Section 3
Construction, Installation and Attachment Details

INTRODUCTION

Steel bridges contain special features that influence the selection, design, and installation of suitable bearing systems and attachment details. The influence of these features is discussed in this section.

SELECTION AND DESIGN ISSUES

Lateral Forces and Uplift

Bearings in steel bridges may be subjected to lateral forces or uplift. However, bridges in which these load effects have a significant influence on the bearing selection and design are the exception rather than the rule. In past years, steel bridge design specifications required that steel bridges be anchored against uplift in all cases, but the AASHTO LRFD Specifications do not contain this arbitrary requirement. Thus the bearings for the majority of steel bridges can be simple and economical.

Lateral forces may arise from wind, traffic, seismic or hydraulic loads. For stream crossings, hold downs, such as anchor bolts, are recommended if the elevation of the bottom of the superstructure is within 600 mm (2 ft) of the design flood elevation. Earthquake forces may be mitigated by the use of seismic isolation bearings, which are beyond the scope of this report. These lateral forces must be accommodated. However the engineer should determine the true magnitudes of the loads and the combinations that can plausibly occur and base the design on them, rather than on empirical rules. Lateral forces are also induced by the resistance to imposed displacements caused, for example, by temperature change.

The potential for uplift under gravity load exists in bridges that are continuous with a high live load to dead load ratio, very uneven span lengths, curved, or heavily skewed. In many cases neither uplift nor lateral loading will occur, in which case the bearing attachment details will be simple and economical.

A variety of attachment details are possible. They generally fall into two categories: those suitable for flexible systems with no mechanical moving parts such as steel reinforced elastomeric bearings, and those suitable for relatively stiff systems such as pot bearings. In all cases and in all potential load directions the engineer is faced with the choice of allowing a displacement to occur or inducing a force if the displacement is restrained. The design will influence the bearing attachment details. Generally, vertical displacements are resisted, rotations are allowed to occur as freely as possible and horizontal displacements may be either accommodated or resisted. The attachment details should be consistent with the behavior of the bridge.

Small Lateral Force and No Uplift

The majority of bearings fall into this category, so it is important. Lateral forces are small in bearings that are equipped with a PTFE slider, or in a flexible bearing adjacent to some fixed point in the bridge. Attachment details for flexible (e.g. elastomeric) and stiff systems are discussed separately. In most cases the details are economical because the requirements are modest.

Minimum Attachment Details for Flexible Bearings

An elastomeric bearing pad or steel reinforced elastomeric bearing may simply be placed under the girder with no positive attachment, as shown in Figure II-3.1. It is held in place by friction and its main function is to accommodate rotations. The detail is the most economical possible.

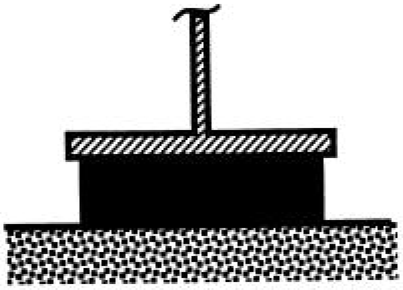


Figure II-3.1: Attachment of an Elastomeric Bearing with Small Lateral Load and No Uplift

The possibility of slip should be checked using the load combination with the maximum possible concurrent ratio of horizontal load/vertical load. Elastomers typically exhibit less friction against steel than against concrete, especially if the latter has been intentionally left rough, so the steel-elastomer interface is the likely location for potential slip. The friction coefficient between elastomer and steel varies with pressure and surface condition, but a value of 0.2 is usually attainable and is recommended in the AASHTO LRFD Specifications(10). This friction value will be high enough to prevent slip, provided that the maximum horizontal load does not occur in conjunction with an exceptionally light vertical load. This follows from the fact that the bearing's shear deformation is limited by the AASHTO LRFD Specifications to 0.5 h_{rt}, and small shear deformations imply small lateral loads.

It should be noted that a recent study(7) has shown that some elastomer compounds exhibit very low friction and that bearings made from them have slipped out of place. The effect was found to occur only with bearings made from certain natural rubber compounds which contain large quantities of anti-ozonant waxes. Furthermore, some of the bearings in question were set on very smooth concrete surfaces.

Minimum Attachment Details for HLMR Bearings

HLMR bearings, such as pot or spherical bearings, theoretically need no attachment for service load since, under the specified conditions of small lateral load and no uplift, friction will be adequate to prevent movement. However, they contain mechanical moving parts, and the consequences of these components becoming misaligned by unexpected bearing movements are grave. Furthermore, small superstructure movements could lead to large forces in stiff bearing systems. Therefore HLMR bearings are required to be bolted to the support.

Uplift Alone

Potential uplift displacements may either be permitted to occur or they may be restrained, in which case a force is developed in the restraining system. Mechanical bearings are almost always restrained against uplift to prevent the bearing damage that might occur if components become misaligned. In elastomeric systems, uplift displacements may be acceptable provided that expansion joint and girder misalignment cannot occur and that the impact loading caused by renewed contact with the piercap is acceptable. Elastomeric bearings are likely to return to their zero strain position during uplift, and therefore the effective installation temperature of the bearing will be the temperature of the bridge when the superstructure and bearing return to contact. This change in effective installation temperature is not a major concern with flexible bearings, since elastomers are quite forgiving of overly large deformations that are infrequently applied. Only in extreme cases, are elastomeric bearings likely to required repositioning after temporary uplift.

Uplift Attachment Details for Flexible Bearings

Elastomeric bearings may be restrained by a simple bolted detail, as shown in Figure II-3.2. Two bolts placed at the axis of rotation provide the least restraint to rotation while preventing the uplift. A sole plate (shown in the Figure) is often used to avoid drilling the girder flange. It also allows some tolerance in the placement of the girder on the sole plate, if the sole plate can be field welded to the girder. (The sole plate is wider than the girder flange so this weld can be made downhand). The erector may also prefer to shop weld this connection. Possible methods are discussed under "Erection Issues" at the end of this section.

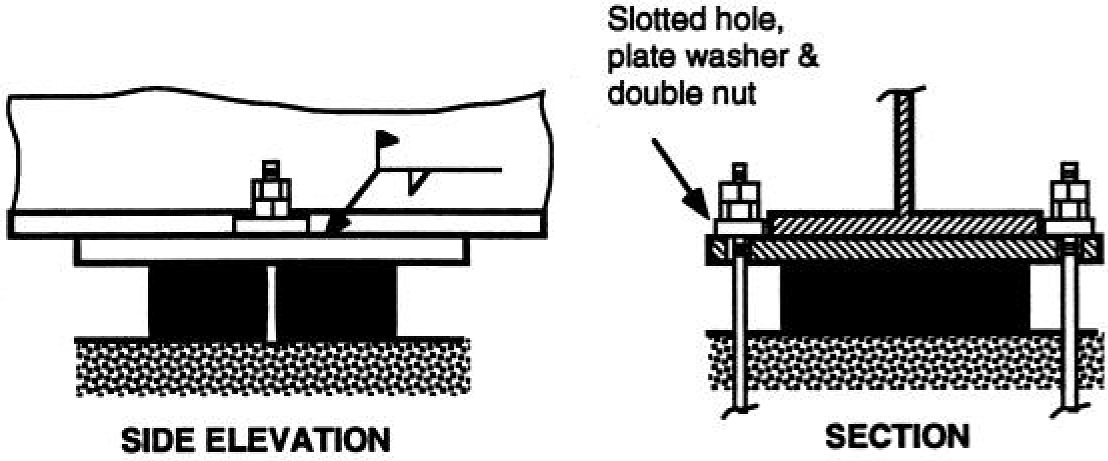


Figure II-3.2: Elastomeric Bearing with Uplift Restraint

Uplift Attachment Details for HLMR Bearings

Uplift restraint of HLMR bearings poses difficult problems. The restraining system must be sufficiently rigid to prevent vertical movement, but it must contain sufficient articulation to allow relative rotation, and possibly relative horizontal movement, of the components. Individual manufacturers have proposed their own hold-down details. Most add significantly to the price of the bearing.

Lateral Load Alone

Some degree of lateral load on a bearing is common. The engineer must decide how many of the bearings are to resist such loads. In stiff bearing systems, such as pot or spherical bearings, it is often best to carry the lateral loads on a small number of bearings. This avoids not only the potential additional loads from restraint of transverse temperature expansion but also the uneven distribution of applied lateral load that can occur with stiff bearing systems. If this philosophy causes the lateral load on a single bearing to be too large, particularly compared with its vertical load, a separate guide system may be used to resist lateral load, as illustrated in Figure II-3.3. The advantage of this approach is that it separates the functions of carrying the lateral and vertical loads and permits a wider variety of choices for the individual components.

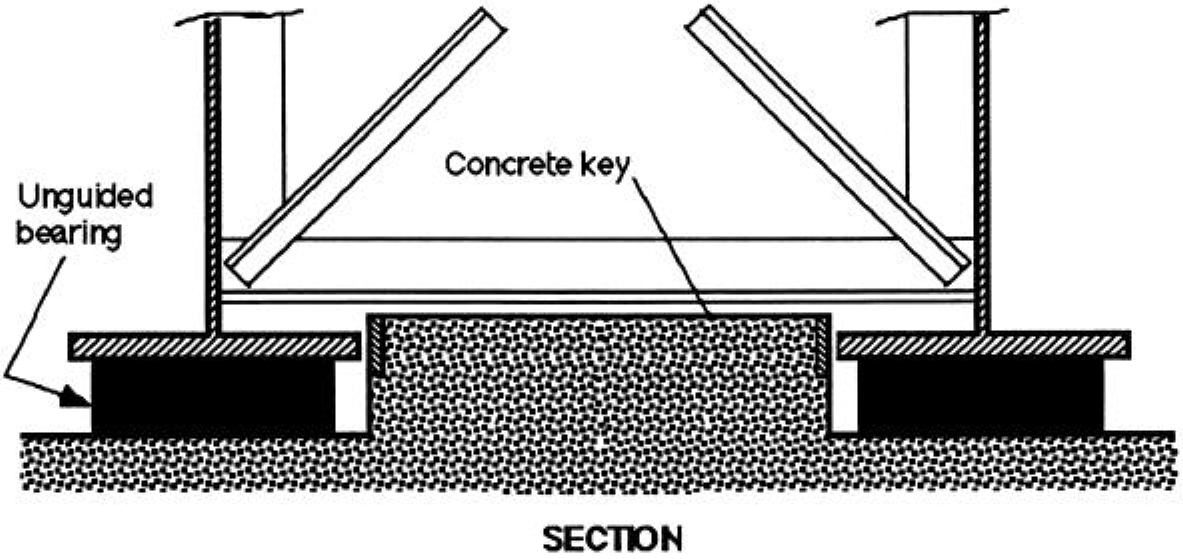


Figure II-3.3: Separate Guide System for Resisting Lateral Loads

With flexible bearing systems, the deformation needed to accommodate the transverse temperature expansion is small compared with the overall bridge movements, so all the bearings can be used for resisting lateral loads.

Lateral Load Attachment Details for Flexible Bearings

Applied lateral loads, such as from wind forces, should be distinguished from applied longitudinal displacements, such as caused by thermal expansion. In the former case the bearing should be stiff enough to prevent excessive movement, or an independent horizontal force resisting system should be used. In the case of expansion, the displacement is a given so the bearing should be flexible in order to limit the forces between the substructure and superstructure.

The simplest arrangement for resisting applied loads is to use a relatively low-profile elastomeric bearing with no external restraint as shown in Figure II-3.1. The thickness and plan area are selected to furnish the required stiffness, but the bearing must still be thick enough to accommodate the required rotation. The possibility of slipping should also be checked. If the lateral loads are caused by wind or traffic forces, they are likely to be small compared to the dead weight of the bridge, in which case this detail is viable.

