California's Bridge Expansion Problems

RAYMOND J. IVY, *Bridge Maintenance Engineer, California Division of Highways*

This paper discusses the maintenance problems in connection with deck expansion joints, expansion bearings and hinges that are used on bridges having span lengths up to 120 feet. Types of such expansion assemblies used in the past are reviewed, their performance studied and the methods used in repairing defects outlined. From the experience gained with these earlier expansion assemblies, improvements have been made and the types currently in use are described.

● EXPANSION assemblies are the cause of some of the most troublesome problems in connection with bridge maintenance. These assemblies which are the deck expansion joints, bridge bearing assemblies and hinges, provide for such movement of the superstructure as expansion, contraction, and deflection. Because the forces that produce the movements can reach very large proportions, the assemblies must be kept in proper working order or the structure will suffer serious damage. In addition, the deck expansion joints and certain types of hinges are subjected to the direct impact of heavy wheel loads and this pounding will cause any latent defects to develop into a hazard to traffic if repairs are not undertaken immediately.

The maintenance of such expansion assemblies presents a challenge to the engineer. Faulty details can and often do cause such damage to the structure that extensive repairs are necessary. These repairs tax the ingenuity and ability of the engineer.

California has some 5250 bridges on its state highway system. Many of the older structures were designed by engineers in private practice for the various counties and these were later taken into the state system. As a result, the bridge maintenance engineer has come in contact with a wide variety of expansion assemblies. The experience gained with these as well as the earlier ones designed by the state has provided much useful data on the functioning, repair and development of bridge expansion assemblies.

The majority of bridges in this state have span lengths of less than 120 feet. While expansion problems are not restricted to such structures, these require the most attention because of their greater number. This discussion will be limited to the problems with expansion details on bridges having span lengths up to 120 feet. The three types of assemblies that provide for expansion in such structures are the deck expansion joint, the expansion bearing assembly and the expansion hinge. These will be taken up in turn and the problems concerning each reviewed from a maintenance standpoint.

DECK EXPANSION JOINTS

The expansion joints on concrete decks of bridges in this state have gone through a series of changes over a period of years. These changes were made with a view toward improving and providing a satisfactory expansion joint for use on new structures. Prior to the 1920's no armor was placed on the deck joint. The joint was separated by a sheet of expansion material. The practice of protecting the edge of the concrete deck at the expansion joint with armor was begun in the 1920's. This armor consisted of light angles, usually about 2 by 2 by ¼ inches. Figure 1 is an illustration of this early type expansion armor.

The late 1920's saw the beginning of the widespread use of the steel stringer spans. With the use of these beams there arose a need for an improved type of deck expansion joint. In the steel stringer span, the deck joint not only had to take care of the expansion in the span, but provision had to be made for support of the wheel load at the edge of the joint. The earlier structures were of the concrete tee beam or truss type and there was no problem of unsupported edges as the deck at the expansion joint was supported by a diaphragm or floor beam. However, this was not

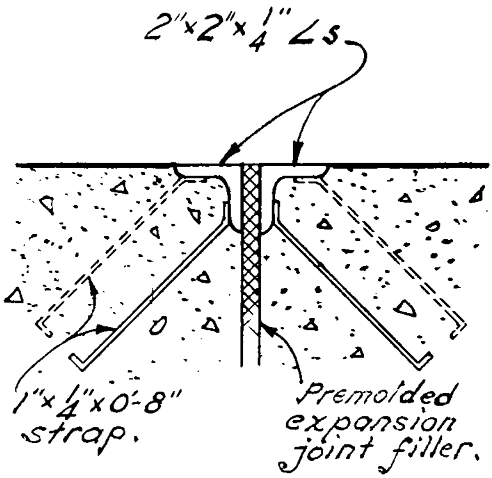


Figure 1. Early type armored deck expansion joint.

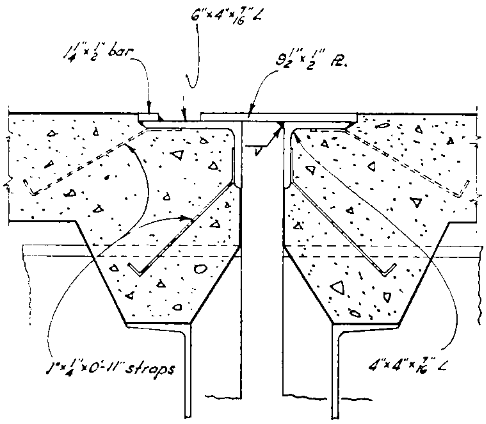


Figure 2. Expansion armor with cover plate.

the case in the steel stringer spans, and provision had to be made for the unsupported edge of the deck slab at the expansion joint.

The width of these joints also had to be increased. With the longer spans and the more prevalent use of continuous structures, the deck joint was increased to the point where provisions had to be made for a cover. The use of only two angles for armor would no longer suffice.

To provide for both a wider joint and the unsupported edge of the deck, a new type of deck expansion armor was developed. This is shown in Figure 2. The armor consists of two angles and a cover plate as shown. When the spacing between the steel beams or girders was large, the armor had to be strengthened to take care of the long length of unsupported deck joint. This was done by increasing the depth of the detail shown in Figure 2 and resting the armor directly on top of the steel beams. Such an arrangement forms an end dam.

The type of armor with the two angles and cover plate as shown in Figure 2 was a standard for deck expansion joints all through the 1940's.

Problems with Armor

The earlier types of armor, both the ones consisting of two angles and the later ones of two angles and a cover plate, were and still are a continual cause of trouble. The angles pulled loose from the anchor straps, the welds would not hold on the cover plate or the whole assembly would break away from the deck. Examples of failure of the expansion armor are shown in Figure 3.

There were many reasons for the numerous failures of the armor on these first expansion joints. Poor construction such as defective welding of the anchor straps to the angles, concrete not being properly placed under the angles, and the tops of the angles or cover plates not being in a true plane with the deck surface, all contributed to the failure of a number of expansion joints. However, most failures can be directly attributed to two factors. The first was that the armor used was too light and the second that the cover plate would not function properly.

The first armor used consisted of 2- by 2- by 1/4-inch angles. When a cover plate was added, the size of the angles was increased but the thickness of the material was rarely over 1/2 inch. This armor proved to be entirely too light for high speed truck traffic. The impact of the heavy wheels would sooner or later cause the joint to fail.

