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Maintenance of Reinforced and Prestressed Concrete Bridges in the Federal Republic of Germany

Entretien de ponts en béton armé et précontraint en République Fédérale d'Allemagne

Erhaltung von Stahlbeton- und Spannbetonbrücken in der Bundesrepublik Deutschland

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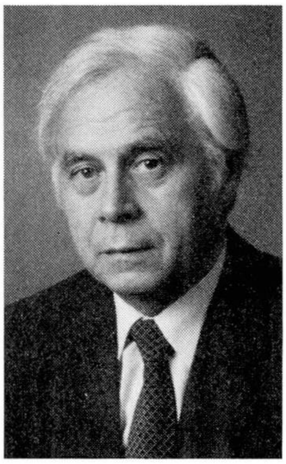

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SUMMARY
The maintenance of existing structures is gaining increasing importance in relation to new constructions. The funds for bridge and civil engineering constructions amount to approx. 50 mia. DM while the cost of their maintenance lies between 1,0 and 1,75 mia. DM per year. A more precise knowledge of expected costs is therefore absolutely necessary. For new building projects, more attention has to be paid in the future to the fact that economy is only guaranteed if costs are minimized for fabrication, maintenance, administration and utilization. Some examples of serious damage as well as interesting repair and renovation works, are given.

RESUME
L'entretien de constructions existantes gagne en importance vis-à-vis de la réalisation de nouvelles constructions. La valeur des ponts et ouvrages d'art est d'environ 50 mia. DM. Les frais annuels d'entretien de ces constructions sont estimés entre 1,0 et 1,75 mia. DM. La connaissance précise des frais futurs est absolument nécessaire. Pour de nouvelles constructions, il faudra se rappeler que la rentabilité n'est garantie que si un minimum de frais pour la réalisation, l'entretien, l'administration et l'utilisation est réalisé. Quelques exemples de dommages sérieux et travaux de réparation et de rénovation intéressants sont présentés.

ZUSAMMENFASSUNG
Die Erhaltung des Bauwerksbestandes gewinnt gegenüber dem Neubau zunehmend an Bedeutung. Das Anlagevermögen an Brücken- und Ingenieurbauwerken beträgt ca. 50 Mrd DM. Die Kosten für die Erhaltung dieses Bauwerksbestandes liegen schätzungsweise zwischen 1,0 Mrd DM und 1,75 Mrd DM jährlich. Eine genauere Kenntnis der zu erwartenden Kosten ist zwingend. Bei künftigen Neubauprojekten ist stärker darauf zu achten, dass die Wirtschaftlichkeit nur dann gegeben ist, wenn ein Minimum an Kosten für Herstellung, Erhaltung, Verwaltung und Benutzung verursacht werden. Einige Beispiele schwerwiegender Schäden sowie interessante Instandsetzungs- und Erneuerungsarbeiten werden aufgezeigt.

1. DEFINITIONS

The general term "preservation" stands for maintenance, repair and "renewal" (rehabilitation and replacement) and comprises the totality of all measures necessary to keep a structure in a safe and serviceable condition.

"Maintenance" comprises all current and partly periodical short-term and small-scale measures necessary for the preservation of the structure. They have no appreciable influence on the service balue of the structure. The measures include, for example, the cleaning of the drainage system or the routine maintenance of the bearings.

By "repair" we understand all measures of a larger scale for the restoration of the service value and the serviceable condition of the structure. It comprises, for example, painting, the repair of expansion joints, the renewal of pavement, the elimination of defects in concrete parts due to de-icing salt, and the injection of cracks.

"Renewal" comprises all necessary rehabilitation and replacement.

2. THE INCREASING SIGNIFICANCE OF MEASURES FOR PRESERVATION

2.1 Growing Bridge Stock

After World War II, the road network in the Federal Republic of Germany, especially the network of federal trunk roads, has been greatly developed. The federal motorways, and to some extent also the federal highways, were designed to have no intersections and were built with a generous allowance.

This contributed to the increase in the number of bridges, especially high and long valley bridges.

The development of the federal trunk road network and of the bridge stock during the past 15 years is shown in Fig. 1.

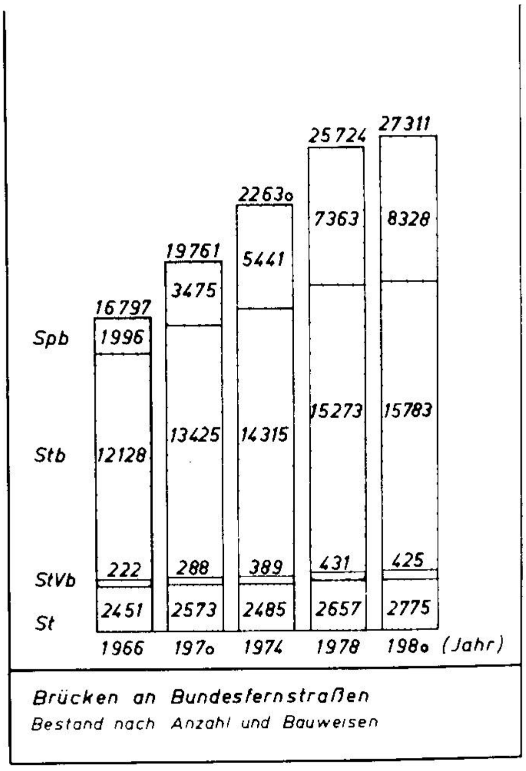


Fig. 1 Bridge statistics/number of bridges

2.1.1 Length of networks (km)

Road category / Year [1]	1965	1980	Increase 1965-1980
Federal motorways	3 204	7 292	4 088
Federal highways	29 906	32 248	2 342
Total	33 110	39 540	6 430

2.1.2 Number of bridges

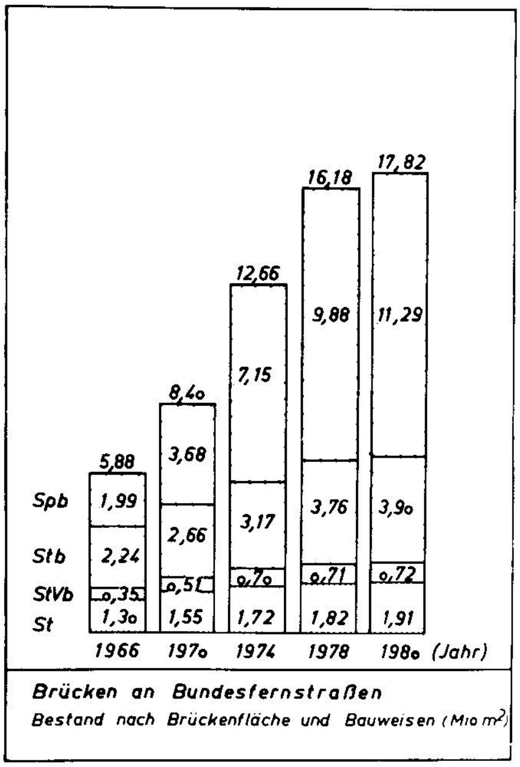
Construction method / Year [1]	1965	1980	Increase 1965-1980
Reinforced concrete	11 449	15 783	4 334
Prestressed concrete	1 725	8 328	6 603
Steel	2 357	2 775	418
Composite bridges	222	425	203
Total	15 753	27 311	11 558

[1] on 1 January of each year

2.1.3 Bridge deck area (in million m^2)

Construction method / Year [1)]	1965	1980	Increase 1965-1980
Reinforced concrete	2.19	3.90	1.71
Prestressed concrete	1.78	11.29	9.51
Steel	1.17	1.91	0.74
Composite bridges	0.32	0.72	0.40
Total	5.46	17.82	12.36

Approximately 11,500 bridges with a deck area of almost 12.4 million m^2 were built on federal trunk roads between 1965 and 1980. Thus, by 1980, the number of bridges carrying or spanning federal trunk roads increased to about 27,000, with their deck area amounting to 18 million m^2 (Fig. 2).



