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Survey of Expansion Joints and Bearings in Britain

Recherches sur les joints de dilatation et les appuis mobiles en Grande-Bretagne

Untersuchungen über Dilatationsfugen und bewegliche Auflager in Großbritannien

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1. Introduction

A programme of road improvements was begun in Britain in 1952 and has accelerated rapidly in recent years. It has resulted in the construction of many new bridges. In the previous 50 years the majority of road bridges were of spans of less than 50 ft. whereas now a considerable proportion of all bridges built are of 100 to 200 ft. span, and there is a significant number of bridges of even larger spans.

It is this large increase in construction of bridges of 100 ft. to 200 ft. span which has emphasised problems in design and construction of joints and bearings. The simplest of treatments of expansion joints consisting of laying a continuous surfacing over a very thin gap filled with compressible fibre board, is in the main satisfactory for spans of less than 40 ft., for spans in excess of 200 ft., joints such as the toothed joint have proved reliable if, at times, expensive; but many different designs have been tried to achieve a simple, satisfactory and economic joint for bridges of intermediate lengths.

The purpose of the present survey is:

- 1.1. To study the temperature movements which must be accommodated by joints and bearings.
- 1.2. To compare the effectiveness of various joints and bearings in common use.
- 1.3. To recommend the most suitable form of joints and bearings which can accommodate various loads and movements for different types of structure.

2. Study of Temperature Movements of Bridges

Some work has begun on items 1.1 and 1.2 and results of the survey to date are outlined below.

Movements of the expansion joints are being measured on a number of bridges for comparison with meteorological data. The bridges have been selected to represent a number of different types of construction.

Changes in the length of the Hammersmith Flyover have been recorded continuously by measurements at the expansion joint since mid-1962. The Flyover has a free length of 2,043 ft. and all the movement is carried to one expansion joint. On four other bridges simple movement gauges are attached at the expansion gap. These gauges are read weekly and record the movement of the bridge from a fixed datum point, as well as the range of movement which occurred during the week. It is planned to fit autographic recorders to these and other bridges as soon as reliable instruments have been developed. The results of measurements made on the Hammersmith Flyover and on three of the other four bridges, are given in Figs. 1 and 2.

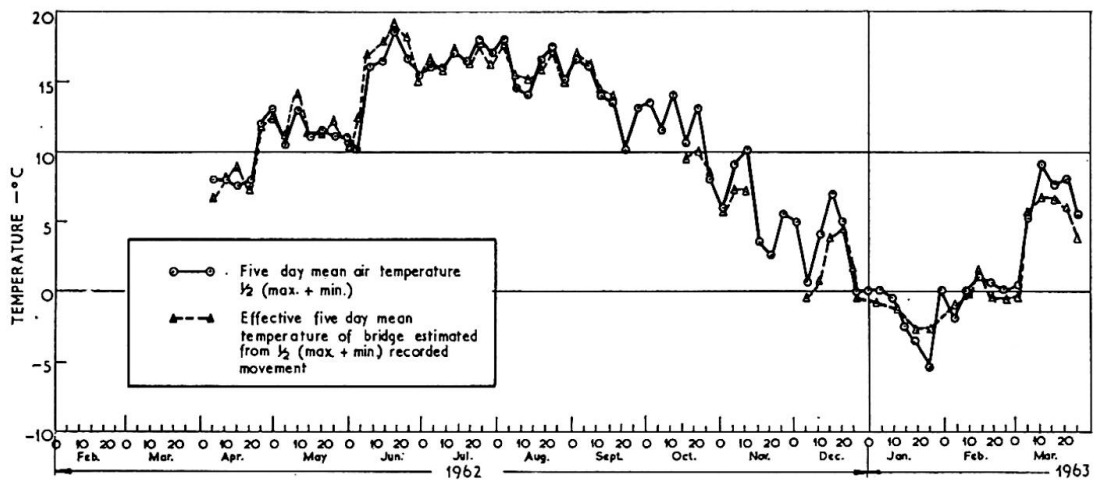


Fig. 1. Comparison of five day mean air temperatures and effective five day mean temperatures of the Hammersmith flyover, estimated from recorded movements at the expansion joint.

