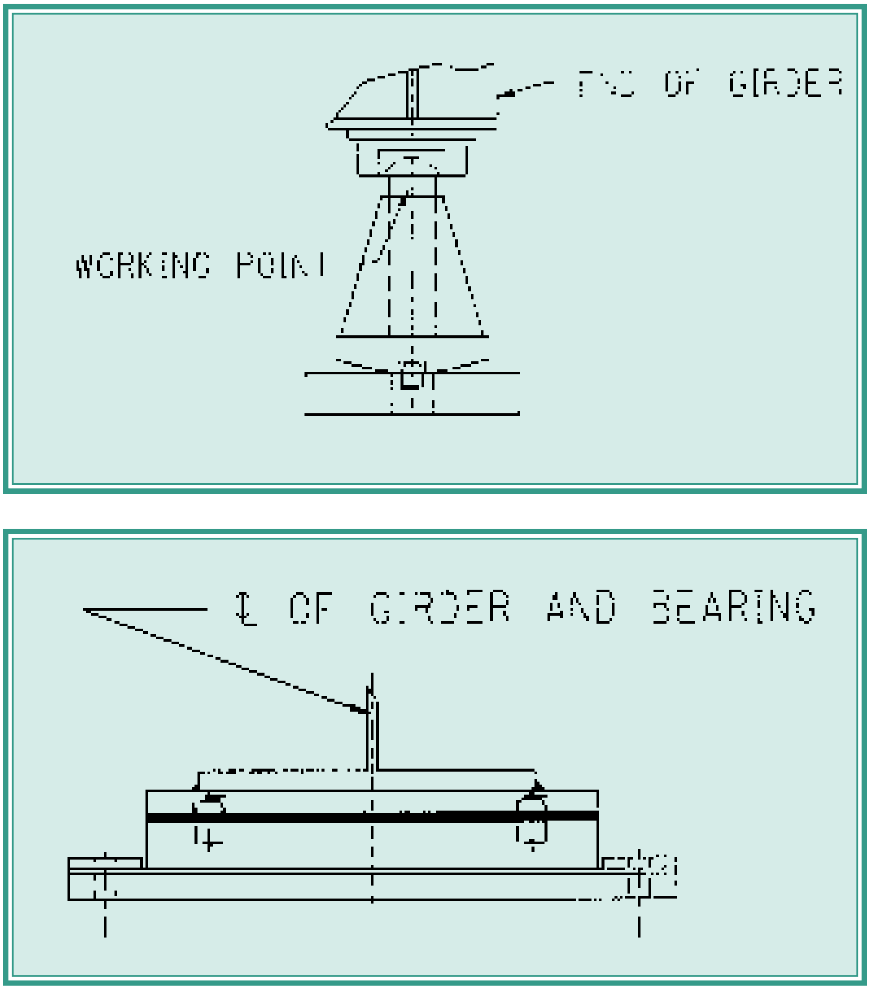
SEISMIC RETROFIT OF STEEL BRIDGES

An overview of the strategies used by the New York State DOT for seismic retrofitting of steel highway bridges



Figures 1 & 2: During an earthquake, bearings are subjected to displacements, rotation and lateral forces in various directions, resulting in brittle failure of the unidirectional steel high rocker and low sliding bearings

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(This article is adapted from a paper presented at the 1996 National Steel Bridge Symposium)

THERE ARE CURRENTLY ABOUT 20,000 BRIDGES IN NEW YORK STATE under the jurisdiction of state and local bridge authorities and agencies, with some bridges dating back more than 50 years and most constructed without any serious consideration for earthquake loadings. However, most of the rehabilitation projects let during the past four years have included seismic retrofitting as part of the work. Because most of the retrofit work encompasses deteriorated elements, the repair/replacement is designed in such a way that it also enhances the seismic resistance of the entire structure.

One major area of retrofit work on the states 11,537 steel bridges revolves around bearings, especially steel rocker bearings and low sliding bearings, which get corroded and are frozen in a tilted position, and therefore need cleaning and lubrication and require resetting after jacking the structure. While most bridge retrofit projects have long included rehabilitation of these bearings, current projects are instead replacing the rocker and low sliding bearings with laminated elastomeric bearings, which perform well under seismic loading and prove to be more economical in the long run. Elastomeric bearings are maintenance free and accommodate thermal movements, rotation due to bending and transmits loads to the substructure.

