Zeitschrift: IABSE proceedings = Mémoires AIPC = IVBH Abhandlungen
Band: 6 (1982)
Heft: P-49: Durable structures: efforts of the German Federal Railway

Artikel: Durable structures: efforts of the German Federal Railway
Autor: Siebke, Hans
DOI: https://doi.org/10.5169/seals-36655

Durable Structures: Efforts of the German Federal Railway

Ouvrages durables: pratique des Chemins de fer fédéraux allemands

Dauerhafte Bauwerke: Vorgehen der Deutschen Bundesbahn

Hans SIEBKE
Ministerialrat, Professor Dr.-Ing.
Deutsche Bundesbahn,
Frankfurt,
Bundesrepublik Deutschland

Prof. Dr.-Ing. Hans Siebke (60), Ministerialrat, seit 1966 Referent für Kunstbauten, Erd- und Grundbau, Bahnübergänge und Baurechtsangelegenheiten in der Hauptverwaltung der Deutschen Bundesbahn, Frankfurt (Main), Bundesrepublik Deutschland. Studium des Bauingenieurwesens und wissenschaftlicher Assistent an der TH Hannover, 1956 Promotion, 1958 zweite Staatsprüfung.

SUMMARY

Apart from the expenditure for its erection, the durability of a structure has a decisive influence on the costs involved. This depends substantially upon the constructional integrity of all its structural members. The requisite rules for creative designing cannot be reduced to mathematical forms. This paper discusses the efforts of the Deutsche Bundesbahn aimed at designing durable permanent structures.

RÉSUMÉ

La durabilité d'un ouvrage a, à côté des dépenses de construction, une influence déterminante sur les coûts. Elle dépend essentiellement de la conception de tous les éléments de l'ouvrage. Les règles d'une bonne conception d'un projet ne peuvent être appréhendées mathématiquement. L'auteur décrit la manière dont les Chemins de fer fédéraux allemands tentent à parvenir à une conception d'ouvrages durables.

ZUSAMMENFASSUNG

Die Dauerhaftigkeit eines Bauwerkes hat neben den Ausgaben für die Erstellung entscheidenden Einfluss auf seine Kosten. Sie hängt wesentlich von der konstruktiven Ausbildung aller Bauwerksglieder ab. Die erforderlichen gestalterischen Regeln sind nicht mathematisierbar. Es wird beschrieben, wie die Deutsche Bundesbahn versucht, die Konstruktion dauerhafter Bauwerke zu erreichen.

INTRODUCTION

In contrast to the rules of technology applied for verifying their stability, the technical rules governing the configuration of structures are merely defectively formulated. To remedy this shortcoming Deutsche Bundesbahn (DB) has developed a system of regulations for projecting railway structures, which provide for

- hitherto proven constructive detail solutions to be combined to form a functional total;
- an evaluation of a structure to be made in terms of its constructional maturity by means of constructive checkpoint readouts;
- the continuous training of engineers by guiding them towards consistent constructive structures design; and
- a cyclic process to be maintained for continually improving the constructive design.

This systematical approach considers in particular the psychological difficulties experienced in the collaboration of engineers performing varying assessment and evaluation assignments.

DIMENSIONING

Conventionally, the stability of a structure is verified by means of a mathematical calculation. Now and again, experimental trials are carried out in support. In all cases, however, statements are made and assumptions come to which relate to a future structure, a structure as it ought to be after having been comissioned.

Only in exceptional cases is time considered as a dimension, such as for determining contraction and creep or material fatigue. Vibrational calculations of the determination of stresses due to forces from dynamic masses are rarely carried out; it is common practice to apply equivalent forces for these effects. The variability of the effects and dimensions over long periods is usually allowed for in terms of safety increments. The problems arising in allowing to a great extent for time dependence will become particularly pronounced when debating a new safety concept based on theoretical probability.

The traditional approach in civil engineering satisfies the utilization requirements and the economic prerequisites in many fields, but it has at the same time promoted the following misconceptions on the part of specialists as well as laymen:

- because the time constituent for verifying stability may either be extensively substituted or neglected it is, therefore, also of no significance for civil engineering;
- structures hold forever - at least if they were built correctly - forever is far too long - the builders are making it too easy for themselves, they ought to build less securely - then building would not be so expensive.

These or similar misconceptions overlook

- that every structure must be maintained during its period of utilization. The maintenance costs and period of practical utilization depend upon the conceptions for temporal modifications which the civil engineer may have had during the constructive design of his project, and

- although the safety of a structure for its users, the public and the environment is conceived and allowed for in the dimensioning method, its guarantee can only be realized by means of continuous control during this period.