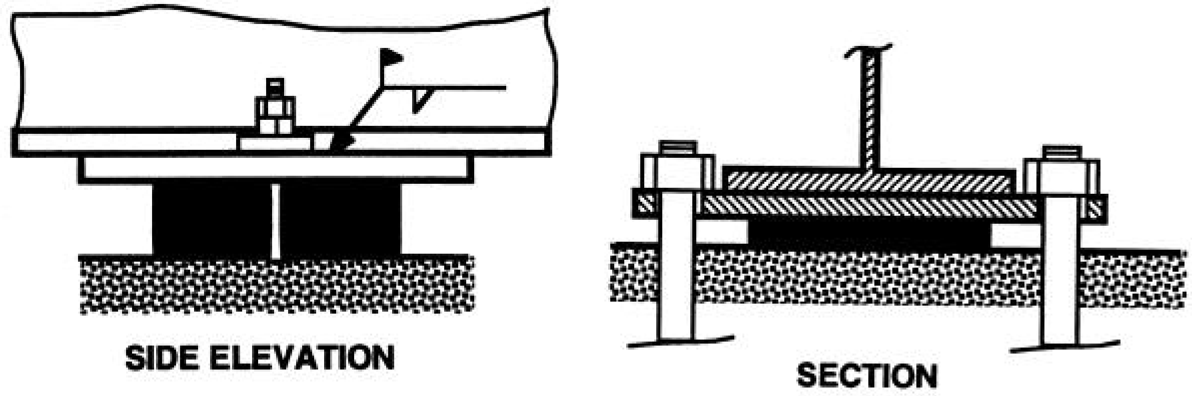


Figure II-3.4: Bolt Detail for Resisting Lateral Loads

If the lateral force is too large for this simple detail, bolts may be used, as shown in Figure II-3.4. The bolts are loaded in bending and shear, so they should be designed properly. Such a detail works if motion in both horizontal directions is to be prevented. If the bearing is to be free to move in one direction and fixed in the other, slotted holes may theoretically be used. However in practice they risk freezing up from accumulation of dirt, corrosion and layers of paint. In this case some separate guide system, such as the one shown in Figure II-3.5, may be used.

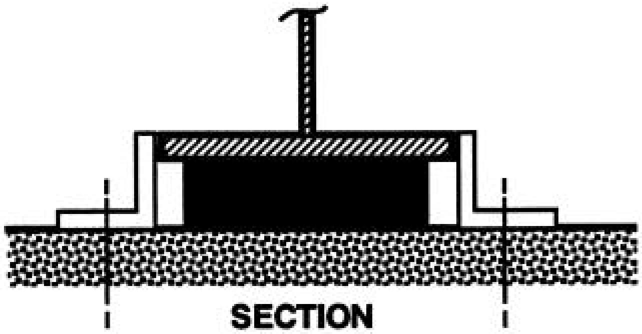


Figure II-3.5: Guide Detail for Resisting Lateral Loads

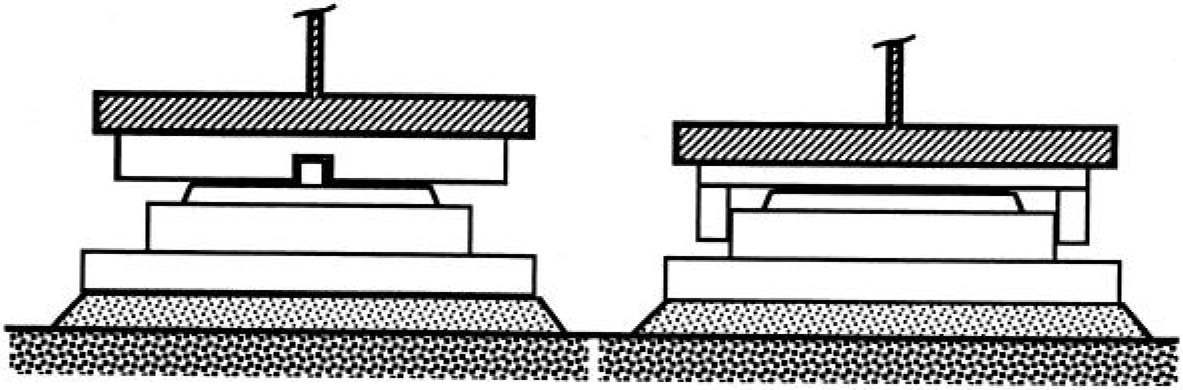
Lateral Load Attachment Details for HLMR Bearings

In stiffer systems such as HLMR bearings, the ability to permit movement or resist load depends on the bearing type.

Among pot bearings, the simplest type is fixed in all directions and permits only rotation. A pot bearing that is free to slide in all directions can be made by adding a PTFE slider, but resisting load in one direction while permitting movement in the other requires both a slider and a guide system. This is therefore the most complex and expensive bearing system.

The same ranking also holds for spherical bearings. However use of spherical bearings should be considered carefully because of their geometry. A nominally fixed bearing uses only a spherical sliding surface, but it is not truly fixed because it rotates about the center of the sphere. This point is usually not at the location of the neutral axis of the girder, so some longitudinal movement must be allowed to occur or else a longitudinal force will be introduced. Use of a sliding bearing at the other end of the bridge allows this movement to occur.

The geometry of the guide system may exert a considerable influence on the forces carried by individual bearing components. For example, in a pot bearing, two external guides or one central 'internal' guide may be used, as illustrated in Figure II-3.6. If the guides bear against the piston (Figure II-3.6a) the lateral forces must then be transmitted from the piston to the pot wall by contact stresses. This arrangement introduces the possibility of heavy wear on the piston rim and so is suitable only if the horizontal loads are low, say less than about 5% of the vertical load. Larger horizontal loads should be carried by external guides that bear against the outside of the pot wall (Figure II-3.6b), but then enough clearance must be left to permit rotation of the bearing. For this arrangement, the outside of the pot wall must also be straight, rather than circular, in plan so a slider can be mounted there. Binding of the guides during rotation will be minimized if the center of the guide is at the same elevation as the center of rotation of the bearing. This may be taken as the top surface of the elastomeric pad in a pot bearing.



a) Internal guide **b) External guide**

Figure II-3.6: Guides for HLMR Bearing

The guides should be designed according to principles of structural mechanics. A horizontal force on a guide typically induces both shear and bending (or overturning) moments. Since guidebars are usually bolted to the top plate, the connection must be designed for the moment as well as the shear. If the bolts are fitted into drilled and tapped holes in the top plate, the plate thickness must be adequate to develop the full strength of the bolt within the thread length available.

Clearances and tolerances are important in the design of guides. Clearance refers to the distance intentionally placed between two components to permit relative movement. Tolerances are the unintentional but inevitable variations from nominal values in component dimensions and locations. They arise from both fabrication and erection. The net clearance is therefore the nominal clearance plus or minus the tolerances on the adjacent parts.

A net clearance that is too small may restrict movement, while one that is too large may cause any lateral loads to be carried by a single bearing, because the guides of the others are not in contact. All guides at a bent must be installed parallel to each other within a small enough angular tolerance to prevent binding of the system. Furthermore, the direction selected for free motion at each bent should be consistent with the that of the movements of the total bridge system, especially in curved or skewed bridges. The use of unguided bearings, possibly in combination with an independent guide system as illustrated in Figure II-3.3, should be considered, since this is frequently the most reliable method of developing large restraint forces or directional guidance for the bearings.

It is clear that guides and restraints should be used only if a clearly identified need for them exists. They have the potential for inducing unexpected and unwanted forces into a structure and the certainty of adding cost to the bridge.

Combined Uplift and Lateral Load

Designing for combined uplift and lateral load is difficult. In pot and spherical bearings, providing restraint against uplift at the same time as allowing free rotation poses problems, and designs for these bearing types therefore tend to be expensive. If the rotation occurs about only one axis and the uplift forces are large, a traditional pin bearing might prove cost-effective. However, many bridges have some degree of skew, which induces rotation about more than one axis and renders this bearing type unsuitable. Furthermore, such bearings have a high profile and are more susceptible than are lower-profile bearings to overturning under seismic loads. Elastomeric bearings provide feasible and economical solutions under many conditions.

The detail shown in Figure II-3.4 for resisting lateral load will also resist uplift forces. It is simple to fabricate and install. The bolts should be installed at the axis of rotation so that they do not develop tension when the bearing rocks.

DESIGN FOR REPLACEMENT

Bearings are subjected to severe service conditions, which may lead to service lives that are shorter than for other bridge components. This is particularly true for systems such as mechanical bearings that require maintenance. Therefore the need for replacement of all or part of the bearing system must be considered in the design. It should be emphasized that designing for potential replacement should not, and normally does not, require the addition of expensive details.

The most important aspect of design for replacement is the provision of jacking locations at every girder. These points must be indicated on the plans. Modern flat jacks make this lifting quite easy because they have a low profile, do not require a large vertical movement, and can lift heavy loads. A typical flat jack and lift detail is shown in Figure II-3.7 There must be space on the piercap and a bearing point on the superstructure to jack up the girder. An alternative to the detail shown in Figure II-3.7 is to use hydraulic jacks under a temporary spreader beam that lifts adjacent girder top flanges simultaneously. If only some of the girders are to be lifted at any one time, the jacking force on each girder may be larger than the nominal load on an individual bearing because the lifting process may attract some load from the adjacent bearings. This process will also induce stress in some of the cross members or diaphragms, so using linked jacks to lift all the girders together should be considered.

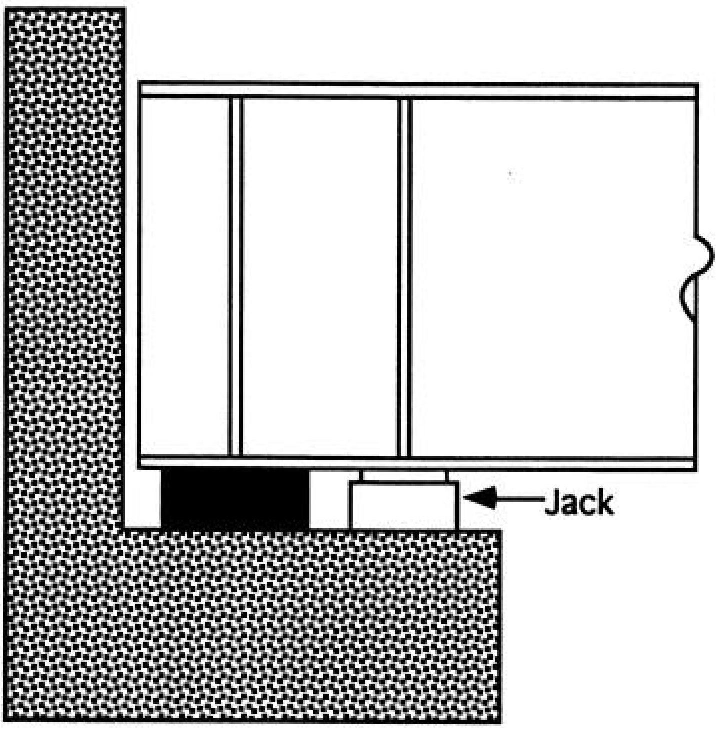
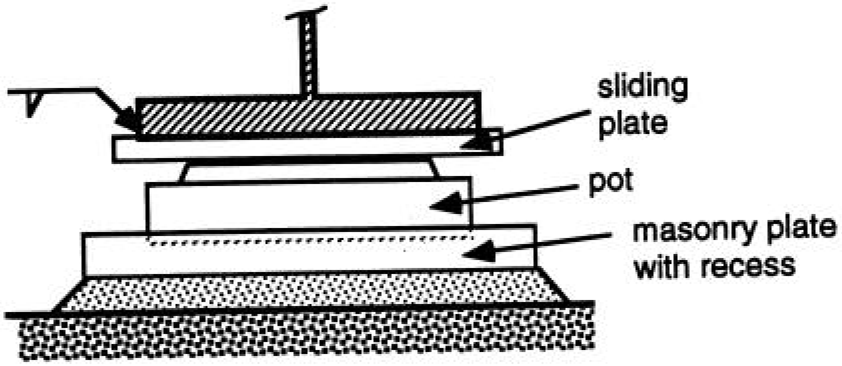
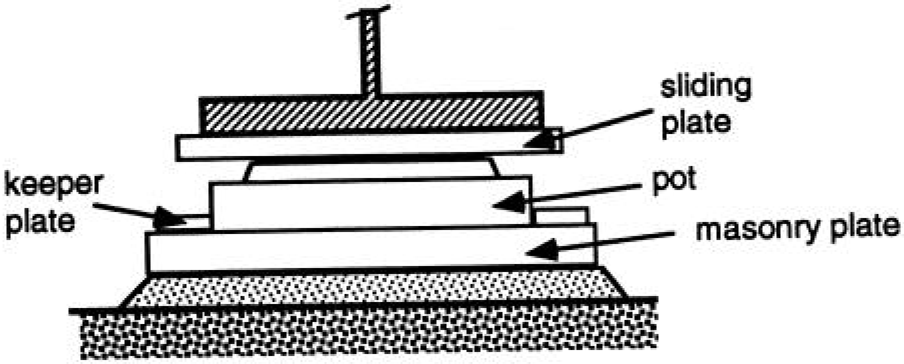


