Experimental Study on Strengthening Effect of High Modulus CFRP Strips Installed onto Lower Plate of I Shaped Girder

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Keynote Lectures and Extended Abstracts of the Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, EASEC12, pp. 219-220, 6pages in CDROM, January 26-28, Hong Kong SAR, China (2011)

Recently, number of steel bridges required to be strengthened to reduce working stress due to deterioration and updated design live load is increasing in Japan. Then additional steel plates are welded and bolted to these existing steel bridges in ordinary cases. However such conventional strengthening techniques have room for improvements onto construction workmanship. The use of high modulus CFRP strip as strengthening material is focused on for more rational and economical strengthening technique of superannuated existing I shaped steel girders.

Then, experimentally investigated in this study is strengthening effect of high modulus CFRP strips installed onto the lower flange plate of I shaped steel girder. Five girder specimens with different adhesive lengths of the CFRP strips to the lower flange plate are used in the bending tests. Also method to prevent CFRP strips from debonding at both ends of them is proposed and investigated in this experiment. Then, the bending strength and behavior of the strengthened I shaped steel girders are discussed.

Knock-off Effect of Steel Side Block as Displacement Restrainers on Dynamic Response of Isolated Bridge Structure

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Keynote Lectures and Extended Abstracts of the Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, EASEC12, pp. 656-657, 8pages in CDROM, January 26-28, Hong Kong SAR, China (2011)

Displacement restrainers of the superstructure in the transverse direction of the isolated bridge are usually installed to protect expansion joints from damage during earthquake. Steel side blocks, one of the displacement restrainers, are set near both sides of isolating bearings. Here, a more rational seismic response of the isolated bridge in the transverse direction can be considered to be that the displacement of the superstructure during a small and moderate earthquake like Level 1 Earthquake defined in the JSHB (Specification of Highway Bridges) is restraint and the displacement during a strong earthquake like Level 2 Earthquake is released to mitigate damage of bridge pier and/or base structure and to enhance redundancy against a strong earthquake. For instance, steel side block, improved to have a knock-off function, will provide these responses of the isolated bridge. This study describes the outline of the side block with slit, which is developed by the authors to control the breaking load accurately. The breaking characteristics of the side block with knock-off function are verified through static breaking test using down-sized specimens with changes in dimension of the slit, like cross-sectional area and height of the slit. Also analytically clarified is the installation effect of the side block on dynamic response of the isolated bridge structures.

Experimental Study on Debonding Prevention Methods of High Elastic Modulus CFRP Strips Installed onto Lower Flange Plate of I Shaped Steel Girder

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Journal of Structural Engineering, Vol.57A, JSCE, pp. 114-124 (2011) (in Japanese)

Installation of CFRP strips of high elastic modulus can be effective for improving the load carrying capacity of a superannuated existing steel I girder. Experimentally investigated in this study are some debonding prevention methods at the edges of the CFRP strips onto the lower flange plate. At the first step, the bending tests are carried out for six girder specimens with different adhesive lengths of the CFRP strips. Then, debonding prevention plates at the edges of the CFRP strips and tie plate and tie rod bridging both edges of the CFRP plates over the steel splice plate of bolted connection is proposed to prevent the debonding and the effectiveness of the methods are examined for the specimens with the debonding.

Analytical Modeling and Seismic Performance on In-plane Behavior of Rigid Framed Steel Bridge Pier

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Journal of Structural Engineering, Vol.57A, JSCE, pp. 94-103 (2011) (in Japanese)

Rigid framed steel bridge piers had several damages like plate buckling by the attack of the Hyogo-ken Nambu Earthquake. To update seismic design adequately evaluating strength and ductility on in-plane behavior of the pier, some analytical modeling, which can consider plate buckling, is required and is available now but not for practical

business use. Then investigated in this study is an adequate modeling method when using beam-column element based on Euler-Bernoulli theory for the analysis and influences of some modeling methods on the seismic performance of the in-plane behavior of the pier.