In this regard, two aspects of civil engineering become evident which ought not to be masked by the increasingly sophisticated dimensioning conceptions: Designing and backfeed control. Deutsche Bundesbahn (DB) is systematically engaged in the perfection of the triad

Dimensioning - Designing - Backfeeding

in order to have bridges that serve their purpose, are ecologically beneficial, easy to maintain and long-lasting, in other words, goodlooking, practical and economic bridges.

DESIGNING

Designing is to specify the dimensional proportions as a function of the jobs to be performed, the building materials and the limiting conditions. The dimensional proportions and the building materials determine the supporting behaviour under the effects to be expected such that the constructively specified dimension regarding the bearing stability may be verified during the dimensioning process at points considered to be critical. It does become evident, however, that despite the significance and, to an extent, also the difficulty of the dimensioning process, it can hardly be considered a decisionmaking aid in terms of practicality, durability, erection and maintenance qualities or beauty. There exists a considerable imbalance in the transmission of experience when designing and dimensioning. Practical knowledge on dimensioning has been extrapolated in standards and regulatory literature for generation. The rules of designing, or even those of aesthetics, are rudimental and widely recorded, although these, too, must be considered as being an integral part of the rules of technology. To the conception that the safety of a structure depends predominantly upon the dimensioning rules must be added the fact that an analysis of cases of damage has shown frequent violations of the constructive principles to exist. Unsatisfactory efficiency of utilization, durability or appearance, apart from the deficiency in design, are almost exclusivley due to constructive defects. The influence upon the economy of a structure has hitherto been overlooked, contested, thrust aside or, at the most, carefully assessed.

The large influence upon the economy has, above all, motivated DB to work systematically towards improvements. Consistent recognition of constructive requirements must lead to a substantiatable uniformity in design detail and thus serve as a basis for industrial fabrication methods, resulting in a better structure as well as in a more favourable price calculation.

At a glance it appears simple to describe the function of a railway bridge; trains have to be guided safely across a natural or man-made obstacle. But at a closer look already a series of questions arise. Is it sufficient just to have a plain stretch of rails on the bridge, do stops have to be reckoned with, passengers have to be able to alight, or are switches, signals, telephone communications, catenary masts, cables or conduits to be considered?

The conditions existing on DB, with its very dense polycentric network, make it rapidly evident that as far as possible standards ought to be attainable on the bridge which are similar to those feasible on the remaining network, i. e. the individual requirements should, if possible, be isolated; where they are in positive contact, tolerance zones are to be interlaced, i. e. commonly held on standby for several components. This requires reciprocal consideration but also exposure of the dimensioning rules and dimensioning hazards relevant to the individual utilization components. These are, in the main, the permanent way as roadbed, the clearance as actual usable space for the vehicle, the catenary with masts and cables, and signal radio-control and telecommunication equipment with related cables and conduits. To achieve consistently substantiated cross-sectional dimensions a method had been developed by which the individual components are allocated isolated free spaces wherein further development can be carried out without regard for any adjacent components. Re-coordination is not necessary until technical requirements demand an expansion or modification of the space. When coordinating, particular care must be taken to ensure that transitions are feasible from one type of cross-section to another. This is especially valid for transitions between embankment-cutting-bridge-tunnel. The resulting cross-sectional dimensions and component allocations, which are in fact dependent upon the remit, significance and speed - in short, the requirement profile of a line - constitute the major limiting conditions for the reference-drawing solutions.

REFERENCE DRAWINGS

Viewed economically, it is not the bridges with large span lengths that play the most important role in communication networks. The main task is to build small und medium-sized bridges.

It was therefore obvious to draw up model plans for these span lenghts, in order to provide the layout, the ratings and the project drawings once and for all, or at least once for many times. During the 1920s, the then Deutsche Reichsbahn (DR) hat drawn up such model plans but they were not destined to be successful. This had most likely been due to a number of reasons, which are also still valid today:

- The technical profession is ostensibly or factually being tied down too rigidly.
- Due to the gradation stages each model solution must inevitably lead to a certain amount of overdimensioning.
- A major reason is the absolute curtailment of intellectual competition on both the client's and the contractor's part.

The subjection to only a single conception for a feasible constructive solution was bound to be unsuccessful in a country, in which highly trained engineers were abundantly available. It would certainly not have been desirable.

