

### **Post-tension Strengthening Via Carbon Fiber Sheet for Existing Steel Bridge Girders**

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As the 20 tons track load had been upgraded to 25 tons in 1993, most of existing bridges are remaining under poor loading capacity and are supporting heavy traffic load. In this study, adoption of carbon fibre reinforced composites (CFRP) where a post-tension is preliminary introduced by using newly developed device is investigated experimentally. A fracture behavior of adhesive interface between the CFRP and steel girder has been investigated on the basis of numerical and experimental results. Then it is found that the opening deflection at the end of bonded CFRP can be extremely prevented by attaching the holding plates even under the pre-tensioned condition of the CFPRs.

### **Devices for CF Sheet Post-Tension Strengthening for Steel Bridge Girder**

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Carbon fiber reinforced composites was tried to adopt as post-tension strengthening materials for the existing steel I shaped girder to improvement the load carrying capacity. Then developments of a prevention technique of the delamination at the tips of the CFRP impregnated by the epoxy resin and tensioning devices of the CFRP to introduce the pre-stressed load to steel girders. Finite element analysis has been carried out to find out the design policy of this post-tension strengthening. And the effectiveness of a holding plate to prevent the delamination of the CFRP is verified. Also suggested are some newly developed devices to introduce post-tension load into a lower flange plate of the bridge girder.

### **Mechanical Characteristics and Load Carrying Capacity of Nielsen-Lohse Bridges under Lateral Loads**

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*Steel Construction Engineering*, Vol.11, No.42, JSSC, pp.89-100, June 2004 (in Japanese).

This paper presents results of a parametric analysis carried out on the mechanical characteristics and load carrying capacity of Nielsen-Lohse bridges subjected to lateral loads (wind loads). First of all, trial design is conducted for various practical bridge models subjected to lateral loads according to the Japanese Specifications for Highway Bridges (JSHB) in order to investigate the mechanical characteristics and load carrying capacity of these models. Second, the exact load carrying capacity of these models under lateral loads is numerically calculated through elasto-plastic and finite displacement analyses using a FEM program named EPASS. Finally, a rational and economical design method for the arch ribs of Nielsen-Lohse bridges is proposed based on the parametric analysis.

### **Experimental Study on Seismic Retrofitting of Circular Steel Bridge Piers Stiffened in Circumference Direction by CFRP Sheets**

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*Journals of the Japan Society of Civil Engineers*, No.766/I-68, pp.17-31, July 2004 (in Japanese).

Proposed in this paper is a seismic retrofitting method utilizing carbon fiber reinforced plastic sheets for circular columns in existing steel bridge piers. The method can be considered to be practical and convenient in retrofitting works compared with other current retrofitting methods. In the method, a circular column is wrapped with CFRP sheets of extremely high tensile performance. The validity of the proposed method is investigated through a bending test, compression test and cyclic loading test. It is concluded that the proposed method can control and improve the ductility capacity of the column without increasing its flexural stiffness and ultimate strength. Applications of the method are also discussed.

### **Fundamental Study on Vibration Characteristics of Marker Columns and Lighting Poles on Highway Bridges**

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*Journal of Steel Construction Engineering, JSSC*, Vol.11 No.43, pp.147-158, September 2004 (in Japanese).

Vibration due to traffic and wind causes almost all fatigue damage to portal marker columns and lighting poles on highway bridges. The vibration characteristics decided by the locations and types of portal marker columns and lighting poles is investigated through modal frequency response analysis in this study. Various types of damage are generated in experimental models for portal marker columns, and a vibration experiment is carried out in this study. The relations between the extent of damage and vibration characteristics can be investigated through the vibration measurement and the analysis of a portal marker column.

### **Static Breaking Test of Rupture Controllable Side Block for Bridge Bearings**

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*Bridges Maintenance, Safety, Management and Cost*, pp.393-395, IABMAS04, Kyoto, Japan (8pages, CDROM), October 2004.

Seismic isolation structures are effective for mitigating earthquake load delivered directly to substructures. However, isolation devices will allow the horizontal move of superstructures and cause the damage to expansion joints even due to normal loads. Development of a rational seismic isolation device is required to support firmly the superstructure against a small earthquake, which occurs sometimes during the bridge design life, and to avoid

a strong earthquake, which rarely occurs. For a simple and economical approach to realize such rational isolation device, it can be a key to improve the function of side blocks for bridge bearings. Pro-posed in this paper is a slit type side block that can control the breaking load and surely breaks at the expected load. The function of the proposed slit type side block is experimentally con-firmed by using full-scale specimens and downscaled ones and is also verified analytically. The design formulae for the slit type side block are also proposed.