With the addition of a cover plate to the joint armor, additional trouble immediately developed. This plate, as shown in Figure 2, was welded to one angle and slid on the other on the opposite side of the joint. All too often the plate did not bear properly on the angle on which it was supposed to slide with the result that it acted as a cantilever. In some cases the distance that the plate was cantilevered out amounted to as much as 6 or 8 inches. Every heavy wheel crossing the joint

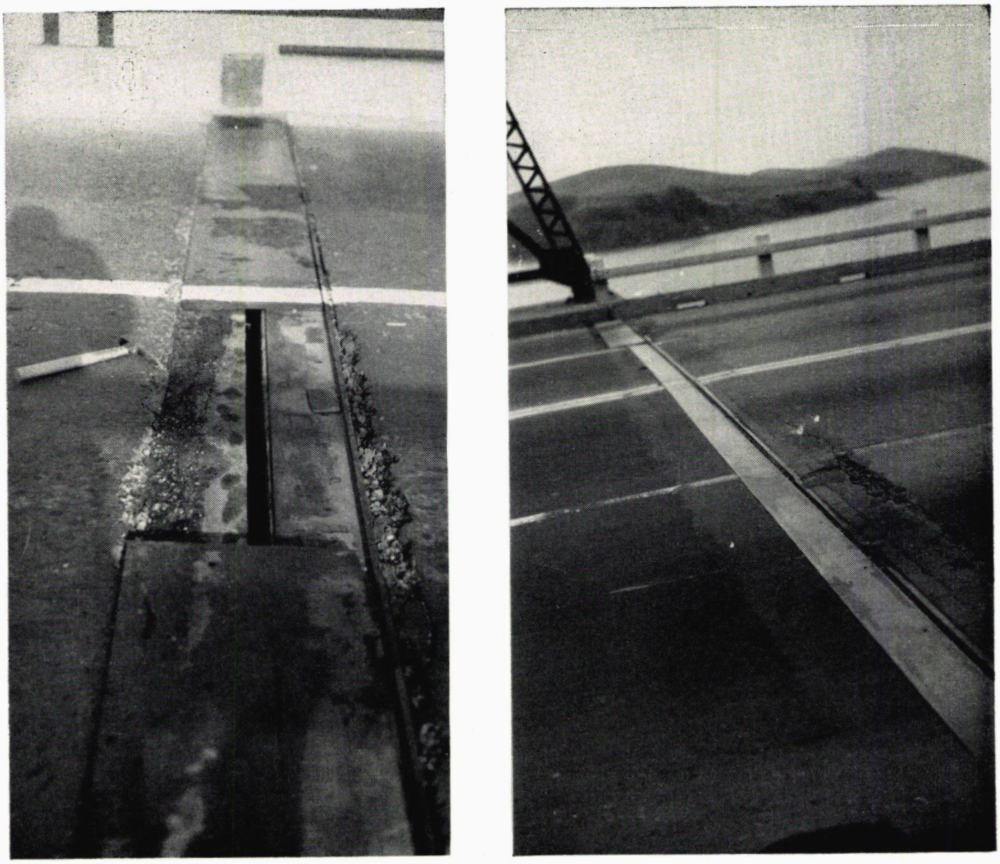


Figure 3. Typical failures of expansion armor and adjacent deck area.

would cause a deflection in the plate and this continual movement would in time cause the entire armor to be pulled to pieces.

Methods of Repairing Joints

Repairing deck expansion armor that has been pounded loose is a costly job and one that is a great inconvenience to traffic. The most difficult repair jobs are those in which the angles have broken away from the anchor straps or the whole assembly has pulled loose from the concrete deck. Where the angles have come loose from the anchor straps, numerous attempts have been made to re-anchor the angles to the concrete with various types of drilled-in anchors. These have not been successful.

Experience has shown that the only satisfactory method of repairing armor that has pulled loose from the anchor straps or has broken up the underneath concrete is to remove and reset the defective armor. To reset the armor so that it is securely anchored, a transverse strip of the concrete deck must be removed and replaced. Figure 4 shows such an operation. The width of the strip removed must be sufficient not only to take care of the anchor straps, but must also expose enough of the reinforcing steel to bond the new concrete to the old. Usually an 18- or 24-inch strip will fulfill both requirements. The key to a satisfactory repair job is in obtaining concrete that is sound and well bonded to the old. This is no small requirement. The repairs usually have to be made on half of the roadway width at a time with traffic using the other part of the deck as illustrated in Figure 4. The vibration of the deck caused by the vehicles

Figure 4. Deck and defective armor removed in preparation for resetting armor.

on the other half has a very detrimental effect on the proper setting of the concrete in the strip. By using high early strength cement and an admixture, the concrete will set properly and will also have sufficient strength so that traffic can be turned on it within 24 hours. This type of a repair is the only sure remedy for an expansion joint that has developed serious defects.

In joints where the cover plate has come loose but the angles are still securely attached to their anchors and no trouble has developed with the concrete, the repairs are rather simple. In most cases the cover plate is removed and replaced with two bars the same thickness as the plate but having such a width that each can be placed on the tops of the exposed angles and welded to them. This makes an open joint but as long as the opening is not over 2 inches in width the joint will function satisfactorily. Such a repair can be made very quickly with a minimum inconvenience to traffic.

Improvements in Expansion Joints

Considerable thought and study have been given to improving deck expansion joints. Experience with defective armor and information gained from the maintenance and repair of such joints have led to the development of armor and types of expansion joints that are comparatively trouble-free.

Much of the trouble with deck expansion joints has been overcome by the simple expedient of eliminating the armor. It is now standard practice to omit the armor on joints that are 1¼ inches or less in width. Most joints are in this width range. The deck concrete is separated by an expansion joint filler material. A joint of this type is shown in Figure 5. A rubber waterstop is shown in this detail but in some cases it can be omitted. This type of expansion joint, but without the waterstop, has been successfully used for years on concrete pavements. It will be noted in Figure 5 that the ends of the deck slab are in the form of beams supported by the steel diaphragms. With this arrangement there is no unsupported edge of the deck slab.

Where the width of deck joint is from 1¼ to 1¾ inches, angles are used to armor the edges of the joint similar to the type shown in Figure 1. However, heavier material is used. The angles are 3 by 3 by ⅜ inches, the anchor

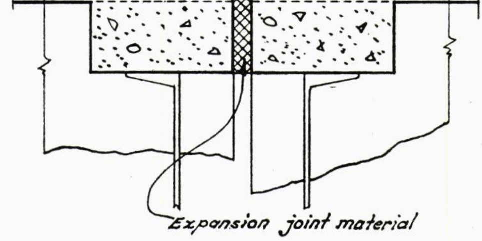


Figure 5. Unarmored deck expansion joint now in use where width of joint is less than 1¼ inch.

straps are sturdier and more welding is provided. Rubber waterstops may be used if deemed necessary.