Figure II-3.7: Typical Jacking Point and Lift Details

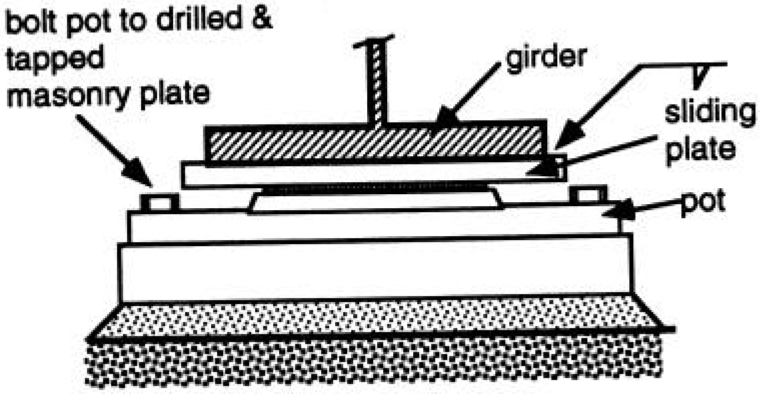
A second issue which affects the cost and ease of replacement is the attachment of the bearing and the space available for access. If the bearing is unattached, it can easily be pulled from its position when the load is removed. Any anchor bolts should be placed so that they do not impede the removal of the bearing. Welds can be cut but doing so requires oxyacetylene equipment that may be cumbersome in the space available. Grinding may also be needed in order to produce a flat enough surface for installing the new bearing. Careful monitoring of the girder centerlines is necessary regardless of the method of bearing removal and attachment. In the case of pot bearings, only some of the components, such as the seals and pad, may need replacing. Installing the new components may then be possible without cutting any welds or removing the bearing, provided the required lift height can be achieved.



a) Recess in masonry plate



b) Keeper plates bolted or welded to masonry plate.



c) Pot bolted directly to masonry plate

Figure II-3.8: Attachment Details to Facilitate Replacement

Last, the bearing and its attachments should also be designed so that the required lift height is minimized. For this reason the use of a masonry plate under a pot or spherical bearing is desirable, even if it is not needed for load spreading. A bearing that is connected directly to the piercap by anchor bolts without a masonry plate must be lifted over the bolts after the nuts have been removed. This arrangement significantly increases the required lift height and complicates the replacement. Three possible details that minimize the lift height by using masonry plates are illustrated in Figure II-3.8. A shallow recess may retain the bearing (Figure II-3.8a), a flat masonry plate may be used with bolted or welded keeper plates (Figure II-3.8b), or the bottom plate of the bearing may be bolted directly into holes that are drilled and tapped into the masonry plate (Figure II-3.8c). The height needed for removing and installing bolts should be accounted for.

BEARING ROTATIONS DURING CONSTRUCTION

Steel girders often have substantial camber before installation and this results in a large initial rotation on the bridge bearing while the compressive load on it is very small. The steel girder is quite flexible until the concrete deck develops composite action, and significant girder deflection and bearing rotation occur during placement of the deck. The bearings must clearly be designed so that they can tolerate these rotations, but the forces that are applied at the same time are usually much smaller than the maximum loads.

In elastomeric bearings, the load that can be carried is related to the rotation(10). However the combination of erection forces and rotations is unlikely to cause problems because it is applied only once during the life of the bridge and damage to elastomeric bearings generally arises from the accumulation of many cycles of stress. The elastomeric bearing design provisions in the AASHTO LRFD Specifications(10) were developed for repeated cycles of service load, so they are not applicable to a single application of a construction load combination.

In bearings such as pots or sphericals, the rotation capacity is limited by metal-to-metal contact and is not related to the accompanying load. These bearings must therefore be designed to accommodate the full rotation.

CONSTRUCTION ISSUES

Erection Methods

Steel bridge superstructures are fabricated in a shop and so they do not offer opportunities for large adjustments to the dimensions on site. Therefore methods of erecting steel bridges have evolved to allow for such adjustments. The primary problem is that the substructure contractor may not have placed the anchor bolts in the piers (or even the piers themselves) with sufficient accuracy to permit easy installation of the bearing, or masonry plate if one exists. Longitudinal location errors are more common than transverse ones. The problems are more severe with stiff systems such as pot, spherical or mechanical bearings than with elastomeric bearings, because they contain more anchor bolts and because the potential for damage by misalignment is greater. Where a bearing has no anchor bolts, the problems are vastly simplified. The real need for anchorage should therefore be carefully assessed.

The most satisfactory approach is to exert strict control over the work of the subcontractor so that the anchor bolts are correctly located, but this is not always easy or even possible. If this is not feasible, there are several possible adjustment locations for achieving the necessary longitudinal tolerance. The piers themselves may be jacked, or adjustments may be made at the interfaces between pier and masonry plate, bearing top plate and sole plate, or sole plate and girder. Each adjustment location has advantages and drawbacks.

Jacking the piers may damage the substructure. The possibility of moving the masonry plate relative to the pier depends on the anchor bolt installation technique. Many erectors like to run an accurate survey of the pier locations, then drill or core the piers so that the bolts can be correctly located for the girder and bearing. This approach solves the adjustment problem, but there is a risk of drilling through critical reinforcement, and in extreme cases, the bolts may be far from their intended location and the reinforcement in the concrete substructure may not be suited for the loading that results. This method may also provide insufficient tension capacity in the bolts in case of uplift if the sides of the holes are smooth. One alternative is to pre-form in the concrete oversize holes that are large enough to provide the necessary tolerance and, in cases where uplift may occur, to use a steel tube with a plate washer at the bottom, such as shown in Figure II-3.9. The holes are grouted after the bearing or masonry plate has been set. Another possibility is to use oversize holes in the bearing plate or masonry plate and to use plate washers over them. This arrangement requires adequate height and may not be feasible with low-profile bearings.

Adjustments may be made between the bearing top plate and the sole plate, if both exist. If the bearing has a top plate, it may be bolted to the sole plate using oversized or slotted holes. Again, vertical clearances for bolting should be verified. The adjustment that can be made by this method is somewhat limited unless the bearing top plate and the sole plate are large.

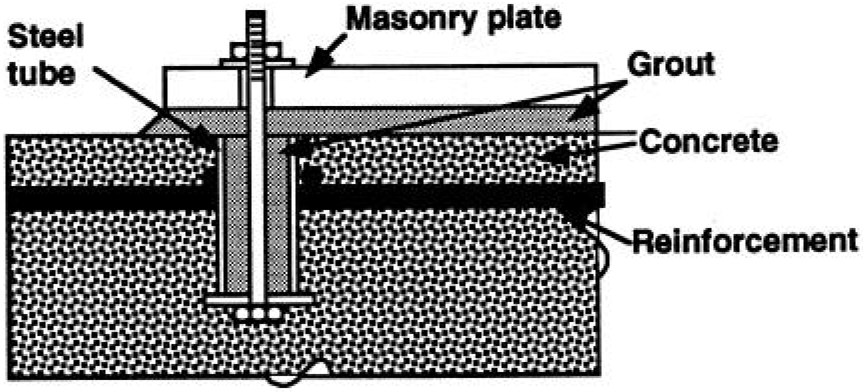


Figure II-3.9: Steel Tube Detail for Anchor Bolts

The sole plate may also be adjusted, at least longitudinally, relative to the girder flange provided that the two are then site welded. This is feasible, but requires site welding under conditions that might be difficult. If the bearing is elastomeric, it also risks heat damage from the welding. Temperature sensitive crayons or other means must be used to ensure that the elastomer is not overheated.

In all cases, dimensional control must be properly maintained. This requires at least that the centerline of the bearing be clearly marked so that discrepancies from the nominal bearing location can be properly identified and monitored.

Stability of Bearing and Girder During Erection

Steel bridges usually contain diaphragms or transverse bracing for lateral support of the girders. The structure is very stable in its complete configuration, but the girders may be relatively unstable during construction. This is particularly true for curved girders but is also true for individual girders on straight bridges. Multiple straight girders installed with diaphragms already in place should significantly reduce the potential for lateral instability for all bearing types, but they require heavier cranes.

The rotational flexibility of the bearings about the girder's longitudinal axis may aggravate this temporary instability, particularly for curved girders or single girders. In service, the girders are stabilized against such rotations by bracing, but it may not be installed until several girders are in place. It is more economical to provide stability by temporary locking the bearing against deformation or by temporary bracing the girder, rather than designing a permanent restraint of some sort. Contractors are capable of providing this bracing, but the need for temporary bracing should be shown on the plans.

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Appendix A:
Test Requirements

GENERAL

A number of tests are required to ensure satisfactory performance of bridge bearings. Most of these tests are described in detail in the AASHTO LRFD Specifications and other documents. These tests are normally used to achieve one of three objectives. First, material tests are used to assure that the properties are consistent with those used in the design. Second, quality control tests on the completed bearing are conducted to verify that the bearing was built to satisfactory quality standards and tolerances. Finally, tests are sometimes conducted to simulate service conditions in order to evaluate the service life of the bearing. These three major objectives are discussed separately, although there is clearly some overlap.

TESTS TO VERIFY DESIGN REQUIREMENTS

Most material tests are outlined in the appropriate ASTM and AASHTO Material Standards. However, PTFE and elastomers require special testing because their behavior can not be predicted by indirect measures or physical examination.

Friction Testing of PTFE

The coefficient of friction in PTFE depends on many variables such as contact pressure, sliding speed and temperature. Friction can have a large impact on the forces transmitted from the superstructure to the substructure, and these forces influence the economy of the entire bridge design.

The material for the test specimens must be identical to that in the manufactured bearing and the test specimens may be comprised of material taken from randomly selected bearings from the lot supplied by the manufacturer; complete bearings may also be used. The test pieces are loaded with a compressive stress corresponding to their maximum stress due to service dead plus live load, which is then held constant for one hour prior to, and throughout the duration of, the sliding test. At least 100 cycles of sliding, each consisting of at least ±25 mm (1 in.) of movement, are then applied at a temperature of 20^{o}C (68^{o}F). Additional low temperature tests may be required if the bridge site is located in a cold region. The tests are normally performed at a uniform sliding speed of 63 mm/min (2.5 in./min). The breakaway friction coefficient is computed for each direction of each cycle, and its mean and standard deviation are computed for the sixth through twelfth cycles.

The initial breakaway coefficient of friction for the first cycle can not exceed twice the design coefficient of friction, and the maximum value for all subsequent cycles can not exceed the design coefficient of friction. A multiplier of 2 is applicable for the first cycle because that criterion would otherwise dominate. It is justified by the low probability of finding the full gravity load on the bearing at the time of initial slip. The very first movement almost always occurs during transportation or bridge erection. Further, the normal margin of safety used in bridge design accommodates some one time overload. These tests assure that the bearing does not deliver a larger force to the superstructure or substructure than considered by the design engineer.

Shear Stiffness of Elastomeric Bearings

The shear modulus of the elastomer is the primary design requirement for steel reinforced elastomeric bearings or elastomeric bearing pads. The shear modulus test can be made from a specimen cut from a randomly selected bearing (an extra bearing must be manufactured to provide this specimen) or a comparable non-destructive stiffness test may be conducted on a pair of finished bearings. The test apparatus and procedure for small specimens are described in Annex A of ASTM D4014, *Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges*. The shear modulus must fall within ±15 percent of the specified value, or within the range for its hardness given in the AASHTO LRFD Specifications if no shear modulus is specified.

