

**STATE COMMITTEE OF THE REPUBLIC OF UZBEKISTAN ON
AUTOMOTIVE ROADS**

**TASHKENT INSTITUTE OF DESIGN, CONSTRUCTION AND
MAINTENANCE OF AUTOMOTIVE ROADS**

As a manuscript

UDC 624.1, 539.3

SHARABOV DOSTONJON QUVANDIQOVICH

**“Study of bridge structures stepped supports strength under seismic
influences”**

DISSERTATION WORK

For an academic master's degree

5A340205 "Construction of bridges, tunnels and subways"

Scientific adviser:

Academician T.R. Rashidov

Tashkent-2017

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**ЎЗБЕКИСТОН РЕСПУБЛИКАСИ АВТОМОБИЛЬ ЙЎЛЛАРИ
ДАВЛАТ ҚЎМИТАСИ**

**ТОШКЕНТ АВТОМОБИЛЬ ЙЎЛЛАРНИ ЛОЙИХАЛАШ,
ҚУРИШ ВА ЭКСПЛУАТАЦИЯСИ ИНСТИТУТИ**

Факультет: “Йул курилиш”

Кафедра: “Кўприклар, тоннеллар ва йўлўтказгичлар”

Мутахассислиги: 5А340205 – “Кўприклар, тоннеллар ва метрополитенларни курилиши”

Магистртура талабаси: 566-15 гуруҳ Шарабов Д.Қ

Илмий раҳбар: Академик Рашидов Т.Р.

Мавзу: “Поғонали кўприк таянчи конструкциясининг сеймик таъсирларга мустаҳкамлигини тадқиқ қилиш”

МАГИСТРЛИК ДИССЕРТАЦИЯСИ АННОТАЦИЯСИ

Мавзунинг долзарблиги

Йўллар, кўприклар, тоннеллар ва бошқа транспорт иншоотлари аҳоли турмуш тарзида алоҳида аҳамиятга эга бўлиб, zilзила таъсирида фақатгина бу иншоотларга моддий зарар кўрсатмасдан, аҳоли яшаш тарзига ва ишлаб чиқариш саноатига ҳам салбий таъсир этади. Шунинг учун транспорт иншоотларини zilзилабардошлилиги тадқиқ қилишга Ўзбекистонда ва бошқа давлатларда катта эътибор қаратилмоқда.

Кўприк таянчларини zilзилабардошлилиги кам ўрганилган, бу диссертацияда поғонали кўприк таянчларини zilзила вақтида грунт билан ўзаро таъсирини ҳисобга олган ҳолда ҳисобалш ишлари амалга оширилган.

Тадқиқот объекти ва предмети

Зилзила пайтида поғонали кўприк таянчи динамикаси. Математик, сонли моделлар, услублар, алгоритмлар ва дастурий таъминот ёрдамида кўприк таянчлари динамикаси ҳисоблаб топилади.

Tadqiqot maqsadlari:

–Зилзила пайтида кўприк таянчига таъсир этувчи юкларни кучларни таҳлил ва тадқиқ қилиш.

–Поғонали кўприк таянчига таъсир қилувчи кучни грунт билан ўзаро боғлиқ ҳолда тадқиқ қилиш.

Tadqiqot vazifasi.

–Сўнги йилларда бўлган зилзилаларни ўрганиш, уларни таҳлил қилиш, бузилиш оқибатларини таҳлил қилиш асосий эътибор марказида бўлиб келаётган халқаро конференциялар(Хитой 2008 йил, Япония 2009 йил)ни ўрганиш.

–Сўнги йилларда бўлган зилзилаларнинг кўприк конструкцияларига ва таянчларига бўлган таъсирини ёки бузилишларни баҳолаш.

–Зилзила пайтидаги поғонали кўприк таянчи горизонтал тебранишини грунтнинг ўзига хос хусусиятига боғлиқ ҳолда ўрганиш.

Илмий янгилиги

Бу каби ишлар олдин бажарилмаган. Тадқиқотнинг асосий вазифаси поғонали кўприк таянчини зилзилабардошлилигини таҳлил қилиш ҳисобланади. Бунда поғонали кўприк таянчи зилзилабардошлилигини ўрганишда таянч билан грунт орасидаги ўзаро боғлиқлик эътиборга олинган ҳолда ҳисоблаш ишлари амалга оширилган.

Амалий аҳамияти

Ҳалокатли зилзилаларни биноларга таъсирини ўрганиш ва таҳлил қилиш, зилзилабардошлилик бўйича келажакда илмий изланишлар олиб бориш натижасида бу олинган натижалар келажакда қўлланилиши мумкин.

Диссертация тузилиши

Диссертация иши кириш, 3 та боб, хулоса, фойдаланилган адабиётлар рўйхати 45 та расм, 5 та жадвални ўз ичига олувчи 81 бетли матндан иборат

Илмий раҳбар _____ академик Т.Р.

Рашидов

(Imzo)

Магистрант _____ 566-15 гр Д.Қ. Шарабов

(Imzo)

**STATE COMMITTEE OF THE REPUBLIC OF UZBEKISTAN ON
AUTOMOTIVE ROADS**

**TASHKENT INSTITUTE OF DESIGN, CONSTRUCTION AND
MAINTENANCE OF AUTOMOTIVE ROADS**

Faculty: "Master"

Department: "Bridges, tunnels and overpasses"

Specialty 5A340205 - "Construction of bridges, tunnels and subways"

Master: groups 566-15 D.Q.Sharabov

Scientific director: academician T.R. Rashidov

Subject: "Study of bridge structures stepped supports strength under seismic influences"

ANNOTATION OF THE MASTER'S DISSERTATION

Relevance of the topic.

Roads, bridges, pipes, retaining walls and tunnels are of vital importance and their failure due to an earthquake entails not only significant material damage, but also a violation of the normal functioning of individual settlements and industrial enterprises or areas in general. Therefore, research in the field of seismic resistance of transport facilities in Uzbekistan and other countries is given great attention.

The problems of seismic resistance of bridge supports have been little studied; in this connection, the strengths of stepped supports of bridge structures under seismic influences are considered, the movements of the base of the bridge support are considered, taking into account the interaction with the ground.

Object and subject of research

Dynamics of stepped bridge supports under seismic loaded. Mathematical, numerical models, methods, algorithms and software solving problems of the dynamics of underground pipelines.

The purpose of the research

Analysis and study of the dynamics of the support of bridges under seismic loads. To investigate the influence of the dynamic characteristics of stepped bridge supports and to reveal the influence of soil properties.

- Evaluate the influence of various factors of the consequence of strong earthquakes on the behavior of bridges and outline ways to study the seismic stability of bridges, the influence of the support part on their behavior;
- analysis of the effect of soil properties on longitudinal seismic vibrations of stepped bridge supports.

Scientific novelty

In this formulation of the question, the work was not carried out. The main task of the study is to analyze the behavior of stepped bridge supports, with seismic actions. On the basis of this, create a design scheme of oscillations of stepped supports of bridge structures under seismic influences.

Practical significance

The study and analysis of the behavior of structures during destructive earthquakes is an important stage in the conduct of studies on seismic resistance, which contributes in the future to the improvement of regulatory documents on earthquake-resistant construction.

Studies related to the study of longitudinal oscillations of the rectilinear final section of the stepped bridge support, under various seismic loads are necessary for calculating bridges for seismic resistance.

Structures of work.

The thesis consists of an introduction, three chapters, conclusion, a list of literature, contains 81 pages of text, including 45 figures and 5 tables.

Scientific adviser: _____ academician T.R. Rashidov
(signature)

Master's degree _____ gr. 566-15, D.Q. Sharabov
(signature)

**ГОСУДАРСТВЕННЫЙ КОМИТЕТ АВТОМОБИЛЬНЫХ
ДОРОГ РЕСПУБЛИКИ УЗБЕКИСТАН**

**ТАШКЕНТСКИЙ ИНСТИТУТ ПО ПРОЕКТИРОВАНИЮ,
СТРОИТЕЛЬСТВУ И ЭКСПЛУАТАЦИИ АВТОМОБИЛЬНЫХ
ДОРОГ**

Факультет: “Магистратура”

Кафедра: “Мосты, тоннели и путепроводы”

Специальность 5А340205 – “Строительство мостов, тоннелей и метрополитенов”

Магистрант: группы 566-15 Д.Қ.Шарабов

Научный руководитель: академик Т.Р.Рашидов

Тема: “Исследование прочности конструкций ступенчатых опор мостов при сейсмических воздействиях”

АННОТАЦИЯ МАГИСТЕРСКОЙ ДИССЕРТАЦИИ

Актуальность темы.

Дороги, мосты, трубы, подпорные стены и тоннели имеют жизненно важное значение и выход их из строя в результате землетрясения влечет за собой не только значительный материальный ущерб, но и нарушение нормального функционирования отдельных населенных пунктов и промышленных предприятий или районов в целом. Поэтому исследованиям в области сейсмостойкости транспортных сооружений в Ўзбекистане и других странах уделяется большое внимание.

Вопросы сейсмостойкости мостовых опор мало изучено, в связи с этим в диссертации рассматриваются прочности ступенчатых опор мостовых конструкций при сейсмических воздействиях, рассматриваются движения основания опоры мостов, с учетом взаимодействия с грунтом.

Объект и предмет исследования.

Динамики ступенчатые опоры мостов при сейсмических нагруженных. Математические, численные модели, методы, алгоритмы и программное обеспечение решение задач динамики опоры мостов.

Цель исследований.

Анализ и исследование динамики опоры мостов при сейсмических нагруженных. Исследовать влияние динамических характеристик ступенчатых опор мостовых и выявить влияние свойств грунта.

Задачи исследования:

- Составить обзор состояния вопроса, изучить последствия землетрясений последних лет и провести их анализ, установить причины этих повреждений;

-оценить влияние тех или иных факторов вследствие сильных землетрясений на поведение мостов и наметить пути исследования сейсмостойкость мостов, влияние опорной части на их поведение;

- анализ влияния свойств грунта на продольные сейсмические колебания ступенчатых опор мостов.

Научная новизна.

В такой постановке вопроса работы не проводились. Главной задачей исследования является анализ поведения ступенчатых опор мостов, при сейсмических воздействиях. На базе этого создать расчётную схему колебаний ступенчатых опор мостовых сооружений при сейсмических воздействиях.

Практическая значимость

- Изучение и анализ поведения сооружений во время разрушительных землетрясений являются важным этапом в проведении исследований по

сейсмостойкости, что способствует в будущем совершенствованию нормативных документов по сейсмостойкому строительству.

- Исследования, связанные с изучением продольных колебаний прямолинейного конечного участка ступенчатый опора моста, при различных сейсмических нагрузках являются необходимыми для расчета мостов на сейсмостойкость.

Структуры работы

Диссертация состоит из введения, трех глав, заключения, списка литературы, содержит 81 страниц текста, включая 45 рисунков и 5 таблиц.

Научный руководитель: _____ академик Т.Р. Рашидов

(подпись)

Магистрант _____ гр. 566-15, Д.Қ. Шарабов

(подпись)

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INTRODUCTION

Uzbekistan pays special attention to the development of the construction of transport infrastructure both inside and outside the Republic. From the first days of independence, the first President I. Karimov identified the design and construction of the most convenient and short high-capacity roads and bridges that would ensure Uzbekistan's access to the world market.