Another area for seismic retrofit focuses on the advantages of continuous structures over simply supported structures in earthquakes. Currently, 10,952 of New York State's bridges are simply supported, while 585 are continuous structures. Damage to highway structures caused by past eathquakes shows the high vulnerability of simply supported structures to earthquake forces. Providing continuity to a series of simple spans improves the seismic resistance of the bridge, makes it a redundant structures, decreases the number of bearings, eliminates expansion joints in the deck and reduces maintenance problems.

BEARING RETROFITTING

Some designers have suggested that steel rocker bearings serve as a fuse, limiting the effect of lateral force from the superstructure to the substructure. However, recent earthquakes, including Kobe, indicate that the failure of the steel bearings caused substantial damage to the superstructure and closed down the highway system.

It is prudent to consider the important role played by bridge bearings in transmitting all the forces and accommodating relative movements between the superstructure and substructure. During an earthquake, bearings are subjected to displacements, rotation and lateral forces in various directions, resulting in brittle failure of the unidirectional steel high rocker and low sliding bearings (figures 1 & 2). Replacing these bearings with ductile, multi-rotational and multi-directional bearings provides safety against potential unseating of the superstructure (figures 3 & 4). During rehabilitation work, existing structures are jacked to remove the existing steel rocker or steel sliding bear-

Figure 3

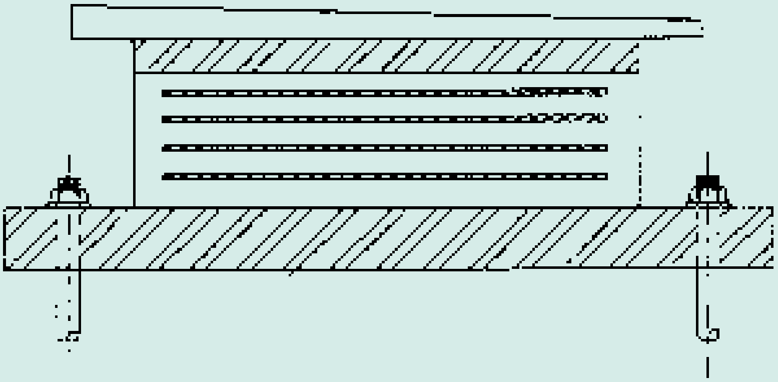
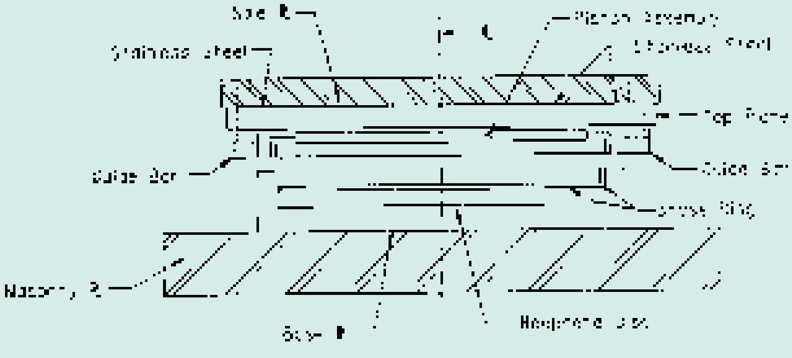
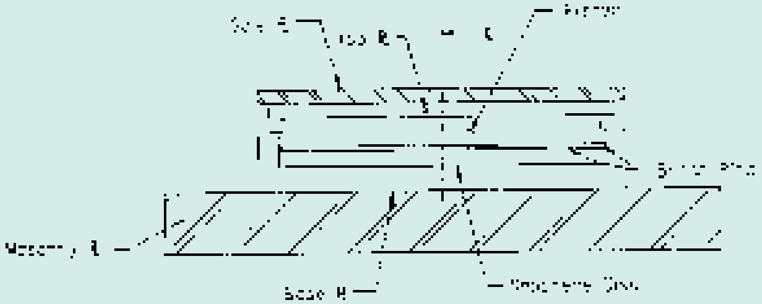


Figure 4



GUIDED EXPANSION BEARING SCHEMATIC
Not To Scale



FIXED POT BEARING SCHEMATIC
Not To Scale

ings.