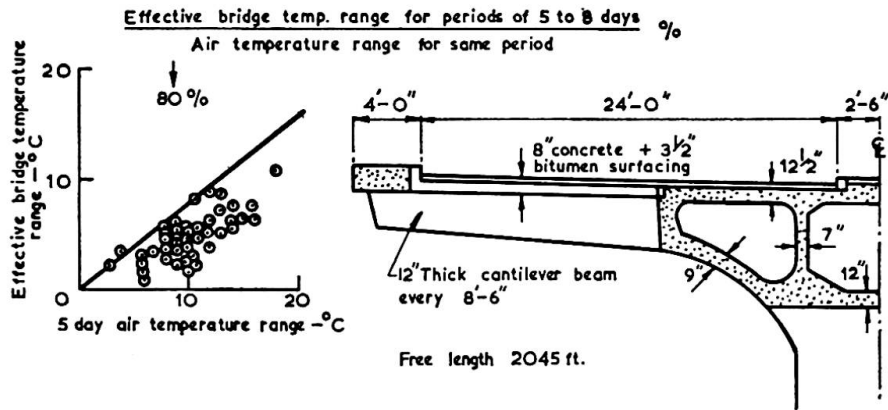
In Fig. 1 a comparison was made of the five-day mean air temperatures at Kew, the nearest Meteorological Station to Hammersmith ($1\frac{1}{2}$ miles distant), and the effective five-day mean temperature of the bridge. The effective five-day mean temperature was estimated on the following assumptions:

1. Free length of bridge, l , = 2,043 ft.
2. Thermal coefficient of expansion, $\gamma = 12 \times 10^6$ per $^{\circ}\text{C}$.
3. All changes in length are due to temperature changes only.

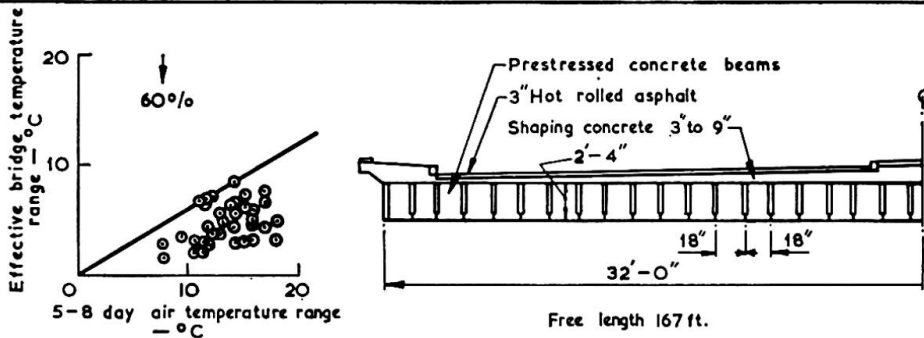
The effective bridge temperature range was then calculated as

$$\frac{\Delta l}{l x} \quad (1)$$

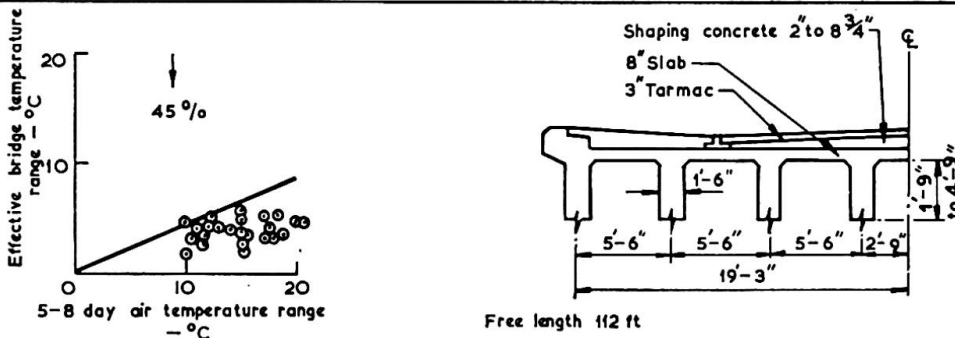
and the result was superimposed on the measured five-day mean temperatures in Fig. 1. This diagram shows that the seasonal and weekly fluctuations of the five-day mean effective bridge temperatures closely follow the five-day mean air temperatures. The agreement is good when it is considered that the effective temperature of the bridge is not necessarily the same as the air tem-