In ensuring sustainable development of the economy, it is necessary to develop and implement comprehensively grounded measures, important tasks and directions for the future.

The most important feature of the road industry is its high social and economic importance, the effective functioning of this system depends on the quality of life of all segments of the population and the development of the economy as a whole.

During the years of independence, the republic has carried out large-scale work on the development of road and transport infrastructure that provides safe interstate transportation and branched transport links between administrative centers of regions and districts.

At the same time, there is a number of unresolved problems related to the management system of public roads, increasing the efficiency of using funds allocated for maintenance, repair, reconstruction and construction of highways, as well as the current state of public roads.

The existing actual condition and level of development of the road network in the country stipulate the development of concrete and effective measures in all areas of the road economy, the adoption of additional measures for managing roads and qualitative changes in the state of the country's road network in accordance with the needs of the economy and the population.

For the formation of an effective road management system based on an integrated approach to the design, construction and operation of highways and artificial structures, improving their financing system, creating a full-fledged customer service that contributes to improving the quality of design and road

construction works, the Decree of the President of the Republic of Uzbekistan Sh. Mirziyayev No. UP-4954 "On measures to further improvement the road management system" [1]. It provides for the establishment of the State Committee of the Republic of Uzbekistan on motor roads on the basis of the abolished State-owned joint-stock company for the construction and operation of highways (SJSC "Uzavtoyul").

The main tasks and areas of activity of the State Committee - as a specially authorized body for the state management of motor roads - are:

Implementation of a unified technical, investment and foreign economic policy for the development and improvement of the road network;

Development and implementation of the strategy for the development of highways;

The formation of international transit corridors of highways;

Providing a comprehensive solution to the issues of financing, designing, building, repairing and operating highways, taking into account the interests of their users in the conditions of modern traffic flows, as well as organizing effective activity of the customer service;

Coordination of works to ensure the safety of the existing network of inter-farm rural roads, city streets, urban settlements, villages and villages with their maintenance at a high transport-operational level;

The organization of research works, the introduction of innovative technologies and modern standards in the design, construction and operation of highways;

Control over the observance of town-planning norms and rules, state quality standards for construction and repair work on roads, and improvement of the quality control services;

Organization of training, retraining and further training of relevant personnel, including training and seminars abroad.

To ensure the implementation of this Program in 2017, construction and reconstruction of roads with a total length of 302 km was established, including

the construction of 125 km of highways with asphalt concrete and 175 km with cement-concrete coating. In particular, in the target program for 2015-2020, the target program includes work on the construction and reconstruction of road sections with in the Uzbek national highway, and over five years, based on international standards and modern requirements, a new construction of the main roads will be carried out in total 2306 Km, including 1,410 km of roads will be four strips (with asphalt-concrete coating). As part of these highways will be built 1910 pm bridges and overpasses, complexes of transport interchanges (nodes) in 7 locations. Considering the role of roads and bridges in the people's life.

Flows of cars with high speeds. Bridges are subject to the active influence of numerous natural factors, including seismic impacts, etc. (heating by sunlight, freezing and thawing, moistening by falling precipitation, groundwater and water coming from the roadside strip, etc.). These features of their work should be taken into account by designers, builders, maintenance workers who are required to provide a normal year-round service of the road for a long time. With the modern growth of the traffic flow, accordingly, bridge structures should also develop. Of course, the construction of the foundations and intermediate bridge supports had to meet the growing requirements for the span structures. At the same time, the level of complexity of the problems associated with the stability of the foundation soils has also changed significantly. Large lengths of spans caused high loads on the supports, while enormous forces were concentrated in small areas, and the span structures became increasingly sensitive to tilt of supports and subsidence even of small dimensions. The longer the length of the span and the height of the supports, the higher the load and the lower the relative value of the allowable drawdown.

In the light of the foregoing, the problem of the seismic dynamics of bridges and bridge structures for seismic impacts, the issues of oscillating the roadway and bridge supports under earthquake conditions have been little studied. Our research is aimed at analyzing the effects of earthquakes on bridge structures. The consequences of these earthquakes in Uzbekistan and CIS countries are studied

separately and special attention is paid to the consequences of earthquakes in far-abroad countries.

The consequences of these earthquakes on various elements in different bridges have been studied. The most vulnerable parts of bridges are identified. The materials of the 14th International Conference on Earthquake Engineering, held in Beijing in 2008, have been studied separately. Special attention is paid to the behavior of the supporting and carriageway parts of bridge structures.

Relevance of the work. Roads, bridges, pipes, retaining walls and tunnels are of vital importance and their failure due to an earthquake entails not only significant material damage, but also a violation of the normal functioning of individual settlements and industrial enterprises or areas in general. Therefore, research in the field of seismic resistance of transport facilities in Uzbekistan and other countries is given great attention.

The problems of seismic resistance of bridge supports have been little studied; in this connection, the strengths of stepped supports of bridge structures under seismic influences are considered, the movements of the base of the bridge support are considered, taking into account the interaction with the ground.

Object and subject of research. Dynamics of stepped bridge supports under seismic loaded. Mathematical, numerical models, methods, algorithms and software solving problems of the dynamics of underground pipelines. The purpose of the research.

Analysis and study of the dynamics of the support of bridges under seismic loads. To investigate the influence of the dynamic characteristics of stepped bridge supports and to reveal the influence of soil properties.

Objectives of the study:

- To provide an overview of the state of the issue, to study the consequences of earthquakes in recent years and to analyze them, to establish the causes of these damages, highlighting the recent International Conference on Earthquake Engineering (Beijing 2008, Tokyo 2009, Lisbon 2012);

- Evaluate the influence of various factors of the consequence of strong earthquakes on the behavior of bridges and outline ways to study the seismic stability of bridges, the influence of the support part on their behavior;

- analysis of the effect of soil properties on longitudinal seismic vibrations of stepped bridge supports.

Scientific novelty. In this formulation of the question, the work was not carried out. The main task of the study is to analyze the behavior of stepped bridge supports, with seismic actions. On the basis of this, create a design scheme of oscillations of stepped supports of bridge structures under seismic influences.

Review (analysis) of literature on the research topic. Large-scale research work in our country was carried out in the second half of the 20th century. At that time, research on seismic resistance was handled by G.N.Kartsivadze, Sh.G.Napetvaridze, G.S.Shestoperov, R.M.Mukurdumov, A.S.Gehman, T.R.Rashidov, G.K.h. Khozhmetov, B.Mardonov, A.A. Ashrabov, A.A. Ishanhodjaev and others.

G.N.Kartzivadze and G.S.Shestoperov generalized the available in the literature materials on seismic resistance of bridges. Their work deserves attention from the point of view of generalization of materials related to the specific crash of bridges from various materials during earthquakes.

Practical significance:

- The study and analysis of the behavior of structures during destructive earthquakes is an important stage in the conduct of studies on seismic resistance, which contributes in the future to the improvement of regulatory documents on earthquake-resistant construction.

- Studies related to the study of longitudinal oscillations of the rectilinear final section of the stepped bridge support, under various seismic loads are necessary for calculating bridges for seismic resistance.

On the theme of the master's thesis 2 articles were published at the Republican Scientific and Practical Conference of Young Scientists and Competitors.

Structures of work. The thesis consists of an introduction, three chapters, conclusion, a list of literature, contains 79 pages of text, including 44 figures and 5 tables.

On the topic of the master's thesis 2 articles were published, 1 of them in the international journal and 1 in the republican scientific and practical conference materials.

CHAPTER I. STUDY OF THE CONSEQUENCES OF EARTHQUAKE ON BRIDGE STRUCTURES

1.1. Review of studies on the problem of seismic resistance of bridges

At present, the Republic of Uzbekistan is rapidly developing day by day. New roads and railways always serve the development of those regions where they are laid both economically and socially.

Currently, on the balance sheet of the State Committee for Roads (hereinafter referred to as the Committee) there are more than 7,000 bridges and overpasses. After taking on the balance of urban, rural and departmental automobile, the number of bridge structures may exceed 15,000. The number of new and reconstructed bridges being designed and under construction annually increases.

According to the State Joint Stock Railway Company (Uzbekistan) Temir Yollari, 2718 ferroconcrete flying structures are operated, including plate ones - 1697, ribbed - 1020. The length of span structures from 4 m to 66 m (through trusses). The largest group (about 96%) consists of beam cut spans up to 23.6 m in length, of which about 24% have an exploitation age of between 45 and 75 years. The total length of the bridges is about 41 km.

The existing approaches to the calculation of bridge supports for seismic impacts have been given separately.

The problems of seismic resistance of bridges and bridge structures play an extremely important role in connection with the fact that strong earthquakes destroy them, hampering the normal functioning of the national economy. Bridges and bridge structures consist of many elements, the most important are the passing and supporting parts. The thesis analyzes in detail the consequences of earthquakes that occurred in various countries of the world: Uzbekistan, CIS and far abroad countries. More attention is paid to the effects of earthquakes in recent years. The materials of the 14th International Conference on Earthquake Engineering, which took place in Beijing in 2008, are analyzed. The problems of

seismic resistance of bridge supports have been little studied, and in this connection different methods of calculation are considered in the thesis: static, dynamic, spectral, the movements of the basis of the support of bridges are considered according to the harmonic law. The effects of cargo at the end - the mass of the bridge on the behavior of the bridge support - will be analyzed. The basic principles of calculation for seismic actions, basic dynamic calculation schemes, frequency variations and oscillation forms are given in detail, which is a novelty. With significant success in the calculation and design of various structures in seismic regions, the theory of seismic resistance of bridges lags far behind the general theory of seismic resistance of buildings and other structures, since the damage to bridges occupies a small fraction of the total volume of damage in the affected areas, which determines the focus in construction in seismic regions Ensuring seismic resistance of residential and industrial buildings. Existing recommendations on the design of bridge designs for seismic calculations do not take into account the principles of multi-level design that have developed in the past 10 years, and new designs of anti-seismic enhancement of bridges based on the principles of seismic isolation and seismic. With a wide use of various types of seismic protection devices, there are practically no studies to substantiate and optimize the parameters of seismic isolation of bridges, although the work of seismically isolated bridges in earthquakes differs significantly from the work of seismically insulated buildings.

The survey on the problem of seismic resistance.

1. General statement of problems of seismic resistance of structures. The consequences of earthquakes, and their analysis.
2. Tashkent earthquake and its impact on the engineering structure.
3. Strong earthquake in the world of recent years and their consequences on the building and construction (Japan, Turkey, USA, CIS countries, Uzbekistan).
4. Damage to bridges and their elements under seismic loads.

5. Element of engineering seismology (causes of earthquakes, seismic scale, seismicity of the territories of the Caucasian countries and countries of Central Asia, the zone of earthquake foci, seismicity of sites, construction bridges.

6. Destruction and damage to bridges in earthquakes (destruction of bridges in the USA, Japan, India, Chile, Italy in the territories of the Russian Federation, CIS countries)

7. Determination of the strength of earthquakes for damage to bridges and other road structures)

8. Construction of bridges in seismic regions (construction of span structures, support structures of stepped bridge supports)

9. Supporting parts and anti-seismic devices.

10. Strengthening of bridges in seismic regions.

At present, the Republic of Uzbekistan is rapidly developing day by day. New roads and railways always serve the development of those regions where they are laid both economically and socially.