Seismic Retrofit for an Existing Network Arch Bridge with Slit-type Knock-off Bearings
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Journal of Structural Engineering, Vol.57A, JSCE, pp. 467- 478 (2011) (in Japanese)
Seismic retrofit of an existing network arch bridge against large-scale (Level 2) earthquake ground motions was performed by modifying existing fixed steel bearings into slit-type knock-off bearings. Three-dimensional non-linear dynamic response analyses were carried out considering site-specific ground motions. It was confirmed that shear panel dampers as passive energy-dissipation were needed on both fixed-side and movable-side pier tops to avoid the potentially difficult retrofit work for the undersea pier anchors and foundations. The authors proposed slit-type knock-off bearings with the knock-off function as triggers against the Level 2 ground motions to provide isolation effect. Performance tests of the slit-type knock-off bearings were conducted to verify the required performance for the seismic retrofit design.

Influence of Corrosion Area of the Girder Ends of Highway Bridges to its Load Carrying Capacity
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Journal of Structural Engineering, Vol.57A, JSCE, pp. 724- 734 (2011) (in Japanese)
In these days, it has been reported that some of steel bridges are deteriorated due to corrosion of the girder ends. Since the evaluation method of the load carrying capacity of the girder ends with corrosion is not established, understanding of mechanical property and ultimate strength of the girder ends is required from the viewpoint of repair works. In this paper, the load carrying capacity of the girder ends with corrosion of Highway Bridges is studied based on FE analysis. In particular, the influence of corrosion area and location of the girder ends to its load carrying capacity are discussed focusing on the height and length of the corrosion area, the size of the sole plate and so on.

Experimental Study on Application of High Strength Bolted Connections to Submerged Structures
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Journal of Structural Engineering, Vol.57A, JSCE, pp. 831- 841 (2011) (in Japanese)
Most of field joints of the submerged structures such as steel penstock or hydraulic gates are welded on site. High strength bolted friction type joints are hardly applied because of change of slip coefficient due to penetration of water, lowering of axial force due to corrosion of bolt, delayed fracture of high strength bolt, and so on. On the other hand, in refurbishment of existing structures it will be difficult to apply welded joints to them in terms of weld ability of existing material, influence of thermal strain on accuracy, and limitation of work space at the site. If high strength bolted friction type joints can be applied to them, they will become one of the alternatives for refurbishment method, and widely contribute to improvement of workability, reliability and economic efficiency. In this paper, the experiment for high strength bolted frictional joints subjected to tensile load considering water pressure and site condition are carried out. Based on the experimental results, slip coefficient of them is evaluated taking into consideration about water penetration into the frictional surface.

Proposal of an Acoustic Method to Evaluate Vertical Misalignment between Plates of Steel Expansion Joints of Finger Type
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Steel Construction Engineering, Vol.18, No.69, JSSC, pp. 1- 8 (2011) (in Japanese)
Mal-function and damages of expansion joints not only affects the smooth traveling of vehicles on the bridge, but are also sources of inconvenient noises and vibrations. In addition, impact due to live loads may cause damages to the girder end structures, being worsened in case a smooth transition between adjacent girders is not assured. The present study performed a series of field and loading tests to investigate the acoustic and vibrational structural effects of vehicles traveling on the surface of steel finger expansion joints. Effects of vertical misalignment between the plates of the joint fingers were investigated and a diagnosis method based on acoustic evaluation is also proposed.

Study on Seismic Performance of a Box Sectional Steel Pier with Transversely Profiled Plates
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Journal of JSCE, Ser. A1 (SE/EE), Vol.67, No.1, pp. 177-192 (2011) (in Japanese)
For a box sectional steel column with transversely profiled plates (TP plate), cyclic loading tests, combined non liner FE analyses, pseudo-dynamic tests and dynamic FE analyses are carried out, in order to investigate its seismic performance. As results of cyclic loading tests and combined non liner FE analyses, it is shown that steel pier with TP plate have good seismic performances, and the taper ratio and the slenderness parameter are the larger, seismic performances are the better. And as results of pseudo-dynamic tests and dynamic FE analysis considering the real seismic acceleration, it is found that the response displacement of steel pier with TP plate is smaller than the one of ordinary steel pier.