Almost 90 % of these (i.e. 24,000 bridges) consist of reinforced or prestressed concrete. The percentage of the deck area of these structures (approx. 15 million m2) to the deck area of all bridges on federal trunk roads is approximately 85 %.

Fig. 2 Bridge statistics/ bridge deck area

1) on 1 January of each year

2.2 Investment Value and Preservation Costs

There is a direct relationship between the preservation costs of engineering structures and their investment value and age. The investment value at present is estimated at 150 billion DM, about 50 billion DM of which accounts for bridges and other engineering structures.

To estimate the financial requirements for the preservation of the structures, we start with the assumption that at present, the annual costs of maintenance and repair - without rehabilitation and replacement - are between 0.75 % and 1.5 % of the investment value. Thus we obtain an amount of between 375 million DM and 750 million DM annually. If we further assume a service life of 50 or 100 years for these structures then we get additional costs for rehabilitation and replacement of 1 billion DM or 500 million DM annually. This sum will only be required, however, when the structures which today are still relatively new, have completed their technical service life and will then require approximately 10 % of the total highway budget for rehabilitation or replacement.

An exact assessment of the financial requirements of measures for preservation is not yet possible, since we are still lacking detailed bases for assessment in the form of records and evaluation procedures.

A particular difficulty in estimating the financial requirements for the preservation can be seen in the age structure of the bridges. About 40 % of all bridges are no older than 15 years! We thus lack long-term experiences with the new construction methods developed after the war, such as prestressed concrete, composite construction, orthotropic plates, cable-stayed systems, etc. Furthermore, the demand on bridges in recent times is growing due to the strong increase in heavy vehicle traffic or due to environmental factors such as de-icing salt and air pollution.

We consider it an urgent task, therefore, to develop - with the aid of a road data bank - an evaluation procedure which will enable us to draw up a requirement plan and to arrange the work to be done according to priorities.

At present, we are still lacking a uniform, i.e. a methodical, systematic, and data-oriented policy in the Federal Republic of Germany that would make it possible to keep the roads and all structures appertaining to them in a safe and efficient state at the lowest possible cost.

The yearly expenses for the preservation of bridges and structures on federal trunk roads has been recorded, for the first time, in 1981. Such data collection will, after a couple of years, permit at least a better estimation of the requirements. It must be remembered however, that expenses will not necessarily be equal to actual requirements, since actual expenses might be limited by financial restrictions, by technical and organizational difficulties or by difficulties due to staff shortages in connection with the preparation and execution of preservation measures.

In any case, within the framework of the envisaged data collection procedure we would want to obtain information on the following parts of and work on bridges:
- surfacing and water proofing
- expansion joints
- bearings
- concrete work
- structural steel
- corrosion protection
- guard rails, railings, drainage
- miscellaneous measures

3. CONSEQUENCES

3.1 General Consequences

The preservation costs depend mainly on the durability of the structure, that means upon its functionality, as well as on the quality of execution and the regular inspection and maintenance. The objective of the highway authorities must be to economize on the total expenditure for construction and preservation. When considering the matter from an overall economic point of view, the road user costs (e.g. on account of traffic jams and a higher accident rate caused by repair work) would have to be included in addition to the above-mentioned costs.

3.2 Consequences for Design and Construction

This general objective results first of all, in consequences for design and construction. Structures of inferior quality can be built cheaper, but they will as a rule, entail higher costs for preservation later. It is therefore often more economical to accept the higher initial costs of construction for more durable structures.

Only durable structures requiring the least amount of maintenance should be constructed ("easy-to-keep-in-good-repair structures"). According to the motto: "Prevention is better than cure" the following aspects should be kept in mind:

- Structural components should be generously dimensioned.
- The structures, construction methods, and materials should be suitable for site and working conditions (uncomplicated). (In the case of reinforced concrete structures, for example, sufficient space between reinforcement for placing and compaction of the concrete should be provided for.
- Continuous girders should be preferred to multiple single-span girders with numerous (often damaged) expansion joints.
- Large surfaces exposed to all weathers and requiring higher inspection and maintenance expenditure should be avoided. As an alternative to slab-and-beam bridges with multiple beam, slabs and hollow box girders which do not have these disadvantages should be used.
- Highly stressed and sensitive components such as expansion joints, bearings, and cables should be easily replaceable.
- Suitable means for the replacement of bearings should be provided for, because subsequent auxiliary means may involve enormous costs. The necessary, somewhat larger dimensions of the substructures do not significantly increase the cost of a newly built structure.
- All components should be easily accessible for the purpose of inspection and maintenance.

3.3 Consequences for the Construction Process

Our experience shows that the quality and thus the durability of structures can be influenced above all by careful quality control and construction supervision. At the centre of all efforts in this field must be the self-supervision of the manufacturer or contractor in his own responsibility. However, supervision and control by official agencies and by the owner cannot, as experience shows, be dispensed with, either.

4. SUPERVISION OF STRUCTURES

4.1 Inspection according to DIN 1076

The first and foremost precondition for the systematic preservation of a bridge is its regular and careful inspection. As early as in 1933, we had the standard DIN 1077 "Rules concerning the inspection of solid road bridges", and this was updated in 1959 by DIN 1076.

Fig. 3 contains the most important engineering structures which are inspected in conformance with this standard. Above all, noise barriers and trough constructions have increased considerably during the past years. The properties of the structures to be preserved are listed in the middle of the figure and on the right those documents that are needed for the inspection of the structures.

The next figure (Fig. 4) shows the types of inspection and the times and intervals at which these should take place. The most important inspection is the so-called main inspection, which is carried out every six years, during which the structure is put to the "acid test".