Increasing year by year, the active pace of construction in seismically active regions of Uzbekistan requires reliable seismologists to know about the seismic hazard of microdistricts and individual construction sites. Map of general seismic

A great contribution to the development of the theory of seismic resistance of transport facilities in Uzbekistan was made by Academician T.R. Rashidov. They are dedicated to information on earthquakes, damage to ground and underground artificial structures in strong earthquakes, the theory of seismic vibrations of artificial structures, the main provisions for the design of surface and underground artificial basics of calculating surface and underground artificial structures for seismic Impact.structures in seismic regions, the design of tunnels, pipes and

retaining

walls,

the



Fig. 1.1. Map of general seismic zoning of the territory of the Republic of Uzbekistan

Brief overview of the history of seismic-resistant bridge construction.

In severe earthquakes, human victims and material damage are associated with civil construction, and it has been given great attention in research in the field of earthquake-resistant construction. However, this problem is especially important in the construction of bridges, since bridges are in this case barrier structures, they are included in the number of life-support structures of the area affected by the earthquake and require considerable forces and means for restoration.

The importance of transport facilities and their work has made it possible to identify the issues of seismic resistance of bridges and other artificial structures into a separate section of the theory of seismic resistance.

In the development of the modern theory of seismic resistance, a decisive contribution was made by AD Abakanov, KS Abdurashidov, AT Aubakirov, Ya.M. Aizenberg, Yu.K. Ambriashvili, AA Amosov, AA Ashrabov, MF Barstein, TABELash, VA Bykhovsky, II Gol'denblat, AB Grossman, T.Zh. Zhunusov, Kh.R. Zaynulbidova, VAILichev, A A.Ishanhodjaev, KNKartsivadze, BGKorenev, VSKirillov, E.V. Kosterin, I.L.Korchinsky, N. A.Krasin,

D.A.Kurbatov, E.N. .Kurbatsky, AIMartemyanov, SVMedvedev, Sh.G.Napetvaridze, NANikolaenko, M.M.Onshtsenko, A.Petrov, S.V. Polyakov, V.T. Raskskazovsky , TR Rashidov, LM Rezniko , OA Savinov, AP Sinitsyn, Yu.M.Silnitsky, V.I. Smirnov, A.Uzdin, M.T.Urazbaev, E.E. Hachiyan, A. A. Tsernant, BC Polyakov, GS Shostoperov, AA Shkuratovsky, including foreign scientists, such as M. Bio, D. Kelly, K. Kubo, M. Mikoshiba, T. Nishiki, Omori, V. Robinson, R. Skinner , Hausner and many others. [7-28].

The beginning of the origin of the theory of seismic resistance of bridges should be attributed to the turn of the late XIX - early XX century, when as a result of a survey of the consequences of the devastating earthquake in 1891 in Mino-Owari (Japan), Japanese scientists were first obtained data on the maximum seismic acceleration of the soil, which allowed the task of determining the seismic Forces that affect the construction of earthquakes. Some time built massive bridge supports, which slightly increased the seismic stability of the structure. To this end, in 1906, Omori conducted a series of experiments to determine the seismic forces occurring in brick columns located on a platform subjected to horizontal harmonic oscillations.

1.2. Damage to bridges in the past earthquakes (Japan, USA, CIS countries, India, etc.)

For the theory of seismic stability, the investigation of the effects of destructive earthquakes serves as one of the main sources of information on the seismic effect. In the works of A.A. Gel'fer, G.N. Kartsivadze, G.S. Shestoper and a number of other authors consider the analysis of bridge damage from strong earthquakes.

Among the devastating earthquakes of recent decades, the following should be noted: Mr.Mehiko (1957), Agadir (Morocco, 1960), Skople (Yugoslavia, 1963); Niigata (Japan, 1964); Tashkent (Uzbekistan, 1966), Karakas (Venezuela, 1967), San Francisco (USA, 1971); Spitak (Armenia, 1987), pcs. California

(USA, 1994), Kobe (Japan, 1996), Taiwan (1999), China (2008), Haiti (2010). Studying the consequences of earthquakes, the engineers of Japan, the United States and in Russia proposed many ways to construct particularly stable buildings and structures that can withstand quite strong tremors.

In the Chilean capital, Santiago, a ruined bridge took the lives of motorists while driving.



Fig. 1.2.1 The destroyed bridge in Chile Santiago



Fig. 1.2.2 The Ruined Bridge in Chile Santiago

Analysis of numerous data on seismic damage to road transport facilities allows us to distinguish three groups of damages of beam bridges, the most massive type of bridge structures:

- Shift of span structures or falling from supports with relatively small damages of the latter;
- destruction or severe damage to supports, supporting parts, causing a complete or partial collapse of the bridge;
- drafts and shifts of the bridge supports, which are the most characteristic damages.



Fig. 1.2.3 The Ruined Bridge in San Francisco

Uzbekistan pays special attention to the development of the construction of transport infrastructure both inside and outside the Republic. From the first days of independence, the first President IA. Karimov identified design and construction of the most convenient and short high-capacity highways and bridges that would ensure Uzbekistan's access to the world market.

Providing seismic resistance of roads and bridges is an important social economic task that is a part of the problem of ensuring the safety and durability of Uzbekistan's transport systems. The seismicity of Central Asia ranges from 4 to 10 points. In Uzbekistan, regions with seismicity of 7 points prevail, but there are areas, for example Andijan, where 60% of the territory has an average seismicity of 9 points and 40% - 8 points. In the seismic regions, large road and

bridge construction is under way. Analysis of data on seismic damage showed that the impact of earthquakes of 7-9 points on transport facilities built according to normal standards leads to significant damage to many structures and serious disruption of transport in the disaster zone makes rescue, emergency and restoration work difficult. Exit from Building on long-term communication routes

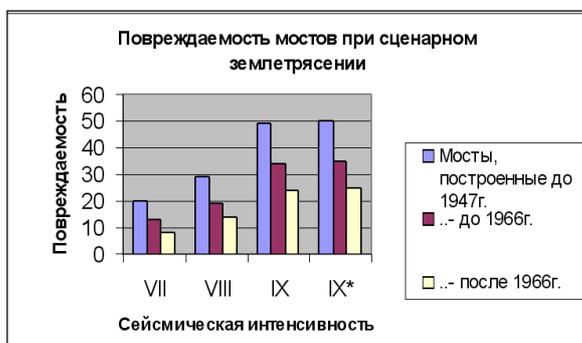


Fig. 1.2.4

complicates the work of industry and agriculture, since the disruption of the supply of products of even one plant, as a rule, causes disturbances in the production rhythm along the whole chain of interconnected enterprises, and reduces the efficiency of production.

Among the various types of natural and man-made disasters that pose a threat to the city, a special place belongs to earthquakes. For its long history, the city of Tashkent has been repeatedly exposed to strong earthquakes, destroying urban buildings and taking away human lives.

The first reliable information about a really strong earthquake on the territory of the city dates back to 1866. At the end of the last century, the city was affected by several more strong earthquakes, the intensity of which, judging from the archival data and using the modern macroseismic scale, can be estimated at the level of 7-8 points. There are a massive 134 bridges on the territory of Tashkent, of which 17 were built before 1947, 30 - in the period from 1947 to 1966, 87 - after 1966 [2].

In addition, their throughput was studied, as well as structural and operational defects. The survey shows that of the 47 bridges built before 1966 (Figure 1.1) in 17 there are places of high vulnerability. With a 9-point seismic effect, they can collapse.

The constant increase in the thickness of the roadway blocks the deformation seams, the drainage pipes of surface water also lead to deformations and fractures of the elements of the upper structure of the bridges. These shortcomings were



Fig. 1.2.5 Damaged motorway.



Fig. 1.2.6 Ruined Bridge in Japan



Fig.1.2.7 The Insu Bridge, located in the epicenter of the earthquake

revealed during the survey of the bridge over the Ankhor channel along Kh. Asamova Street, built in 1954, and the bridge over the Ak-Tepa Canal, built in 1983. A route laid along Bobur Street towards the airport, built in the early 70's Years, has vulnerabilities, which are being strengthened. It follows that with a 9-point seismic impact, 10% of all bridges in the city of Tashkent should be destroyed [3].

The damage from the earthquake in Japan, which occurred on March 11, 2011, is estimated at 16-25 trillion yen (198-309 billion dollars). This is reported by the Japanese agency Kyodo News with reference to the calculations of the local government. The evaluation of officials takes into account the costs of restoring social infrastructure, residential real estate and plants. Thus, the total losses do not include the decline in industrial growth, GDP and trade volumes caused by the natural disaster. The earthquake on March 11, 2011 in the media is usually compared with the earthquake in Kobe on January 17, 1995. Then Japan's losses amounted to 9.6 trillion yen (119 billion dollars) [4]. More than a million houses were turned off from water supply. Many sections of the Insuyu highway (Figure 1.4) in the Tohoku region serving northern Japan were destroyed, a large number of roads linking the city and prefectures were destroyed. The difficulty was in helping the victims, due to the destroyed overpasses (Figure 1.2.5) and bridge structures (Figures 1.2.6, 1.2.7).

Bridges and multi-tiered highways are highly vulnerable in seismic zones. Suffice it to say that of the 59 lives carried out by the catastrophic earthquake in San Francisco

(October 17, 1979), the cause of 42 death was the collapse of the upper tier of the interstate highway [5].

According to the American international group for assessing the effects of the earthquake, EQECAT [6], it is estimated that the earthquake losses in Chile vary from \$ 15 to \$ 30 billion. The catastrophe deprived about 2 million people of homelessness, 1.5 million houses were damaged. Great damage was given to roads and bridges. Broken bridge structures in the industrial area of the city were destroyed.

In the Chilean capital, Santiago, a ruined bridge took the lives of motorists while driving. (Figure 1.2.8).

This is the largest earthquake that led to such significant destruction and economic losses in Chile over the past 50 years.

The epicenter was in the entrance area to the tunnel leading to Lyttelton, at 9.7



Fig. 1.2.8 Destruction of the roadway on the highway in the Rakaya gorge area

Km from the central square in Christchurch, and the hypocentre at a depth of only 5 km. A repeated underground thrust with an epicenter 10 km from Christchurch occurred 13 minutes later, and lay at a depth of only 7 km. The second aftershock of magnitude 5.5 occurred at 14 hours 50 minutes. Its epicenter was 36 km

northeast of Christchurch and lay at a depth of only 10 km. The only major destruction of the road outside Christchurch was in the Rakaya gorge (Figure 1.2.8), which made it difficult to drive along the state highway in Caiapa. Movement on the main road for several days was prohibited. Large cracks on the roadway did not allow safe movement of vehicles. After the survey, it was decided to reconstruct the damaged sections of the motorway.

1.3. Conclusions on the chapter.

1. The problem of seismic resistance of bridges and bridge structures plays an extremely important role in connection with the fact that strong earthquakes destroy them, hindering the normal functioning of the national economy. Bridges and bridge structures consist of many elements, the most important are the passing and supporting parts. The article analyzed in detail the consequences of earthquakes that occurred in various countries of the world: Uzbekistan, CIS and far abroad countries. More attention is paid to studying the consequences of earthquakes in recent years.