Breaking Effects of Displacement Limiting Devices for Rubber Bearings
Masahide MATSUMURA
The 4th Taiwan-Japan Workshop on Bridge Engineering, 3pages, Kyoto Univ., Kyoto, April 2-3 (2011)

Study on Mechanical Behavior of High Strength Bolted Friction Panel Joint Members of Steel Truss Bridges and Calculation Method of its Effective Width
Takashi YAMAGUCHI, Shinsuke YOSHIDA (Kyoto University), Kunitaro HASHIMOTO (Kyoto University) and Kunitomo SUGIURA (Kyoto University)
Steel Construction Engineering, Vol.18, No.71, JSSC, pp. 27- 42 (2011) (in Japanese)
In this study, in order to clear the mechanical behavior of panel point of steel bridges using high strength bolted frictional joints, tensile loading experiment is carried out at first. Secondly, in order to make more detail clarification of the mechanical behavior and to examine the effective width of the gusset plate, finite element analysis has been executed by using the model which has same configuration of the specimen. From the results of this experiment and analysis, the collapse behavior of panel points of steel truss bridges is discussed and applicable evaluation methods of the load carrying capacity for yielding of such panel points are proposed.

Analytical Study on Rigid Connection Detail of Steel-Concrete Composite Rigid Frame Bridge Using Bearing Plate
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35th International Symposium on Bridge and Structural Engineering (IABSE), London, UK, September 20-23, (2011)
Recently, the number of steel-concrete composite rigid frame bridges in Japan is increasing for short and medium span length. To make this type of bridge more rational, it is important to ensure a good performance of the rigid connection. Therefore, a new type of the connection detail with bearing plate has been proposed by the authors. In this study, effectiveness and applicability of the proposed rigid connection detail with the bearing plate was examined by elasto-plastic finite displacement analysis. Mechanical behaviour of the connection detail up to the ultimate limit state is investigated based on them. It is found that the load can be securely transferred from the steel girder to the abutment through the bearing plate. It is concluded that the proposed connection detail can become one of the practical and effective rigid connection considering easiness of construction.

Study on Residual Strength of Riveted Joints Damaged by Corrosion
Kunitaro HASHIMOTO (Kyoto University), Takashi YAMAGUCHI and Kunitomo SUGIURA (Kyoto University)
35th International Symposium on Bridge and Structural Engineering (IABSE), London, UK, September 20-23, (2011)
In this study, in order to clarify a relationship between a residual strength and a level of corrosion damage, and to investigate a mechanical behaviour of riveted joints damaged at rivet head by corrosion, experimental and analytical studies are carried out. In the experiments, are used the specimens which cut off from the demolished exiting steel bridge members. Experimental specimens of single lapped joints which are varied the corrosion levels are prepared and tensile tests are executed. In FE analysis, the corrosion levels of a rivet head and joint type which are single and double lapped joints are dealt with and parametric analyses are carried out. As the results of this study, it is found that the residual strength of the riveted joint damaged by corrosion is much decreased when a rivet head is corroded heavily in especially the case of the single lapped riveted joint.

Model Test of Isolated Bridges with Displacement Control Device which Brakes under Strong Earthquake by Shaking Table and Its Dynamic Response Analysis

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The 2011 World Congress on Advances in Structural Engineering and Mechanics (ASEM'11+), pp. 2754-2762, 18-22 September, Seoul, Korea (2011)

In isolated bridges, some displacement restrainers of superstructures in the transverse direction of the bridge axis, like steel side block (SB), is usually installed for damage protection of expansion joints during earthquakes. However, it can be rational to expect the isolation effects in the transverse direction as well as in the bridge axis against a strong earthquake. Then, recently developed and proposed by the authors is the steel side block with the knock-off function (CSB), which breaks at a pre-set breaking load and provides smooth shift to the isolated conditions. In this study, small-size shaking table tests and dynamic response analysis of the isolated bridge models installed the CSB are carried out by changing breaking characteristics of the CSB. Then, analytical modeling method of the CSB is proposed and the validity of it is verified as compared with the tested dynamic responses.