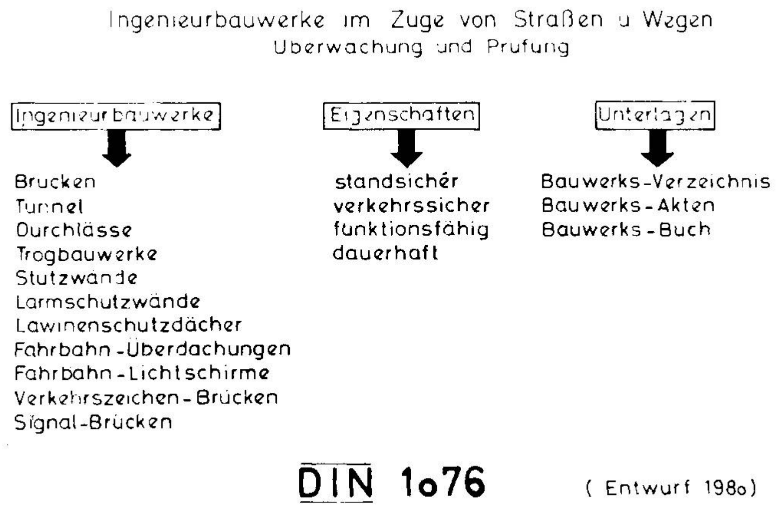


Fig. 3 DIN 1076; inspection structures/properties/documents

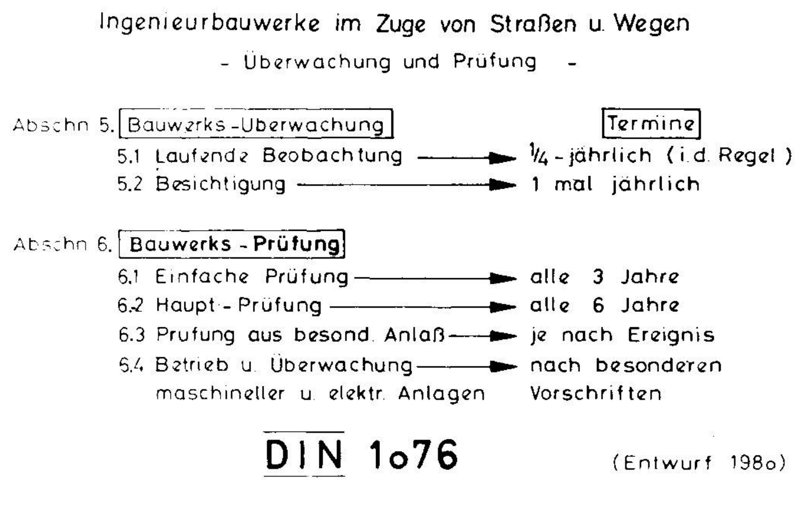


Fig. 4 DIN 1076; inspection intervals

Was ist zu prüfen ?

Gründungen

- Setzungen
- Unterspulungen, Auskolkungen

(2) Massive Bauteile

- Risse, Hohlstellen, Durchfeuchtungen
- Betondeckung, freiliegende Bewehrung
- Abplatzungen u. Risse parallel zu Spanngliedern
- Karbonatisierungstiefe

(3) Stahlkonstruktionen

- Risse, Beulen, Verbiegungen
- Schweißnähte, Anschlüsse
- Schrauben, Niete
- Korrosion (insbes. bei Kabeln, Seilen, Hängern)
- Ortsfeste Besichtigungseinr. (Stege Podeste, Leitern, Treppen)
- bewegl. Besichtigungseinrichtg (Bühnen)

Hauptprüfung nach DIN 1o76
(Entwurf 198o)

Fig. 5 DIN 1976;
subjects of inspection

Was ist zu prüfen ?

(4) Holzbauwerke

- Schrauben, Leimfugen, Anker
- Wassersäcke, Fäulnis

(5) Lager, Übergangskonstruktionen, Gelenke

- Beweglichkeit, Dichtigkeit
- Sauberkeit, Korrosion, Verformungen, Verankerung
- Planmäßige Stellung

(6) Abdichtungen, Fahrbahnen, Entwässerung

- Feuchte Stellen
- Vergußfugen
- Risse, Blasen, Hohlstellen, Verdrückungen
- Kappen, Schrammborde, Schachtabdeckungen
- Straßeneinläufe, Entwässerungs-Leitungen

Hauptprüfung nach DIN 1o76
(Entwurf 198o)

Fig. 6 DIN 1076;
subjects of inspection

Was ist zu prüfen ?

(7) Wand- u. Deckenverkleidungen

- Befestigung
- Risse, Verformungen, Hohlstellen, Korrosion, Ausblühungen

(8) Lärmschutzwände

- Befestigung, Verankerung
- Risse, Verformungen

(9) Schutzvorrichtungen

- Schutzplanken
- Geländer
- Rauch-, Berührungs- Blendschutzanlagen, Erdungen

Fig. 7 DIN 1076;
subjects of inspection

Was ist zu prüfen ?

(1o) Versorgungsleitungen

- Gas, Wasser, Öl, Schwach- u Starkstrom
- Befestigungen, Entlüftungen

(11) Vermessungstechn. Kontrollen

- Festpunkte, Meßpunkte
- Lichtraumprofile
- Verschiebungen, Neigungen, Biegungen am Bauwerk
- Gradienten-Lage

Hauptprüfung nach DIN 1o76
(Entwurf 198o)

Fig. 8 DIN 1076;
subjects of inspection

A survey of the focal points of the main inspection is given in Figs 5, 6, 7, and 8.

4.2 Organization of the Supervision of Structures

Fig. 9 shows how the supervision of structures is organized within our highway administration, taking the main inspection as an example. The main inspection is generally carried out by special inspection parties. Depending on the kind and the significance of the defects detected, the test results will set off different activities, which range from minor maintenance measures by the responsible road or motorway maintenance depot to the immediate closure of the bridge.

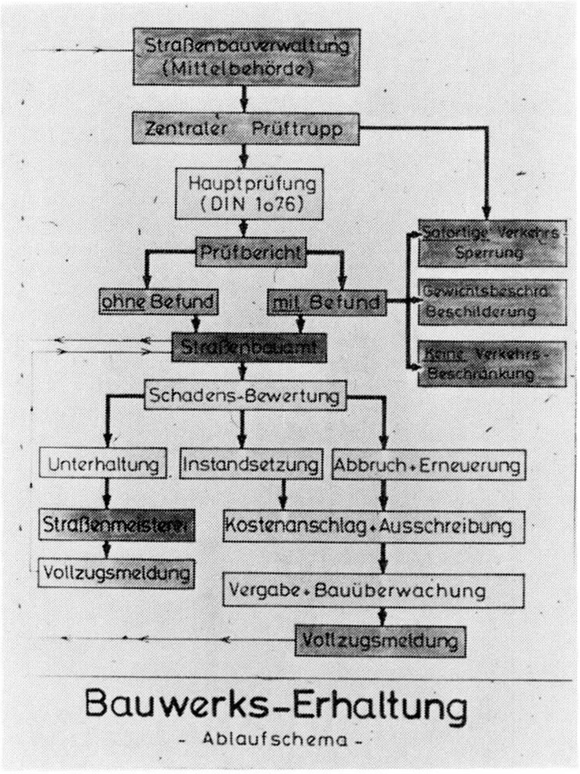


Fig. 9 Preservation of the structure - organization scheme

4.3 Inspection Equipment

A thorough inspection of all components of the structure above ground is only possible with appropriate equipment. Large and high bridges require equipment that can be driven as a vehicle on the road. Here we distinguish two different types, depending on their use:

- Figure 10 shows a double telescope with elevator and three joints with a working and inspection bucket for two men. The extension under the bridge is 9.10 m, the lifting height 28 m. Such equipment is particularly suitable for the local inspection of bearings, drainage installations, etc.
- For wide motorway bridges, inspection equipment with working platforms of up to 16 m extension under the bridge are necessary. Figure 11 shows such equipment in action. There can be no doubt that such platforms give much better access to underbridge areas and make it possible to do minor repair work.
- Other equipment, such as inspection trains from the German Federal Railways or an inspection ship from the Waterways and Shipping Administration, can be used for the necessary inspection of road bridges over electrified railway lines and across canals.