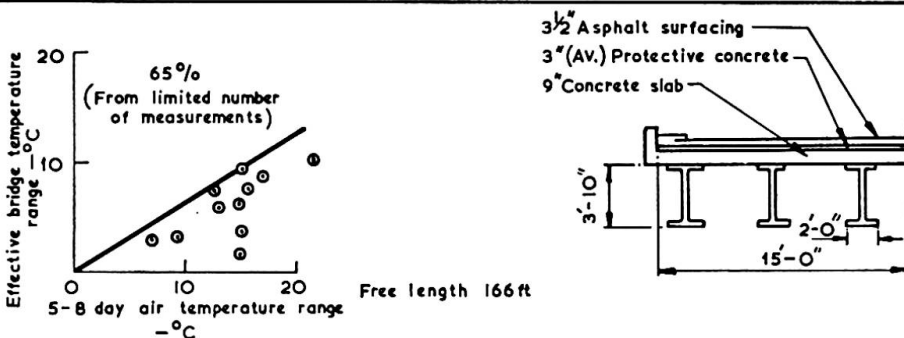
(a) Hammersmith flyover - Prestressed concrete box section



(b) Huntercombe Spur bridge - Prestressed concrete slab



(c) Haversham bridge - Reinforced concrete T beam



(d) South Mimms flyover - Composite construction, welded girders R.C. deck slab

Fig. 2. Comparison of 5 to 8 day air temperature ranges with the 5 to 8 day effective bridge temperatures for various bridges.

perature. A few measurements made on a bridge of more massive construction suggests that this relation is likely to be general. This would enable the probable range of five-day mean movements to be computed from published five-day mean air temperatures.

For British conditions for instance, the maximum range of 5-day means observed at Kew, in the South of Britain is 27°C , and at Aberdeen in the north it is 21°C for the same period. Hence the changes in length between periods of five days can be estimated from average values quoted for coefficients of thermal expansion and the free length of the structure.

Superimposed on the movement due to the five-day mean temperatures variation is that due to the diurnal temperature cycle. This diurnal movement does not correlate so well with ambient temperature, because the high frequency fluctuations are influenced to a greater extent by the size and nature of the structure.

Some assessment of the weekly range of temperature changes can be gained from Fig. 2. In this figure, the effective bridge temperature range for periods of 5 to 8 days was plotted against air temperature range for the same period, for four bridges. These results showed that the maximum effective temperature range of these bridges for the 5 to 8 day periods considered was from 45 per cent to 80 per cent of the 5 to 8 day air temperature range. Analysis of weekly air temperature ranges is not complete, but the minimum value must be at least equal to the maximum daily range of temperature, which, for instance, is 21°C at Kew. An estimate of the minimum effective temperature range can then be derived by adding to the maximum range of 5-day mean air temperatures, taken over many years, the fraction of the daily range of temperature, as given in Fig. 2. Thus for a concrete beam and slab type bridge at Kew, the minimum effective temperature range is $(27^{\circ} + 21^{\circ} \times 45/100)^{\circ}\text{C} = 36^{\circ}\text{C}$. The corresponding figure for Aberdeen is 30°C . For the light box section shown in Fig. 2a, the minimum effective temperature ranges at Kew and Aberdeen are 44°C and 38°C respectively. The significance of these figures in relation to a survey of joints is that a joint filler in a light bridge at Kew of 100 ft. span would suffer the same extension as the joint filler in a more massive bridge at Aberdeen of 150 ft. span.