### **Experimental Study on New Types of Composite Panel Point Structure Proposed for Truss Bridges**

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*Bridges Maintenance, Safety, Management and Cost*, pp.929-930, IABMAS04, Kyoto, Japan (8pages, CDROM), October 2004.

The new panel point structure of truss bridges without gusset plates is proposed in this study. The proposed panel point is a composite structure made of concrete and steel tube connected with high strength long bolts. A loading test subjected to bending moment and shear force is carried out in order to examine the mechanical behavior of the proposed panel point. 3 specimens are prepared paying attention to difference of the panel point structure. From the experimental results, the slippage behavior and bending behavior of the panel point, the behavior of the bolt axial force and separation of the joint section are discussed in detail.

### **Experimental Study on Strengthening of Superannuated Steel Bridge Girders by Installing Pre-tensioned CFRP Sheets**

Takeshi KITADA, Masahide MATSUMURA, Toshiyuki KITADA, Masaki HOJO (Kyoto University), and Hironori NAMIKI (Kyobasi Mentec Co.,Ltd.)

*Bridges Maintenance, Safety, Management and Cost*, pp.427-429, IABMAS04, Kyoto, Japan, October 2004.

Strengthening of the superannuated steel girder bridges confronted with the lack of load carrying capacity is an important issue to be solved in Japan. The authors are focused on utilizing Carbon Fiber sheets impregnated with epoxy resin as a new retrofitting material in-stead of some conventional ones like steel plate or steel bar. Presented in this paper is a strengthening technique for the lower flange plate in steel bridge girders of I cross section using a pre-tensioned CF sheets. Also investigated both experimentally and analytically is an issue on stress concentration and debonding at the both tips of CFRP. The pre-tension is introduced to the Carbon Fiber sheet for more effective use of it and a holding plate is employed to avoid the debonding of CFRP at their both edges.

### **Mechanical Behavior of High Strength Bolted Tensile Joints with Sealant**

Yasuo SUZUKI, Takashi YAMAGUCHI, and Toshiyuki KITADA

*Journal of Constructional Steel, JSSC*, Vol. 12, pp.453-458, November 2004 (in Japanese).

In this study, 3D-F.E.Analysis of two types of high strength bolted tensile joints is carried out. One is the split tee

joint type and the other is the joint in which the contact area is located only at the center of tee flange plate with/without sealant. Discussed herein are the effects of the later type of joints and of Young's modulus of the sealant installed the joint surfaces on the mechanical behavior of this type of the joint. It is concluded that the strength and the rigidity of the later type of the joint with sealant of which Young's modulus is about 0.01GPa is almost equal to those of the joint with no sealant.

### **Vibration Characteristics of Marker Columns without/with Damage on Highway Bridges by Field Measurement and Analysis**

Hideo ISHA and Toshiyuki KITADA

*Memoirs of the Faculty of Engineering, Osaka City University, Vol.45, pp.37-46, December 2004.*

A practical system for detecting Portal marker columns with damage without stopping traffic flow and for evaluating their safety is developed. For obtaining fundamental data on the development, the vibration characteristics of two standard marker columns with rigid frame Portal Gate-type and F-type were measured. The following points on the development are found out through the measurement. (1) The natural period of first vibration mode can be easily and exactly measured by an ordinary digital video camera. (2) Described in this paper is the outline of the vibration measurement and the vibration analysis for evaluating the results of the measurement.

### **Experiment on Static Breaking of Rupture Controllable Side Block for Bridge Isolation Device**

Masahide MATSUMURA and Toshiyuki KITADA

*Memoirs of the Faculty of Engineering, Osaka City University, Vol. 45, pp.47-52, December 2004.*

After the Hyogo-ken Nambu Earthquake, a seismic isolation of structure becomes very popular and is able to mitigating earthquake load, which is delivered directly to substructures without some isolation device. However, isolation devices tend to allow the horizontal move of superstructures. Development of a rational seismic isolation device, therefore, is required to protect expansion joints even against a small earthquake and to isolate the superstructure reliably. The rational isolation device should be designed to support firmly the superstructure against a small earthquake, which occurs sometimes during the bridge design life, and to avoid a strong earthquake, which rarely occurs. Pro-posed in this paper is a slit type side block that can control the breaking load. The function of the pro-posed slit type side block is experimentally confirmed by using full-scale specimens and downscaled ones. The design formulae for the slit type side block are also proposed.