So as not to relapse into the same mistake and at the same time not to leave the obvious equivalence of numerous constructive problems to an arbitrary variety, a new method for systematic design improvement was adopted towards the end of the 1960s. Based on the conception of solving similarities repeatedly by similar means, of adapting individualities by combining proven basic elements, of gaining substantiatable experience by using a great number of fragments, and of acquiring a variety of potential solutions through interchangeability, the reference-drawings instrumentum was called into life. Reference drawings are graphic representations of constructive detail problems such as already occur on railway bridges tendered and built to up-to-date designs. The problem having been recognized by the designer and solved as a concrete individual case, such

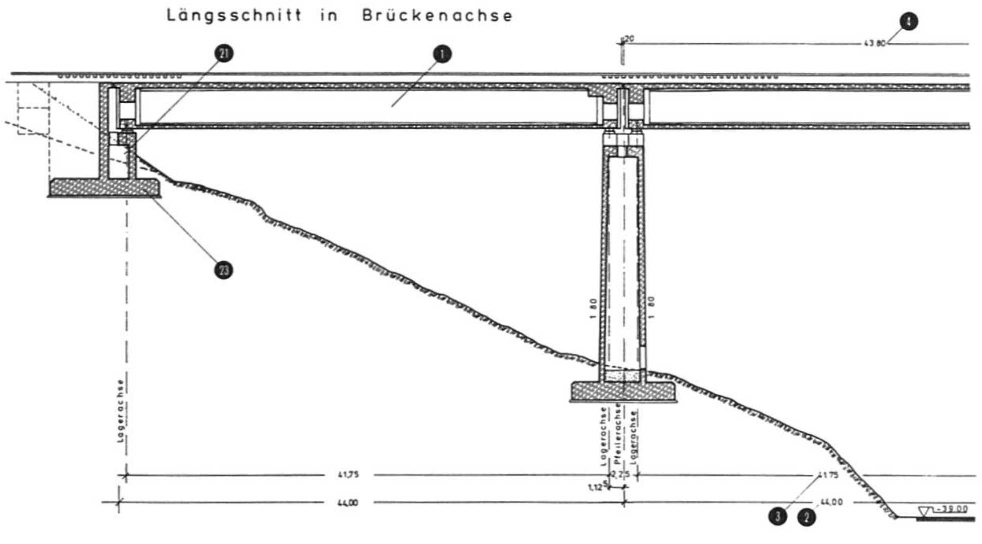

Fig. 1: Example of a planning reference drawing

a solution is to be passed on to the Bundesbahn-Zentralamt (BZA) München, where it is graphically revised and, having been incorporated into the library of reference drawings, is placed at the disposal of all design engineers. Thus, the following is achieved:

- At least one engineer or design team identify themselves with the proposed solution. This solution has been positively impressed upon the awareness of the contributors. It is to be expected that they will find similar solutions to similar future problems.

- Designers not in agreement with the solution are encouraged to also submit their own conceptions in the shape of a reference-drawing proposal, else they are required to accept the "extraneous" solution into their own designs. Thus, a substantiatable variety of differing solutions is made available. Minor and unsubstantiated deviations from established reference drawings are not converted into alternative reference drawings by BZA München.

- Due to the limited quantity of alternative solutions a large number of similar solutions are provided. Systematic errors are provoked which, if safely verified as such, will contribute to the systematic improvement of the reference drawing.

- The technical progress is not arrested, as solutions requiring new materials or shapes may be added at any time als alternative reference drawings.

- Similar solutions stimulate industrial fabrication methods, reduce design work and localize the hazard.

- By means of the reference-drawing solutions, engineers alien to railway work will rapidly attain the proficiency for providing useful designs.

Reference drawings are not hard and fast solutions; they are intentionally characterized by tentativeness, and do not exempt from creative phantasy, from contemplating about improvements and, above all, from checking whether the expected and hoped for result has actually come about at the building site and on the structure itself, where the first downpour of rain may thwart many an idea.