Some measurements of the transverse movement of the Huntercombe Spur Bridge, Fig. 2b, relative to the abutment are being made. Between November, 1962 and April, 1963, the greatest movement measured was 0.024 in., which is equivalent to an effective temperature difference between the bridge and the abutment of $2\frac{1}{2}^{\circ}\text{C}$.

3. The Effectiveness of Various Joints in Common Use

A limited number of the more common joints are discussed which have been inspected during the part of the survey completed. The period of detailed

observation has been too short for firm and final conclusions to be reached and the results of the survey are amplified from the experience of the Bridges Branch of the Ministry of Transport over the past 35 years.

The qualitative assessment of performance of joints was based on the following requirements:

- 3.1. It should allow unrestricted movement of the bridge so as to relieve stresses due to temperature, creep, shrinkage and loading, unless the bridge is designed to accept the temperature stresses.
- 3.2. It should give a good riding quality and generate neither noise nor vibration due to traffic.
- 3.3. It should have a life at least equal to the life of the surfacing and, preferably, the life of the bridge.
- 3.4. It should have provision for easy replacement, if its life is less than the life of the bridge.
- 3.5. It should either be water-tight, or have provision for carrying away water and grit.

Fig. 3a and 3b. These illustrate a type of joint having many minor variations consisting of tiles or plates bridging a gap and covered with the surfacing. Invariably in the past, these types of joints have given trouble. When a bent copper strip was used as the gap-bridging material, the metal strip cracked, the surfacing material fretted and infiltration of surface water often damaged the fabric of the bridge. However, this joint is still being experimented with and after two years' service in the North of England, including the very cold winter of 1962/63, no cracking has occurred above any of the joints designed as in Fig. 3a. None of these bridges has a free length greater than 60 ft. Several joints designed as in Fig. 3b have withstood 5 winters without any visible cracking, although many of the joints do allow some water to pass through. The maximum length of bridge with this joint is 120 ft.

Fig 3c. In this joint a high quality concrete plinth was brought to the surface at the joint and the top $1\frac{1}{2}$ inches of joint was filled with a polysulphide rubber. This type of sealer can make a very strong bond with the concrete; spalled concrete edges are more common with this sealer than with those which do not bond so well to the concrete.

Figs. 3d, 3e and 3f. The use of angles with the vertical leg turned upwards has given very serious trouble and these joints are no longer accepted by the Ministry of Transport. Large numbers of joints of this type have had to be replaced. There are, however, numerous cases where these have been tried with various modifications in recent years. Several examples of the simplest type shown in Fig. 3d, composed of a compressed butyl-rubber strip between $3\text{ in.} \times 4\text{ in.} \times \frac{3}{8}\text{ in.}$ angles, failed rapidly. The deformation in the vertical leg amounting in some cases to $\frac{1}{2}\text{ in.}$ over a length of 1 ft. A number of other cases designed as in Fig. 3e still with $\frac{3}{8}\text{ in.}$ angles but the vertical leg only