### **Applicability of Seismic Retrofitting Technique by Setting Steel Segment into Existing Steel Bridge Pier with Rectangular Cross Section**

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*Steel Construction Engineering, JSSC, Vol. 11, No. 44, pp.45-55, December, 2004 (in Japanese).*

Steel column members with Embedded Plastic Segment (EPS) has been developed and proposed as a new seismic retrofitting technique for existing steel bridge pier to enhance the ductility with less increment in the ultimate strength of the columns. In this paper, the effect of the seismic retrofitting technique on the ductility and ultimate strength of a steel column member is investigated by comparing with a concrete filled column member and a constitutive model of EPS with the proper length is proposed for the elasto-plastic analysis in the design. Also presented is an application example of the seismic retrofitting technique into an actual existing steel bridge pier required to be retrofitted.

### **Analytical Study on Ultimate Strength and Contact Force of High Strength Bolted L-Stub Joints**

Yasuo SUZUKI, Takashi YAMAGUCHI, and Toshiyuki KITADA

*Journal of Structural Mechanics and Earthquake Engineering*, No.780/I-70, pp.87-96, January 2005 (in Japanese).

High strength bolted L-stub joints are expected to be used in connections of members with box cross section, because of their good mechanical properties and appearance. However, they are not utilized for connecting these members of actual bridge structures due to lack of enough information of their mechanical behavior for design. The deformation of the tee flange/web plates of L-stub joints may considerably affect the mechanical properties of this type of joints such as the ultimate strength, the distribution of contact stress between the joint surfaces and so on. In this study, the effect of the thickness of the tee flange/web plates on the mechanical behavior of L-stub joints is discussed analytically.

### **Strength and Ductility of Transversely Profiled Simply Supported Steel Plate under Compression**

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*Journal of Structural Mechanics and Earthquake Engineering, JSCE*, No. 780/I-70, pp.231-239, January 2005 (in Japanese).

Studied herein is the strength, ductility and energy absorption capacity of simply supported steel plate profiled transversely under uniform compression. In order to assess the effect of the taper ratio of steel plate thickness on the structural performance, the elasto-plastic finite displacement analysis is carried out, varying the taper ratio as well as the plate slenderness parameter. It is concluded that the transversely profiled steel plate in the shape of concavity can have superiority in strength, ductility as well as energy absorption capacity.

### **Energy Absorbing Capacity of Steel Bellows Attached in Transverse Direction of Steel Girder Bridge**

Kentaro TANAKA, Hiroshi ZUI (Setsunan University), Toshiyuki KITADA and Masahide MATSUMURA

*Proceedings of the 8th Symposium on Ductility Design Method for Bridges*, pp.185-190, JSCE, February 2005 (in Japanese).

In this paper, the energy absorption performance in both the longitudinal and transverse directions of steel bellows as one of energy absorbing devices for bridge girder connectors is investigated through cyclic loading tests. The effectiveness of the steel bellows adopted for a three-span girder bridge supported by abutments at both the ends against a strong earthquake is also analyzed by a non-linear time-history analysis. In the analysis, a non-linear behavior of the steel bellows, which are experimentally obtained through the loading tests, are modeled into the analytical model for the steel bellows. It is confirmed that the steel bellows possess a great energy absorption performance and reduce the displacements of the superstructure and bridge piers substantially in both the longitudinal and transverse directions.

### **Verification of Fracture Characteristics of Slit Type Side Block using Reduced Model**

Masahide MATSUMURA, Masahiko YOSHIDA (Kawaguchi Metal Industries Co.,Ltd.), Minoru SAKAIDA (Teikoku Engineering Consultants Inc.), Maski MORITA (Kawaguchi Metal Industries Co.,Ltd.), and Toshiyuki KITADA

*Proceedings of the 8th Symposium on Ductility Design Method for Bridges*, pp.191-196, JSCE, February 2005 (in Japanese).

The Authors suggest a slit type of the side block as a rupture controllable side block to assist an bridge isolation system and its design method. An availability of the design formula is evaluated through a few numbers of static breaking test using 1/2 size specimens of the side block. In this paper, 4 specimens of the slit type side block with an adequate slit shape and length and the other conventional type side blocks are tested by the static loading test. Then it is founded that the slit type side blocks show stable breaking load and displacement and the breaking load obtained both from the static breaking tests and the design formula is approximately the same value. On the contrary, the conventional types of the side block indicate indicates great differences.

### **Study on Influence of Bridge Bearings on Seismic Performance of Horizontally Curved Girder Bridges**

Koji TAKENO (Yokogawa Bridge Corp.), Yuya UCHIDA (Kurimoto, Ltd.), Kazuo KOSAKA (Mitsui Engineering & Shipbuilding Co.,Ltd.), Toshihiko TAKADA (Hanshin Expressway Public Corporation), and Toshiyuki KITADA

*Journal of Structural Engineering, JSCE*, Vol. 51A, pp.1749-1758, March 2005 (in Japanese).