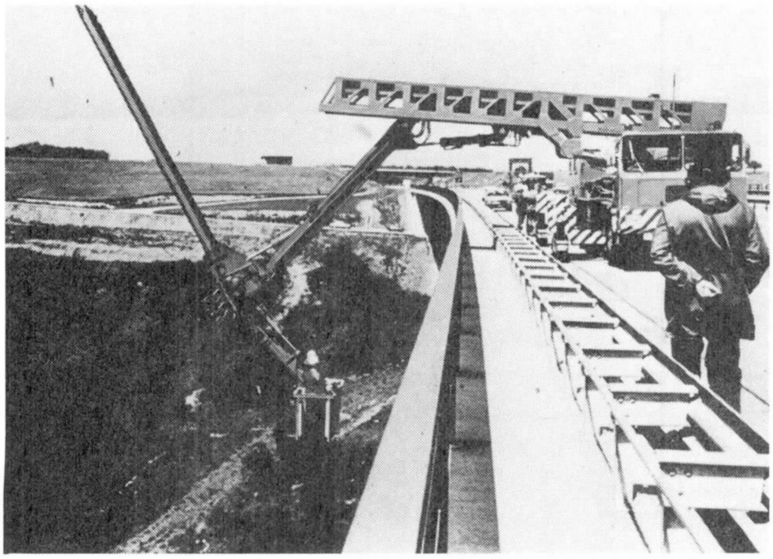


Fig. 10 Bridge inspection equipment Ruthmann double telescope with elevator and three joints US 260

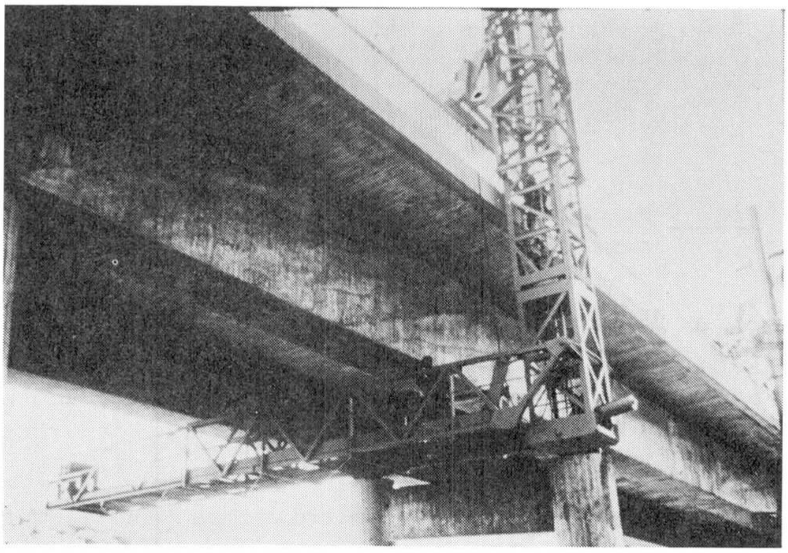


Fig. 11 Bridge inspection equipment Passarella

- However not only large equipment is needed for the inspection of bridges. About three quarters of all structures on federal trunk roads are bridges with a length of up to 30 m. A large part of these structures can be inspected with the aid of simple, often stationary means, such as ladders, platforms, catwalks, and through access openings.

5. DISCOVERY OF DEFECTS DURING INSPECTION

5.1 General

The regular employment of the bridge inspection equipment enables us to recognize damage as early as possible, thus ensuring immediate remedy. In fact, we have found that for the most part the structures are in a safe and serviceable condition, fulfilling the demands in this respect. We attribute this to the fact that highway authorities have always endeavoured to eliminate immediately all defects discovered in regular inspections.

5.2 Types and Distribution of Defects and Damage

The few defects that do occur can be broken down into the following types of damage, which have been found with the following frequency in one Federal Land during main inspections (according to standard DIN 1076) (Fig. 13):

- open reinforcement, rusting	17 %
- hollows/defects in the concrete of the superstructure	13 %
- cracks of more than 0.2 mm width in the superstructure	11 %
- damage due to de-icing salt along footpaths	14 %
- surfacing cracked, deformed	32 %
- joints in kerbs leaky	31 %
- waterproofing defect	21 %
- rails and posts rusting; sealing compound defect	58 %
- drainage intakes blocked	27 %
- bearings defect	14 %
- substructures: concrete deterioration, cracks	27 %

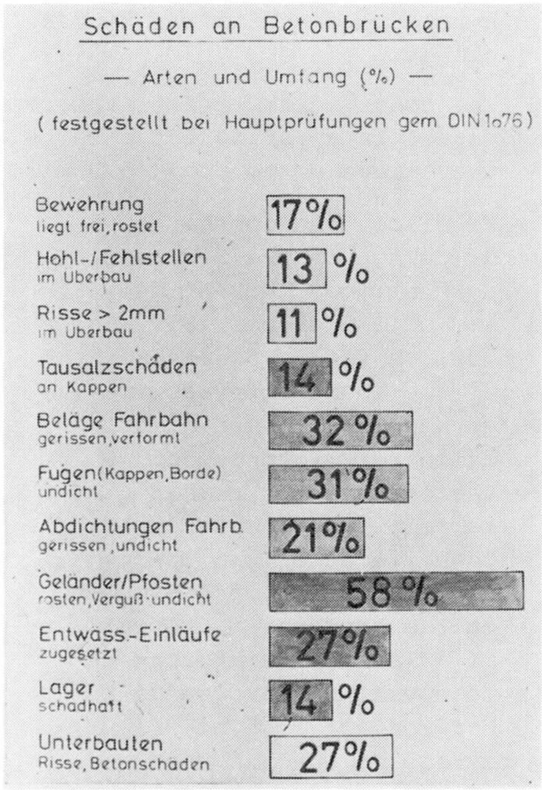


Fig. 13 Damage to concrete bridges; type and extent

These figures refer in each case to 100 inspected bridges, but they do not say anything about the extent and the degree of the damage, and are therefore limited in their statistical value.

According to the experiences gained by our highway authorities, we distinguish between three main categories of causes of damage:

- damage due to discrepancies in the design, incorrect assumptions in calculations, and faulty detailing;
- damage due to mistakes made during the execution of the constructions work;
- damage due to unforeseen or unforeseeable and thus unplanned stresses through utilization (traffic), operation (de-icing salt), and environmental influences.

Damage mostly results from a combination of these causes.

5.3 Serious Damage That Occurred in Recent Years

Let me show you now a few examples of damage to reinforced and prestressed concrete bridges that were found in recent years and which attracted much attention, but which should by no means be considered as representative of damage to bridges in general:

- About 10 % of the 8,300 prestressed concrete bridges on federal trunk roads have been built with coupling joints.