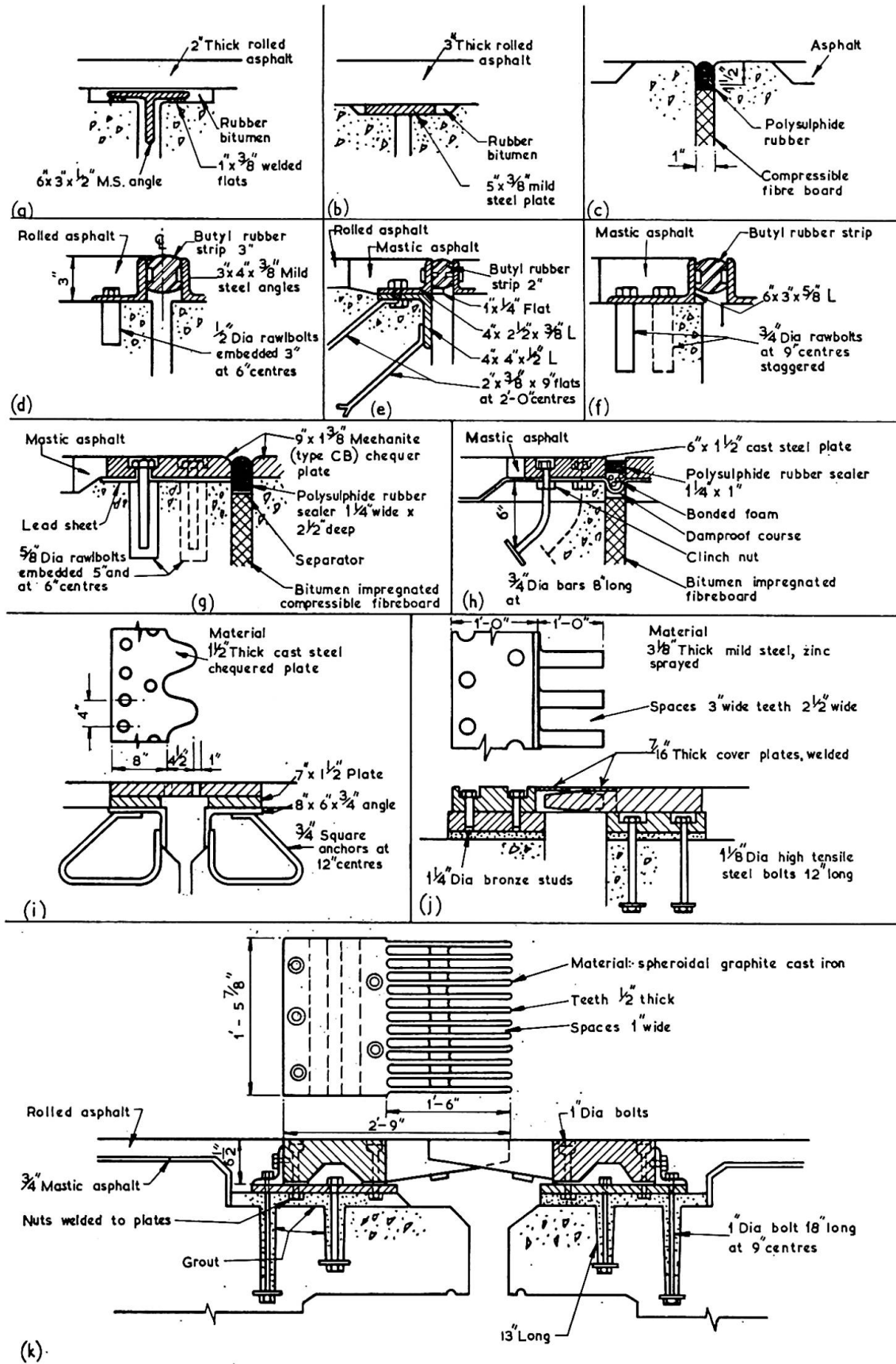


Fig. 3. Examples of joints.

2½ in. high have shown signs of deformation after two years of service. So far the deformation is not greater than ¼ in. over a 5 ft. length in the worst case seen. Two examples of the 6 in. × 3 in. × ⅝ in. as in Fig. 3f are satisfactory after 2 years' service, but several others have failed by extrusion of the lead sheet and loosening of the Rawlbolts. Angles braced with triangular fillets at frequent intervals have been tried; a few examples using 6 in. × 3 in. × ½ in. braced angles show no signs of deformation after 2 years. Both of these latter types will be examined at intervals to determine their effective life. Most of the joints of this type allow some surface water to pass through. Joints in Fig. 3d—3f are used for bridges having lengths between 60 ft. and 200 ft.