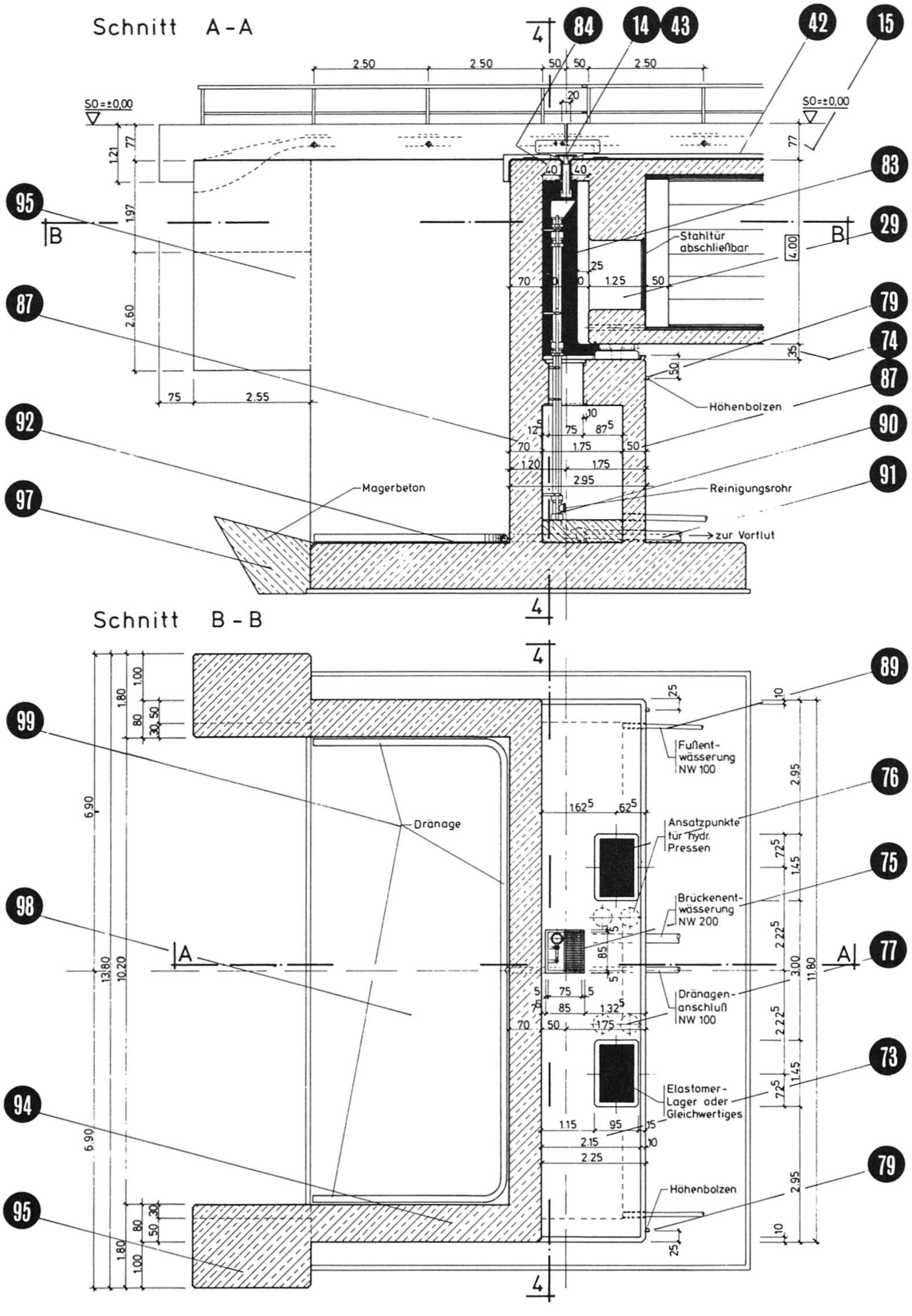

Fig. 2: Example of a design reference drawing

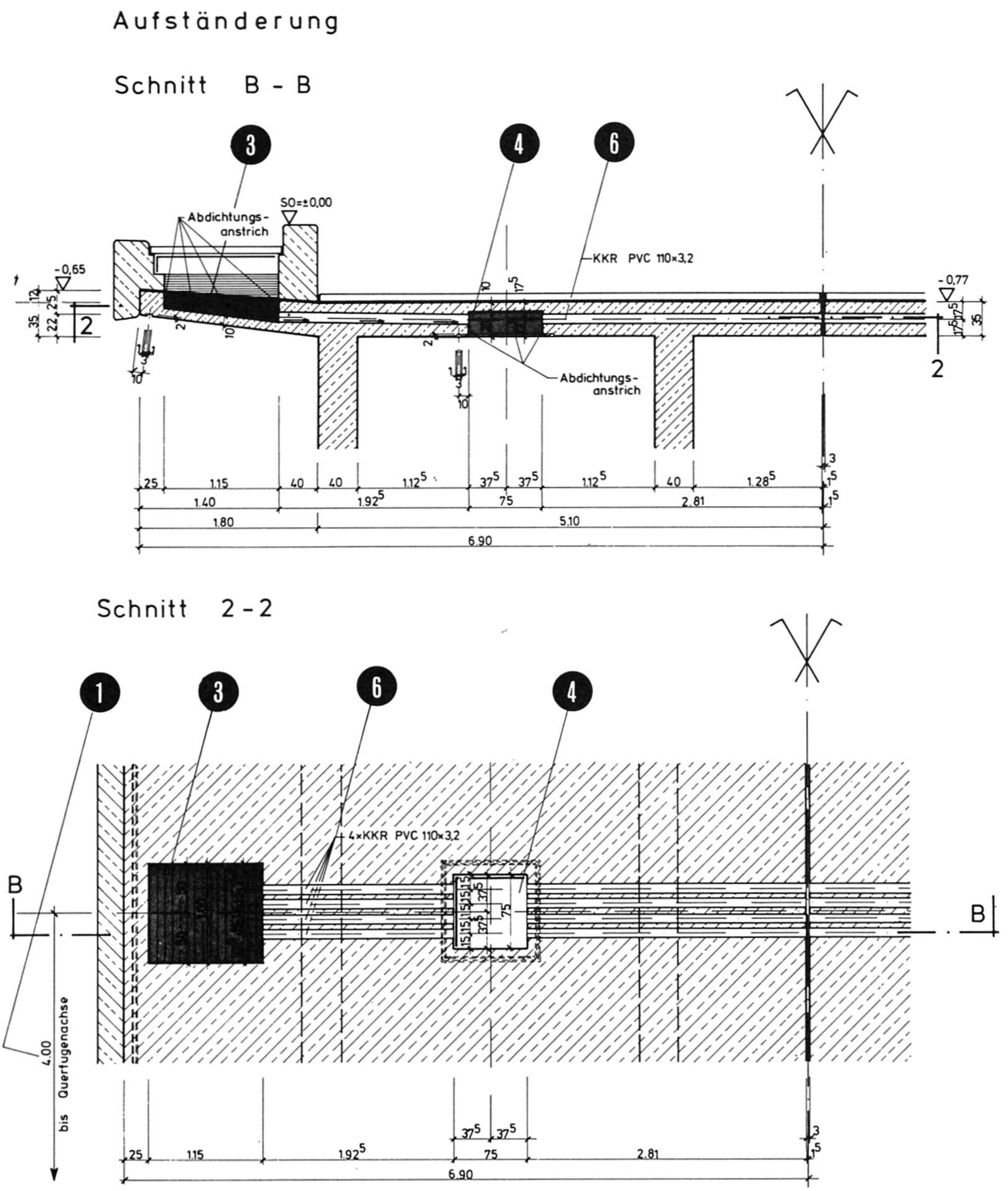

Fig. 3: Example of an element reference drawing

However, they do require implicitly the documented reasoning for any deviation, else here arbitrary variation will be allowed to take its course, for the luxury of which there is no place in an era of scarce resources and acute problems in times ahead.

All things considered, it is thus expected that the constructive quality will improve substantially by adopting this approach. This effect has become clearly evident since the introduction of the first reference drawing.