If the test is conducted on finished bearings, the material shear modulus must be computed from the measured shear stiffness of the bearings taking due account of the influence on shear stiffness of bearing geometry and compressive load. There are considerable difficulties associated with predicting bearing shear stiffness from material modulus, or vice versa, because of the complex interaction of compressive and shear loads in an elastomeric bearing. For this reason, it is important not to specify both material modulus and bearing stiffness.

Elastomers stiffen at low temperatures. The extent depends upon the elastomer compound, the temperature and the duration of exposure. If an inappropriate elastomer compound is used the shear forces may be more than 100 times as large as those obtained at room temperature. They can cause severe damage to a bridge. The materials for bearings to be used in extremely cold climates must be subjected to the low temperature shear test. The three primary tests to be used are the Low Temperature Brittleness test (ASTM D746), the Instantaneous Low Temperature Stiffness test (ASTM D1043) and the Low Temperature Crystallization test (ASTM D4014). The test temperature depends upon the elastomer grade, and the required grade depends upon climatic conditions at the bridge site. For the low temperature crystallization and low temperature stiffness tests, the stiffness at the test temperature cannot exceed 4 times the stiffness noted at room temperature.

Low temperature testing is important only for bearings to be used in colder climates in the United States, so it is required only for elastomeric bearings made from low temperature grades 4 and 5. The low temperature tests are more expensive than the basic physical property tests, so the AASHTO LRFD Specifications require the manufacturer to provide certified test results conducted on the same compound within one year of the date of manufacture of the bearings, unless specific testing is required by the engineer.

TESTS TO ASSURE QUALITY OF THE MANUFACTURED PRODUCT

These tests are intended to assure that the bearings are manufactured to appropriate tolerances and clearances. Engineers are familiar with many tests of this type and little additional discussion is required. However, a few tests such as proof load tests on elastomeric bearings require some illustration.

Short Duration Proof Load Test of Elastomeric Bearings

Elastomeric bearings are different than most structural components. Satisfactory bearing behavior requires a well manufactured product. Appropriate curing is needed to obtain the correct elastomer material properties and scrupulous cleanliness is needed to achieve satisfactory bond.

Division II of the AASHTO *Standard Specifications for Highway Bridges* requires that every elastomeric bearing which is designed for high stress applications be subjected to a short duration load test. The bearing is loaded in compression to 150 percent of its rated service load. If the bearing is subjected in service to a rotation and compression, a tapered plate should be introduced in the load path so that the bearing sustains the load at the maximum simultaneous design rotation. The load shall be held for 5 minutes, removed, then reapplied for a second period of 5 minutes. The bearing should be examined visually while under the second loading. Any defect results in rejection of the bearing. A good bearing manufacturer can do this test very quickly and economically, since the press needed to manufacture the bearing can also be used to test it.

The test provides valuable information since any instances of poor dimensional tolerances and poor bond between the steel and elastomer will usually be visible. Further, it provides the owner a quick check of the manufacturer, since the test can be repeated on randomly selected bearings. No deflection data is required.

Long Duration Load Test for Elastomeric Bearings

Division II of the AASHTO *Standard Specifications for Highway Bridges* requires a long duration proof load test on a small number of bearings, randomly selected from any lot, which are designed for high stress applications. The test is conducted in the same way as the short-duration proof load test except that the second load is maintained for 15 hours. If the load drops below 90 percent of its target value during this time, the load must be increased to the target value and the test duration must be increased by the period of time for which the load was below the required value. Any splits, cracking, delamination, or improper placement of steel plates results in rejection of the lot of bearings. The long duration load test is important because it will reveal poor bond which is missed in the short duration load test.

Tests to Verify Manufacturing of Special Components

Tests may be required to verify that some special components have been manufactured properly. Examples are guides and their attachments for sliding pot bearings, and durability tests on elements such as seals in pot bearings. The intent is to ensure that the finished bearing will behave as specified by the designer. However, these tests differ from materials tests in that the item being verified is part of the manufacturing process rather than a material that is incorporated in it.

Criteria for such tests should be specified by the engineer, should be related as closely as possible to the service function of the component, and should be agreed upon with the manufacturer before production starts.

PROTOTYPE TESTS

Most bearing problems in the field arise from the accumulation of many cycles of load and movement. Tests that simulate field conditions are useful but are too expensive and time-consuming to be used as quality control tests. However, they provide an excellent basis for evaluating the suitability of a new bearing system or creating a performance specification.

To accelerate the testing, use a smaller number of cycles than would occur during the design life of the bearing along with larger loads and displacements. It is seldom possible to provide an exact equivalence between such a test and real field conditions. However, accelerated testing is valuable for ranking the behavior of different systems and for illuminating defects. Tests of this type can be used to explore the effects of factors such as debris accumulation and contamination. Care must be taken to avoid introducing new conditions in the test, such as elevated temperatures caused by high speed testing.

One such accelerated test program has been proposed for rotational elements. It was used on an extensive series of tests on pot and spherical bearings. This test consisted of 5000 cycles of ±0.02 radians rotation at a rate of approximately 1.5 cycles/min. The rotation limit was chosen because many bearing systems are designed for a rotation capacity of ±0.02 radians, so it represented a way of applying the most severe movements possible without exceeding the design limits. The best available evidence suggests that cyclic rotations in the order of ±0.005 radians are more common for traffic loading or temperature effects, but millions of cycles of rotation due to traffic loading and many thousands of temperature cycles are possible. As a result, this test procedure was applied for 5000 or 10 000 cycles to simulate a substantial service life.

Appendix B
Steel Reinforced Elastomeric Bearing Design Spreadsheet and Examples

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INTRODUCTION

This Appendix contains instructions and examples that illustrate the use of the included spreadsheet titled AISIBRGS.XLS for designing rectangular steel-reinforced elastomeric bearings. The objective is to achieve a design that satisfies the constraints of the AASHTO LRFD Specifications with the least effort on the part of the engineer. The spreadsheet offers the advantages of allowing alternative designs to be assessed quickly to avoid tedious and potentially error-prone numerical calculations.

USE OF SPREADSHEET

This Microsoft Excel spreadsheet is largely self explanatory. Data must be entered in the outlined cells. The equations used by the spreadsheet can be seen in Figures B-1a and B-1b. Alphabetic entries (e.g. y or n) are not case-sensitive. The information given in this appendix is general in nature. Whenever possible the designer should consult with a bearing manufacturer who is likely to supply the bearings being designed to gather information on material properties and fabrication practices. This information will ensure the economy of the bearing design.

Input Data

In the section of the spreadsheet marked "INPUT DATA", the material properties and loads are defined by the user. Variables are defined in Table B-A.

Care must be taken with the co-ordinates. Rotation is assumed to take place about only one axis, which is defined as the *y* axis. In most bridges this will be the transverse axis. Buckling must eventually be checked for both directions, so the fixity against translation must be entered for both. In a bridge that is fixed against longitudinal and transverse movement at one end but free to expand at the other, the fixed end will have translation fixed for both the *x* and *y* directions. The expansion end will be fixed in the *x* direction and free to translate in the *y* direction (the *x*-fixity arises because the bridge is fixed against longitudinal translation at the other end and it does not stretch).

Variable	Unit	Description
Date		Cell is formatted to accept six digit numerical entry corresponding to ##/##/## for date.
Job Title		Cell is unformatted. Entry of any data is permissible.
G_{min} G_{max}	MPa	Minimum and maximum elastomer shear modulus. If the elastomer selected is specified by hardness, enter minimum and maximum shear modulus values into the appropriate cells. If the chosen elastomer is defined by shear modulus, enter that single value into both the minimum and maximum fields. Shear modulus values range from 0.55 to 1.25 MPa. A typical elastomer with a 55 Shore A Durometer hardness would have about a 0.7 to 0.9 MPa shear modulus range.
k_{bar}		Elastomer material property. This material property is used to calculate the effective modulus of the elastomer in compression. It is defined in NCHRP report 248 and varies from about 0.9 to 0.5 as the Shore A Durometer hardness varies from about 40 to 70. A value of **0.6** is suitable for most bridge bearing elastomers.
F_y	MPa	Yield strength of steel reinforcement. In general, bearing manufacturers do not use steel reinforcement grades other than AASHTO M270 Grade 250, F_y = **250** MPa.
$(\Delta F)_{TH}$	MPa	Fatigue limit stress of steel reinforcement. As defined in Table 6.6.1.2.5-3 of the AASHTO LRFD Specifications, $(\Delta F)_{TH}$ for steel reinforcement layers without holes or discontinuities is **165** MPa.
h_{cover}	mm	Thickness of elastomeric cover layer. This dimension is used to calculate the total height of the bearing. A typical cover of **3** mm is usually applied.
P_{DL}	kN	Service dead load.
P_{LL}	kN	Service live load.
rotn.	rad	Rotation of girder at bearing concurrent with specified loads.
Δ_s	mm	Shear displacement of bearing concurrent with specified loads.
Trans. fixed x?		Translation fixed in the *x* direction. The *x* direction is assumed along the longitudinal axis of the bridge. Enter y if the bearing is fixed against translation in this direction or n if the bearing is free to sway in this direction.
Trans. fixed y?		Translation fixed in the *y* direction. The *y* direction is assumed along the transverse axis of the bridge. Enter y if the bearing is fixed against translation in this direction or n if the bearing is free to sway in this direction.

Table B-A: Descriptions of Variables for "INPUT DATA"

Bearing Design

In the section of the spreadsheet marked "BEARING DESIGN" the user defines the geometric properties of the bearing through an interactive process. Variables are defined in Table B-B. The most efficient bearing design is likely to be achieved by balancing N_{lay}*(comp)* and N_{lay}*(uplift)*. That is, using a bearing geometry that requires about the same number of internal elastomer layers to satisfy both the combined compression and rotation limits of Eq. 2-7 and the uplift requirements of either Eq. 2-10a or Eq. 2-10b.

Variable	Unit	Description
L	mm	Bearing dimension perpendicular to rotation axis. This is in the assumed *x* direction or along the longitudinal axis of the bridge.
W	mm	Bearing dimension parallel to rotation axis. The rotation axis is assumed to be in the *y* direction or along the transverse axis of the bridge. In general, this dimension should be as large as practical to permit rotation about the transverse axis and to stabilize the girder during erection. However, the bearing should be slightly narrower than the flange unless a stiff sole plate is used to insure uniform distribution of compressive stress and strain over the bearing area.
h_{ri}	mm	Thickness of a single internal elastomer layer. Although a minimum elastomer thickness of 3 mm is achievable by most manufacturers, typical bearings have a layer thickness in the range of 6 to 15 mm. In general, an initial trial of a **10** mm layer thickness is used.
N_{layers}		Number of internal elastomer layers. See discussion below.
h_s	mm	Thickness of steel reinforcement layer. Although a minimum steel reinforcement thickness of 2 mm is achievable by most bearing manufacturers, a **3** mm thickness or greater is preferred due to tolerance control limitations during the fabrication process.

Table B-B: Descriptions of Variables for "DESIGN BEARING"

Limiting values for each variable in question are reported on the left side of this spreadsheet section. In some cases, more than one behavioral characteristic influences the variable, so more than one limit exists. For example, the number of elastomer layers is influenced by uplift, combined compression shear and rotation, and stability in both the *x* and *y* directions. Some limits are upper bounds and some are lower bounds.

The entry boxes on the right side of this spreadsheet section are to be used by the designer to select a bearing parameter based on the reported limits. As each value is entered, the reported limits change appropriately. A check (OK or NG) appears on the extreme right side. If some of the multiple limits are mutually exclusive, the design is impossible and the user must select a different value for one of the earlier variables. For example, the number of layers may have to be less than 10 and greater than 20, in which case a different layer thickness or plan dimension should be tried.

The four variables related to the elastomer layers are interdependent, and should be selected first. The steel thickness is independent of other variables and may be selected last.