Fig. 3g and 3h. These joints comprising thick steel or mechanite plates, held down with substantial bolts, are becoming increasingly popular for bridges between 80 ft. and 200 ft. in length. The bolt heads are well recessed and protected with a bitumen filling. If the joint between the plates is left open the gap is sloped back gradually below the plates so that any loose material dropping into the opening may fall clear. A drainage channel is then required: these channels soon get filled with grit and require frequent rodding. In most cases seen to date, however, the joint is sealed. No perfect sealing material has yet been found, but initially at least, polysulphide rubbers have been shown to give a good bond to steel or cast iron and after two years' service satisfactory bond is still achieved. For good bond, the joint must be clinically clean, the metal not galvanised and the sealer needs to be poured at a suitable temperature to the manufacturers' instructions. Fig. 3h illustrates the use of clinch nuts as levelling devices. These enable heavy plates to be set up accurately before grouting beneath them.

Fig. 3i, 3j and 3k. These illustrate examples of toothed joints used to accommodate the temperature movements of free bridge lengths of 300 ft., 800 ft. and 2,043 ft., respectively. Very little trouble has been reported from toothed joints and, so far, there is no criterion for judging whether an economic as well as an effective joint is achieved in any given case.

The examples in the figures were chosen to illustrate several features. A wide range of materials are used including mild steel, cast steel and spheroidal graphite cast iron. Simple plate joints may be flame cut. Thicker teeth such as in Fig. 3j may be either machined from the solid or fabricated by welding. Lighter joints are commonly held down with anchor bars embedded in concrete, as in 3i, but heavier joints invariably use holding down bolts of a minimum diameter of 1 in. Joint 3j employs bronze set screws to hold down the cover plates, which is uncommon. But there is at least one example of joints working loose after 20 years due to corrosion of holding down bolts. In that case, replacement of the bolts would have been simple but for the fact that the sockets into which they were screwed were also corroded beyond repair. One problem of toothed joints is the provision of an adequate drainage system.

Even 6 in. diameter channels quickly silt up and, if access to the channel is not easy or maintenance infrequent, defacement of piers or abutments occurs, bearings are corroded and water may enter the fabric of the bridge. A type of joint which is fairly common, but has not yet been included in the survey, is the one in which the expansion gap is covered by a plate fixed to one side and sliding on a metal surface on the other. Previous experience has shown that thicknesses of plate, sections of angle and size and number of anchor bolts for securing the plate to the angle on the one side of the joint, which gave satisfactory service before 1939, are now inadequate because of the great increase in weight and frequency of the heavier vehicles on the public highway. It has been found essential to thicken up the sliding plate very considerably and to secure it with two rows of very substantial anchor bolts. It has been found that more efficient registering of the plate on the angles is obtained by reducing the area of contact and confining this to a number of small areas. Again first-class workmanship is essential. The use of inadequate sections has led to the bursting of the holding-down bolts, and to undesirable noise and vibration as the vehicles pass over the joint. Many joints fail because bolts are inadequately secured against loosening by vibration.

4. Notes of Bearings

In old bridges, failure of two types of bearings was not uncommon. The plain steel bearings corroded rapidly and became ineffective; the multiple roller bearing failed prematurely because of the difficulty of maintaining even loading of the rollers. Neither of these types of bearing are in common use now. In plain bearings, copper strips bearing on steel have been tried, but cold welding of asperities between the metals has occurred in some cases so that there is little improvement from the use of copper. A qualitative assessment can be made of the performance of bearings in terms of the degree to which they achieve the following desirable characteristics:

- 4.1. They should give adequate support.
- 4.2. They should permit rotation and translation in the direction and to the extent which the designer requires. They should not permit any movement in other directions.
- 4.3. They should have a predictable performance as it ages.
- 4.4. They should require no maintenance and last the life of the bridge or be easily replaceable.