Dynamic analyses are carried out for an actual horizontal curved girder bridge with three spans (30+40+30m) and the radius of curvature of about 90 m under the following four support conditions, Case 1-4, of the bearing in order to investigate the influence of the support conditions of the bearing on the seismic performance of the bridge. The direction of fix/movement of the metal bearings in Case 1 coincide with the direction of the movement of the bridge girders due to temperature change and that of Casa 2 is tangential to the bridge axis. All the original metal bearings are changed to the seismic-elastomeric rubber ones in Case 3. The horizontal displacement perpendicular to bridge axis is fixed in the bearing at the bridge ends in Case 4 compared with Case 3. Predominant difference can be observed between the metal bearings in Cases 1,2 and the rubber ones in Cases 3,4 while predominant

difference can not be observed between Cases 1 and 2. It can be concluded that relationship between the ultimate strength of bridge piers and the support condition of bearings is very important in the seismic design of horizontal curved girder bridges.

### **The Study on the Relation between the Ratio of the Slip Strength to the Yielding Strength and Slip Coefficient of High Strength Bolted Friction Joints**

Takashi YAMAGUCHI, Takeshi MORI (Hosei University), and Kunitaro HASHIMOTO

*Journal of Structural Engineering, JSCE*, Vol. 51A, pp.1737-1748, March 2005 (in Japanese).

In this study, first of all, a lot of past experimental results for high strength bolted frictional joints subjected to tensile force are summarized paying attention to the ratio of the slip strength to the yielding strength. In addition, are carried out the experiment and FE analysis in order to clarify the limit states and the slip coefficients considering the ratio of the slip strength to the yielding strength. In particular, are varied the width of the plate, thickness of the plate, yielding strength and arrangement of the bolts in FE analysis. As a result, it is concluded that the slip coefficient is evaluated by the ratio of the slip strength to the yielding strength. And it is cleared that the 3 limit states are close related to the ratio of the slip strength to the yielding strength. It is confirmed that the slip coefficient is influenced by the local plastic zone around the bolt-hole.

### **Study on Post-Tension Strengthening Method of Existing Steel Girder Using Pre-Stressed CFRP and Its Effect**

Masahide MATSUMURA, Toshiyuki KITADA, Takeshi KITADA, and Hironori NAMIKI (Kyobasi Mentec Co.,Ltd.)

*Journal of Structural Engineering, JSCE*, Vol. 51A, pp.183-192, March 2005 (in Japanese).

As one of strengthening techniques for superannuated steel bridge girders with insufficient load carrying capacity, Post-tension strengthening method through pre-stressed carbon fiber reinforced plastic (CFRP) is proposed by the authors. In this study, the effects of the post-tension strengthening method by CFRP are experimentally and analytically investigated. Also dealt with is the problem of debonding at the tips of CFRP. The effect of a holding plate newly employed to prevent the debonding of CFRP strips is examined experimentally. Finally applicability of the post-tension strengthening method by CFRP to making the plate thickness of the web plates thinner in a steel girder bridge to be constructed is analytically investigated.

### **Fundamental Study on Buckling and Ultimate Strength of Right-Angled Isosceles Triangular Plates**

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*Journal of Structural Engineering, JSCE*, Vol. 51A, pp.211-217, March 2005 (in Japanese).

A right-angled isosceles triangular plate is used for reinforcement at the connection part between the beam and column in a steel bridge pier with fatigue cracks, between a lateral member and a girder in a steel girder bridge,

between a column and a base plate of portal marker columns and lightning poles and so on. As the thickness of the triangular plate is decided not to arise plate buckling according to restrictive value on the ratio of the plate thickness and the maximum width. This restrictive value is proposed according to the research results in 1960-70s, however, the investigation on the buckling and ultimate strength of the triangular plate is not studied recently. In this paper, the elasto-plastic and finite displacement analyses are carried out for the right-angled triangular plates to verify the buckling and ultimate strength of them by focusing on the supporting conditions of the hypotenuse, shape of initial deflection and plate thickness.

### **Ultimate Strength Interaction Curves of Steel Decks subjected to Biaxial In-Plane Forces and Wheel Load**

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*Journal of Structural Engineering, JSCE*, Vol.51A, pp.221-230, March 2005 (in Japanese).

Steel decks are generally used in long span bridges such as cable stayed bridges. Not only biaxial in-plane stresses and wheel loading should be considered in the design against the buckling of wide steel decks. However, there are no specifications considering the buckling of deck plates due to the biaxial in-plane stresses as well as wheel loading in Japan. This paper deals with the ultimate strength and interaction curves of stiffened plates subjected to the biaxial in-plane stresses wheel loading for the purpose of providing reference data for an appropriate design against the buckling of wide steel decks.