2. The most characteristic seismic damage to bridge structures has been revealed, which indicate that in the general case they are caused by a complex of causes that constitute the main factors of seismic action. Two groups of damage to bridge structures can be distinguished:

- Damage to span structures, their displacement along sub-platform platforms or falling from supports with relatively small damages of the latter;
- destruction or severe damage to the supports, resulting in a complete or partial collapse of the bridge.

CHAPTER II. ANALYSIS OF MODERN RESEARCH ON SEISMIC RESISTANCE OF BRIDGE SUPPORTS AND THEIR ELEMENTS.

2.1. Bridge construction

Progress in constructive and technological solutions of foundations, in particular, the widespread use of reinforced concrete piles and piles, and the increase in the power of crane equipment, led to the creation of pile supports from reinforced concrete piles in the middle of the 20th century.

The main features of the current state of development of bridge supports are:

A) High level of typification of structures and their elements.

Virtually all supports of small and medium-sized bridges are built according to standard designs. When individual design of the supports of large bridges, typical elements and parts are widely used.

B) Orientation to lightweight structures.

Instead of the previously used massive stone, concrete and concrete pillars, rack, frame, hollow structures are used. In the foundations, the use of massive structures has practically ceased. In the intermediate supports, massive concrete structures survived only with heavy ice drift, severe climatic conditions and other complex applications.

C) Refusal from granite facing.

D) A sharp reduction in the volume of foundation works.

In bridge construction, the use of caisson foundations has practically ceased. Wells are found in isolated cases; The volume of construction of supports with foundations of a small laying (on a natural basis) is reduced. Pile foundations from pile, bored and drill-lower piles of various designs have been widely used [7]. In small and medium-sized bridges, pile supports are widely used, consisting of piles and joints (crossbars) joining them on top. In such supports piles are simultaneously elements of the foundation and the body of the support. For the supports of the traditional scheme (including the foundation and the support

body), there has been a tendency to place the grill plate above the ground level or working horizon of the water.

E) Increasing the level of assembling of supports by using prefabricated units.

The level of assemblage of supports of small and, in part, medium bridges exceeds 90%. There is a mass production of piles, racks, baits in factories of MZHBK. The industrial bases of the bridge building organizations produce in sufficient quantities the cabinet blocks of foundations, the elements of the foundations, the contour blocks, etc. In connection with the increase in the lifting capacity of the crane equipment, the mounting weight of the blocks increases, the cross-section increases and, accordingly, the load-bearing capacity of the frame racks

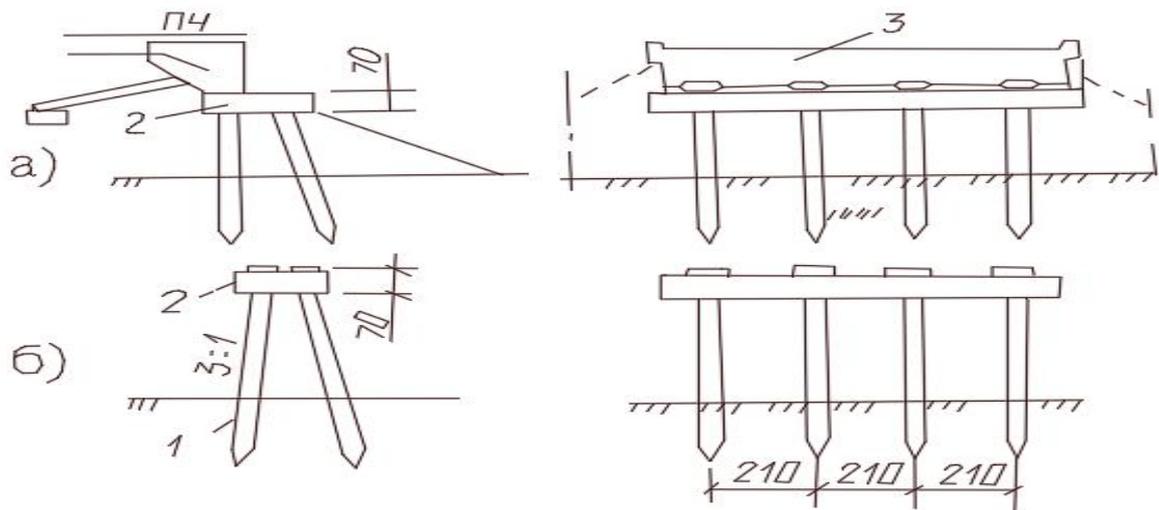


Fig. 2.1.1. Pile supports: a - the bridge of the road bridge;

B - intermediate support of the road bridge;

(1 - pile, 2 - nozzle, 3 - cabinet unit)

In addition, include cabinet blocks, which are elements of the interface of the bridge with the approach embankment. Prefabricated nozzles have homogenous through the installation through holes in which the reinforcement of piles is started. Pile piles, as a rule, can not be loaded exactly to the design mark. Therefore, the upper parts of the piles are cut with the exposure of the reinforcement. With a drill-down method of sinking the piles, the marks can be

maintained with great precision, and the outlets of the reinforcement are provided in piles in advance, at the factory manufacturing. Cabinet units of the foundations are attached to the nozzles with the help of welded or bolted joints of the embedded parts.

For road bridges, flat cabinets (cupboards) are usually used, on which soft entry plates are installed, which ensure a gradual change in the rigidity of the road surface at the entrance to the bridge. Depending on the cross-section and the way the piles are immersed, the supports are divided into:

- actual pile supports (Fig. 2.1.1), which use square pile driving piles with dimensions of 350×350 or 400×400 mm most often, as well as hollow round junctions 400 or 600 mm in diameter;
- columnar supports (figure 2.1.2), in which round-boring piles are used (diameter 600-800 mm) or rectangular section (for example, 500×800 mm);
- pierless supports (Fig. 2.1.3), in which shell piles or metal tubular piles with a diameter of 1000 mm or more are used, bored structures (for example, consisting of a bored pile at the bottom and sections of piles in the upper part).

An approximate field of application of pile supports is given in Table. 2.1.

H	Beaches supports						Middle supports					
	12,0	15,0	18,0	21,0	24,0	33,0	12,0	15,0	18,0	21,0	24,0	33,0
2	/											
4	/											
6	/											
8										①	②	
10												

The geological conditions for the use of pile supports are mainly determined by the capabilities of the equipment used: diesel hammers, steam hammers and vibratory pile drivers for driven piles, drilling equipment for boring and drilling piles [5].

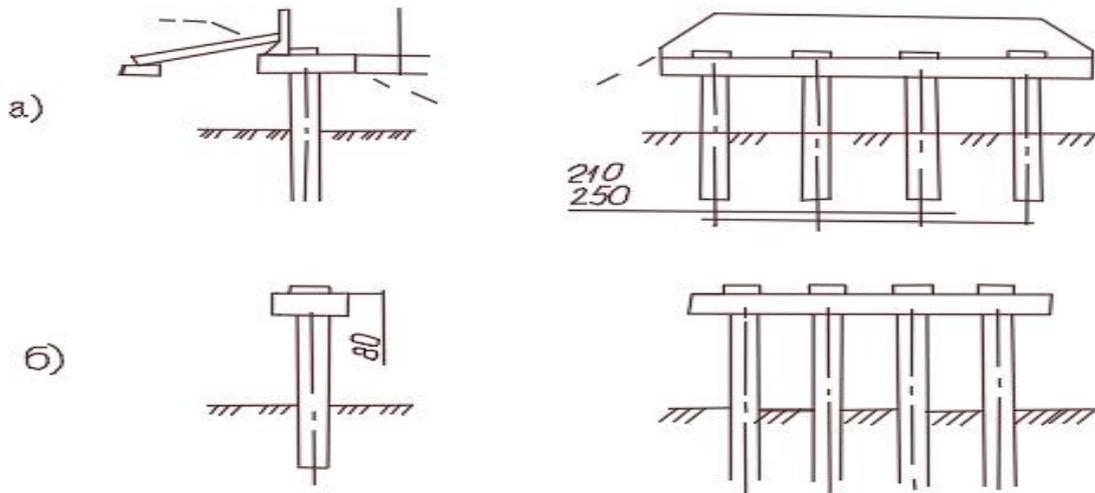


Fig. 2.1.2. Column supports: a - bridge of the road bridge;
 B - intermediate support of the road bridge;
 (1 - well, 2 - pillar, 3 - nozzle, 4 - cabinet unit)

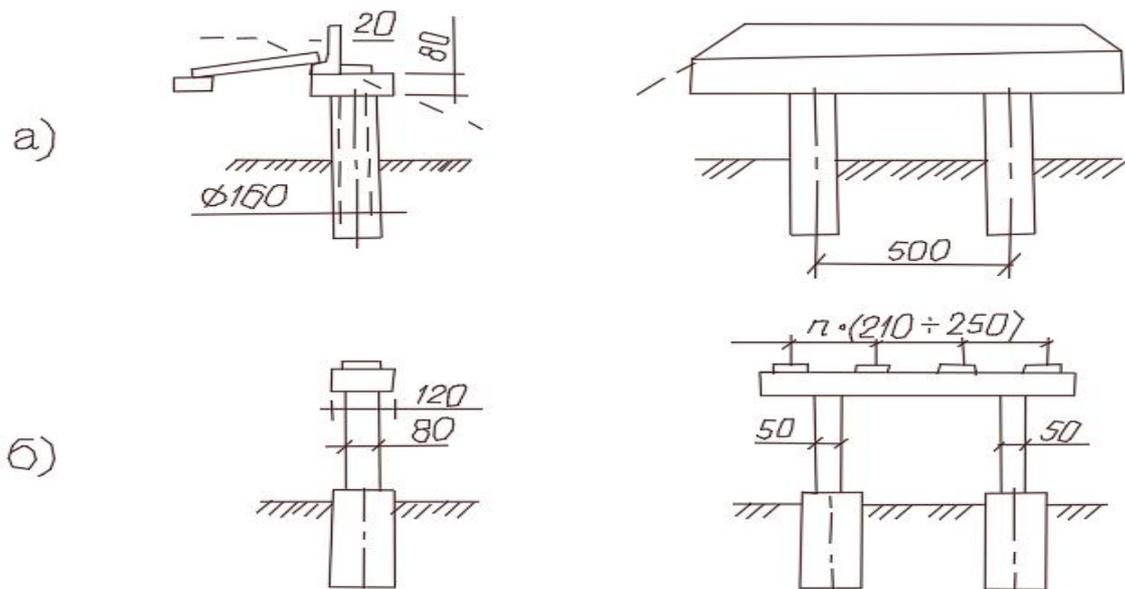


Fig. 2.1.3. Fingerless supports: a - foundations of a road bridge;
 B - intermediate support of a road bridge

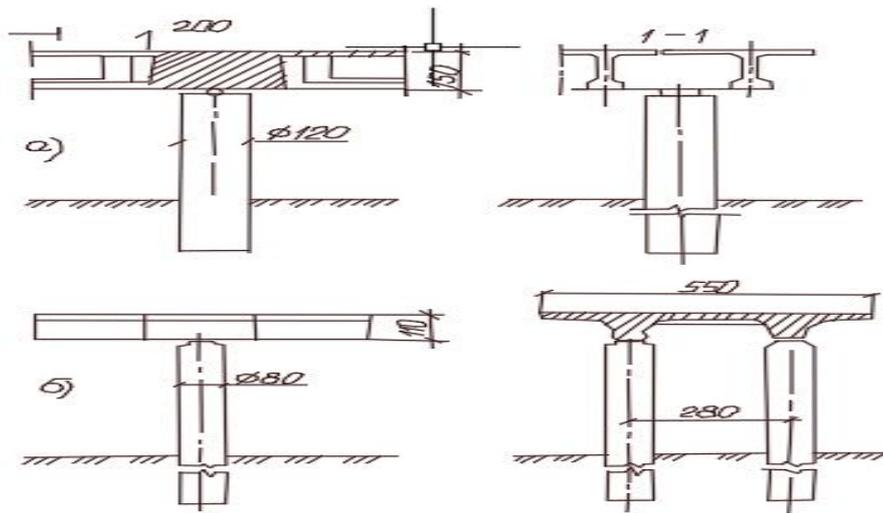


Fig.2.1.4 Free support:

A - support for a span structure with a monolithic diaphragm;

B - support for the fly by systems PRK-ZNIIS [17]

The type of support foundation is chosen depending on specific geological conditions. The union of the pillars with the foundations is carried out using foundation cups (Fig. 2.5) in the absence of significant tensile forces in the stacks, and the joining of the reinforcement bars with the reinforcement releases from the foundations - in the remaining cases.