  Proof of the stresses due to non-uniform temperature through the cross-section of the superstructure not previously required, moments in the coupling joints not covered by reinforcement, as well as the lack of sufficient minimum reinforcement at the coupling joints caused serious cracks in some bridges, and in one case even the breaking of tendons at such a joint. It will probably be necessary in the long run to reinforce about 15 prestressed concrete bridges by means of additional tendons or bonded plates or bonded reinforced concrete plates.

  The costs of the repair and reinforcement work are not inconsiderable in these cases. In a particular case, e.g. the fly-over Prinzenallee in Düsseldorf, they amounted to about 5.5 million DM (Figure 14).

- We discovered another type of damage in the Schmargendorf bridge. This bridge was built between 1959 and 1961. A faulty assessment of the shear stresses together with insufficient ordinary reinforcement, the omission of reinforcement to counteract the effects of the indirect support of stringers at the cross-beam, as well as a lack of reinforcement to cover the forces due to horizontally curved prestressing tendons resulted, in this case, in severe cracking and corrosion of some tendons. Despite repeated rehabilitation and strengthening measures it was not possible to restore the service level of this bridge permanently. We decided, therefore, to dismantle the existing bridge and to build a new one at the same place for about 60 million DM (Figures 15 and 16).

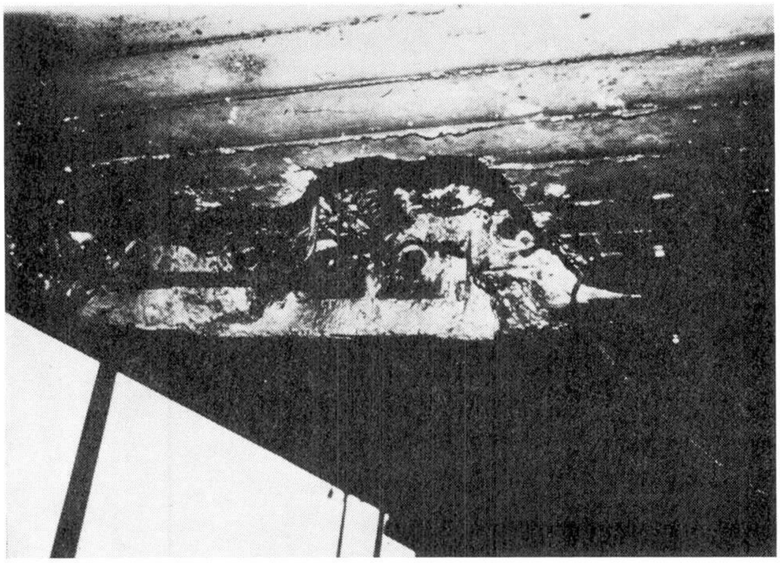


Fig. 14 Underside view of hollow box in the region of coupling joint - laid open (flyover Prinzenallee)

- Different causes led to extensive damage to three neighbouring 15-year-old valley bridges on the Krefeld - Ludwigshafen motorway west of the Rhine. Rehabilitation costs amounted to a total of 45 million DM. The bridges were built as a single-span girder system with prefabricated main girders. The numerous expansion joints required became leaky and to some extent broke under the high traffic loads. This enabled surface water containing de-icing salt to penetrate to the ends of the prefabricated girders and to cause severe damage there.

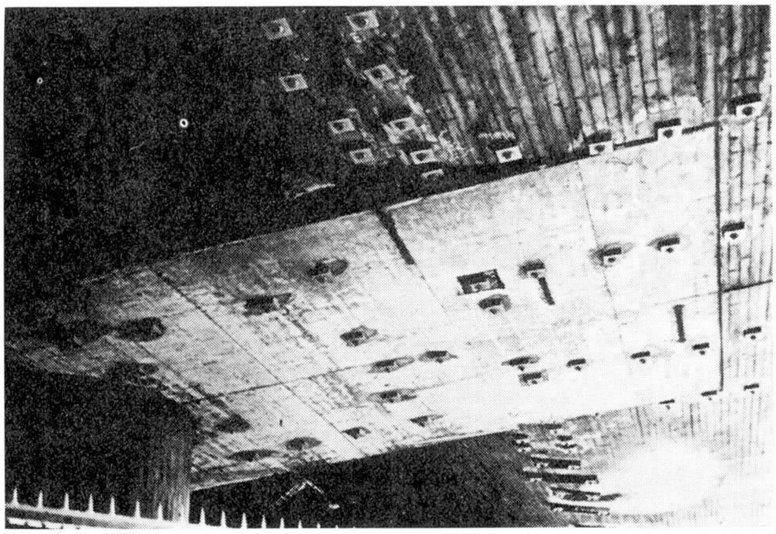


Fig. 15 Underside view of the region of pier with vertical additional tendons inside the structure (1st rehabilitation) (Schmargendorf bridge)

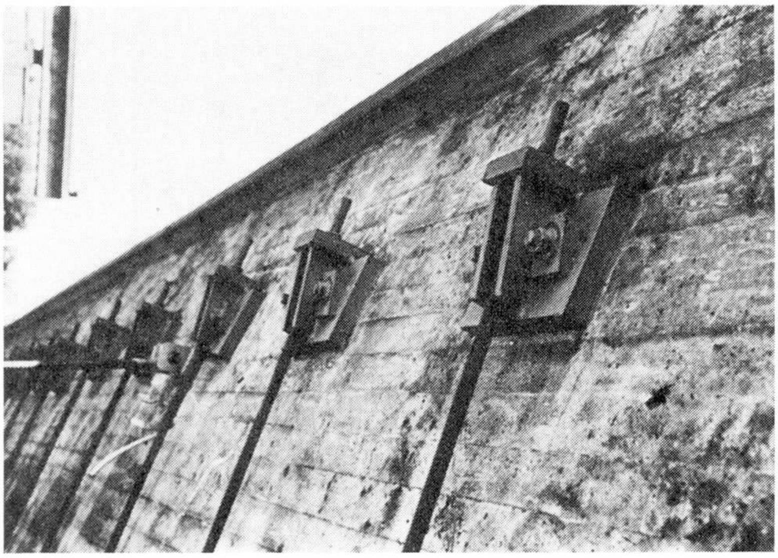


Fig. 16 Underside view with anchoring of outside additional tendons (1st rehabilitation) (Schmargendorf bridge)

A great number of cracks and surface scaling of the concrete, especially at the ends of the prefabricated girders and at the cross beams, constituted a risk to the stability at the points of support (Figures 17 and 18).

- As an example of severe damage caused by the failure of bearings I would like to mention the valley bridge Blockheide.

There, extremely low temperatures led to the roller bearings rolling off. The expansion movements were calculated in accordance with the code valid at the time the design was made. However they did not contain any calculational or constructional safety in view of the probable deformation values.