Due to the height differences between the elastomeric bearings and the existing rocker bearings, existing pedestals are built up to a higher elevation, as recommended in the Seismic Retrofitting Manual for Highway Bridges (FHWA RD-94-052). Alternately, steel extensions can be bolted to the bottom flange to adjust the height difference. Fixed steel bearings are replaced in a similar manner with fixed elastomeric bearings. New anchor bolts are set into the built-up pedestals or drilled into the existing pedestals to prevent "walking out" of the bearing due to earthquake forces or due to the dynamic action of the vehicular traffic.

Depending upon the capacity of the existing substructure, it is prudent to investigate seismic demand due to a design earthquake on the substructure. When warranted, the seismic demand can be reduced by adjusting the bearing configurations in one of the following manners:

- Providing a fixed bearing at one of the abutments and expansion bearings at the pier(s) and the other abutment, which will help to reduce the seismic demand at the pier(s).
- Providing all expansion bearings with transverse restraints, thus reducing the transverse force demand by distributing it to all the substructures through expansion and fixed bearings. Providing conventional laminated elastomeric bearings at the expansion supports and using a lead core base-isolation bearing at the fixed support. This will reduce the seismic demand, even at the fixed substructure. For thermal expansion and contraction, the lead core bearing acts as a fixed bearing.
- Providing guided pot bearings at the expansion supports and a lead core base-isolation bearing at the fixed support. Since the coefficient of friction for expansion pot bearings is less than for elastomeric bearings, it will further cut down the demand on the substructure.

Retrofitting For Continuity

Multiple Simple Span. The length of superstructure that can be made continuous is a function of thermal movement. By providing continuity coupled with replacement of bearings, the lateral resistance of a superstructure will be enhanced and seismic loads will be distributed among all the substructure elements. When connecting the unrestrained ends of adjacent girder spans, it is important to provide a complete splice between the flanges and the webs. When warranted, flange splice plates can be extended to accommodate the additional