During the present survey no serious case of bearing failure has been detected and hence no new guidance can be given on the choice of bearings on grounds of serviceability. The choice of the type of bearing depends largely on four factors namely, cost, loading, available headroom, resistance to move-

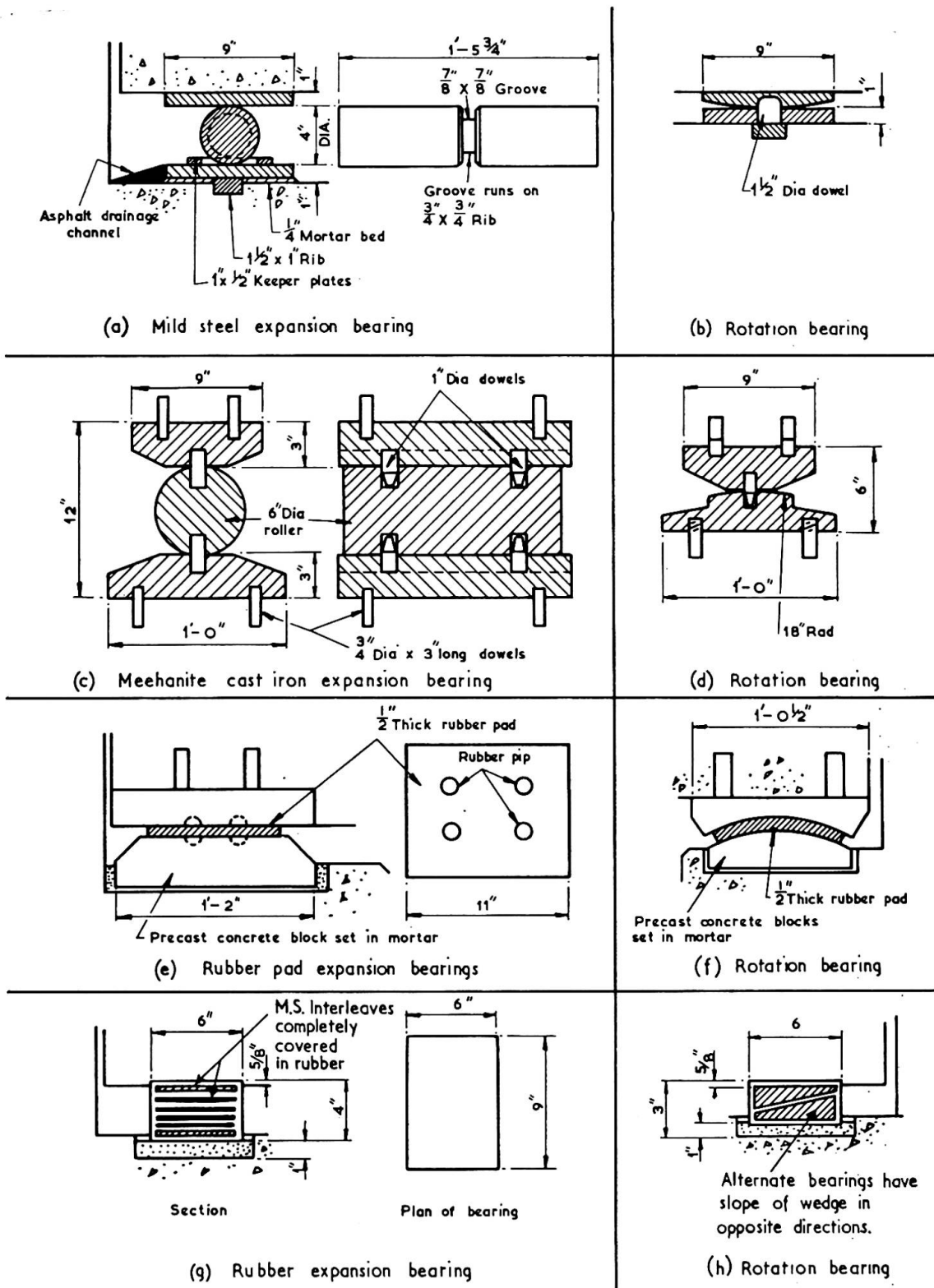


Fig. 4. Examples of expansion and rotation bearings for bridges up to 200 ft. free length.

ment. True costs are difficult to evaluate, whilst the two latter factors may be interconnected. Lack of headroom may require a very slender bridge and in that case low friction bearings may be required even on a short span to limit the moments applied by the bearings to the bridge deck. On the other hand, where a more massive bridge is designed, plain bearings may be satisfactory if the structure can accept the loading applied by the bearings during expansion.

