

BOX GIRDER BRIDGE HINGE RESTRAINER  
TEST PROGRAM

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SUMMARY

Full scale structural testing of bridge components with earthquake inputs has been missing from experimental research programs in the USA. Facilities that are required must be substantial, but they can be developed at University Laboratories. Bridge structural components have geometric size and strength capabilities that are comparable in magnitude with full scale building components.

A structural test facility which accommodates full scale bridge component specimens has been constructed at UCLA. The initial experiments conducted using the facility focus on testing the restrainers which are used to retrofit box girder highway bridges. The restrainers are installed so that hinge separation is prevented during earthquakes.

INTRODUCTION

Background

Post-earthquake investigations of box girder highway bridges after the 1971 San Fernando Earthquake (Ref. 1) showed that the decks pulled apart at the hinge and bearing seat locations. In 1980, two box girder spans of the Fields Landing Overhead near Eureka, California dropped when the hinge seats opened during the Trinidad-Offshore Earthquake (Ref. 2).

By the end of 1982 a significant amount of bridge strengthening or retrofitting had been performed by the State of California, Department of Transportation (CALTRANS). The unrestrained joint seats represent the prime focus of the CALTRANS retrofit program (Ref. 3). Six hundred ninety bridges out of 1240 identified as deficient had joint restrainers installed by that time.

Two types of longitudinal restrainers used for retrofitting are favored by CALTRANS bridge engineers (Ref. 4): 1) the Type C1 Hinge Restrainer consists of 7-3/4"  $\phi$  galvanized cables, bearing plates, and drum, and 2) the restrainer bar is a 1 1/4"  $\phi$  high strength steel rod

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satisfying ASTM A-722 (Ref. 5). Both types of hinge restrainers are under investigation in experimental test programs (Ref. 6,7).

The structural configuration of the hinge region of a box girder bridge is shown in Fig. 1. The box girder bridge is hollow and so it is possible for workmen to enter existing construction for installation of the restrainers. A cable installation is shown in Figs. 1 and 2. A rectangular cross section called a bolster (Ref. 8) is added to thicken the hinge diaphragm (Fig. 1) so that punching shear failures are avoided.

A retrofitted hinge seat subjected to an opening displacement experiences a complicated distribution of stresses in the bolster, hinge diaphragm, webs, soffit slab, and deck slab that are adjacent to the restrainer. The restrainer carries a tension force which causes it to lengthen. As the opening displacement becomes larger and the tension forces increase then there is an increased likelihood of failure. CALTRANS bridge engineers have selected the restrainer properties so that failure will occur in the restrainer instead of the hinge diaphragm or adjacent components.

Soon after the 1971 San Fernando Earthquake it was decided (Ref. 9) that longitudinal hinge restrainers should be capable of resisting a minimum force equal to 25% of the weight of the lighter segment joined. Bridge designs at the time were based on working stresses. The reduction of force in the restrainers due to shears carried in the piers was neglected in the design procedure.

When load factor design methods are used almost identical results are obtained using 33% of the dead load (Ref. 6). Recently, CALTRANS bridge design specifications (Ref. 10) have adopted use of the actual ground acceleration at the site with a minimum 35% value. The loads based on the controlling acceleration are applied to the bridge structure allowing the columns to carry their share. Restrainers are designed to carry the remaining forces at the joints.

The longitudinal restrainer design force values were established more from judgement than from analysis. Dynamic analyses using linear and non-linear mathematical models have been performed (Ref. 11) on curved bridges fitted with hinge restrainers, but there is some question concerning the veracity of the results. The computer representations of the longitudinal force-deflection properties of restrained hinge seats has not been verified by experimental testing. Structural dynamic analysis computer programs use the hinge seat force-deflection properties so that the effect of the retrofitted hinge seat is represented in the model. If the computer representation of the force-deflection were confirmed then designers would have greater confidence when using the structural dynamic idealization of the bridge. The required longitudinal restrainer design force in terms of dead load percentage could be established with a verified force-deflection relation, and then used in subsequent bridge designs.

## Objective

The objective of the present paper is to discuss the box girder bridge restrainer test program. The development of the testing facilities, equipment, and specimens at UCLA is emphasized.

## FACILITIES AND EQUIPMENT

### Reaction Frame

A reinforced concrete reaction or loading frame composed of a test bed and two reaction blocks is capable of resisting 1500 kips (6666 kN) and is depicted in Figs. 1 and 2. A bridge specimen's anchor bars are shown protruding through the west reaction block of the loading frame in Fig. 3. Alternating tension-compression forces up to 1500 kips (6666 kN) can be applied to full scale bridge components. The 4 ft (1.22 m) thick reaction blocks have numerous 3 in. (7.6 cm) diameter pipe passages used for tension anchors which restrain the actuators and components to be tested. The 32 ft (9.75 m) clear distance between the reaction blocks permit static and dynamic structural testing of components up to 22 ft (6.71 m) in length.