For expansion joints that are 2 inches and over in width, the opening is covered. To avoid the troublesome cover plates that are noisy and always coming loose, an assembly has been developed that uses an angle and a tee. Such an assembly is shown in Figure 6. The flange of the tee makes a sturdier cantilever than a plate and there are no welds to break loose. Heavy sections are used for both the angle and the tee. This armor assembly has proved to be very satisfactory.

The improvements in the types of deck expansion joints and armor together with greater care given in the field to proper construction and placing have resulted in better riding joints and ones that are comparatively trouble-free.

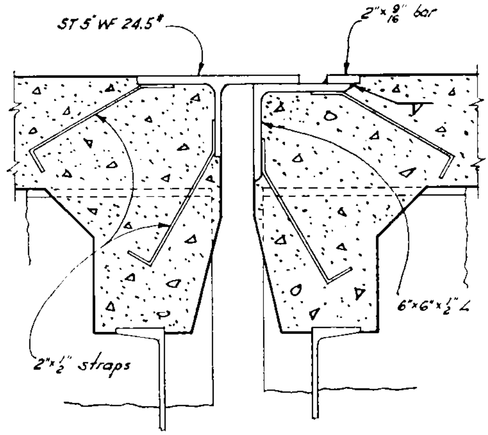


Figure 6. Armor now in use on wide deck joints. Structural tee has replaced cover plate.

BRIDGE EXPANSION BEARINGS

While armor and many of the details of deck expansion joints are of fairly recent development, expansion bearing assemblies of one type or other have been in use on the earliest bridges. Two types of bearing assemblies were used on the early-day bridges to provide for expansion. The first was the sliding plate bearing as illustrated in Figure 7 *A* in which the sole plate slid on the fixed masonry plate. These plates were of either steel or bronze and were separated by a thin sheet of graphite-coated material to facilitate sliding. Plate assemblies to provide for expansion were used on all concrete girder bridges and for plate girder and steel truss spans up to 80 feet in length. For spans over 80 feet, which in the early days were either plate girders or trusses, the second type of bearing assembly was used which consisted of rockers or segmental rollers, either singly or in nests.

As the concrete girder spans began increasing in length the sliding plate bearings would not function properly because of the heavy dead load. For spans in the range of 50 to 60 feet a rocker type bearing was developed. This was a single segmental roller. Both the rocker and plates were of cast steel. Figure 7 *B* shows this type of expansion bearing.

The development of the wide flange beam with its rapid and widespread use in steel stringer spans during the 1930's pointed up a need for a simple and inexpensive expansion bearing for this type of a bridge. The sliding plate bearing was not satisfactory because the deflection of the beams caused very high edge bearing stresses. To overcome this, a bar type expansion assembly was developed. Figure 7 *C* is an example of this type. The bar, usually about 2 inches wide, 4 inches high, and of the required length, was placed between the masonry and sole plates. The top of the bar on which the sole plate slid was made curved slightly. The bottom of the bar was welded to the masonry plate. A grout pad 1½ inches in thickness was called for between the masonry plate and the concrete bridge seat. This grout pad was placed after the steel was erected and facilitated leveling the beams and connecting the diaphragms.

In passing, a note might be given to the fixed bearing used in connection with the bar type expansion bearing on steel stringer spans. Both the fixed and expansion bearings were identical except for the openings in the keeper plates. The similarity of both bearings was one of the main advantages of this bar type assembly.

The curved sole plate type assembly as shown in Figure 7 *D* is often used for short spans. It provides for the deflection of the beam and is an improvement on the sliding plate bearing.

Problems with Expansion Bearings

Some of the early types of bridge expansion assemblies functioned satisfactorily while others caused serious trouble. The roller or rocker type assembly has a very good record.

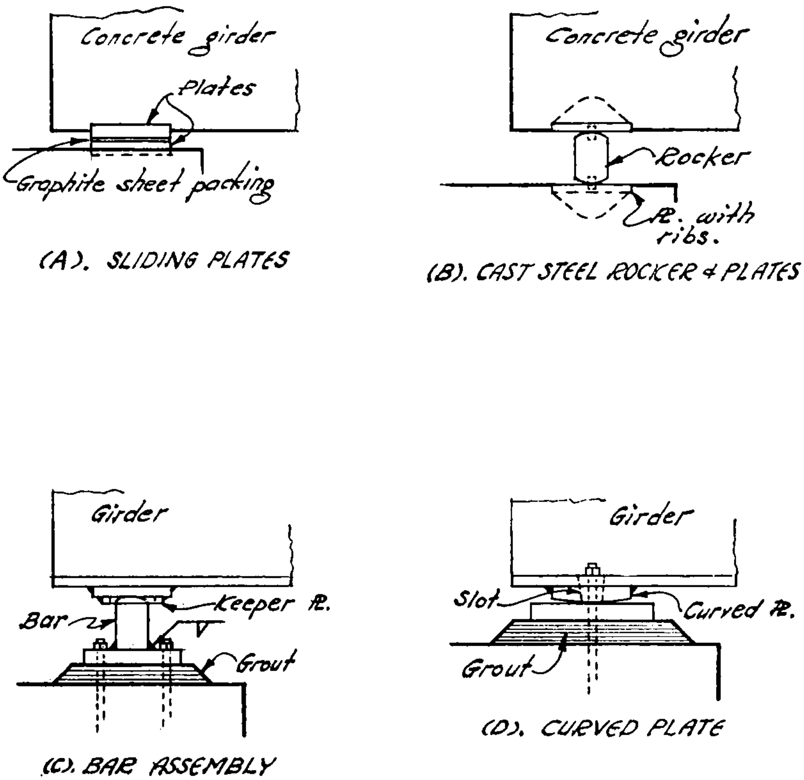


Figure 7. Typical expansion bearings that have been used in the past.