Summary

The section of the spreadsheet marked “SUMMARY” reports the final bearing properties. The maximum shear force occurs at the design displacement. If the maximum shear force is unacceptably large, it can be reduced by making the bearing thicker or by adding a slider.

EXAMPLE 1: BEARING FOR TYPICAL LONG-SPAN BRIDGE

Same as example in Section 2.

Dead Load	2400 kN (540 kips)
Live Load	1200 kN (270 kips)
Longitudinal Translation	100 mm (4 in.)
Rotation	0.015 rad
Buckling	fixed longitudinally free transversely
Elastomer	55 Shore A Durometer 0.690 MPa < G < 0.896 MPa
Steel	$F_y = 250$ MPa $(\Delta F)_{TH} = 165$ MPa

Referring to Figure B-2a, initial plan dimensions of 475 x 725 mm are selected to be slightly above the absolute minimums. It is usually beneficial to make the bearing as wide as possible (in the direction parallel to the axis of rotation) because this alleviates potential problems with uplift and combined stress constraints.

The elastomer layer thickness is initially assumed to be 10 mm in order to provide a high shape factor and good compressive strength. However, as shown in Figure B-2a, the assumed thickness leads to mutually exclusive limits on the number of layers, which must simultaneously be greater than 41.6 and less than 40.5. Comparison of the values for combined stress and uplift points out the problem. The elastomer layers are relatively thin for this application and produce a high rotational stiffness which induces uplift stresses and require a large number of layers to overcome. Since the resistance to combined stress is high, the need to minimize the rotational stress by using a large number of layers is not appropriate. Thus the number of layers is controlled by uplift.

Increasing the layer thickness to 15 mm (near the maximum permissible), as seen in Figure B-2b, reverses the situation making the combined stress limit control over the uplift limit. This occurs because the compressive stress limit is lower when the layers are thicker and the shape factor is smaller, and the uplift stresses induced by rotation are smaller. As stated earlier, the most efficient bearing is likely to be achieved by balancing $N_{lay}(comp)$ and $N_{lay}(uplift)$. This is done by selecting 14 mm thick layers (see Figure B-2c), in which case a total of 17 internal layers will be needed. This number is small enough that stability in both the x and y directions is also assured. Theoretically 16 layers at 13.78 mm each would be satisfactory, but controlling the layer thickness to ±0.01 mm is impractical.

The steel reinforcement thickness is subject only to lower bounds and so can be selected without trial and error.

It should be noted that the bearing was designed on the basis of elastomer hardness, in which case the AASHTO LRFD Specifications require that the least favorable value of *G* be used for each calculation. This provision exists because shear modulus and hardness are only loosely correlated, yet shear modulus is the property that controls design. If the material is defined by its hardness, and the bearing manufacturer provides the necessary test data, then economies can be realized. This is shown by the design in Figure B-2d.

EXAMPLE 2: BEARING FOR TYPICAL MEDIUM-SPAN BRIDGE

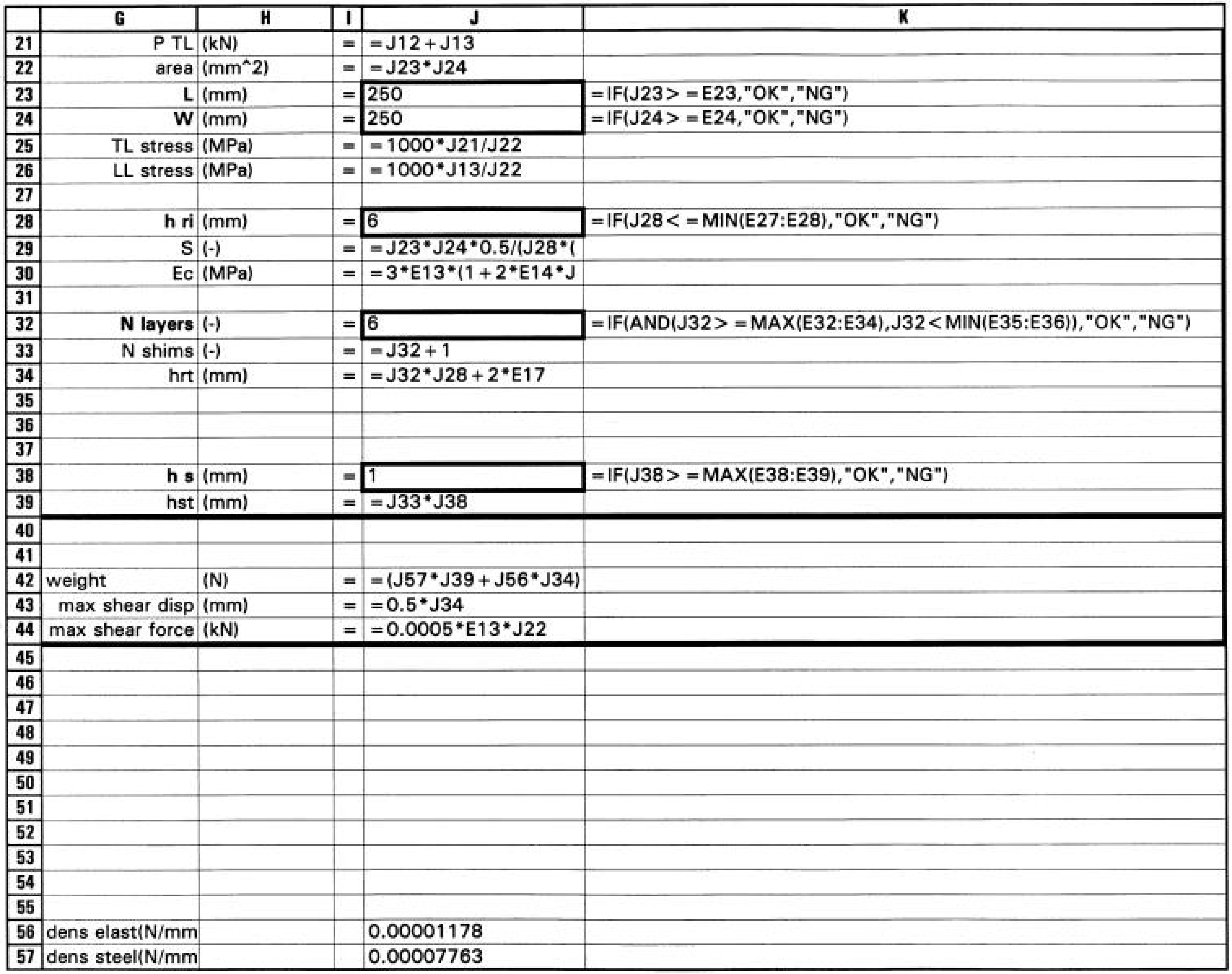
Dead Load	400 kN (90 kips)
Live Load	160 kN (36 kips)
Longitudinal Translation	15 mm (0.6 inches)
Rotation	0.01 rad
Buckling	fixed longitudinally free transversely
Elastomer:	55 Shore A Durometer $0.690 \text{ MPa} < G < 0.896 \text{ MPa}$
Steel	$F_y = 250$ MPa $(\Delta F)_{TH} = 165$ MPa

Two solutions, one with a 500 mm bearing width and one with a 250 mm bearing width, are shown in Figures B-3a and B-3b respectively. In the first design, Figure B-3a, the engineer has a considerable design latitude. The selected geometry uses a plan area near to the minimum acceptable with 6 elastomer layers. A design with a larger plan area, lower stresses and fewer layers (and so fewer steel reinforcing layers) might prove more economical. If the length becomes too short, rollover due to longitudinal displacement becomes possible. In this case the length is still 9 times the estimated longitudinal displacement, so rollover is not a problem.

When the width is restricted to 250 mm, Figure B-3b, the bearing must become longer in order to provide the necessary area. Uplift and combined stress limits become active and rotation becomes critical in the design, forcing the use of more layers. The resulting bearing is about twice the height and weight of the 500 mm wide design.

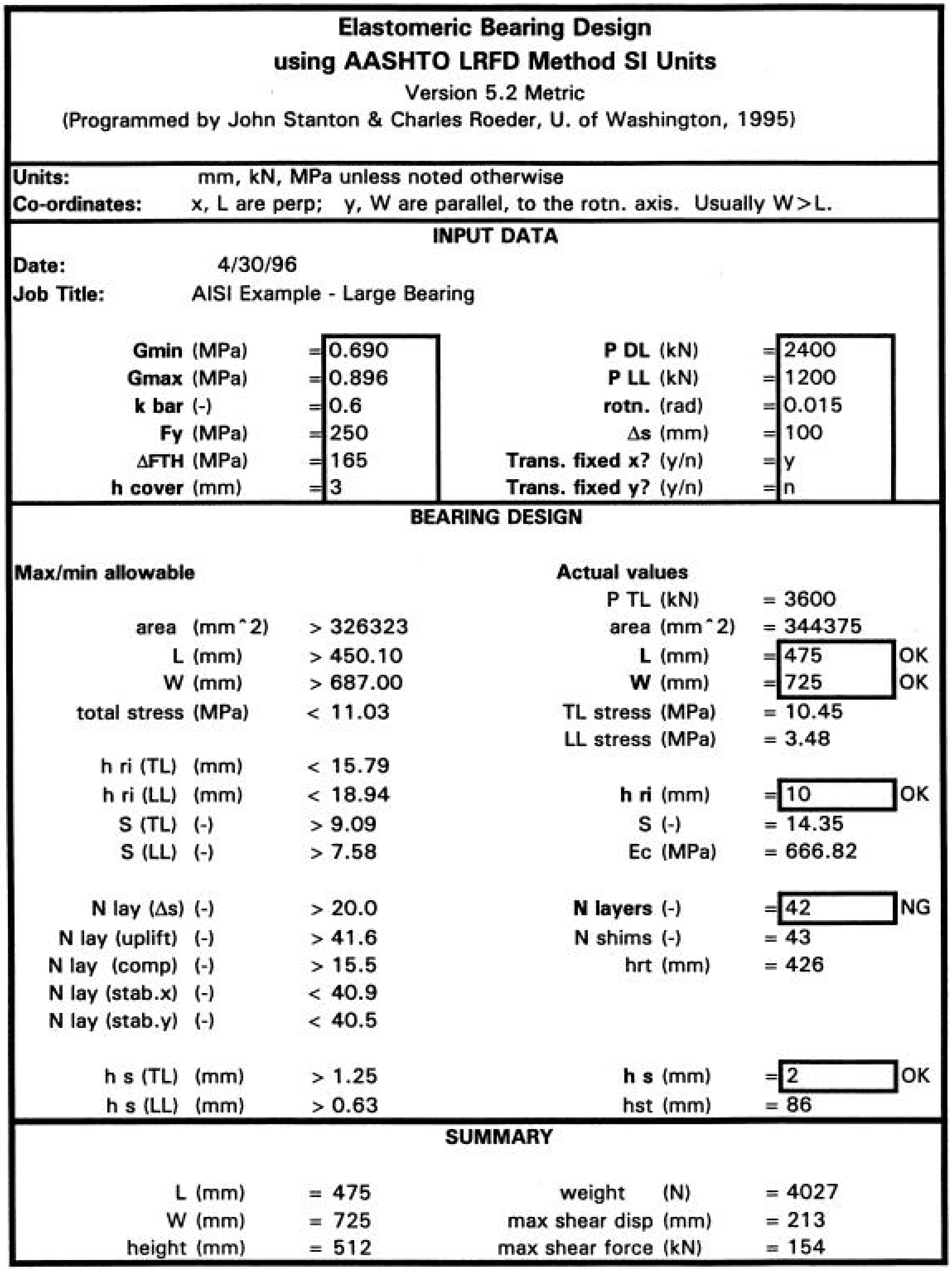
	B	C	D	E	F
22	area	(mm^2)	>	=1000*J21/E25	
23	L	(mm)	>	=E22/J24	
24	W	(mm)	>	=E22/J23	
25	total stress	(MPa)	<	11.032	
26					
27	h ri (TL)	(mm)	<	=J23*J24*0.5/(E29*(J23+J24))	
28	h ri (LL)	(mm)	<	=J23*J24*0.5/(E30*(J23+J24))	
29	S (TL)	(-)	>	=J25/(C54*E12)	
30	S (LL)	(-)	>	=J26/(C55*E12)	
31					
32	N lay (Δs)	(-)	>	=2*J15/J28	
33	lay (uplift)	(-)	>	=(E13*J29/J25)*J14*(J23/J28)^2	
34	lay (comp)	(-)	>	=C57*J14*(J23/J28)^2/(1-J25/(C56*E12*J29))	
35	lay (stab.x)	(-)	<	=($E$12/$J$25+E52)/(F52*C52)	
36	lay (stab.y)	(-)	<	=($E$12/$J$25+E53)/(F53*C53)	
37					
38	h s (TL)	(mm)	>	=3*J28*J25/E15	
39	h s (LL)	(mm)	>	=3*J28*J26/E16	
40					**SUMMARY**
41					
42	L	(mm)	=	=J23	
43	W	(mm)	=	=J24	
44	height	(mm)	=	=J34+J39	
45					
46					
47					
48					
49					
50	**Intermediate**	**calculations**			
51		c1		c2	k.eff
52	stability	=(3.84*$J$28/J23)/($J$29*SQRT(1+2*$J$23/$J$24))		=2.67/($J$29*($J$29+2)*(1+0.25*J23/J24))	=IF(OR(J16="Y",J16="y"),0.5,1)
53	stability	=(3.84*$J$28/J24)/($J$29*SQRT(1+2*$J$24/$J$23))		=2.67/($J$29*($J$29+2)*(1+0.25*J24/J23))	=IF(OR(J17="Y",J17="y"),0.5,1)
54	S.TL fac	=IF($J$15=0,2,1.66666666)			
55	S.LL fac	=IF($J$15=0,1,0.66666666)			
56	sig.comb fa	=IF($J$15=0,2.25,1.875)			
57	sig.comb fa	=IF($J$15=0,1/6,0.2)			

