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SOME PROBLEMS OF ENSURING THE SEISMIC RESISTANCE OF BRIDGES

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ABSTRACT

The report reviews the development of theory and practice of the seismoresistant bridge building in Russia and in the states of the former Soviet Union, shows the most essential specific features of the seismic vibrations of bridges, control methods if these specific features during the estimation of the seismoresistance of bridges, analyzes technical solutions of the seismoprotection of bridges, developed in Russia.

KEYWORDS

bridges, seismoresistance, specific features, seismoprotection.

INTRODUCTION

Bridges are important engineering constructions playing a specific role in seismic regions. Bridges damage during earthquakes makes it difficult to help the calamity region and leads to the breach of the work of enterprises in the calamity area. Fukia earthquake (1948) and Alaska earthquake (1964)show all the disaster of bridges'destruction during earthquakes, when railway net in the calamity area was out of order for about one month. The importance of transport constructions and the difficulty of their functioning during earthquakes brought about putting the problems of their calculation and designing into a separate section in the theory of seismoresistance. Monographs by Kartsivadze (1980), Okamoto (1973), Shestoperov (1984), Uzdin (1993) are devoted to these problems. Nevertheless, till the present time significant difficulties have been caused by the task of calculation and designing of bridges. These difficulties are connected with specific features of seismic vibrations of bridges, caused by specific character of constructive decisions and location of the constructions. Analysis of these specific features can be found below.

BRIEF REVIEW OF THE DEVELOPMENT OF TRANSPORT SEISMORESISTANT BUILDING IN RUSSIA AND IN THE STATES OF THE FORMES SOVIET UNION

From the mid 20-ies in the USSR new regions of Trans-Caucasis and Middle Asia situated on the outskirts of the former Russia have started to be developed. These regions are known to be of high seismoactivity. Academician K.S.Zavriev was the first one in Russia to study problems of the theory of seismoresistance for the ensuring of bridges'security while building and reconstruction of Trans-Caucasian railway. In 1924 first designs of seismoresistant bridges were produced under his supervision. These were stone arch bridges. Detailed inspection and calculation of these bridges, done in the end of the 80-ies showed that they completely correspond to modern demands for the seismoresistant building. However transport building experience in Trans-Caucasis did not become popular in the USSR.

After a number of destructive earthquakes 1926-1928 and also in connection with the building of Turkistano-Siberian railway research work on ensuring of the seismoresistance of bridges had been held by the beginning of the 30-ies.

A number of preliminary normative documents was made with consideration of above works. First norms of the Building Committee of Kazakhstan appeared in 1930 for the builders of Turk-Sib. In 1931 "Technical conditions of designing and building of civil and constructional works in seismic regions of Trans-Caucasis Federative Republic" were published. Dynamic characteristics of the construction were taken into consideration for the first time in these norms, developed under the supervision of K.S.Zavriev, by introducing ratio of dynamics in the formula of seismic forces for high constructions (1936). In 1933 "Preliminary technical conditions of designing and constructing of civil building in seismic regions of Kazakhstan" were published.

In 1939 an instruction of the Building Committee on calculation and designing of building in the seismic regions was published as common norms. These norms were based on the static theory of seismoresistance (1937).

From 1930 till 1950 a considerable number of buildings and constructions was designed in the USSR using the static theory. Calculations were formal and slightly influenced the sizes of the bearing elements, that is why designing in fact was made according to the reception rules, not connected by the calculation. Especially this is related to the railway bridges, where in the longitudinal direction the limiting charge is usually not seismic, but braking, and in the lateral-cross blows of the rolling stock.

Spectral methods have been introduced in the calculation norms of constructions in the USSR since 1957, and of bridges only since 1962. From 1924 to 1972 a considerable number of railway and road transport bridges was built in the USSR, using different normative documents. However, detailed research of seismostability of bridges has been started in the USSR from the mid 70-ies in connection with the building of the Baikal-Amur line. The research work was held under the supervision of professor G.N.Kartsivadze (1980). Starting from that time problems of seismostability of bridges were made in the USSR into a separate part of the general theory of seismostability. From the end of the 70-ies standard projects of road transport and railway bridges for different building conditions had been produced by design organizations of the USSR, and in 1985 and in 1995 standard technical solutions of seismostability of bridges, including the design of the systems of seismosuppression and seismoisolation, were published by the "Lengiprottansmost" institute. During the last years the amount of transport building in Russia and the states of the former USSR has considerably reduced. At present such problems as antiseismic strengthening of bridges of old construction are topical as they do not correspond to the demands of modern norms of seismoresistant building. This problem has been thoroughly studied and general approach to the antiseismic strengthening of old bridges is described in the monograph of A.M.Uzdin (1993) and in a normative document, published in Turkmenia (1988).

All the above designing and instructive research was held in consideration with specific features of seismic vibrations of bridges, indicated below.