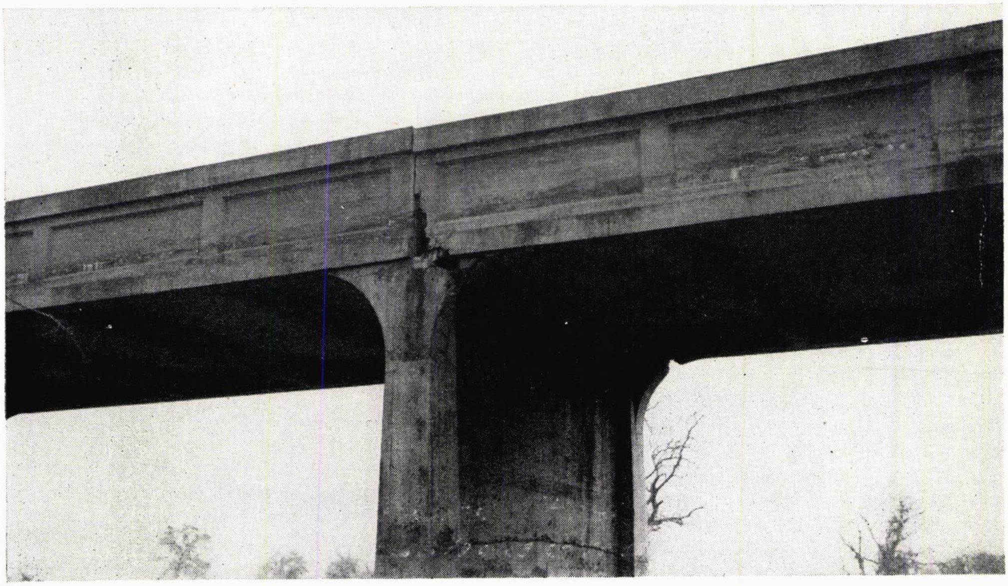
Bearings of this type have been in service for many years without causing any difficulty. They have given the best performance of any of the expansion assemblies.

The same cannot be said of the sliding plate bearings. They have been a prolific cause of trouble. The numerous ruptured bridge seats all testify to the poor performance of this type of bearing. Figure 8 shows some typical failures involving plate bearings. These failures are caused by several factors. The plates freeze up for one reason or another and will not slide. The deflection of the beam or girder caused either by heavy loads or by plastic flow in the concrete itself sets up very high pressures at the edges of the plates. Often the plates were not set properly. The result of any of these and possibly a combination of all was a spalling of the concrete or a broken bridge seat.

The bar type of assembly which was to be an improvement on the sliding plates for use with steel stringers developed trouble in an unexpected place. The curved top of the bar provides for the deflection of the beam and the sole plate slides on it fairly well if the end reaction is not too large. However, the grout pads which were used as an expedient in steel erection, have proven to be a major source of trouble. These grout pads have broken up on many structures within the first six months or year. Figure 9 illustrates the failure of grout pads. There is apparently sufficient friction on the bar to cause a slight movement of the masonry plate and a number of repetitions of this movement causes the pad to go to pieces. Failures are most prevalent on skewed structures. In places where the grout was built up above the bottom of the masonry plate, breakage was certain to occur. The number of group pads breaking up became so large that the use of this bar type of expansion bearing assembly was discontinued.

Repair

Repairing the damage resulting from an improperly functioning expansion bearing assembly is quite often a major job. Figure 8



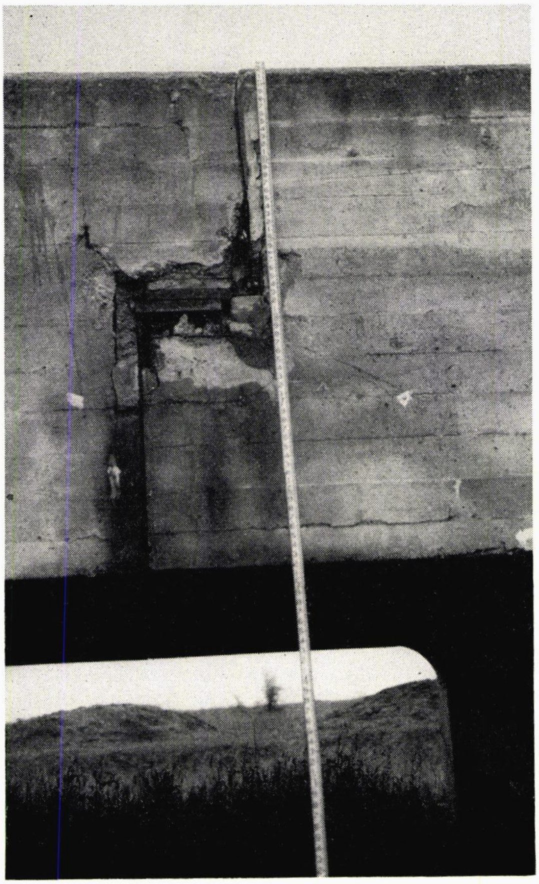
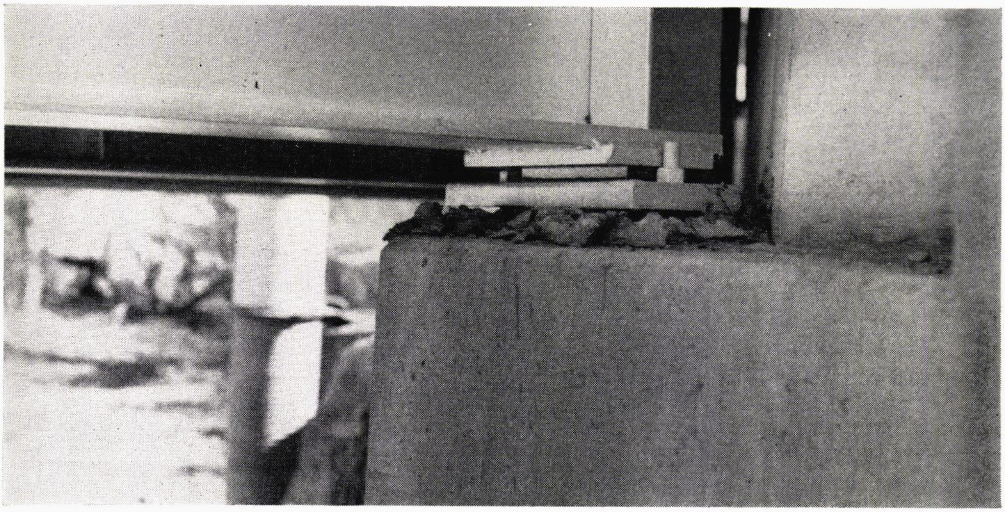


Figure 8. Results of improperly functioning sliding plate bearings.