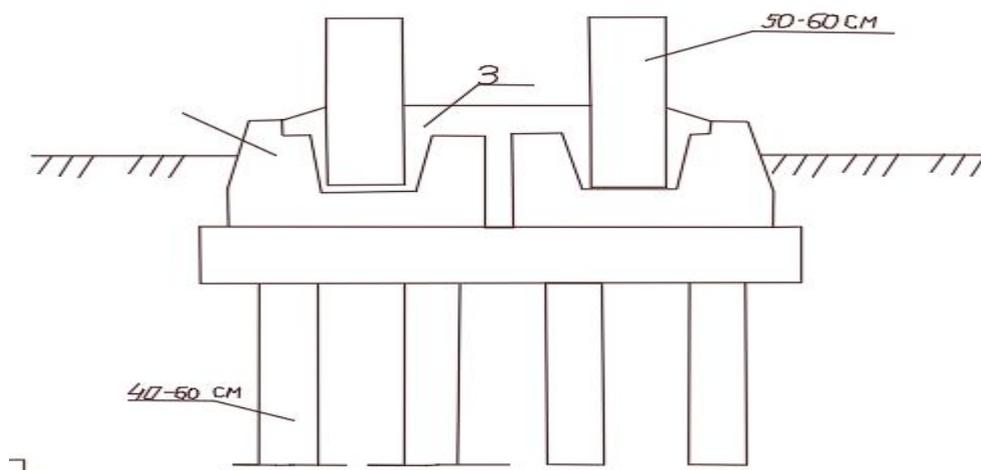


Fig. 2.1.5 The foundation of the rack:

1 - foundation glass; 2 - grill plate; 3 - mono-concrete

In road overpasses and medium bridges and urban conditions, single-pillar supports are often used, consisting of a reinforced concrete pillar and bolt, made of prefabricated elements or monolithic. Possessing high architectural and planning qualities, which is especially important in construction in cramped conditions (for example, with oblique overpasses), such designs require significant reinforcement costs.

The disadvantage of rack-mount supports in the form of spatial frames with inclined pillars is a considerable expenditure of materials on the foundations. To reduce the material consumption of the foundation and the support as a whole can be achieved by combining the elements of the bridge into a single system (Figure 2.1.5a). In this case, flat frame supports can be used. Since the horizontal forces are distributed in the system in proportion to the stiffnesses of the supports, due to the more rigid (due to the low altitude) of shore and name bearings, the channel supports will be less loaded. Several constructive methods of combining supports and span structures into a single system are known:

A) for road bridges:

- installation of beam split spans on rubber-metal bearing parts (ROH). The forces between the supports are distributed taking into account the stiffness characteristics of the supports and the deformability of the RPC [6];
- Arrangement of a continuous carriageway by unmatting the plate in above the support area and thus turning the bridge into a temperature-continuous system;
- installation of a beam-continuous span structure only to fixed support parts (with flexible supports).
- the arrangement of elastic gaskets between span structures and foundations. Such a solution in single-span bridges allows to significantly simplify the foundations;
- the device of hinged connections between adjacent span structures (Figure 2.1.6 b, c) - for bridges up to 150-200 m in length.

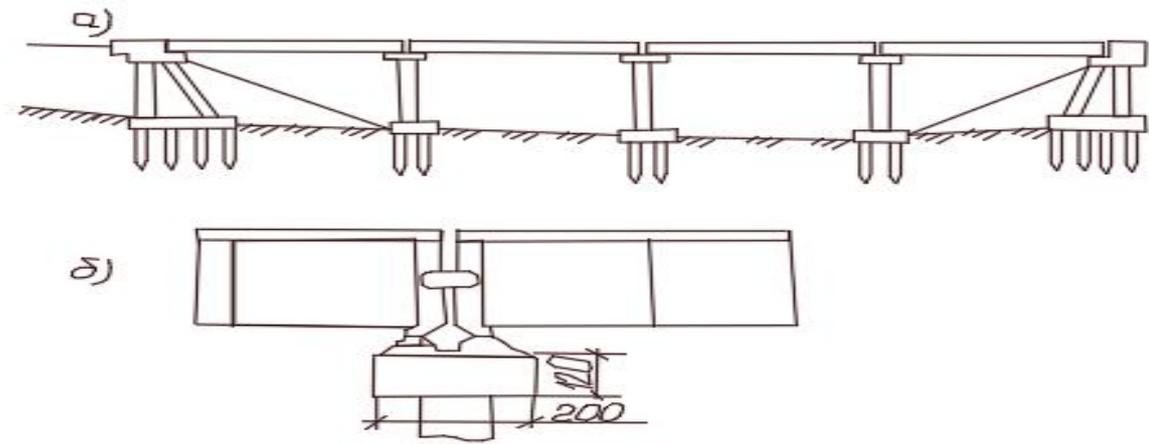


Fig. 2.1.6 Integrating the elements of the bridge into a single system:
 A - scheme of the viaduct; B - unification of metal beams;

Hollow support

Hollow supports occupy an intermediate position between massive and frame supports and are used in cases where massive structures are not required (for example, on dry lands or above the level of ice drift), and the use of frame supports is not technologically feasible or economically feasible (for example, at high altitude Supports).

Hollow supports (Fig. 2.1.7) can be made of prefabricated blocks of closed outline, united on glue, or monolithic.

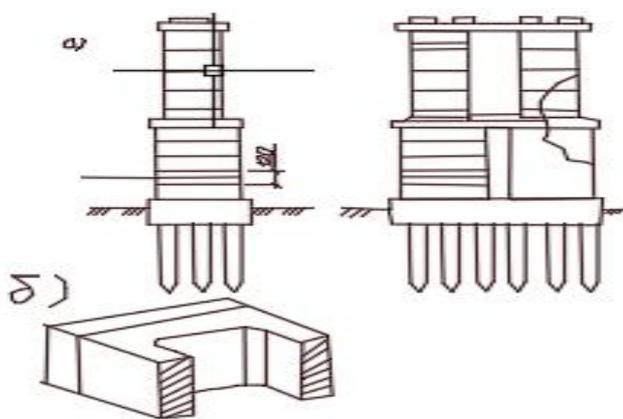


Fig. 2.1.7 Hollow support of two
 - an acceptable viaduct:

A - support scheme; B - block with dot locks;
 C - block with contour fixators

Supports can be designed and concrete, and reinforced concrete. In the second case, in the blocks of prefabricated supports, coaxial channels are arranged to accommodate the working armature.

Very promising is the technological solution proposed by the Trust [43] and allows one to make hollow blocks with different wall thicknesses and blocks of solid cross section in one tooling (Fig. 2.1.8). Using this technology, it is possible to obtain a support of constant cross-sectional height, having a continuous cross-section in the zone of ice flow and a hollow section in the upper part.

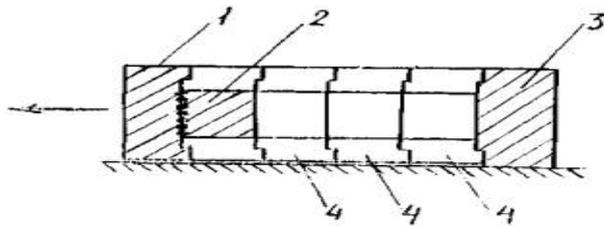


Fig.2.1.8 Diagram of manufacturing hollow support blocks:

1 - movable stop; 2 - loose leaf; 3 - fixed stop; 4 - blocks

2.2. Features of support structures in seismic conditions

Studying the experience of operating bridges in seismic regions has made it possible to work out a number of important requirements for the ground on which to base the foundations of bridge supports, as well as the construction of foundations and above the foundation part of the supports. In particular, it is recommended that the lower ends of piles, pillars and shells be immersed to a layer of low-deformable soils (rocky, coarse-grained, gravelly dense sands, clay soils of a solid and semi-solid consistency) [9, 4, 12].

When constructing bridge supports in seismic areas, it is desirable to use materials and structures that allow the development of cracks and plastic deformations at the stage preceding destruction. Such structures are capable of withstanding significant short-term loads, so that their resistance to seismic actions is high enough [5].

Good plastic properties are possessed by conventional and prestressed reinforced concrete structures, designed taking into account seismic influences. The high strength of reinforced concrete with stressed states of various types also makes it possible to significantly reduce the weight of reinforced concrete supports in comparison with stone and concrete structures and thereby reduce the

seismic load. This is especially important in the case of a calculated seismicity of 9 points, when the cost of materials for the construction of supports significantly increases as a result of their verification for seismic action. With a calculated seismicity of 7 and 8 points, concrete supports are also effective, the strength of which is ensured without a significant increase in the size of supports erected in non-seismic regions. To increase seismic resistance, concrete supports are reinforced with structural reinforcement, therefore reinforcement is one of the main antiseismic measures in the construction of supports. There are other techniques to ensure seismic resistance of supports. These include the increase in the brand of concrete, the use of epoxy glue to connect blocks of prefabricated-monolithic supports, the use of hollow structures to reduce seismic load.

The noted shortcomings have largely been eliminated in prefabricated monolithic supports from contour blocks with a figured face, used in the construction of some large road bridges. Supports with cross-section of different sizes (the step size of the cross section of the support is 10 cm) is assembled from concrete blocks of three basic types. During installation, the first row of blocks is installed on the foundation or the lower part of the support. Blocks of this series are laid on the solution, blocks of the subsequent rows - on epoxy glue. When concreting the core, vertical dowels are formed, since the face of the blocks, normal to the cross-section of the support, has a figured outline. These keys, located near the lateral surface of the support, fix the position of all the blocks. To ensure the seismic stability of the structure in the vertical keys have a longitudinal reinforcement. In seismic regions, it is advisable to use supports with as small a mass as possible, for example, in the form of one or several reinforced concrete pillars joined by a bolt (Fig. 2.2.1) [3, 4, 7].