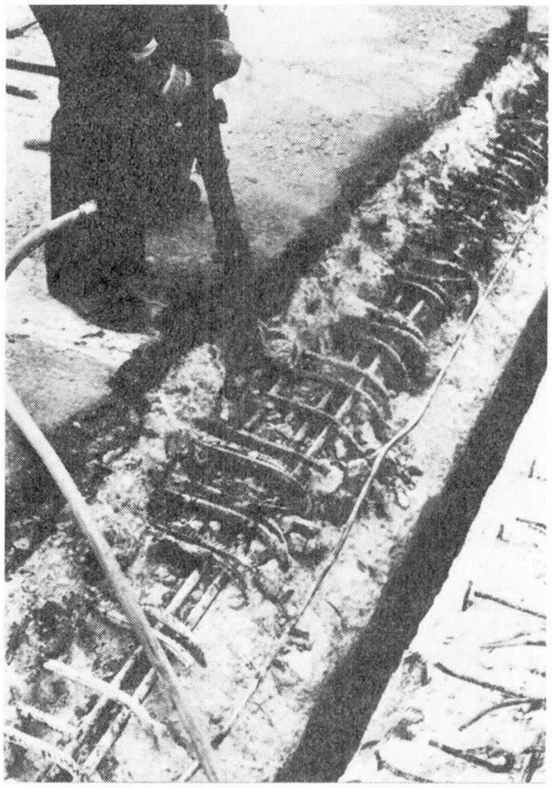


Fig. 17 Expansion joint removed (valley bridge Pfädchensgraben)

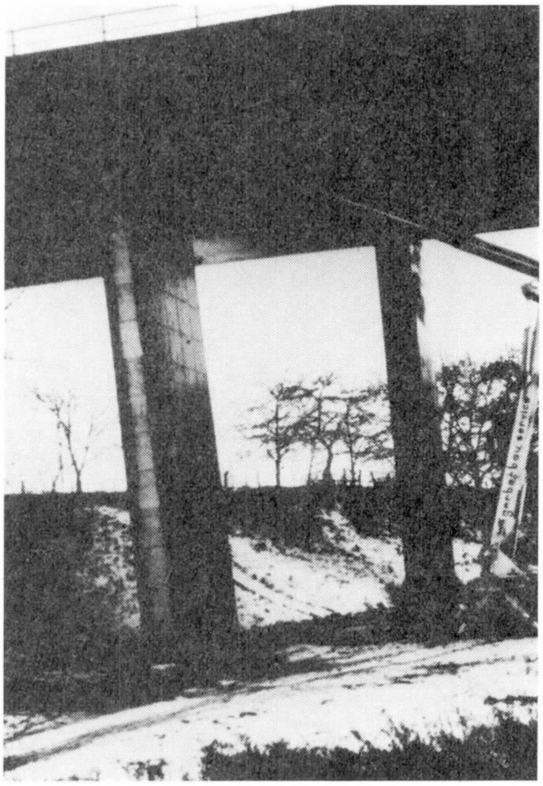


Fig. 19 Damage to the pier due to rolled off bearing (valley bridge Blockheide

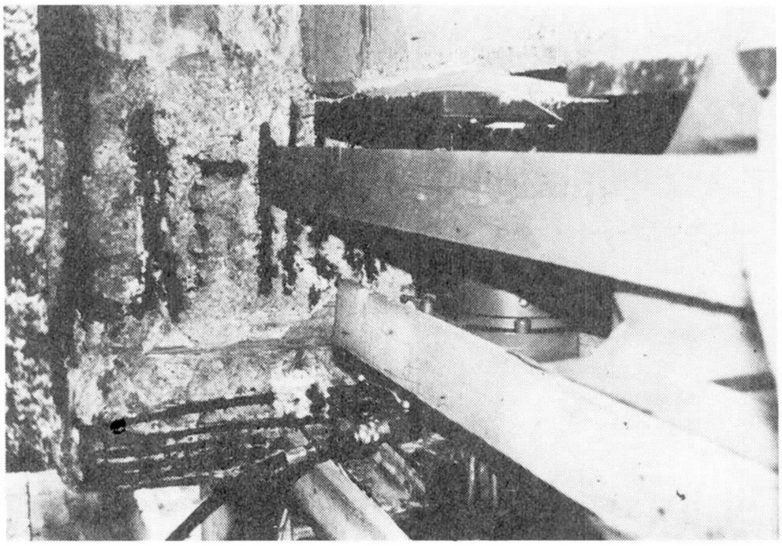


Fig. 18 Jacks under cross-beam to relieve longitudinal girder during repair work (valley bridge Pfädchensgraben)

Owing to the failure of a roller bearing the superstructure sagged by 27 cm which caused an eccentric load on the pier and entailed heavy damage to the super- and substructures (Figure 19).

5.4 Documentation of Damage

In order to be able to cope with the task of preservation of bridges both financially and organizationally, it is necessary - as was emphasized previously - to prepare an extensive survey and evaluation of the types and the frequency of damage. For this purpose, a first publication containing 84 cases of damage has been worked out by the Federal Ministry of Transport, and will be published shortly. (The above mentioned cases are contained in this publication.) It describes systematically and in the same pattern the structures concerned and the damage, specifies its causes, shows the rehabilitation, and gives possible advice for the design, its analysis, the work undertaken, the execution and supervision as well as bridge inspection. The purpose of such documentation, which will be extended as new cases of damage are recorded, is to sharpen the sensitivity of all parties involved in construction engineering - i.e. engineering offices, proof-engineers, construction companies, highway authorities, and students of construction engineering at institutes of technology, universities, and specialized institutes, to possible sources of damage. Such information is of particular importance to educational establishments, since the knowledge of possible damage to bridges, its causes, and its remedy has hitherto not been among the subjects taught.

I am also of the opinion, however, that analyses of the causes of damage should not only be exchanged at national level, but also at international level, and on a large scale and in good time, so that such damage can be avoided as far as possible in the future. A first approach in this respect can be seen in the work of Commission IX of the Comité Euro-International du Béton (CEB). This work should be supported and promoted by all countries.

6. EXAMPLES OF INTERESTING REPAIR AND REHABILITATION WORK

In the future, we will have to occupy ourselves increasingly with measures of repair, rehabilitation and strengthening. Suitable methods must be developed for carrying these measures through. These would have to take into account the fact that most of the work would have to be done while traffic is flowing, and that traffic should be interrupted as little as possible. In this context some research projects have already been commissioned by the Federal Ministry of Transport during the past years.

In case repair and rehabilitation are no longer possible, suitable methods for demolition must be developed before erecting a replacement structure, since in most cases explosives will be out of the question because of nearby traffic routes and buildings. Demolition procedures employing diamond saws, oxygen lances, or hydraulic loosening for large reinforced and prestressed components still have to be thoroughly tested.

Furthermore, difficulties often arise in connection with the tender and the award of the contract, since in most cases the exact extent of the damage can only be determined after the work has begun (leaky waterproofing, not grouted and broken tendons) and, unlike with a new bridge, the work involved is often difficult to estimate.