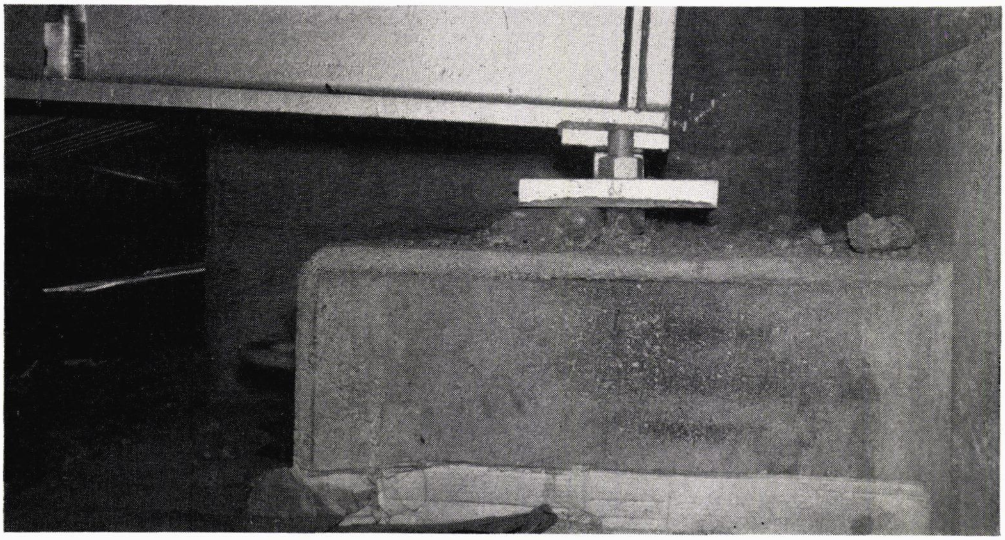


Figure 9. Examples of failure of grout pads under bearings for steel stringer spans.

indicates this very vividly. In most cases not only is the bridge seat damaged but also the end of the concrete beam. The weight of the structure as well as the live load has to be carried by falsework while the damaged portion is removed, new bearings set and new concrete placed. It is an expensive operation as well as a difficult one but if repairs are not made or if they are delayed too long, the entire span might collapse.

Defective bearing plate assemblies are usually replaced with a roller or rocker type. This requires some changes to take care of the added depth of the rocker but an expansion assembly that will function properly is insured. A multiple span structure having bearing plates that are showing signs of giving trouble can often be repaired by placing a rocker type assembly at every third or fourth span. This will usually provide for enough movement and relieve the intermediate joints.

The repair of grout pads in use under

steel stringer spans is not as expensive an operation as is required for the sliding plate assembly. Usually only the grout pad is damaged. Often the masonry plate can be supported by temporary shims while new grout is placed and allowed to set. Where large loads are involved, the end of the beam may have to be supported by falsework until the work on the grout pad is completed. This insures a good job but it is expensive. An admixture is added to the cement and sand to give additional strength, prevent shrinkage, and speed the setting time. The top of the pad is finished flush with the bottom of the masonry plate and extended beyond the edge of the plate an inch or so. With this arrangement any slight movement of the plate will not tend to break up the grout.

Types Now in Use

Past experience with the sliding plate and bar types of expansion bearing assemblies has shown that such friction bearings are not suitable for use in present day structures. The sliding plate type has not been used for several years and recently the bearing bar has been discontinued. The rocker type is now used for all expansion assemblies.

Figure 10 shows the standard expansion bearing assembly used with concrete tee beam or box girder structures. No grout pad is used with this assembly. Concrete is poured around both the top and bottom plates.

Figure 11 shows the standard expansion bearing used with steel stringer structures. The grout pad has been retained as it is considered an advantage in construction. It allows the beams to be leveled and aids in fitting up the diaphragms during erection. Some improvements have been made which are expected to overcome the past troubles with the grout pads breaking up. The bridge seats have been recessed 1 inch which will give a 3-inch thick pad and will allow for easier placement. The recess will also tend to confine the grout. An additive is to be used to insure high early strength and prevent shrinkage. Fabric washers are called for between the bottom of the masonry plate and the leveling nuts on the anchor bolts. These are to prevent the leveling nuts from supporting the plate and will insure it resting firmly on the grout pads.

On some of the heavier beam or plate girder spans an expansion assembly similar to that shown in Figure 11 is being used but in place of the grout pad an impregnated fabric pad is being tried. This pad is ½-inch thick and rests directly on the concrete bridge seat. Such an arrangement is an ideal one from the maintenance standpoint but it does not allow for any adjustment during the erection of the steel.

Mention should be made of the fixed bearing assemblies that are used in connection with the expansion bearings shown in Figures 10 and 11. The fixed bearing used on steel stringer spans is shown in Figure 12. This is used in conjunction with the expansion bearing shown in Figure 11. It will be noted that the details of both are similar except for the fixed bar and the rocker. The fixed bearing for use on concrete tee beam or box girder structures is similar to the expansion bearing shown in Figure 10 except a fixed bar is used in place of the rocker.

The use of rockers in all expansion bearing assemblies will insure a minimum of maintenance on these assemblies in the future as the roller type bearings have a very good performance record. However, the large number of friction type bearings still in use such as sliding plate or bar assemblies will keep the maintenance crews busy making repairs for a long time to come.

EXPANSION HINGES

Hinges have come into common use with the continuous span structure. They provide for the expansion of the superstructure and are usually placed near the quarter point of a span. Because of their location hinges must be designed to take care of deflection as well as expansion.

Three types of hinges are used in California. These are the hanger type employed on steel stringers and girders; a sliding plate type for concrete tee beams and box girders; and a combination deck expansion joint and hinge used for flat slab structures.

The hanger type hinge employed on steel beams and girders is universally used and well known. The details for the pins and hanger plates have been standardized to conform to good shop practice. Hinges are used more frequently on steel beam and girder bridges than on other types of structures. This is partly because the hanger type hinge is a very suitable expansion assembly and partly