Analytical Study on Elasto-Plastic Behavior of Steel Members Predominantly Subjected to Cyclic Axial Force

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Proceedings of the 6th International Symposium on Steel Structures ISSS-2011, pp. 64-68, Seoul, Korea, 3-5 November (2011)

The seismic performance of steel bridge piers which predominantly subjected to cyclic bending moment and methods to evaluate seismic performance of steel bridge piers have been already proposed. On the other hand, there are little studies about the elasto-plastic behavior and the seismic performance of steel members predominantly subjected to cyclic axial force like chord members of steel truss bridges. The seismic performance of steel members predominantly subjected to cyclic axial force and the major buckling parameters affecting the seismic performance may be different from those of steel piers and it is not clear whether the previous seismic evaluation methods for steel bridge piers can be applied to the steel members predominantly subjected to axial force. Therefore, it is necessary to grasp the elasto-plastic behavior and the seismic performance of steel members predominantly subjected to cyclic axial force. In this paper, the elasto-plastic behavior of steel members predominantly subjected to cyclic axial force is investigated by the finite element analysis.

Modeling and Ultimate Strength of Steel Column Members Subjected to Predominant Axial Force in Truss Bridges

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Proceedings of the 6th International Symposium on Steel Structures ISSS-2011, pp. 275-282, Seoul, Korea, 3-5 November (2011)

Plate and member buckling greatly influence on the ultimate state of thin-walled steel column members which are widely used in steel truss bridge. Such members will show an elasto-plastic behavior when subjected to an excess load, though the column members are designed elastically. Then a beam-column element, by which the plate buckling cannot be considered, is generally used for modeling the column member in the analysis of the truss bridge. Therefore, a local buckling of the component plate panels and initial imperfections are not taken into account for the model. Then investigated analytically in this paper is the ultimate state of a steel truss bridge, which is designed based on the Specification for Highway Bridges in Japan and is subjected to an increasing monotonic load in the downward direction. Also carried out are static loading tests using such column specimens subjected to an increasing eccentric predominant axial load. The effect of the plate buckling on the ultimate strength of the member is discussed based on the analytical and experimental results.

Static and Cyclic Loading Test of Steel Bellows Made of Various Steel Materials in Axial Direction

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Proceedings of Constructional Steel, Vol.19, JSSC, pp. 395-402 (2011) (in Japanese)

Steel bellows as energy absorbing bridge connector is proposed by the authors. In this paper, cyclic behaviors of steel bellows with the same shape and with different steel materials are investigated by static and cycling loading test. Also discussed is a simplified stress-strain relationship used in FEM analysis by considering an increased yield stress due to bending process of the steel bellows. It is concluded that the yield ratio of the steel materials

greatly influenced the energy absorbing capacity of the steel bellows. The increased yield stress is necessary to be considered in the analysis to obtain equivalent energy absorbing capacity of the steel bellows made of steel materials with smaller yield ratio and subjected to large cyclic displacement.

Shaking Table Test of a Small Vibration System Considering Member Knocking-off
Nobuhito OCHI (Akashi National College of Technology) and Masahide MATSUMURA
Proceedings of Constructional Steel, Vol.19, JSSC, pp. 375- 380 (2011) (in Japanese)
In isolated bridges, some displacement restrainers of superstructures in the transverse direction of the bridge axis, like steel side block (SB), is usually installed for damage protection of expansion joints during earthquakes. However, it can be rational to expect the isolation effects in the transverse direction as well as in the bridge axis against a strong earthquake. Then, developed and proposed by the authors is the steel side block with the knock-off function (CSB), which breaks at a pre-set breaking load and provides smooth shift to the isolated conditions. In this study, small-size shaking table tests and dynamic response analysis of the isolated bridge models installed the CSB are carried out by changing breaking characteristics of the CSB. Then, modeling method of the CSB in the analysis is proposed and the validity of it is verified as compared with the tested dynamic responses.