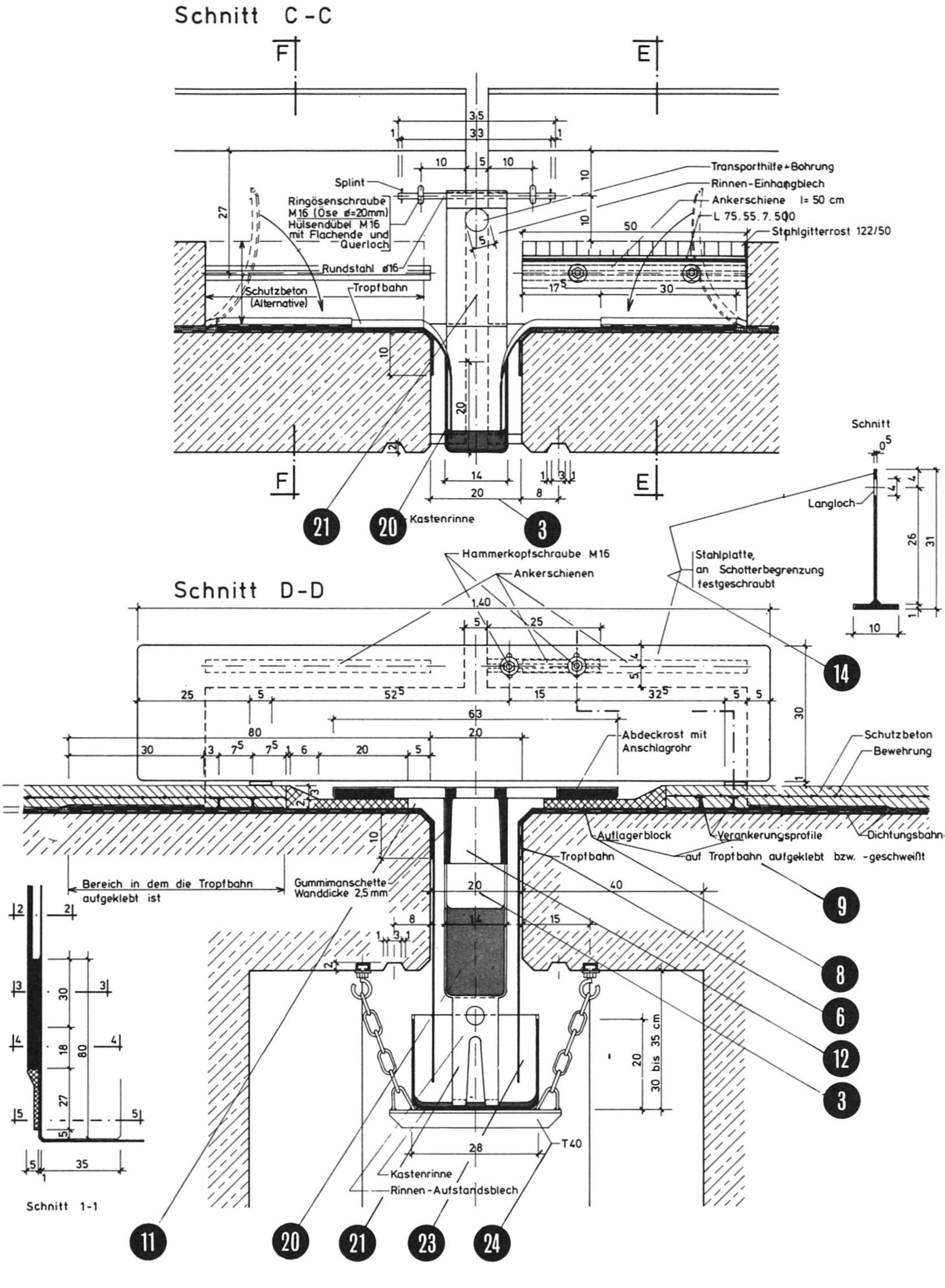

Fig. 4: Example of a detail reference drawing

A process has been set in motion which, due to its circulatory course, is expected to show great stability and to lead to continual advancement. However, several new requirements, too, suggest themselves:

- The library of reference drawings is becoming so comprehensive that aids will have to be introduced to maintain its neat arrangement and to ensure rapid access.

- To achieve verifiable unambiguousness the layout of the represenations is to be improved such that only one solution appears on any one sheet and under any one reference.

- The question of unambiguousness has raised a fundamental problem, which is based on man's peculiarity that the ability of being able to identify a shape or model is a qualification found in the subconscious (Riedl). He is, therefore, unable to pass on directly any relevant information to others. He will have to restore his perceptions to the conscious mind to be able to make himself understood to others by means of gestures, speech, writing, calculations, pictures or drawings. Because in his design work the civil engineer must concern himself - actively and passively -with shapes and forms, draughting and/or the drawing itself play a decisive role in this case.

- The drawing is termed the language of the engineer - but, although being able to pass on a lot of information to a third party, a drawing does possess the shortcoming that its composer cannot be certain whether the third party is in fact capable of recognizing and interpreting correctly those motives having led to the indidivual details of the drawing. It will necessitate a verbal or written supplement to restrict the ambiguity of the graphical representation. This problem has also been recognized in the application of reference drawings. They are, therefore, being gradually supplemented by information to elucidate the dimensions or specific features of the illustration.

Although the hitherto existing reference drawings do help to solve numerous detail problems and may also be compiled into designs in toto, there are sill overlapping problems which they cannot yet help to solve. Above all, there is a tendency for considering the detail solutions from the point of view of a single plane only, but often it is especially the spatial coordination of the individual elements that pose the decisive questions; these have been tackled consistently and systematically with relevance to the structures earmarked for the new lines and have brought about a hierarchic classification of the reference drawings which, in future, will differentiate between:

planning, design, element and detail reference drawings
(Figs. 1 to 4).

Moreover, in future all reference drawings are to contain additional point by point elucidations with regard to their dimensions and/or specific constructive features. These points are referenced and in their compilation provide check-lists with the aid of which the constructive quality also of such structures having not been designed in accordance with the reference drawings may be examined objectively. It is aimed to make this evaluation so reliably transferable that it may also be utilized for assessing the costing economy and thus, too, for the recognition of quotations.

A steady improvement of the reference drawings can be realized only if there is a feedback of in how many instances their application had been possible, for how many cases reference-drawing solutions had been chosen and which of the alternative solutions had been prefered, in which instances it would be of interest to learn why reference-drawing solutions had been objected to.

The particular problem that arises here ist that such beackfeeding is kept simple and uncomplicated and carried out with justifiable means, but above all not with the negative aspect of a compulsory check.

CHECKPOINTS

The system of reference drawings is to be complemented by a supplementary system in the shape of yet a further component. Whereas the reference drawings are predominantly interdependent and applicable in combination, the checkpoints are to provide a completely isolated and punctiform determination and registration of constructive micro-aspects. Every experienced designer will, upon studying the design drawing, when attending a building site or when inspecting a completed structure, always find some minor details that are constructively unsatisfactory, do not turn out as planned of fail to uphold what had been visualized.

