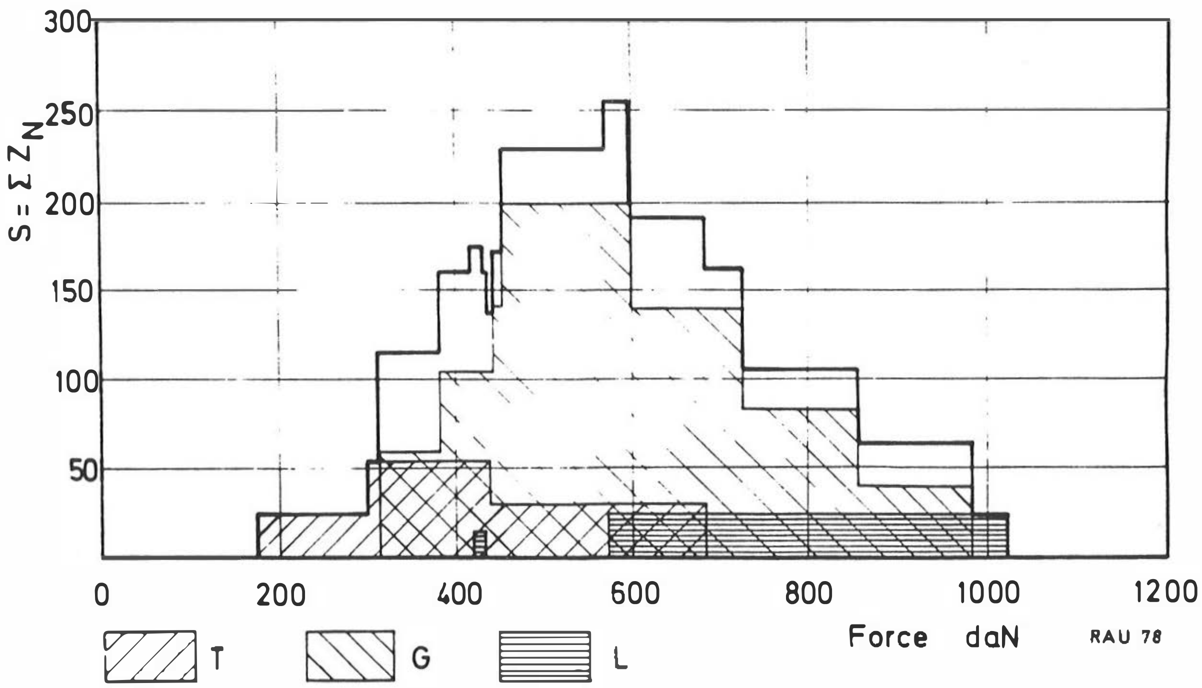

Fig. 13 Superimposed weighted loading apectrum for rib serial fractures