The test bed section of the reaction frame extends 4 ft. (1.22 m) below grade. At the location of the reaction blocks the test bed is thickened to 6 ft (1.83 m) to provide sufficient anchorage distance for the vertically oriented flexure reinforcement in the reaction blocks. The test bed is extended 5 ft (1.52 m) outside of the reaction blocks so that the longitudinal reinforcement of the test bed is sufficiently anchored.

Twenty-one "tie-downs", positioned in a 3 x 7 grid with 4 ft (1.22 m) intervals in both directions, are embedded in the test bed between the reaction blocks. A 4 in x 8 in (10.2 cm x 20.3 cm) rectangular cross section shaft extends 4 ft (1.22 m) deep into the bed. The shaft then enlarges to a 12 in (30.5 cm) diameter and extends 15 in (38.1 cm) deeper to a total depth of 63 in (160.0 cm). The top of the shaft is at grade level while the top of the cavity is located below the test bed reinforcement. The "tie-downs" are used to hold actuators which in turn impart vertical and horizontal shears to specimens. For example, a specimen with one end anchored to the east reaction block can have its other end subjected to two components of shear in addition to an axial force component generated by an actuator affixed to the west reaction block.

The test bed and reaction blocks were constructed as a class project by undergraduate and graduate engineering students of the School of Engineering and Applied Science, University of California, Los Angeles between October 1982 and June 1983. Excavation necessary for the test bed was performed by a private contractor.

Grade 60 reinforcing steel is used throughout the installation. Top and bottom reinforcement in the test bed consists of 18 - #14 bars at both elevations. Three 50 ft long cages with 70 - #4 stirrup ties and 10 or

11 - #14 bars in each cage were fabricated above grade. Before lowering the cages into the test bed the tie-down forms were installed between the longitudinal bars from below.

The flexure reinforcement for each reaction block consists of 36 - #9 "U" bars with the tails pointing downward. The "U" bar tails penetrate through the horizontal #14 bars of the test bed. Horizontal cross ties are used for shear reinforcement and for prevention of buckling of the #9 U flexure bars. Vertical shear reinforcement is also placed in the reaction block. Transverse horizontal #9 bars are also placed on the wide faces of the reaction blocks so that concentrated forces are distributed to the #9 "U" bars.

The concrete was placed in two separate pours: 1) 100 yd<sup>3</sup> of 7.5 scy stone concrete was cast against excavation for the test bed, and 2) 20 yd<sup>3</sup> of 7 scy concrete with superplasticizer donated by Conrock, Inc., Los Angeles, was cast in forms for the reaction blocks. Both concretes reached 28 day compressive strengths in excess of 5000 psi.

#### Actuators and Controllers

One 18 in (45.7 cm) diameter by 12 in (30.5 cm) stroke actuator and two 12 in (30.5 cm) diameter by 24 in (61.0 cm) stroke actuators are used in the testing. They are controlled by Moog servovalves and controllers. A 5 HP pump drives the system with a maximum speed of 1 in/min (2.54 cm/min).

### SPECIMENS

#### Bridge Test Components

The hinge region of a box girder bridge in service is duplicated by the components which are constructed for testing. All structural properties that are used by CALTRANS (Ref. 10) including dimensions and material properties are matched during the construction of the bridge components for testing.

The dimensions used in old construction are the same for most bridges. Only the cross section depth is changed for different span lengths. The thicknesses used in the test components are as follows: 1) webs or stems - 12 in (30.5 cm); 2) hinge diaphragm - 10 in and 25 in (25.4 cm and 63.5 cm); 3) bolster - 9 in (22.9 cm); 4) soffit slab - 5.5 in (14.0 cm); and 5) deck slab - 7.5 in (19.1 cm). The bridge component length dimension on each side of the hinge is 10 ft (3.05 m) making a total length of bridge that is represented equal to 20 ft (6.10 m). The bridge component width used in the test is 10 ft (3.05 m) which is equivalent to the distance between webs or stems of an actual bridge. The height of the test component is 4 ft (1.22 m). All except the height dimension are standardized box girder bridge dimensions.

The concrete proportions used in the bridge test components follow the CALTRANS specifications in force during the 1950-1970 period, i.e.

the cement content is 6 sacks per cubic yard, 1½ in (3.81 cm) is the max aggregate size, and the design slump is 4 in (10.2 cm). The design  $f'_c$  is 3250 psi (22.39 MP). The concrete is placed in three separate pours in accord with CALTRANS procedure as follows: 1) soffit slab, stems, and hinge diaphragm, 2) deck slab, and 3) bolster. The same forms are used for the east and west test components.