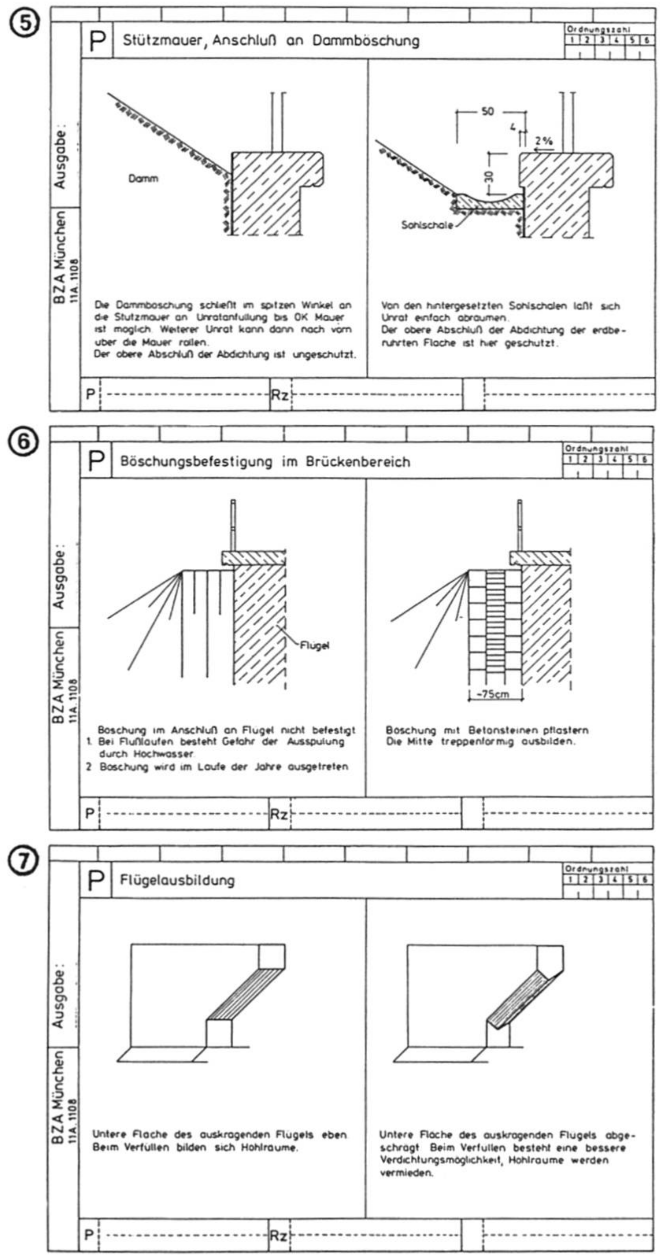

Fig. 5 to 7: Checkpoints for earth works

Immediately, a remedy is either thought of or actually looked for. The numerous rectifications, which are repeatedly observed, are often based upon a store of personal experience passed on only to the most closest colleague. By means of the checkpoints (Figs. 5 to 10), these tips are to be elevated to the fullest awareness of the discoverer and then with the aid of a very simple method made transferable to other designers. In many instances these will be foregone conclusions which one would hardly venture to point out, yet upon further pursuit one is surprised to learn how little self-evident something really is. On a record card of DIN A5 format the checkpoints indicate to the left the solution derived at and to the right the one considered to be the better. The argumentation is given in brief key-words.

It is intended to reference the checkpoints such that it will be possible to select the most likely correct ones with the aid of a data processing programm solely by indicating the design task to be performed. The quality of a design is to be assessed on the basis of the first 10 randomly outprinted and for the