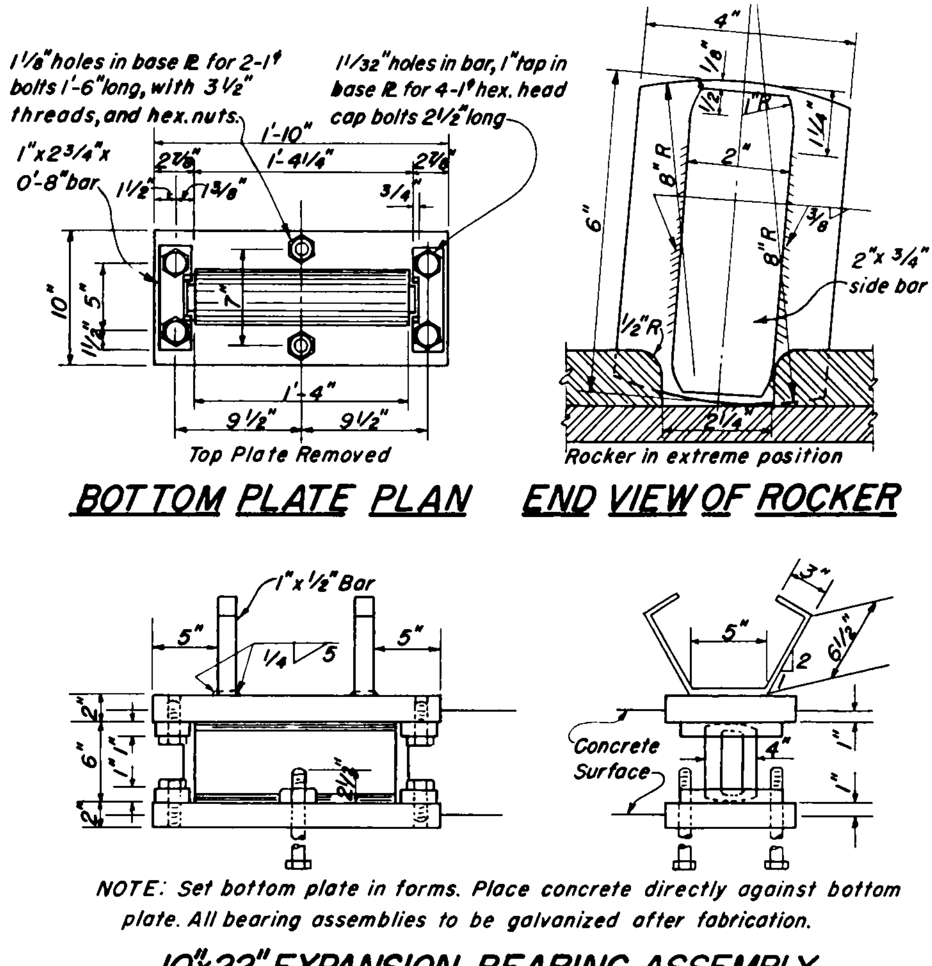


Figure 10. Standard expansion bearing assembly now used on concrete tee beam and box girder spans.

because suspended spans are so commonly used on steel beam and girder bridges.

The hinge used on concrete tee beam and box girder structures is a sliding plate type of expansion assembly. Figure 13 shows the details of such a hinge. The two angles with the sheet packing between is in effect the same detail as the early day bearing assembly that gave so much trouble. However, this hinge detail has been used numerous times and has functioned very satisfactorily. The length of the angle assembly is 3 feet for the outside girders and 5 feet for the interior girders. An assembly is placed at each girder. The bearing of the angle on the concrete is less than 700 psi. It will be noted that no armor is used on the deck joints. A rubber waterstop is employed where deemed necessary.

The satisfactory performance of this hinge is in contrast to the sliding plate bearing assembly whose use was discontinued because of the trouble it caused. The proper functioning of the hinge can be attributed to the angles being well embedded and anchored to the concrete; the comparatively low bearing of 700 psi on the concrete; and to the relatively small deflections in concrete girder spans.

The third type of hinge is a combination deck expansion joint and hinge for use on continuous flat slab spans. Figure 14 shows the

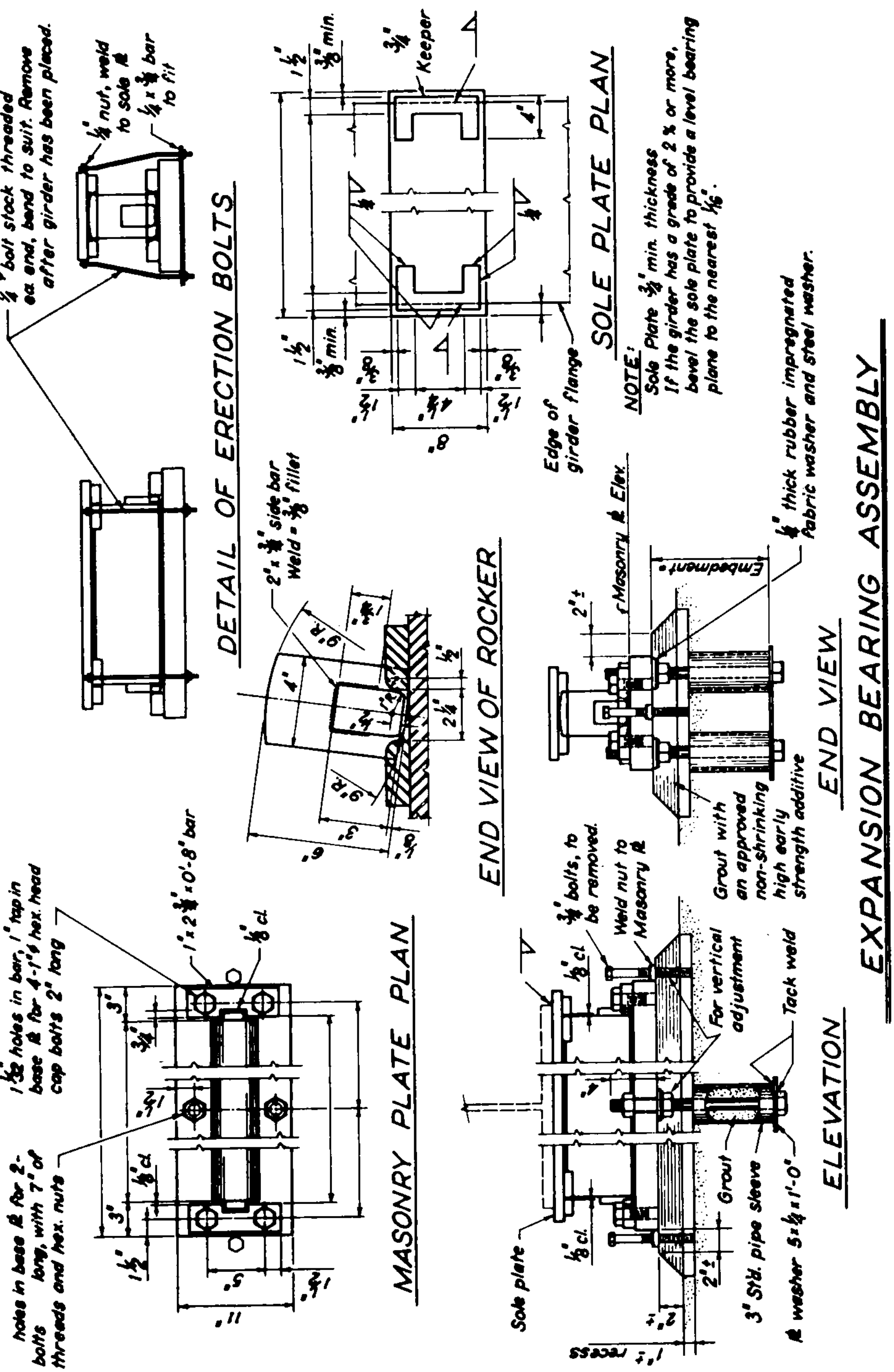


Figure 11. Standard expansion bearing assembly now used on steel stringer spans.