Such a slab was designed (Figure 2.2.2) [7] for a 23.5-meter steel span structure for a seismic area of 9 points. The body of the pillar is made of ferroconcrete pillars \varnothing 80 cm, located in the transverse axis of the bridge. The nozzle of the stand and the plate of the columnar foundation are made of monolithic reinforced concrete. The columnar pillars and the intermediate

supports located beneath the tapered channel for reinforced concrete span structures up to 16.5 m in length are constructed in seismic regions. When building viaducts in seismic regions, some intermediate supports have the form of reinforced concrete spatial frames. Racks of frames of constant section 800×800 mm are located obliquely in two planes. When the height of the supports is high, the racks are made bunk, carrying out the assembly joint on the flange joints and combining the racks with each other by horizontal spacers. Compared with monolithic supports, the volume of concrete in prefabricated frame supports decreases 2 to 2.5 times.

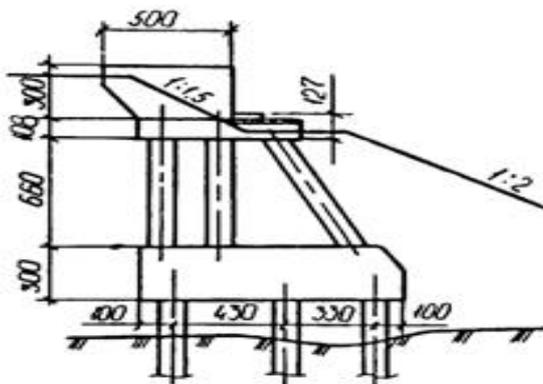


Fig. 2.2.1 Steady light

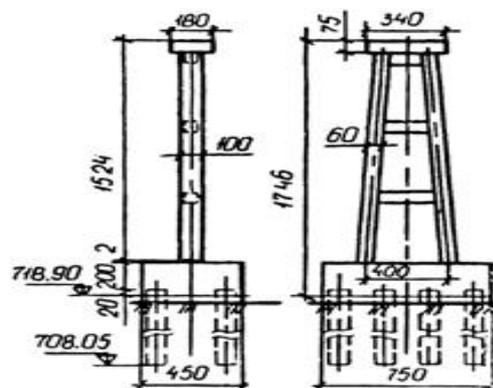


Fig. 2.2.1 Steady light

Under favorable ground conditions, the intermediate supports of the viaduct are made in the form of flexible flat reinforced concrete frames. In this case, the longitudinal loads on the foundations are transferred by connecting the split flying structures to the temperature-cut whips with the help of hinges that take longitudinal forces.

Light supports are widely spread in road and city bridges, overpasses and overpasses. To reduce the weight of supports used concrete of increased strength, reinforcement of the structures of rod and high-strength wire reinforcement.

Supports of a hollow structure of prestressed reinforced concrete were constructed according to the project of Tbilgiproavodortrans [44] in the seismic region of 9 points. Three - span bridge over the river canyon. Naryn with an

uninterrupted steel-fiber span structure, the scheme of which is 40 + 68 + 40 m, has intermediate supports with a height of more than 40 m. The foundations and socle parts of the supports are monolithic, the upper parts of the supports are assembled from ferro-concrete box-section blocks, , And in the vertical - 64 bundles of prestressed reinforcement. The upper ends of the bundles are zaankeren in transverse diaphragms 25 cm in thickness, located 7 m along the height of the support, the lower ends of the bundles are zankereny on the outer surface of the basement of the supports. The intermediate bridge supports of overpasses and overpasses are usually made of precast reinforced concrete pillars. The lower ends of the pillars are fixed in the foundation with the help of a joint of a glass type, the design of which should be given special attention, since the destruction of some bridges abroad during earthquakes was due to the lack of reinforcement of reinforced concrete pillars in the foundations.

2.3. Studies on the calculation of seismic effects on bridge supports.

The engineering analysis of the consequences of earthquakes indicates [2, 11, 15, 22, 24, 25, 29] that bridges of various designs often get serious destruction as a result of seismic action. If in massive and heavily stiff old bridge structures, the main fractures were observed usually in the foundation part and in the supports, then lighter and more flexible modern bridges are often destroyed because of the intensive oscillations of the span structure. In the construction of modern highways and transport interchanges, curved in terms of reinforced concrete bridges, based on a number of columns, have become widespread. During the earthquake on February 9, 1971 in San Fernando [36] (California), these bridges received a series of serious injuries, including the collapse of two spans. The cause of most accidents was the presence in the bridges of thermal seams, which violate the integrity of the structure and are its "weak" place.

At the Center for Engineering Studies of the University of California (USA) on a powerful vibro platform of 6.1 x 6.1 meters in size, a dynamic test of the

model, a curved reinforced concrete bridge that collapsed as a result of the earthquake in San Fernando, was carried out. In terms of the bridge is outlined along an arc of a circle 410 m long and 208 m in radius. Panels of its roadway are separated by temperature seams and are supported by a series of supports located along the axis of the bridge, from 4.5 to 43 m in height. Scale 1/30 of the natural size.

During the tests, the deformations and damping coefficients of the oscillations are assumed to be the same for the model and full-scale design; The time scale for the model changes by a factor, and the scale of the stresses in the material in $m_r / 30$, where m_r is the ratio of the distributed masses of the model to the actual structure. Since the same material (concrete) was used for the model as in the bridge structures, the stresses (with equal strain) were the same in the model and the real structure, and in order to achieve dynamic similarity, additional masses were installed on the model in such a way as to ensure equality $M_r = 30$ without further increasing the stiffness of the model. Calculations and trial experiments have shown that for modeling, the first seven frequencies and forms of natural oscillations of the bridge, we can confine ourselves to a simplified model on three columns with two temperature seams EJ1 and EJ2, shown in Fig. The horizontal panels of the span structure of the model, separated by a temperature seam, were connected by longitudinal longitudinal tightening of steel with increased plastic properties along the edges. The columns were rigidly connected to the horizontal panels and to the base.

Preliminary static and dynamic tests of the model and its elements were carried out to determine its stiffness characteristics, oscillation damping coefficients, and also the shapes and frequencies of natural oscillations. The first waveform has a frequency of 5 Hz and corresponds to a horizontal displacement of the entire span structure, as a rigid whole, in the longitudinal direction, i.e. Along the OX axis (see Fig. 16). The second form with a frequency of 6.7 Hz

corresponds to the transverse (along the axis OY) horizontal displacement of the span structure as a rigid whole. With vertical action, we can .

$$\left(\frac{\varphi u}{\varphi y}\right)_c = 1 + C \left[\left(\frac{\varphi u}{\varphi y}\right)_{c=1} - 1 \right] \quad (1)$$

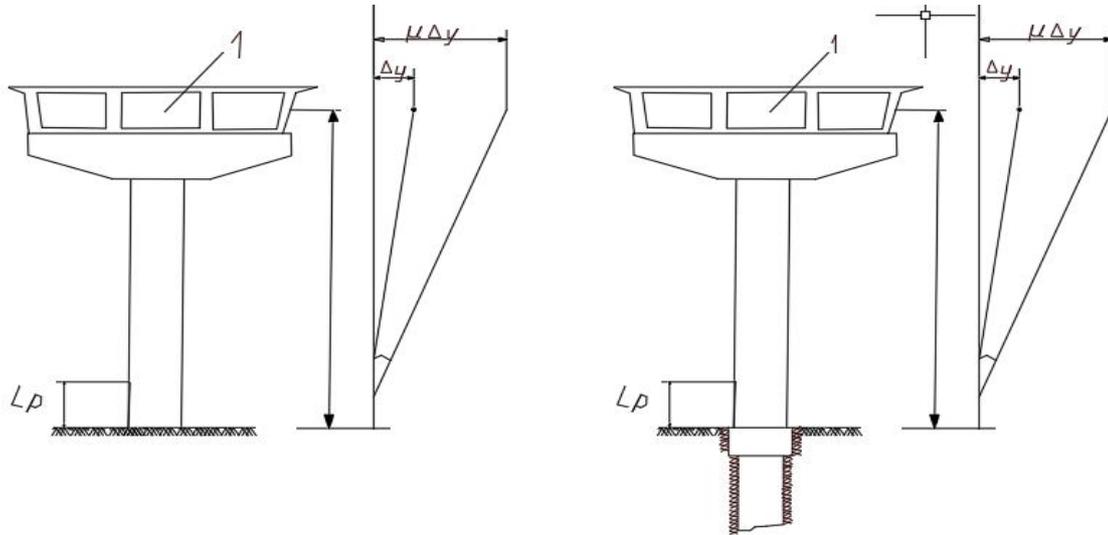


Fig. 2.2.3. Effect of elastic compliance of the base on the magnitude of plastic deformations in the plastic hinge:

A - a pylon on a rigid base with a rigid fixing of the span structure; B - pylon on a flexible base with elastic fastening of the span structure 1 - center of mass

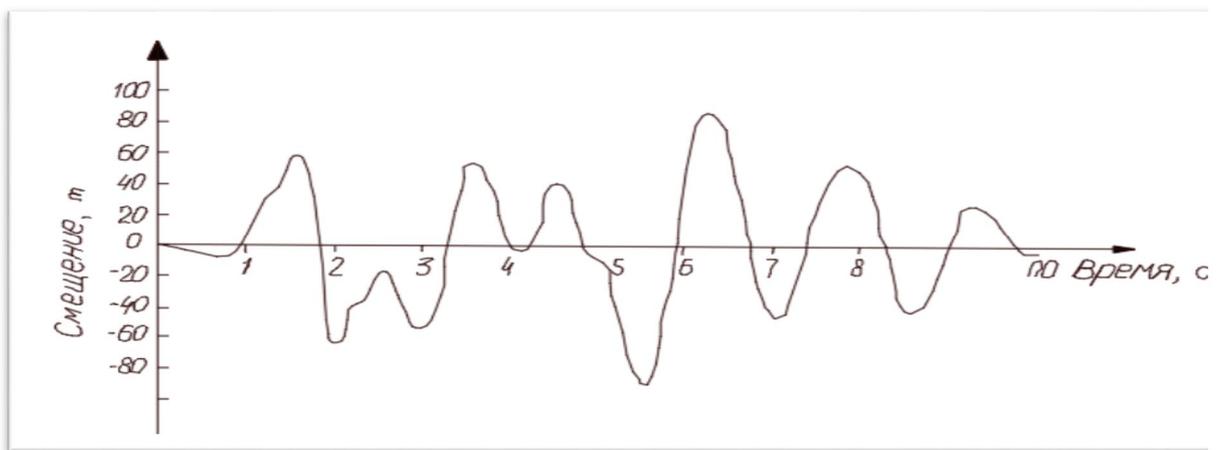


Fig.2.2.4 Displacement of span for elastic and inelastic reaction of the base:
 1 - for a soil model with elastic deformation;
 2 - for the model of soil with plastic deformation.

For sufficiently rigid designs of pylons $C \geq 5$, and hence the value of the coefficient of ductility by curvature can increase significantly, taking into account the compliance of the base with a constant value of the plasticity coefficient from the displacements. Naturally, the yielding of the base also leads to an increase in the period of the fundamental pitch of the pylon oscillations by a factor of.