SPECIFIC FEATURES OF SEISMIC VIBRATIONS OF BRIDGES AND THEIR CONSIDERATION DURING THE ESTIMATION OF THEIR SEISMORESISTANCE

Among the specific features of bridges, determining the nature of seismic vibrations are the following:

- non-linear nature of interaction of span structures among themselves and with support;
- considerable length of structure;
- availability of temporary mobile charge;
- considerable heterogeneity of constructions, especially for bridges with metal span structures;
- availability of specific foundations, in many cases - deep foundations.

For the interaction control in the system of "supports-span structures-rolling stock" it is necessary to make correctly the calculation scheme of bridges. Research works ( ) show, that supporting parts of bridges almost do not cause constraint of span structures on the supports. That is why for cross vibrations of bridges multispan frame with pivot on the supports is used.

For the analysis of the longitudinal vibrations of bridges the purpose of the calculation scheme is determined by the type of supporting parts. For roller-bearings, roll and sectorial parts forces of friction are overcome at the effect of magnitude 7, and the supports vibrate like separately standing console bars. Till the present moment the question of the purpose of the calculation scheme for bridges with flat and tangent supporting parts has been debatable. In the research works of A.M.Uzdin and M.A.Schvarts ( ) the absence of slipping in the mobile supporting parts is shown and it is recommended to use the frame calculation scheme.
These research works were based on the vibration analysis of the simplified model of the single- span bridge with supports of the same type. More complete research of vibration of two or three span frames with friction joints of supports with girder, held by the authors, show that during certain correlation of the supports' rigidity slipping becomes possible at the effect of magnitude 7, however, the distribution of forces in the system remains close to the similar distribution of forces in the frame system. For engineering calculations it is possible to calculate using the frame calculation scheme for the estimation of the general seismic charge on the span structure with the later redistribution of this charge, in case horizontal forces exceed the force of friction in a supporting part.

Considerable length of bridges first of all leads to the fact, that different supports can be in different seismic conditions. For large bridges the rated seismics of the building site usually changes along the length of the bridge's passage. Besides, even with the homogeneous soil conditions it is important to take into account correlation of the influence under different supports. The above problems are discussed in a number of Russian and foreign research works, but not in the valid normative documents. Meanwhile even in the simplest case of single span beam vibration with the mass concentrated in the middle, during synchronous vibration of its supports and during casual non correlative movement of supports this mass accelerations differ in V2 times.

Correct control of the temporary mobile charge is rather important for bridges, as the weight of the rolling-stock can exceed the weight of span structures. Research of G.S. Shestoperov (1984) being held at the present moment make it advisable to take into account the cushion of the rolling-stock during the analysis of the cross bridge vibrations. During the longitudinal bridge vibrations the influence of the rolling-stock on the bridge can be changed to the braking force (1980). The problem of allocation of the ratio of combination K of mobile charge with seismic one is rather important during the control of this charge. For the estimation of the value K equiprobable pairs (A, q) are determined, where A is the rated amplitude of the seismic force, and q - the rated weight of the rolling-stock. The most unfavourable for construction pairs are chosen, that is to say ratios of combination are introduced for seismic, as well as mobile charges. The justification for the ratios of combination for the road transport bridges are given in the book of G.S.Shestoperov (1984). On the basis of these research works ratios of combination K=0.3 for the automobile charge and K=0.8 for the seismic charge were introduced in the valid norms of bridge calculation. Similar research work for railway bridges was held in Bridge Research Institute (A.Uzdin, 1983). On the basis of these research works it is recommended to introduce ratio of combination K=0.7 for the seismic charge and ratios 0.7, 0.5 and 0.2 for the temporary charge at the average repetition of earthquakes once in 100, 1000 and 10000 years appropriately. The latter recommandation has not yet been given in the valid Building Norms and Regulations, but was adopted in a number of normative documents on estimation of seismoresistance of the exploiting bridges, for example, in Instruction (1988).

Heterogeneity of construction is determined by different dynamic features of the elements of the system "span structure - supports - foundation soils". To control different dampings in the elements turns out to be mostly difficult in this case. In this case the spectrum of system damping which represents the value of parameters of damping ζ_j on the vibration forms, is introduced in the estimation as well as the spectrum of frequencies. Then the correction on each vibration form is introduced in the formulae for determination of seismic forces depending on value ζ_j. Detailed justification of this approach and methods of determination of the appropriate corrections are given in the works of A. Uzdin (1983, 1993). The methodics was approved during the estimation of bridges' seismoresistance in Turkmenia, Baikal-Amur line and in Armenia after the Spitak's earthquake in 1987. Rather detailed recommendations on damping and interaction control of construction with soil foundation are available in the above Instruction (1988).

The complex of the research works made it possible to develop new technical solutions of seismoprotection of bridges.