Figure B-1a: Spreadsheet Equations



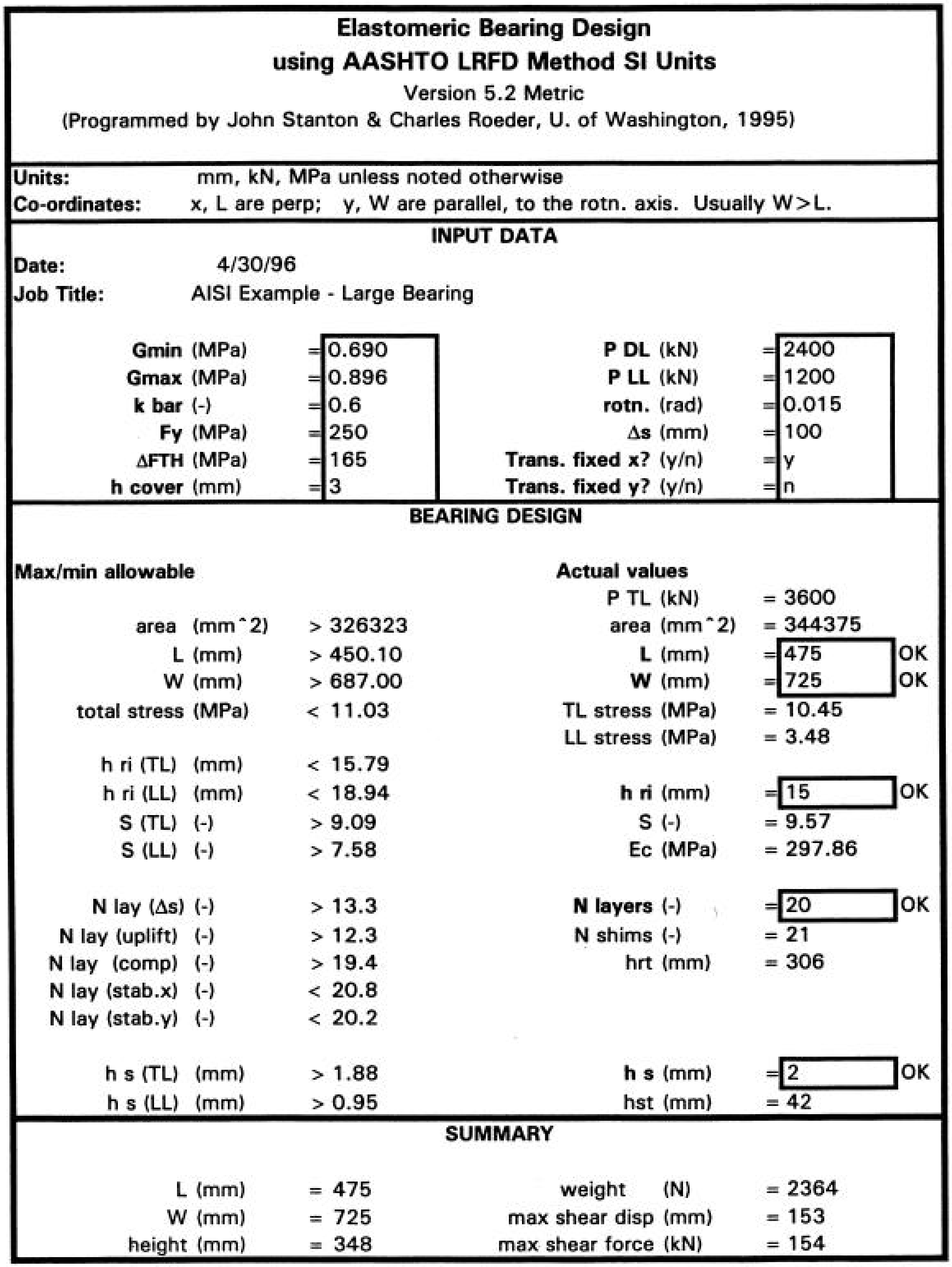
	G	H	I	J	K
21	P TL	(kN)	=	=J12+J13	
22	area	(mm^2)	=	=J23*J24	
23	**L**	(mm)	=	250	=IF(J23>=E23,"OK","NG")
24	**W**	(mm)	=	250	=IF(J24>=E24,"OK","NG")
25	TL stress	(MPa)	=	=1000*J21/J22	
26	LL stress	(MPa)	=	=1000*J13/J22	
27					
28	**h ri**	(mm)	=	6	=IF(J28<=MIN(E27:E28),"OK","NG")
29	S	(-)	=	=J23*J24*0.5/(J28*(	
30	Ec	(MPa)	=	=3*E13*(1+2*E14*J	
31					
32	**N layers**	(-)	=	6	=IF(AND(J32>=MAX(E32:E34),J32<MIN(E35:E36)),"OK","NG")
33	N shims	(-)	=	=J32+1	
34	hrt	(mm)	=	=J32*J28+2*E17	
35					
36					
37					
38	**h s**	(mm)	=	1	=IF(J38>=MAX(E38:E39),"OK","NG")
39	hst	(mm)	=	=J33*J38	
40					
41					
42	weight	(N)	=	=(J57*J39+J56*J34)	
43	max shear disp	(mm)	=	=0.5*J34	
44	max shear force	(kN)	=	=0.0005*E13*J22	
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56	dens elast(N/mm			0.00001178	
57	dens steel(N/mm			0.00007763	

Figure B-1b: Spreadsheet Equations (Continued)



```
                        Elastomeric Bearing Design
                   using AASHTO LRFD Method SI Units
                           Version 5.2 Metric
  (Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units:              mm, kN, MPa unless noted otherwise
Co-ordinates:       x, L are perp;   y, W are parallel, to the rotn. axis.  Usually W>L.
                                  INPUT DATA
Date:                  4/30/96
Job Title:          AISI Example - Large Bearing

          Gmin (MPa)      =0.690                 P DL (kN)        =2400
          Gmax (MPa)      =0.896                 P LL (kN)        =1200
         k bar (-)        =0.6                  rotn. (rad)       =0.015
            Fy (MPa)      =250                    Δs (mm)         =100
          ΔFTH (MPa)      =165         Trans. fixed x? (y/n)      =y
       h cover (mm)       =3           Trans. fixed y? (y/n)      =n
                                BEARING DESIGN

Max/min allowable                              Actual values
                                                  P TL (kN)       = 3600
          area  (mm^2)    > 326323                area (mm^2)     = 344375
             L (mm)       > 450.10                   L (mm)       =475        OK
             W (mm)       > 687.00                   W (mm)       =725        OK
  total stress (MPa)      <  11.03             TL stress (MPa)    = 10.45
                                               LL stress (MPa)    = 3.48
     h ri (TL)  (mm)      <  15.79
     h ri (LL)  (mm)      <  18.94                  h ri (mm)     =10         OK
        S (TL)  (-)       > 9.09                       S (-)      = 14.35
        S (LL)  (-)       > 7.58                      Ec (MPa)    = 666.82

    N lay (Δs)  (-)       > 20.0                N layers (-)      =42         NG
  N lay (uplift)  (-)     > 41.6                 N shims (-)      = 43
  N lay  (comp)   (-)     > 15.5                     hrt (mm)     = 426
  N lay (stab.x)  (-)     <  40.9
  N lay (stab.y)  (-)     <  40.5

     h s (TL)  (mm)       > 1.25                    h s (mm)      =2          OK
     h s (LL)  (mm)       > 0.63                    hst (mm)      = 86
                                   SUMMARY

             L (mm)       =  475             weight      (N)      = 4027
             W (mm)       =  725        max shear disp (mm)       = 213
        height (mm)       =  512       max shear force (kN)       = 154
```

Figure B-2a: Large Bearing: Trial Design with 10 mm Elastometer Layers



Elastomeric Bearing Design
using AASHTO LRFD Method SI Units
Version 5.2 Metric
(Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units: mm, kN, MPa unless noted otherwise
Co-ordinates: x, L are perp; y, W are parallel, to the rotn. axis. Usually W>L.

INPUT DATA

Date: 4/30/96
Job Title: AISI Example - Large Bearing

Gmin	(MPa)	=	0.690	**P DL**	(kN)	=	2400
Gmax	(MPa)	=	0.896	**P LL**	(kN)	=	1200
k bar	(-)	=	0.6	**rotn.**	(rad)	=	0.015
Fy	(MPa)	=	250	**Δs**	(mm)	=	100
ΔFTH	(MPa)	=	165	**Trans. fixed x?**	(y/n)	=	y
h cover	(mm)	=	3	**Trans. fixed y?**	(y/n)	=	n