Grade 60 reinforcement is used in the tested components. The reinforcement configuration is shown in Fig. 4. For the cable restrainer test 20. - #14 bars are used to anchor the west bridge component to the reaction block (Fig. 3). The anchor bars are necessary because of the projected 750 kip (3,333 kN) cable strength. A similar number is used to join the east bridge test component to the actuators (Figs. 1 and 2). The large anchor bars are spread outward to the stems in the hinge region so that only the standard reinforcement (Refs. 4,8,10) of the hinge diaphragm and bolster remain at that location (Fig. 4). Therefore an accurate experimental representation of the hinge diaphragm is obtained.

#### Type C1 Hinge Restrainer

The Type C1 Hinge Restrainer (Ref. 4) consists of 7 - 3/4 in (1.91 cm)  $\phi$  cables which lash the hinge diaphragms together (Figs. 1 and 2). The seven cables are anchored on the face of the west bolster, pass through both hinge diaphragms, wrap around a drum located on the face of the east bolster, pass back through the second hole, and are anchored again on the west bolster. The cables are swaged to 1 in (2.54 cm) studs which pass through a plate for the anchorage.

#### Restrainer Bars

Two 1.25 in (3.18 cm) restrainer bars are installed through both hinge diaphragms at two transverse locations. The ends of the bars are threaded for anchorage nuts.

#### TESTING ARRANGEMENT

The test arrangement is indicated in Figs. 1 and 2. The west test component is fixed to the west reaction block by the anchor bars which have the ends threaded. The bars pass through the reaction block and are held with washers and nuts. The east test component rolls on solid steel round stock. The rounds bear on steel strip rails embedded in the test bed and the east bridge test component so that frictionless motion occurs.

Servo-controlled actuators are mounted to the east reaction block. Steel fittings join the actuators to the anchor bars of the east test component so that the test component is moved by the jacks. Load cells are used to measure the jacking force. Three LVDT's are mounted across the hinge joint in order to measure and assist in controlling the opening displacement. The experiment is conducted so that the displacement history of the opening is controlled at all times.

## CONCLUSION

The testing program for reinforced concrete box girder hinge restrainers is underway in the Department of Civil Engineering at the University of California, Los Angeles. Full scale box girder bridge test components and prototype restrainers used in the CALTRANS earthquake retrofit program are subjected to cyclic loadings which represent seismic inputs.

A reaction frame capable of accommodating the large dimensions and forces of the bridge test components and restrainers has been constructed. The reaction blocks and test bed of the reaction frame can impart three dimensional force distributions to full scale bridge components to be tested.

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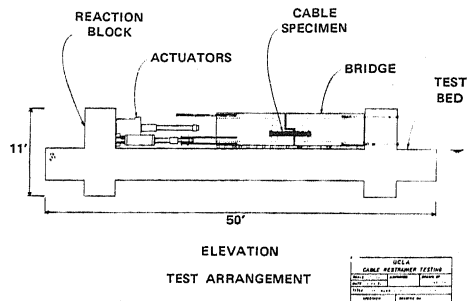


Fig. 1 - Elevation View of Bridge and Reaction Frame

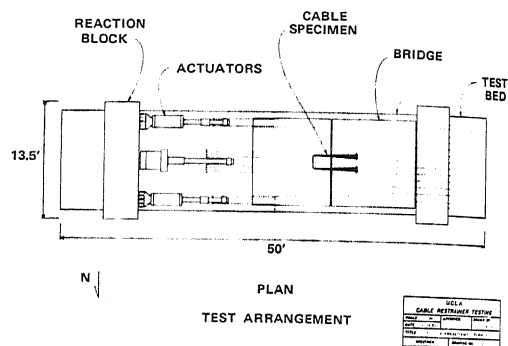


Fig. 2 - Plan View of Bridge and Reaction Frame



Fig. 3 - Bridge Component Installed in Reaction Frame

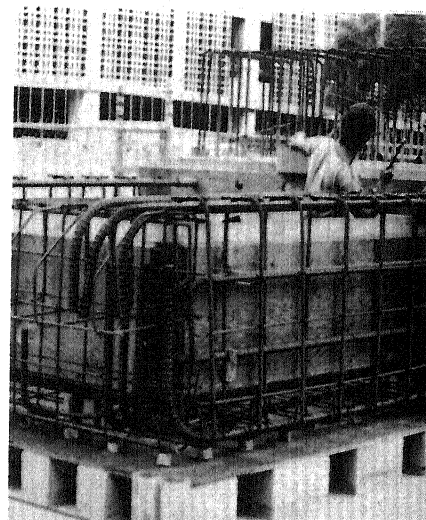


Fig. 4 - Reinforcement for Box Girder Hinge Component