TECNICAL SOLUTIONS OF THE SEISMOPROTECTIVE MECHANISMS OF ROAD TRANSPORT BRIDGES

Mechanisms of seismoprotection of bridges were developed in Russia according to the principle of work and are subdivided into seismoisolating and seismosuppressing. More detailed classification is shown on Fig.1.

Adaptive systems of seismoisolation represent a double system of span structures' support - on rigid or flexible supporting parts. Rigid supporting parts with some reserve take exploiting charges. During extreme charges destruction of rigid supporting parts and operating of the second group of supporting parts - flexible - are taking place. The proposed technical solutions ensure realization of the principle of the construction designing with given parameters of maximum conditions (GPMC) and are protected by author's certificates (a.c. n°n° 781253, 1300742).

Fixed seismoisolation systems comprise 4 groups of technical solutions. The first two groups of solutions are "flexible" supporting parts, where the resumption force is ensured by the elasticity force (rubber metal supporting parts - RSP) or forces of gravity (gravity supporting parts - GSP).

GSP are designed using the V.P.Tchudnetsov's proposals (1980) during the closer definition of the methods of their calculation and the field of effective application. Application of RSP is traditional in the seismoresistant building especially abroad. At the same time cases when RSP's installation is completely useless and can even worsen construction work are possible. During the analysis of the RSP constructions supporting parts made at Tcherkesky plant (Russia) and by Italian company FIP - industriale were compared. An additional effect of RSP application is achieved during the combination of span structures into a chain and regulation of the RSP rigidity on different supports.

The composition of designing solutions comprise the connection elements of span structures and supporting parts' construction. In the second case units of connection of supporting parts with supports and span structures by means of friction mobile bolted joints (FMJ) are designed. Such joints are put on supports, taking considerable seismic charges. During the exceeding of a certain maximum value by the actual charge FMJ's sheets' slipping and the shift of the span structure concerning the axis takes place. Reconstruction works are

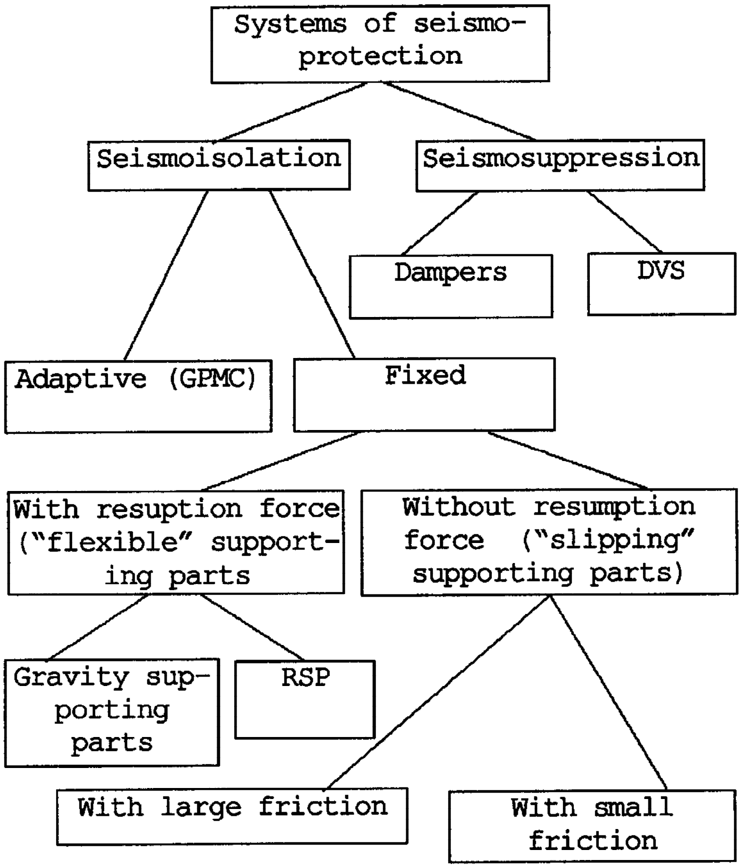

Fig.1. Cassification of technical solutions being developed on the principle of their work.

Dampers should be used in combination with seismoisolation and seismosuppression systems and put in the places of the maximum mutual system's shift. At present a considerable number of damping devices was proposed in the world practice, however during the development of technical solutions a special damper of dry friction with regulable force of resistance was designed.

In the DVS constructions the usage of span structure as suppressing mass, which is connected to the bridge supporting by the restoring link, is previewed. 3 types of links are suggested: two in shape of flexible table with and without transfer on it of the vertical charge and the third one in shape of the axis' spring connected to the detent and span structure (A.c. n°n° 1162886, 1335612). In the cases when it is possible ti ensure the conditions of flexibility and strength of the restoring link, DVS turns out to be the most effective seismoprotection system.

While developing technical solutions required computer program was made for the calculation of bridges with special means of seismoprotection and methods of passportization of supporting elements of seismoisolating and seismosuppressing devices.

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