A few examples of bearings commonly used on motorway bridges up to say 200 ft. span are illustrated and discussed below.

Fig. 4a and 4b. Simple mild steel rollers and rockers of the type shown in Figs. 4a and 4b were in common use some years ago. Corrosion protection was by coating with water repellent grease. For larger spans, mild steel rockers are still commonly used and are frequently encased in grease boxes.

Fig. 4c and 4d. Since mechanite cast iron has better corrosion resistance than mild steel, these rollers are becoming increasingly popular, and are replacing those shown in Figs. 4a and 4b. Location of the rollers can be either by dowels, as shown, or by an integral tooth cast either on the end of the rollers or on the plates. It is common practice to use rollers only at the expansion gap and to use rockers, 4d, on intermediate piers. The piers then have concrete hinges at their base to allow for movement at the bearings.

Fig. 4e and 4f. For short span bridges, simple rubber pad bearings are being widely adopted. The example shown has rubber locating dimples but in many cases pads are used without any means of location. The pads may also be glued in position.

Fig. 4g and 4h. Rubber bearings composed of laminations of rubber (or other elastomeric materials) and steel are also being widely adopted. The steel interleaves may be either exposed or encased in rubber, as shown, for corrosion protection and for reduction of the surface stresses which cause cracking of the rubber. One type of rotation bearing is shown. Alternate bearings are placed with the slope of the wedges in opposite directions.

The use of rubber bearings is a recent innovation, and considerable development is taking place of a variety of different types. It is, therefore, too soon to assess their relative merits or durability, but it is felt that in these early stages some provision should be made to facilitate their replacement in the event of premature failure. In an attempt to achieve minimum standards of serviceability and life, rules for the use of rubber bearings in highway bridges have recently appeared in Britain as the Ministry of Transport Memorandum No. 802. By the time this paper is published, a form of rubber bearing, in which the rubber is confined laterally by a steel cylinder, known as a pot bearing, will have been installed in several bridges in Britain. This bearing can accept heavy loads, and has low rotational stiffness. Steel rollers or a disc of polytetrafluoroethylene may be interposed between the top of the pot and a stainless steel plate to accommodate translational movement.

Summary

This paper gives the preliminary results of a survey of expansion joints and bearings in Britain, being undertaken by the Road Research Laboratory.

The magnitude of the movement to which joints and bearings are subjected in bridges is being measured, and an attempt is made to correlate the results with the expected temperature range and the type of structure. A number of joints and bearings have been examined, and the paper summarises the main features of their performance.

Résumé

On rapporte ici les premiers résultats obtenus par le Road Research Laboratory au cours des recherches qu'il poursuit sur les joints de dilatation et les appuis mobiles en Grande-Bretagne.

On a mesuré les déplacements des joints et des appuis dans divers ponts, et on tente de rapporter ces mesures aux variations de température attendues, selon les différents types de construction. Plusieurs sortes de joints et d'appuis sont étudiées, et on présente brièvement les principales caractéristiques de leur comportement.

Zusammenfassung

Die Verfasser berichten über die ersten Ergebnisse einer vom Road Research Laboratory in England durchgeführten Untersuchung an Dilatationsfugen und beweglichen Auflagern.

Bei verschiedenen Brücken wurde die Bewegung der Fugen und der verschieblichen Auflager gemessen, und es wurde versucht, die Größe der Bewegung in Funktion des Temperaturverlaufs und des Brückentyps darzustellen. Der Beitrag enthält überdies eine kurze Beschreibung der gebräuchlichsten Fugen- und Lagerkonstruktionen, die in bezug auf ihre Eignung geprüft werden.

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