In order to verify the described theoretical provisions, which are the basis of elastoplastic calculation of pylons for seismic impacts in the building codes of New Zealand, the authors made a direct calculation of four pylon designs, taking into account the compliance of the base. One pylon had a frame circuit with two columns and a fundamental pitch period of natural oscillations of 0.2 s. The remaining three pylons consisted of one column, the length of which was selected from the condition that the periods of the fundamental pitch of the oscillations were 0.5, 1, and 2 s. An approximate account of the elastic compliance of the base was due to a conditional increase in the height of the pylon L by an amount L .

For a pylon with two columns, for which the period of the fundamental pitch of the natural oscillations was less than the value corresponding to the maximum in the calculated reaction spectrum, allowance for compliance led to a significant increase in the reaction, as well as the coefficient of ductility with respect to curvature with an almost constant value of the plasticity coefficient with respect to displacements. In this case, the increase in plasticity by curvature is even more significant than it follows from relation (1). However, for the other three more flexible models of pylons, in which the pitch periods of the oscillations exceed the value of the period corresponding to the maximum of the reaction spectrum, a significant decrease in and a preservation of the coefficient of plasticity along the curvature at the same level is observed with increasing compliance of the base.

Thus, for sufficiently flexible pylon designs, the recommendations of the New Zealand building codes that regulate the constant value of for any compliance of the foundation should be considered excessively conservative, and the calculation

based on the designation of a constant plasticity coefficient for curvature in the plastic hinge is more preferable.

A dynamic analysis of a single-column pylon of a real bridge design was also carried out, taking into account the plastic deformation of the base. Figure 2.2.4 shows the results of the calculation for an elastic and non-elastic reaction of the base, which was modeled by a set of elastoplastic springs. In both cases, the formation of the plastic hinge in the pylon was taken into account. Allowance for plastic deformation of the base leads to a decrease in the displacement of the span structure, which is equivalent to assigning in the design scheme with an elastic base an attenuation coefficient equal to 9% of the critical, instead of the 5% accepted in calculation. The increase in attenuation associated with the plastic deformation of the base is more important for rigid frames of frame-type pylons.

Seismic impact was simulated using real accelerograms. In total, four series of tests were carried out, and in the first series of acceleration the vibroplatforms were directed, only along the OX axis, and in the remaining series along the OC axis and, sometimes simultaneously along the vertical axis of the OC. In the third series of tests, in contrast to the second, more rigid longitudinal tightening was used between the panels at the temperature seams, and in the fourth series, two columns were installed under the middle span panel, i.e. The whole model had four columns.

The tests showed that horizontal longitudinal seismic accelerations directed along the OX axis do not represent a significant hazard for the bridge model even when their maximum values reach $0.87 * g$. At the same time, fluctuations occur mainly in the first form and minor damage can occur at the base of the columns and destruction in the zone of temperature, seams, which do not threaten the load-bearing capacity of the structure as a whole. The transverse seismic accelerations represent a significantly greater danger. The curvature of the span structure increases the stiffness of the bridge in the direction of the OS, but the temperature seams, violating the integrity of the structure, significantly reduce this rigidity. The main fractures are concentrated in the area of thermal seams, where very high

relative displacements are produced by shear forces that can lead to the destruction of the span structure. In the case of transverse horizontal oscillations in the temperature seams, there is a shock interaction between the panels, which leads to rapid brittle fracture of the concrete. The installation of more rigid puffs between the panels helps to reduce the relative displacements of the edges of the seam, but only for relatively small seismic accelerations. With a high level of external influence in the seams, as before, there are great disruptions. The installation of each panel on several columns favorably affects the load-bearing capacity of the thermal joints and the structure as a whole. Specialists of the United States believe that, whenever possible, we should strive to design the construction of bridges in general without thermal seams. If we eliminate all the temperature sutures from the model in question, then the calculations show that the frequency of its first form of transverse horizontal vibrations will increase by a factor of 2.5, and the maximum displacement for seismic action in the direction of the op amp will be reduced by a factor of 20. If the temperature seam can not be avoided, It is desirable in

Table 2.2.

Years of construction of the bridge	Valves	
	Support of circular section	Support of rectangular section
Before 1972,	$\rho_t = 0,0015$	$\rho_t = 0,0015$ $\lambda_e = 0.0007$
From 1972 to 1992	$\rho_t = 0,005$	$\rho_t = 0,005$ $\lambda_e = 0.003$
After 1992,	$\rho_t = 0,007$	$\rho_t = 0,007$ $\lambda_e = 0.005$

The relationship of reinforcing intersections or restrictions that can be expected during different years of construction.

Procedure

1. Calculation of the fluid shear (γ_u). For the case of a single column convoy, equation 2 is used in the span console.

$$\gamma_y = \frac{1}{3} \phi_y H \quad (2.1)$$

For multicolumnic foundations (solid decking in the form of a membrane) can be calculated by the following equation:

$$\gamma_y = \frac{1}{6} \phi_y H \quad (2.2)$$

2. Calculation of the final shift (γ_u). This parameter is calculated by equation 2.4.

(2.3)), and (2) the probability of the change in

$$\gamma_u(\%) = \beta_0 + \lambda_c \frac{f_{yt}}{14f_c} \left(\beta_1 + \beta_2 \frac{P}{A_g f_c} \right) + \beta_3 \left(\frac{P}{A_g f_c} \right) \quad (2.3)$$

The corresponding error, the forecast of the lateral displacement capacitance, is recommended to obtain a shift amount that was multiplied by a factor of 0.8; For the favorable side.

3. Achievement of the branch of the plastic shear (μ)

$$\mu = \frac{\gamma_u}{\gamma_y} \quad (2.4)$$

4. Obtaining a period of structural vibration (T_{cr})

5. Evaluation of the fluid side force (V_y). Obtained by equation 5.

$$V_y = K_{cr} \gamma_y H \quad (2.5)$$

6. Estimate of $R\mu$. The attenuation coefficient of 0.05 from the studies (Arroyo and Terán, 2002):

For hard soil:

$$R_{\mu} = (1.11\mu - 1.0119) \left(\frac{T_{cr}^{1.2}}{0.002 + T_{cr}^{1.2}} \right) + 1 \quad (2.6)$$

For soft soils:

$$R_{\mu} = \frac{\left(\frac{T_{cr}}{T_g}\right)^{\theta}}{0.175 + \left|\frac{T_{cr}}{T_g} - 1\right|} (0.5529\mu - 0.55) + 1 \quad (2.7)$$

$$\theta = \frac{\mu^4}{2.5 + \mu^4} \quad (2.8)$$

Where, T_g is the period of the soil of the bridge located on the section

7. Calculation of spectral acceleration (S_a). Acceleration that begins to damage (weak cracks in places with longitudinal reinforcement) Say

$$S a_y = \frac{V_y}{W_T} g \quad (2.9)$$

The acceleration that causes column failure, Say

$$S a_u = \frac{V_y}{W_T} R_{\mu} g \quad (2.10)$$

Where, W_T is the total mass of the bridge being analyzed, g is the acceleration due to gravity.

8. The output of the vulnerability function. In the output of the physical damage index (IDF) function, called in this work as a vulnerability function, these are the two main points of the function curve: the beginning of the fault and the end of the fault, then a and m are obtained. Corresponding to this vulnerability function:

$$I_{DF}(S a_i) = 1 - e^{-a u^m} \quad (2.11)$$

$$u = \frac{S a_i}{S a_u} \quad (2.12)$$

$$m = \frac{(-5.69734)}{\ln\left(\frac{S a_y}{S a_{pu}}\right)} \quad (2.13)$$

$$m = \frac{\ln(0.99)}{\left(\frac{S_{ay}}{S_{apu}}\right)^m} \quad (2.14)$$

Where, S_{ai} is the required bridge acceleration for which it is required to know its vulnerability degree, and $S_{apu} = 0.95S_{au}$

The Interpretation of the Physical Damage Index (IDF) was proposed in the main papers that examined the relationship between the structural response and their respective level of damage (Rivera, 2005; Karim and Iamazaki, 2001). Table 2.2.1 shows the amplitudes of the IDF values associated with the level of damage and the type of vulnerability.

Table 2.2.1

Interpretation of IDF

IDF	Damage level	Vulnerability
$0 < IDF < 0.05$	Zero	Very low
$0.05 \leq IDF \leq 0.15$	Nearly zero	Low
$0.15 < IDF \leq 0.40$	Average	Average
$0.40 < IDF < 0.95$	Heavy	High
$0.95 \leq IDF$	Full	Very high

The structural configuration of both bridges is similar in the longitudinal direction, but not in the transverse direction, as shown in Figure 1.20 (Chapter 1). It is believed that the type of foundation is hard ground. Based on the location of the bridge, the information received is reported in Table 2.2.2.

Table 2.2.2

Dates of construction of bridges

Bridge	Cross Section slit	Section size (mm)	Stake height,, H (mm)	Relative Species	Year Construction
1	Rectangular	B=1000 L=1250	6250	H/L=5	Between 1972 1992
2	Circular	D=1000	8000	H/2D=4	After 1992

Based on the data in Table 2.2.1 and Table 2.2.2, the values of the vulnerability parameters of each bridge were obtained (Table 2.2.2). Replacing these quantities by Eq. 15, the curves shown in Figure 2.2.5

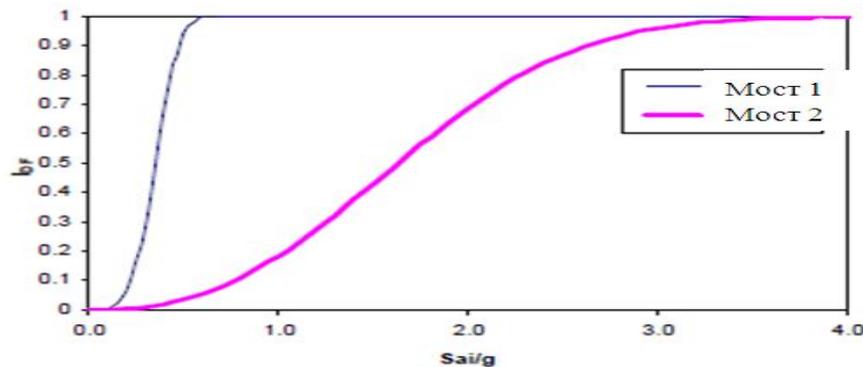


Figure 2.2.5 The vulnerability function of both bridges

To assess the acceleration requirements (S_{ai} / g) of each bridge, the CFE design guide (1993) was used, assuming that the bridge is located in seismic region D (high seismicity) and that bridges are located on hard ground. Substituting S_{ai} / g on the vulnerability of bridges 1 and 2, comparing with IDF, the damage and vulnerability level of each bridge (Table 2.2.3).

2.4. Conclusions on the chapter

1. Approaches, methods and studies on the effects of earthquakes on bridge structures of various designs and types are presented. The most objective information was obtained on the results of vulnerability studies for various types of bridge structures, special attention was paid to physical damage to the support parts, since the support parts of bridges are the main part of the seismic resistance of the entire bridge structure.

2. The information studied is of value for assessing the degree of safety of bridge structures under seismic action, and the ability to field data to simplify the seismic assessment of the vulnerability of reinforced concrete bridges.