I would like to discuss now some examples of more frequently occurring or particularly interesting repair and rehabilitation work:

(a) Rehabilitation of defects due to chloride/scaling of concrete (Figures 20 - 23)

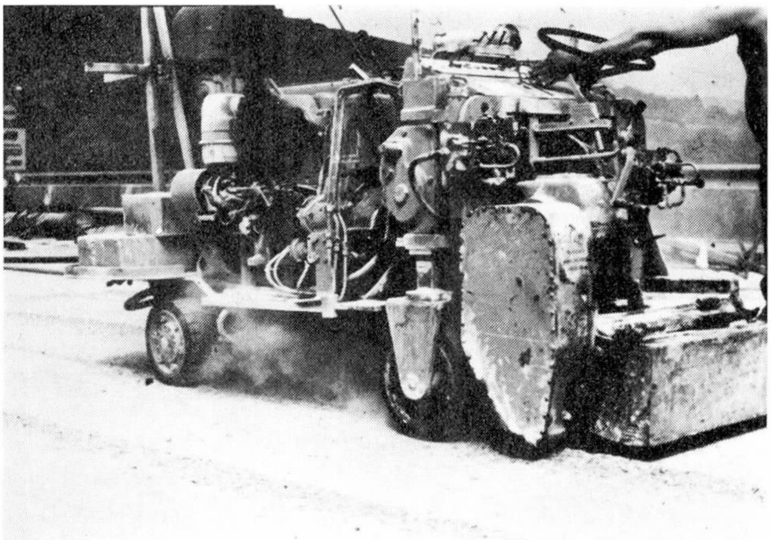


Fig. 20 Mechanical removal of carbonated top concrete layer from carriageway (bridge over the river Nahe at Dietersheim)

Fig. 21 Spreading of the bitumen epoxy resin waterproofing by hand (bridge over the Kocher valley at Geislingen)

- In the case of damage to the concrete deck slab due to chloride, both the pavement and the waterproofing must first be removed. In case of surface contamination the concrete is either treated mechanically or by high-pressure water. If required, deteriorated concrete should be removed. In case of contamination to greater depths, contaminated concrete is completely removed and replaced by new concrete with resin applied as a bonding agent. After that a bituminous waterproofing or an elastic plastic coating is applied by spraying. The advantage of the spraying method is that subsequently occurring cracks can be bridged and the structure thus be permanently protected.

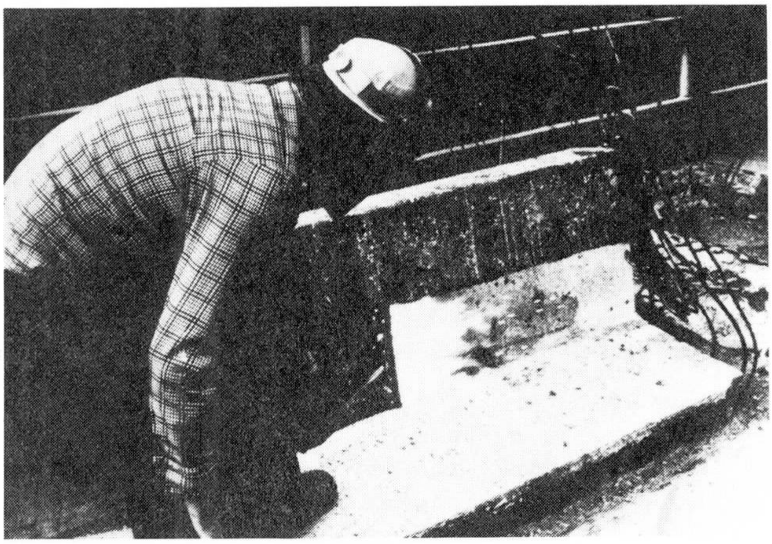


Fig. 22 Flame-cleaning of carbonated top concrete layer of concrete guard kerbs (valley bridge Pfädchensgraben)

- Chloride-contaminated surface concrete is often removed from small horizontal and vertical areas (concrete footpaths, kerbs) by flame cleaning; exposed reinforcement will receive a double corrosion protection.

  Damaged parts of the concrete will be filled with resin mortar, especially where the concrete protective covering of the reinforcement has to be strengthened. After that footpaths and kerbs receive, as a rule, a cloride-resistant coating.

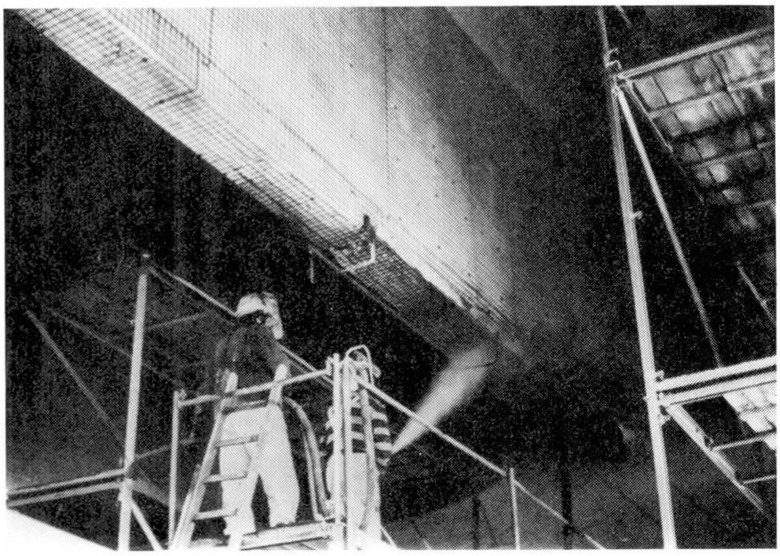


Fig. 23 Restoration of the required dimension by means of shotcrete (bridge over the river Lahn at the Taubenstein)

- In the case of defects in load-carrying concrete components, the loose and the chloride contaminated concrete is removed and the reinforcement sandblasted and corrosion-protected by a double coating. Then the concrete is replaced by shotcrete to the required dimension.

(b) Injection of cracks (Figure 24)

For the sake of durability cracks in reinforced concrete components should be sealed or injected if there is a potential danger of corrosion of the reinforcement. Besides providing corrosion protection, the objective of injection of cracks in load-carrying components is to close the cracks in such a manner as to enable the concrete cross-section to withstand tensile stress. (Restoring the condition of uncracked concrete).

Only cold-hardening, solvent-free epoxy resin systems are suitable for injection work. The crack width at the place of injection must have a minimum width of 0.1 to 0.2 mm in order to achieve a successful injection. Injection of cracks is then possible for crack widths up to less than 0.02 mm. Before injection the crack must be sealed at its surface.

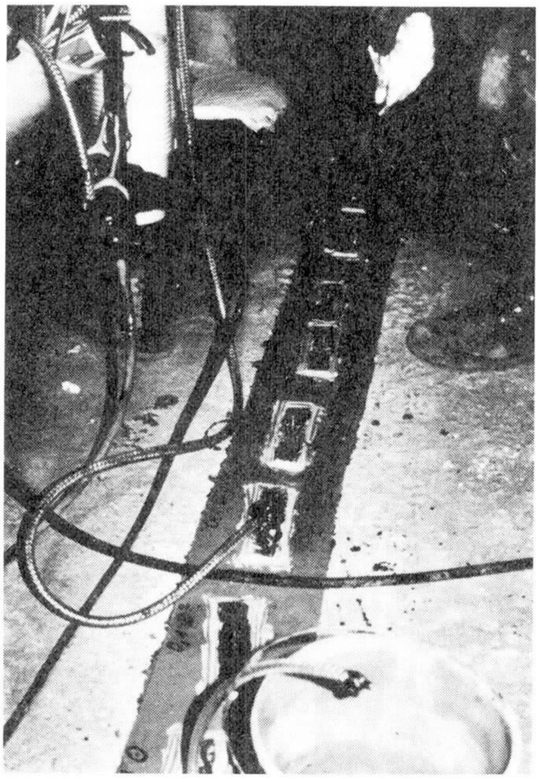


Fig. 24 Injection of joints with epoxy resin (bridge over the Lahn valley near Limburg)

(c) Rehabilitation of damage in coupling joints (Figures 25 and 26)

Besides the method of crack injection, as mentioned above, it may become necessary to increase the amount of ordinary reinforcement in the region of coupling joints in order firstly, to reduce the stress variation in the coupling elements and secondly, to minimize the crack width of new cracks under repeated loads. Two methods are under investigation (within the framework of research initiated by the Ministry of Transport): strengthening by bonded steel plates and strengthening by bonded reinforced concrete plates.