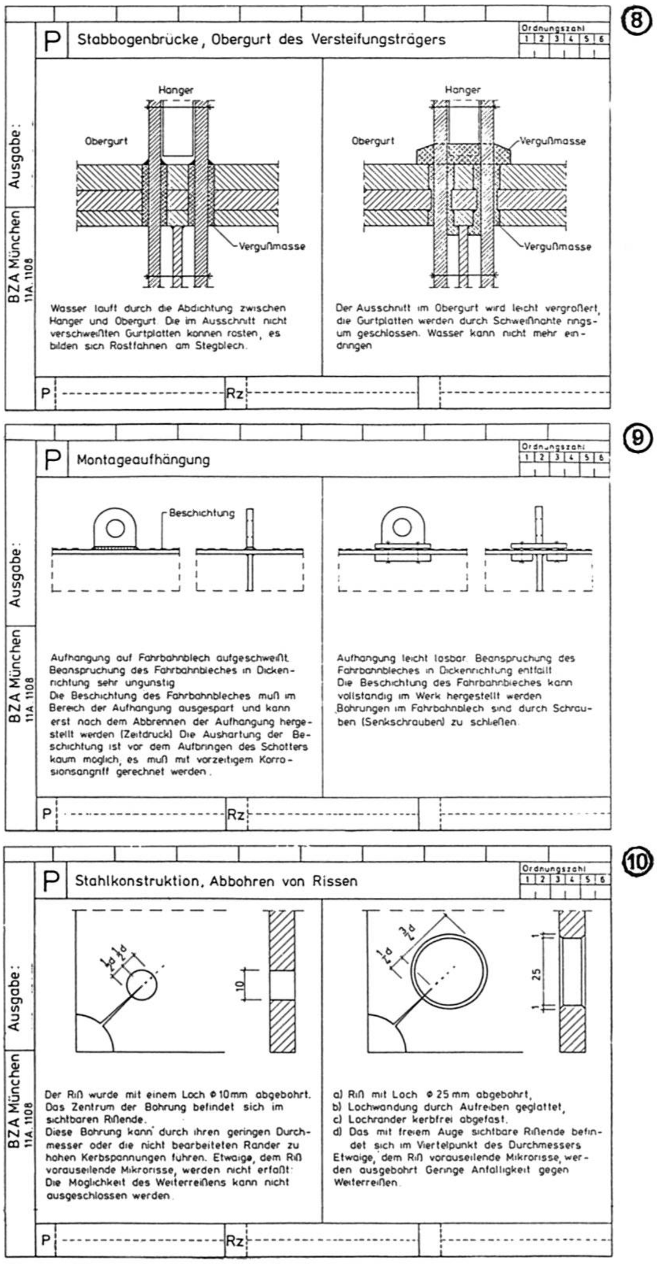

Fig. 8 to 10: Checkpoints for steel constructions design in question applicable checkpoints, of which the number of points satisfied are used to determine the quality. If the findings are considered unsatisfactory a further 10 randomly outprinted checkpoints are interrogated. As the design engineer carrying out the check and the assessment will in time be confronted with few points for interrogation in continuously varying combinations,

- the schematization, in which one solidly relies solely upon the fulfillment of certain points, will be avoided, but
- on the other hand, the design engineer will be made aware of the continuously changing design points to be considered such that his designing ability is constantly maintained at a high standard.

Currently, about 500 checkpoints are available and the collection is continuing zealously to increase their number tenfold, for only then will the utilization of data processing become worthwhile.

CONTROL AND BACKFEEDING

Despite thorough planning, perfected design and supervised construction a structure is subjected to natural ageing and wear, but also to unforseeable influences which affect its bearing capacity, lasting qualities or safety. The law itself demands that DB must ensure the safe operation of its network. Regular supervision is therefore imperative. Apart from the "normal" inspection of line installations by track patrolmen and heads of Maintenance of Way Works Departments, bridges and other structures are scheduled to undergo general and auxiliary inspections at 6 year intervals. The general inspections are carried out by the bridge inspector after thorough cleaning and preparation by an insepction gang. Since the introduction of the "Regulation for the supervision and inspection of structures (VÜP)" - DB issue DS 803 - the result of the general inspection is recorded on diagnosis and assessment sheets which are statistically evaluated for the purpose of long-term maintenance planning or for the identification of unserviceable structural elements. They serve as decision-making aids for controlling the preservation work and for the Bridge Construction Yard to commence and prepare the task of repairing the damage.

The initial general inspection of a new structure is due together with its acceptance test, and the second prior to the termination of the warranty period. The initial insepctions are not expected to indicate any serious damage and are, therefore, mainly designed for providing feedback material for the continuous design improvement cycle. Already identifiable weaknesses in the structure are recorded on special design assessment sheets and centrally evaluated, resulting in improved reference drawings or additional checkpoints. It remains to be said that between every two general inspections an auxiliary inspection is carried out by the head of an Operations Department who, by comparing the records listed by the bridge inspector, has to visually ascertain any apparent changes in the structure. His main task, however, is to identify any environmental variations and to assess their possible effects upon the structure. Altering the water course, rededicating the roadway and similar occurrences can directly or indirectly have a positive or negative effect upon the lasting qualities of a structure.

The feedback form structure to design office closes the circle of organizational measures taken of attain lasting, good-looking and economic structures for DB's track routes. To reach this objective in laboriously small steps it is necessary to have designers who were not only profoundly trained as engineers and have accrued their knowledge form personal experience, but who, above all, must possess the human maturity of unconditionally allowing others to learn from their own mistakes.