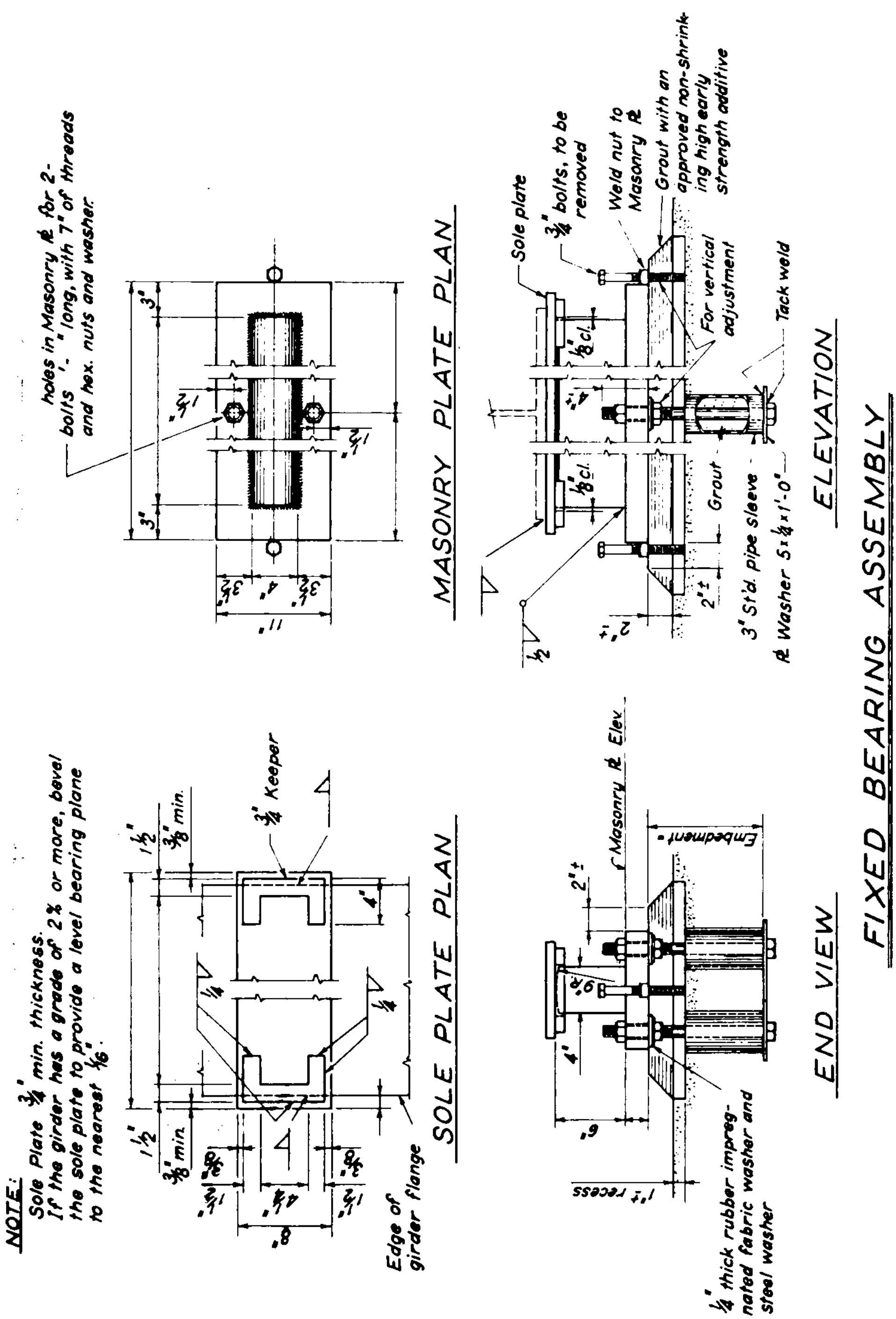


Figure 12. Standard fixed bearing now used on steel stringer spans.