In the case of bonded reinforced concrete plates, the surface treatment is such that mechanical bond is achieved. Additional anchorage is provided by drilled-in threaded bolt and nut anchors. Reinforcement is laid and secured on the anchors and the concrete placed.

In the case of strengthening by bonded steel plates, the concrete surface is properly cleaned and prepared for bonding and the surfaces of the steel plate are sandblasted to a metallic clean surface condition. The steel plates are bonded to the concrete by epoxy resin adhesives.

Another possibility for strengthening prestressed concrete components in the region of coupling joints is the application of outside prestressing elements.

(d) Replacement of bearings (Figure 27)

A relatively frequent repair measure is the replacement of bearings. Damage to bearings could be the result of:

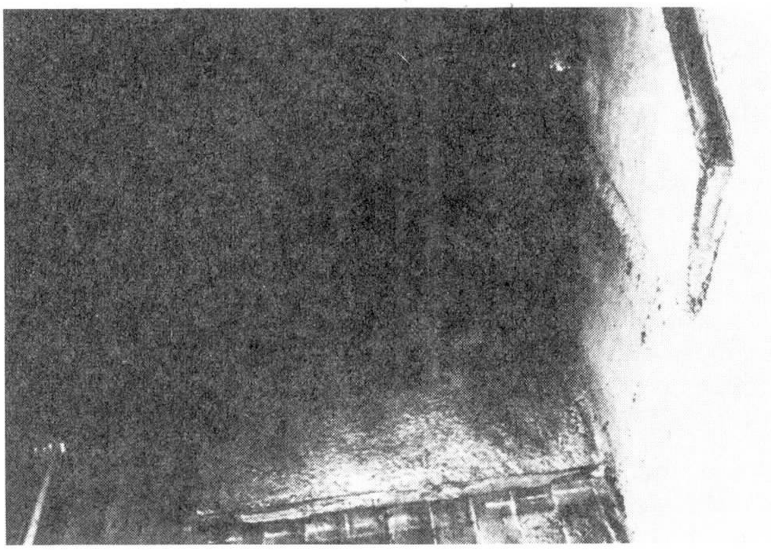


Fig. 25 Strengthening of coupling joints by means of bonded reinforced concrete plates in the hollow box (bridge over the Lahn valley near Limburg

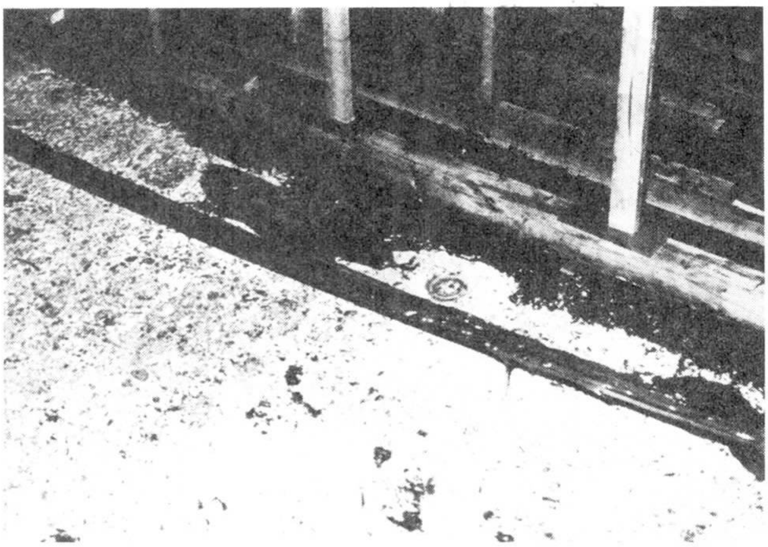


Fig. 26 Application of the steel plate (valley bridge Sterbecke)

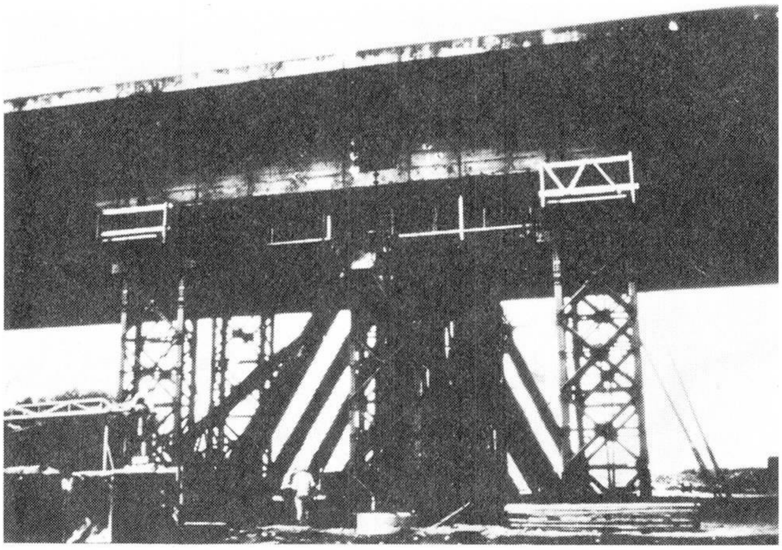


Fig. 27 Erecting tower for the replacement of the bearing (bridge over the river Main at Hochheim

- exceeding the limits of foreseen movement (rolling off the bearing plate),
- fracture of the rolls,
- overstressing and failure of elastomeric bearings,
- failure of neopreme pot bearings due to fracture of the sealing ring or insufficient lubrication or sliding surface area.

Lifting the superstructure and exchanging a defect bearing is a relatively simple operation if suitable means for placing jacks have been provided for. Extensive and costly provisional facilities are often required where jacks cannot be employed directly.

7. SUMMARY

To sum up:

- As the preservation of existing structures gains more importance over new construction in the future, attention should be paid to all questions of preservation.

- It is necessary to introduce and maintain on a wide basis, an exchange of experience on all types of damage and their causes as well as their rehabilitation. Both the administration and the building industry must have the necessary theoretical knowledge or must acquire it.

- Finally, it is indispensable that the necessary funds for the preservation of existing structures be provided.

- Only if the afore mentioned demands are met will it be possible to carry out the immense task of preserving the existing bridge stock in a satisfactory manner.