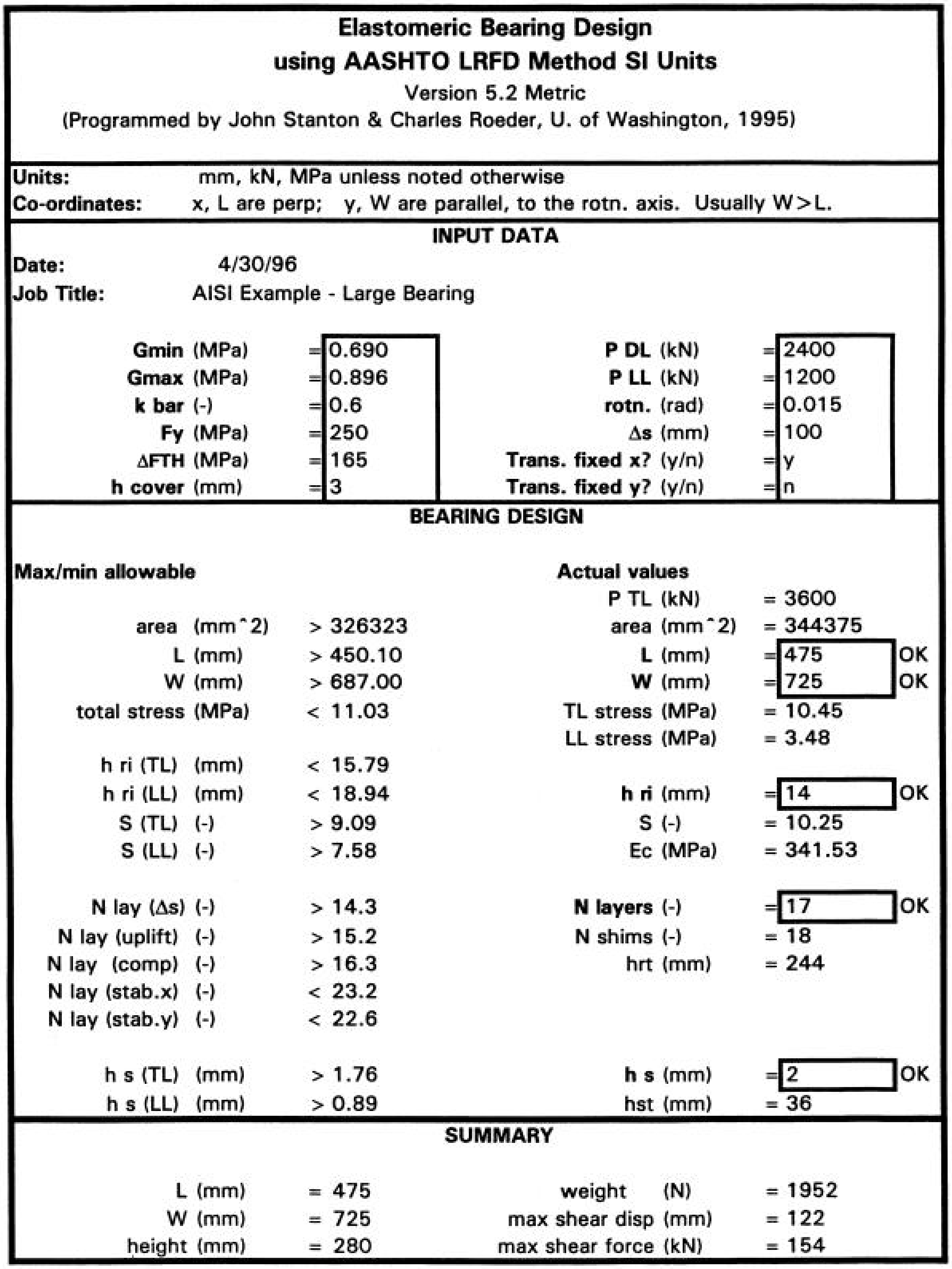
BEARING DESIGN

Max/min allowable			**Actual values**			
			P TL	(kN)	= 3600	
area	(mm^2)	> 326323	area	(mm^2)	= 344375	
L	(mm)	> 450.10	**L**	(mm)	= 475	OK
W	(mm)	> 687.00	**W**	(mm)	= 725	OK
total stress	(MPa)	< 11.03	TL stress	(MPa)	= 10.45	
			LL stress	(MPa)	= 3.48	
h ri (TL)	(mm)	< 15.79				
h ri (LL)	(mm)	< 18.94	**h ri**	(mm)	= 15	OK
S (TL)	(-)	> 9.09	S	(-)	= 9.57	
S (LL)	(-)	> 7.58	Ec	(MPa)	= 297.86	
N lay (Δs)	(-)	> 13.3	**N layers**	(-)	= 20	OK
N lay (uplift)	(-)	> 12.3	N shims	(-)	= 21	
N lay (comp)	(-)	> 19.4	hrt	(mm)	= 306	
N lay (stab.x)	(-)	< 20.8				
N lay (stab.y)	(-)	< 20.2				
h s (TL)	(mm)	> 1.88	**h s**	(mm)	= 2	OK
h s (LL)	(mm)	> 0.95	hst	(mm)	= 42	

SUMMARY

L	(mm)	= 475	weight	(N)	= 2364
W	(mm)	= 725	max shear disp	(mm)	= 153
height	(mm)	= 348	max shear force	(kN)	= 154

Figure B-2b: Large Bearing: Trial Design with 15mm Elastomer Layers



Elastomeric Bearing Design
using AASHTO LRFD Method SI Units
Version 5.2 Metric
(Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units: mm, kN, MPa unless noted otherwise
Co-ordinates: x, L are perp; y, W are parallel, to the rotn. axis. Usually W>L.

INPUT DATA

Date: 4/30/96
Job Title: AISI Example - Large Bearing

Gmin (MPa)	= 0.690	**P DL** (kN)	= 2400
Gmax (MPa)	= 0.896	**P LL** (kN)	= 1200
k bar (-)	= 0.6	**rotn.** (rad)	= 0.015
Fy (MPa)	= 250	Δs (mm)	= 100
ΔFTH (MPa)	= 165	**Trans. fixed x?** (y/n)	= y
h cover (mm)	= 3	**Trans. fixed y?** (y/n)	= n

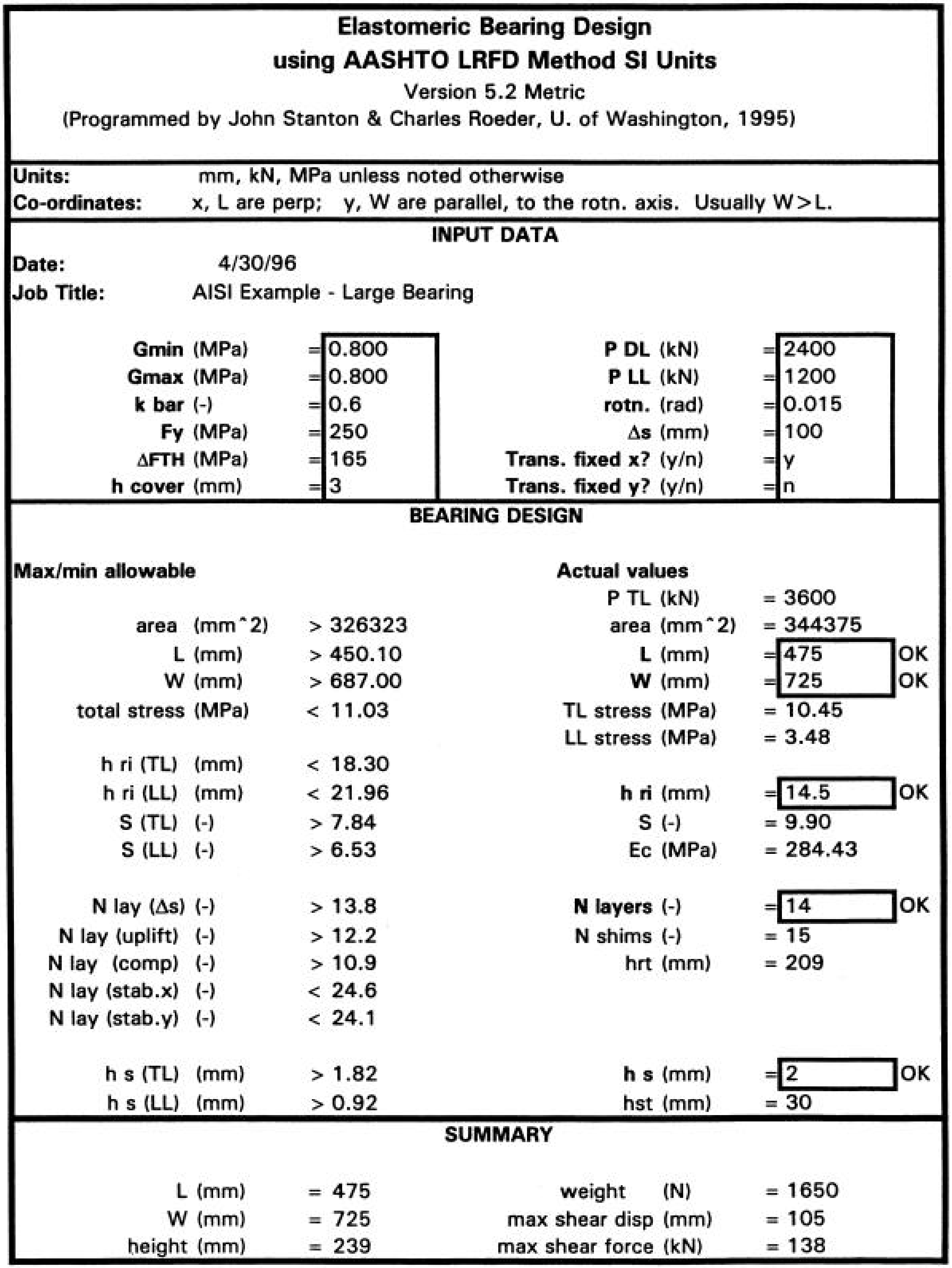
BEARING DESIGN

Max/min allowable		**Actual values**		
		P TL (kN)	= 3600	
area (mm^2)	> 326323	area (mm^2)	= 344375	
L (mm)	> 450.10	**L** (mm)	= 475	OK
W (mm)	> 687.00	**W** (mm)	= 725	OK
total stress (MPa)	< 11.03	TL stress (MPa)	= 10.45	
		LL stress (MPa)	= 3.48	
h ri (TL) (mm)	< 15.79			
h ri (LL) (mm)	< 18.94	**h ri** (mm)	= 14	OK
S (TL) (-)	> 9.09	S (-)	= 10.25	
S (LL) (-)	> 7.58	Ec (MPa)	= 341.53	
N lay (Δs) (-)	> 14.3	**N layers** (-)	= 17	OK
N lay (uplift) (-)	> 15.2	N shims (-)	= 18	
N lay (comp) (-)	> 16.3	hrt (mm)	= 244	
N lay (stab.x) (-)	< 23.2			
N lay (stab.y) (-)	< 22.6			
h s (TL) (mm)	> 1.76	**h s** (mm)	= 2	OK
h s (LL) (mm)	> 0.89	hst (mm)	= 36	

SUMMARY

L (mm)	= 475	weight (N)	= 1952
W (mm)	= 725	max shear disp (mm)	= 122
height (mm)	= 280	max shear force (kN)	= 154

Figure B-2c: Large Bearing: Final Design with 14mm Elastomer Layers



Elastomeric Bearing Design
using AASHTO LRFD Method SI Units
Version 5.2 Metric
(Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units: mm, kN, MPa unless noted otherwise
Co-ordinates: x, L are perp; y, W are parallel, to the rotn. axis. Usually W>L.

INPUT DATA

Date: 4/30/96
Job Title: AISI Example - Large Bearing

Gmin (MPa)	= 0.800	**P DL** (kN)	= 2400
Gmax (MPa)	= 0.800	**P LL** (kN)	= 1200
k bar (-)	= 0.6	**rotn.** (rad)	= 0.015
Fy (MPa)	= 250	Δs (mm)	= 100
ΔFTH (MPa)	= 165	**Trans. fixed x?** (y/n)	= y
h cover (mm)	= 3	**Trans. fixed y?** (y/n)	= n