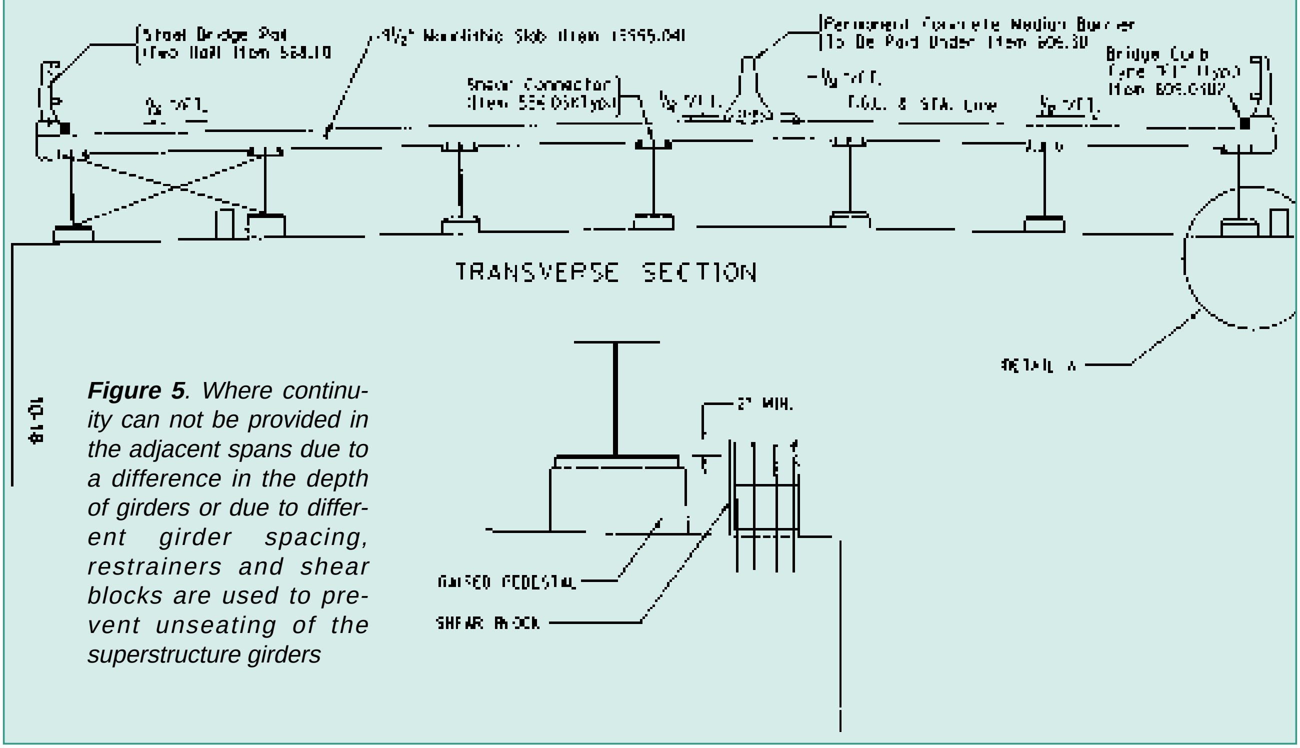


***Figure 5**. Where continuity can not be provided in the adjacent spans due to a difference in the depth of girders or due to different girder spacing, restrainers and shear blocks are used to prevent unseating of the superstructure girders*

stress in the vicinity of the proposed continuous support. Existing diaphragm connection plate/bearing stiffeners may be reattached to accommodate a large number of bolts for the web splice. Bolted splices should be used since they provide ductility to the connection. Because of the increased demand due to continuity, all the connections should be investigated to satisfy the capacity-demand ratio (>1). The use of slotted holes to allow any movement in the connection may cause brittle failure of the connection. The two lines of bearings at the piers are replaced with a single elastomeric bearing, thus eliminating the dead load and/or live load eccentricity on the pier column(s). Fatigue critical details at the end of bottom flange partial cover plates (if any) are retrofitted by a bolted splice as per the AASHTO Standard Specifications for Highway Bridges. These ends will experience stress reversal due to continuity.

Pin and Hangar. For structures with pin and hangar systems, the remaining fatigue life of the girders should be investigated and the suspended spans are fully spliced with the cantilever to eliminate the vulnerable pin and hanger system. Overstressing due to the continuity is controlled by using a lightweight exodermic deck, which in effect will cut down the seismic force level for the substructure.

Restrainers. Where continuity can not be provided in the adjacent spans due to a difference in the depth of girders or due to different girder spacing, restrainers and shear blocks are used to prevent unseating of the superstructure girders (figure 5). Restrainers should be placed on the bottom flanges of the adjacent girders such that there is no out-of-plane bending of the web due to seismic forces. Restrainers should not be designed to lock thermal movement of the superstructure, which could cause distress on the substructure elements. Similarly, shear blocks should be designed to resist the movement of the superstructure beyond the anticipated thermal movement. A detailed method is provided in the FHWA Retrofitting Manual for designing the restrainers and shear blocks.

Connections. All connections and anchor bolts should be designed for a minimum lateral force of 19% of the dead load plus live load reactions at the support. Anchor bolts should be anchored into the bridge sea to resist uplift.

Cost Of Retrofitting

The following is the average cost of retrofitting various elements for projects rehabilitated between 1991 and 1995 in New York State:

Seismic retrofitting as part of the regular rehabilitation program is designed to provide increased assurance against catastrophic failure due to earthquakes. It is important to examine the wide variety of structures individually to arrive at a cost effective approach.

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Retrofitting Costs

Continuity	
cost per splice	$1,900.00
Plates & Bolts	
plates, bolts remove existing diaphragms plate & reinstalling existing diaphragms	$6,300
Cover Plate Retrofit	
cost per location	$360.00
Restrainers	
cost per set of restrainers	$3,750.00