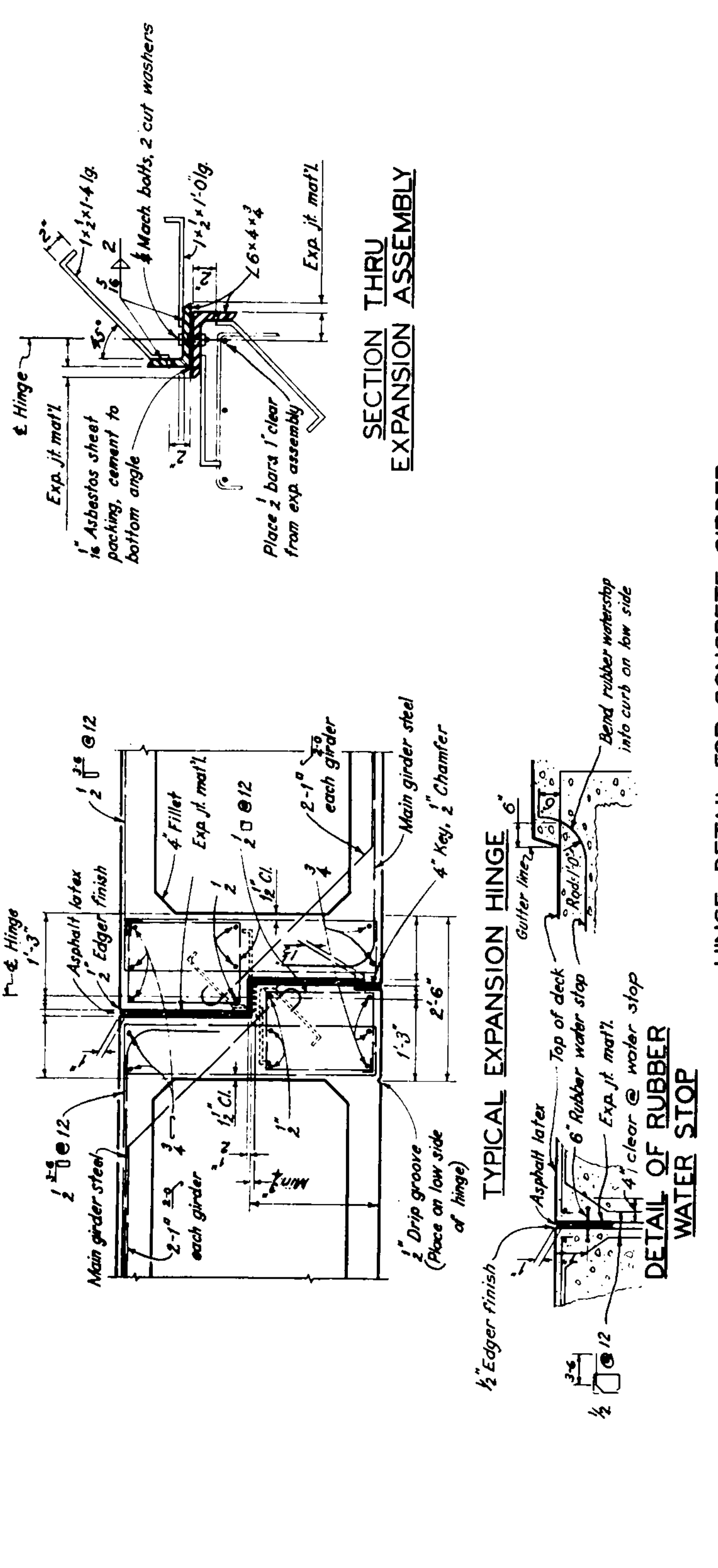


Figure 13. Expansion hinge in use on concrete tee beam and box girder spans.

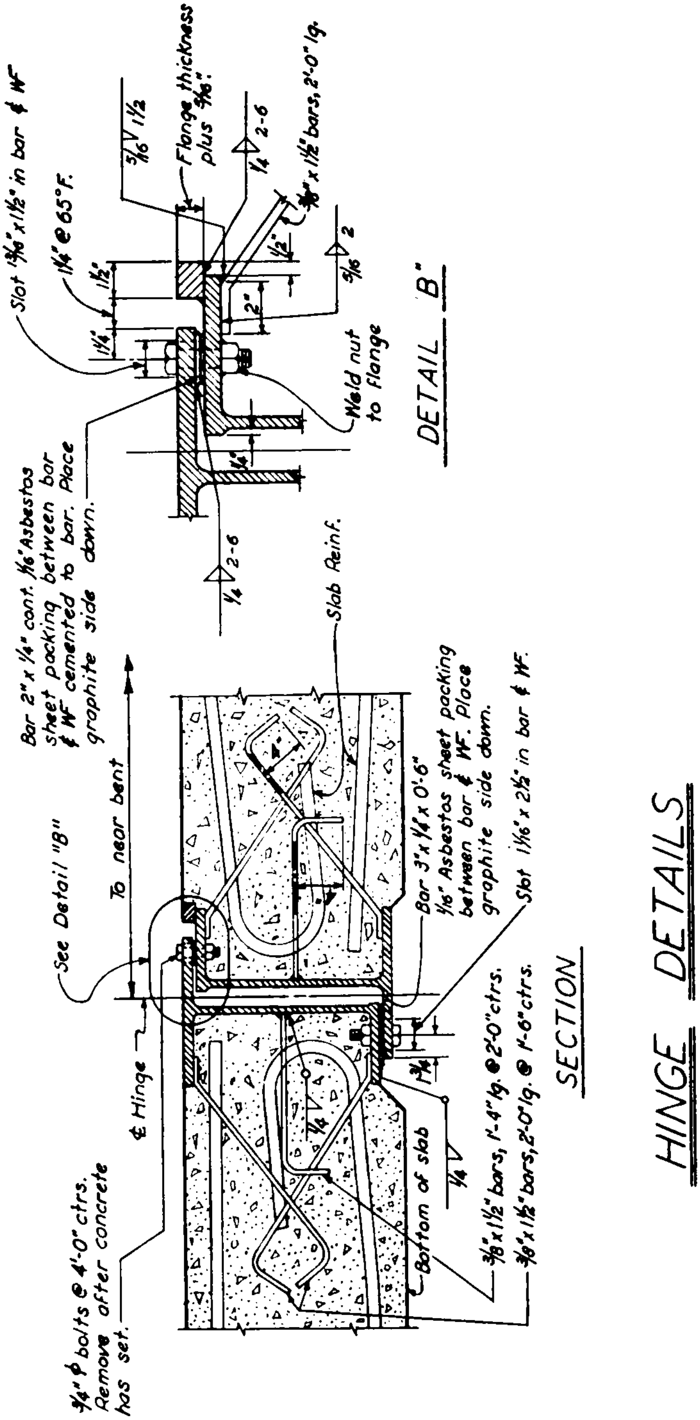


Figure 14. Combination hinge and deck expansion joint in use on continuous flat slab bridges.

details of such a hinge. The assembly is made up of sections cut from wide flange beams. For a bridge having 16-foot spans, the slab depth would be 10 inches and 8-inch, 53-pound wide flange sections would be used. For 44-foot spans, the slab depth would be 22 inches with 21-inch, 127-pound wide flange sections. Such an expansion hinge is required for every 150-foot length of bridge. As the total length of most flat slab structures is less than this, hinges are not often required. However, these assemblies have given very good service both as hinges and as deck expansion armor.

The performance of all three types of hinges has been excellent. This is fortunate as the hanger type and the sliding angle detail for concrete girders are used on a large number of bridges. To have such assemblies that are trouble-free is a relief to the maintenance engineer.

SUMMARY

Expansion assemblies used on bridges having span lengths of less than 120 feet are of three types. These are the deck expansion joint, the expansion bearing assembly, and the expansion hinge.

Most problems encountered with deck expansion joints are caused by armor which is too light or by the use of a cover plate which is a source of trouble. The repairs arising from such defects are difficult to make as usually part of the concrete deck slab must be removed and replaced. Joints have been improved by simply eliminating the armor where the width of opening is less than 1¼ inches. Where the width is from 1¼ to 1¾ inches, comparatively heavy angles are used to armor the edges. For wider deck expansion joints, heavy armor is used and the cover plate is replaced by a structural tee.

Two types of bridge expansion bearing assemblies have been generally used in the past to provide for the expansion in bridge superstructures. One was the rocker or segmental roller. Very little trouble has developed when this type of expansion bearing has been used. The other type commonly used was the friction type consisting either of sliding plates or a bar upon which the sole plate slid. Both of these have been a prolific source of trouble. The numerous broken grout pads, ruptured bridge seats and spalled concrete all testify to their inefficiency. This friction type has been discontinued and the rocker is now used in all bridge expansion bearing assemblies.

Three types of expansion hinges have been developed for use on continuous span structures. These are a hanger type used on steel stringers and girders; a sliding plate type for concrete tee beams and box girders; and a combination deck expansion joint and hinge used for flat slab structures. All three types have proved to be trouble-free and very satisfactory.

The experience gained in handling and solving expansion difficulties has led to the development and improvement of assemblies which are performing satisfactorily. These new types that are now being used will relieve the maintenance engineer of most of the bridge expansion problems that have plagued him in the past.