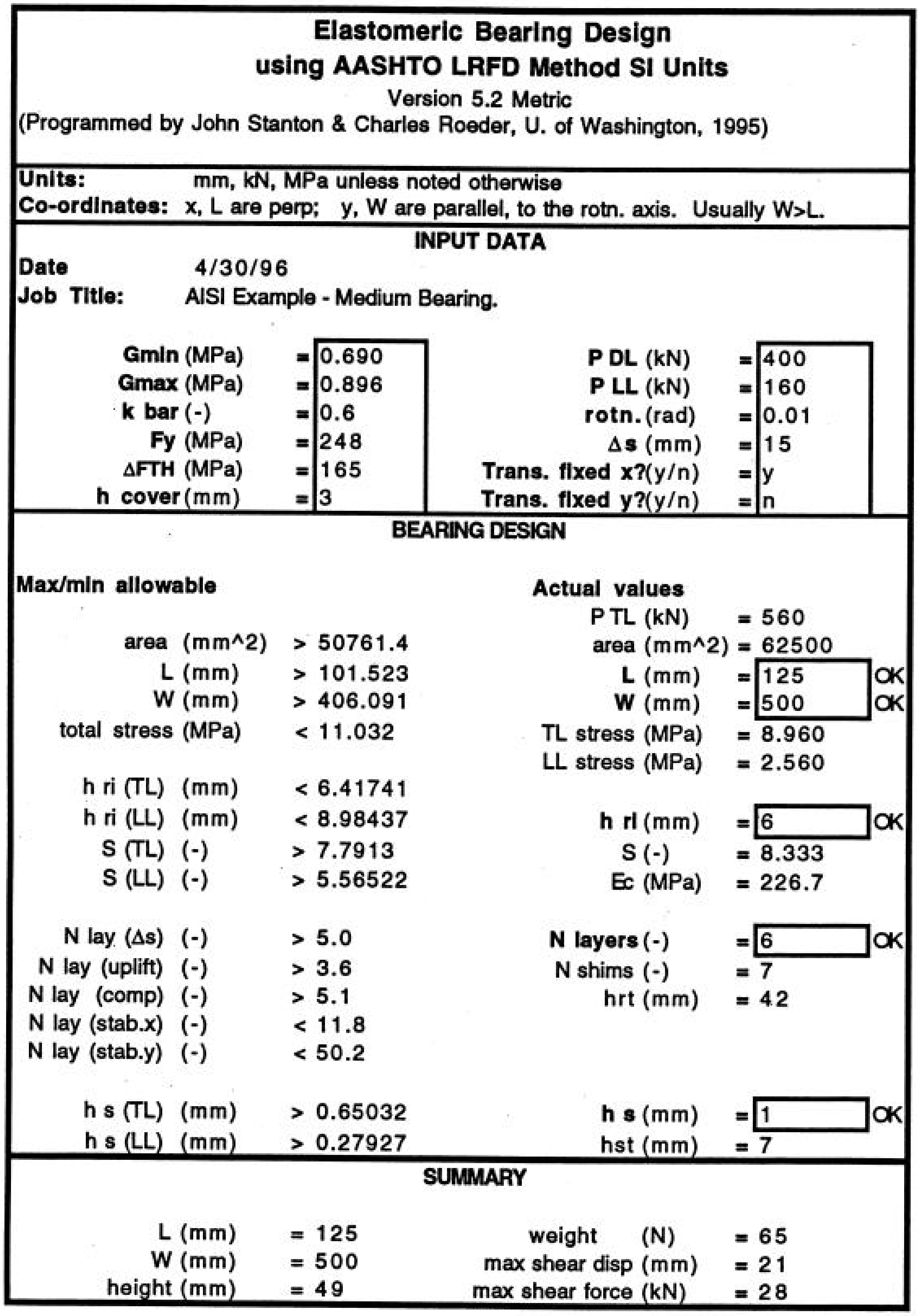
BEARING DESIGN

Max/min allowable		**Actual values**		
		P TL (kN)	= 3600	
area (mm^2)	> 326323	area (mm^2)	= 344375	
L (mm)	> 450.10	**L** (mm)	= 475	OK
W (mm)	> 687.00	**W** (mm)	= 725	OK
total stress (MPa)	< 11.03	TL stress (MPa)	= 10.45	
		LL stress (MPa)	= 3.48	
h ri (TL) (mm)	< 18.30			
h ri (LL) (mm)	< 21.96	**h ri** (mm)	= 14.5	OK
S (TL) (-)	> 7.84	S (-)	= 9.90	
S (LL) (-)	> 6.53	Ec (MPa)	= 284.43	
N lay (Δs) (-)	> 13.8	**N layers** (-)	= 14	OK
N lay (uplift) (-)	> 12.2	N shims (-)	= 15	
N lay (comp) (-)	> 10.9	hrt (mm)	= 209	
N lay (stab.x) (-)	< 24.6			
N lay (stab.y) (-)	< 24.1			
h s (TL) (mm)	> 1.82	**h s** (mm)	= 2	OK
h s (LL) (mm)	> 0.92	hst (mm)	= 30	

SUMMARY

L (mm)	= 475	weight (N)	= 1650
W (mm)	= 725	max shear disp (mm)	= 105
height (mm)	= 239	max shear force (kN)	= 138

Figure B-2d: Large Bearing: Design Based on Specified Shear Modulus



Elastomeric Bearing Design
using AASHTO LRFD Method SI Units
Version 5.2 Metric
(Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units: mm, kN, MPa unless noted otherwise
Co-ordinates: x, L are perp; y, W are parallel, to the rotn. axis. Usually W>L.

INPUT DATA

Date 4/30/96
Job Title: AISI Example - Medium Bearing.

Gmin (MPa)	= 0.690		**P DL** (kN)	= 400	
Gmax (MPa)	= 0.896		**P LL** (kN)	= 160	
k bar (-)	= 0.6		**rotn.** (rad)	= 0.01	
Fy (MPa)	= 248		**Δs** (mm)	= 15	
ΔFTH (MPa)	= 165		**Trans. fixed x?**(y/n)	= y	
h cover (mm)	= 3		**Trans. fixed y?**(y/n)	= n	

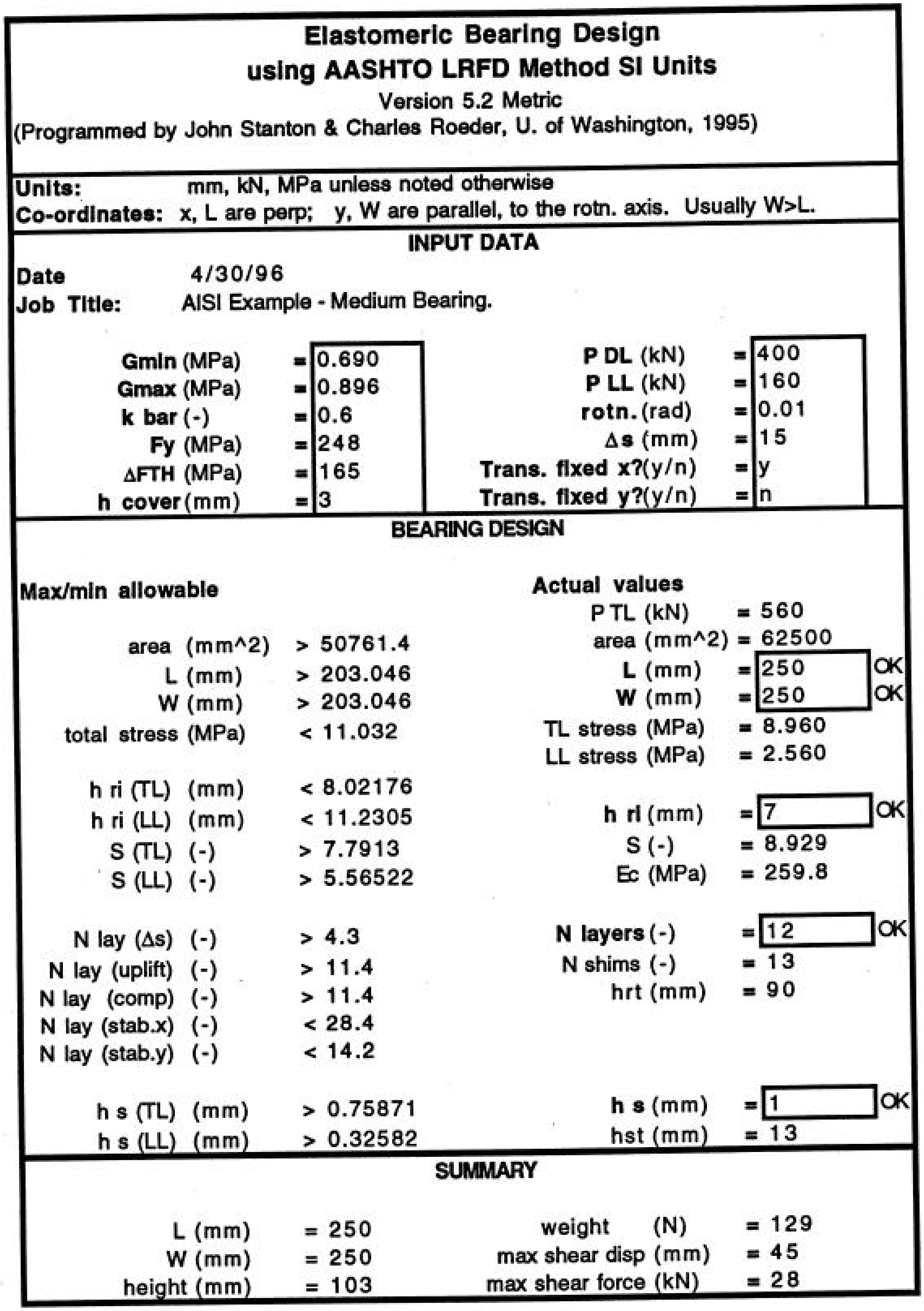
BEARING DESIGN

Max/min allowable		**Actual values**		
		P TL (kN)	= 560	
area (mm^2)	> 50761.4	area (mm^2)	= 62500	
L (mm)	> 101.523	**L** (mm)	= 125	OK
W (mm)	> 406.091	**W** (mm)	= 500	OK
total stress (MPa)	< 11.032	TL stress (MPa)	= 8.960	
		LL stress (MPa)	= 2.560	
h ri (TL) (mm)	< 6.41741			
h ri (LL) (mm)	< 8.98437	**h ri** (mm)	= 6	OK
S (TL) (-)	> 7.7913	S (-)	= 8.333	
S (LL) (-)	> 5.56522	Ec (MPa)	= 226.7	
N lay (Δs) (-)	> 5.0	**N layers** (-)	= 6	OK
N lay (uplift) (-)	> 3.6	N shims (-)	= 7	
N lay (comp) (-)	> 5.1	hrt (mm)	= 42	
N lay (stab.x) (-)	< 11.8			
N lay (stab.y) (-)	< 50.2			
h s (TL) (mm)	> 0.65032	**h s** (mm)	= 1	OK
h s (LL) (mm)	> 0.27927	hst (mm)	= 7	

SUMMARY

L (mm)	= 125	weight (N)	= 65
W (mm)	= 500	max shear disp (mm)	= 21
height (mm)	= 49	max shear force (kN)	= 28

Figure B-3a: Medium Bearing: Final Design, Width = 500 mm



Elastomeric Bearing Design
using AASHTO LRFD Method SI Units
Version 5.2 Metric
(Programmed by John Stanton & Charles Roeder, U. of Washington, 1995)

Units: mm, kN, MPa unless noted otherwise
Co-ordinates: x, L are perp; y, W are parallel, to the rotn. axis. Usually W>L.

INPUT DATA

Date 4/30/96
Job Title: AISI Example - Medium Bearing.

Gmin (MPa)	= 0.690	**P DL** (kN)	= 400
Gmax (MPa)	= 0.896	**P LL** (kN)	= 160
k bar (-)	= 0.6	**rotn.** (rad)	= 0.01
Fy (MPa)	= 248	**Δs** (mm)	= 15
ΔFTH (MPa)	= 165	**Trans. fixed x?**(y/n)	= y
h cover (mm)	= 3	**Trans. fixed y?**(y/n)	= n

BEARING DESIGN

Max/min allowable		**Actual values**		
		P TL (kN)	= 560	
area (mm^2)	> 50761.4	area (mm^2)	= 62500	
L (mm)	> 203.046	**L** (mm)	= 250	OK
W (mm)	> 203.046	**W** (mm)	= 250	OK
total stress (MPa)	< 11.032	TL stress (MPa)	= 8.960	
		LL stress (MPa)	= 2.560	
h ri (TL) (mm)	< 8.02176			
h ri (LL) (mm)	< 11.2305	**h ri** (mm)	= 7	OK
S (TL) (-)	> 7.7913	S (-)	= 8.929	
S (LL) (-)	> 5.56522	Ec (MPa)	= 259.8	
N lay (Δs) (-)	> 4.3	**N layers** (-)	= 12	OK
N lay (uplift) (-)	> 11.4	N shims (-)	= 13	
N lay (comp) (-)	> 11.4	hrt (mm)	= 90	
N lay (stab.x) (-)	< 28.4			
N lay (stab.y) (-)	< 14.2			
h s (TL) (mm)	> 0.75871	**h s** (mm)	= 1	OK
h s (LL) (mm)	> 0.32582	hst (mm)	= 13	

SUMMARY

L (mm)	= 250	weight (N)	= 129
W (mm)	= 250	max shear disp (mm)	= 45
height (mm)	= 103	max shear force (kN)	= 28

Figure B-3b: Medium Bearing: Final Design, Width = 250 mm