3. An assessment of the seismic vulnerability of bridges was carried out - which is a complex process. In particular, the assessment of the expected seismic response of bridge structures is still due to many uncertainties about the most important elements of the bridge structure. For this reason, the effective use of modern methods and calculation tools, to determine the seismic stability of bridge structures is very important.

4. The behavior of supports with circular and rectangular sections of different configurations with a span structure is studied. The types and types of modern supports that meet modern requirements and design and bridge construction standards are given.

5. Some features of support structures that are used mainly in seismic construction areas are considered. Features include the possibility of allowing the development of small cracks in structures. Such structures are capable of withstanding significant short-term loads, so that their resistance to seismic actions is high enough.

CHAPTER III. INVESTIGATION OF SUPPORTING BRIDGES OF STEPPED SECTION WITH THE ACCOUNT OF INTERACTION OF THEIR BASED ON SEISMIC IMPACT

3.1. Oscillation support of bridges stepped section.

To assess the seismic resistance of the foundations of the supports of the overpass, it is necessary to determine seismic forces and forces from permanent and temporary loads (bending moments, horizontal and vertical forces) on the base of the foundations on a natural basis.

Seismic loads acting along and across the axis of the overpass should be considered separately [5]. The definition of a seismic load directed along the axis of a beam overpass is described below.

When determining the seismic load acting along the axis of the overpass, the mass of the rolling stock is not taken into account [5].

Regulatory constant loads and impacts, regulatory loads from rolling stock and reliability factors for loads and impacts are taken by [52]. When calculating road overpasses taking into account seismic impacts, the coefficient of η for seismic loads, whose action is taken into account, together with the loads from the rolling stock of highways, is 0.8.

Dynamic design scheme of the section of the overpass (bridge) is adopted in the form of an elastic weightless cantilever rod of variable cross-section with 4-5 weights for supports up to 20 meters high. Calculation of supports with many degrees of freedom is very complicated and requires the use of special applications on the PC (Lira, Stat Pile, Pontiflex). The number of natural modes considered in the calculation is recommended to be at least three if the periods of the first (lower) tone of the natural oscillations T_1 are more than 0.4 s, and taking into account only the first form, if T_1 is equal to or less than 0.4 s [5]. In a number of cases, the calculation of seismic efforts using simplified schemes differs little from the calculation of relatively accurate schemes. For example, when calculating the longitudinal seismic loads of beam overpasses (bridges) with small

spans, often resort to approximate schemes. Taking into account the small height of the supports, in the calculation they are limited to taking into account the first form of natural oscillations [5].

The design scheme is adopted in the form of an elastic weightless rod that oscillates in the plane of the bridge or overpass in Figure 3.1.1 (a, b).

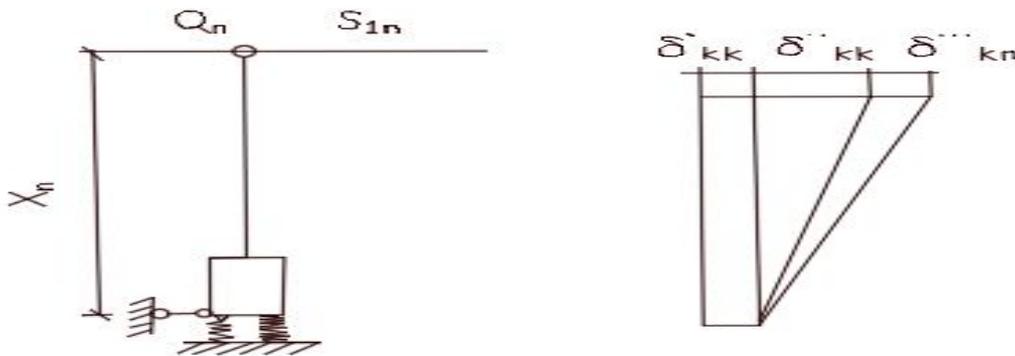


Figure 3.1.1 Dynamic calculation schemes

According to [5], in determining the seismic load, it is necessary to take into account the elastic deformations of the structure and the base of the overpass (bridge).

When calculating overpasses with small span lengths, frictional forces in the moving support parts are significant and can not be overcome during the oscillation process. It is believed that on each support, irrespective of the type of support parts, both buildings supported on it are affected.

With massive supports, overpasses or bridges with small spans usually have a period of longitudinal oscillations (the main tone) $T_1 < 0.4$ s. In this case, the norms allow us to take the dynamic coefficient for the basic vibration form $\beta = 2.7$, and our own form is assumed to be rectilinear.

Thus, in the calculation of overpasses and bridges of small spans, in most cases, it is not necessary to determine the exact periods and forms. This greatly simplifies the calculation of overpasses (bridges) with a short span length.

Below are the general principles for calculating the bases of supports (viaducts) for seismic actions, taking into account the elastic deformations of the support structure, the foundation shift along the ground, and the elastic rotation of the foundation along the base. The mass of the support with the foundation, the attached mass of span structures supported by the support, is replaced by the total mass applied at the common center of mass.

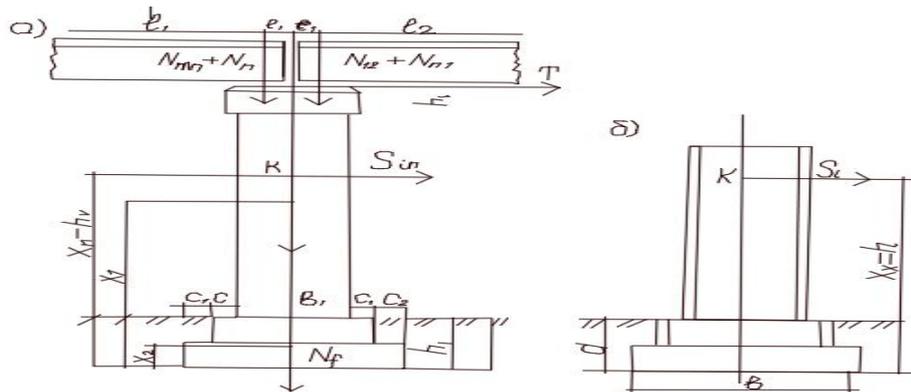


Figure 3.1.2 Schemes for calculating the support of the overpass for seismic impacts

The calculated horizontal seismic load S_{ik} in the calculation of bridges is determined by the formula:

$$S_{ik} = \eta_{18} K_1 A K_{\psi} \beta_i \eta_{ik} Q_{k.red} \quad (3.1)$$

Where η_{18} is the coefficient of combinations for the seismic load, taken in conjunction with loads from the rolling stock of highways, equal to 0.3 (2, 2.5);

K_1 - coefficient taking into account permissible bridge damage,

$K_1 = 0.25$;

K_{ψ} is a coefficient that takes into account the damping of the structural vibrations, when $H_0/B = 8.9/4.6 = 1.9 < 15$ $K_{\psi} = 1$, где H_0 , where H_0 is the height of the column above the foundation edge, c is the column size in the direction of the seismic load action;

A is the coefficient taken to be 0.1; 0.2; 0.4; Respectively, with a calculated seismicity of 7.8.9 points;

$Q_{k,red}$ - design weight of the structure, referred to the point K (Fig. 3.1.3, 3.1.4);

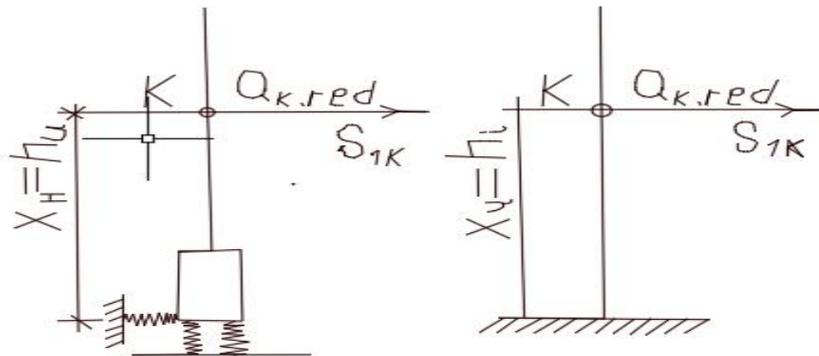


Figure 3.1.3 Dynamic calculation schemes of intermediate supports

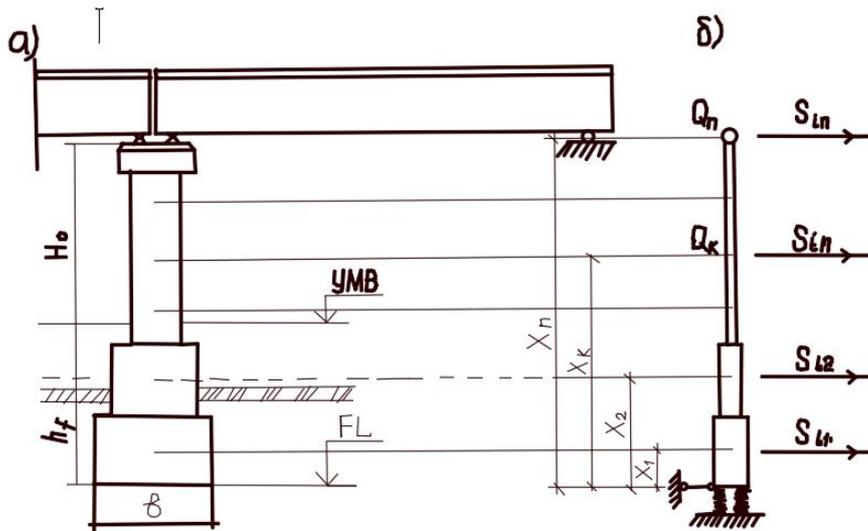


Figure 3.1.4 Dynamic calculation schemes of intermediate supports

$B_i \eta_{ik}$ are the coefficients of dynamism and the shape of the oscillations, determined from [5] or Fig. 3.5.

The dynamic factor is determined by formula 16 or in Fig. 3.1.5b.

$$\beta_i = \frac{I_i}{T_i} \quad (3.2)$$

Where T_i is the period of natural oscillations of the overpass (bridge) in the i -th tone, s.

The value of the coefficient β_i should be less than 0.8 and not more than 2.7

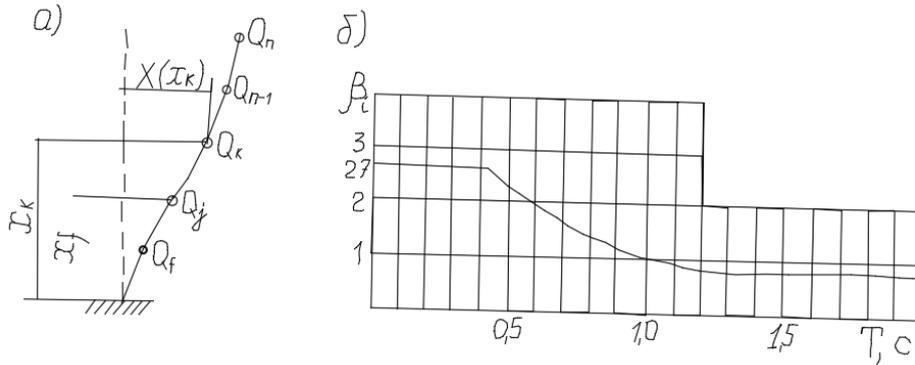


Figure 3.1.5 Schemes for determining the coefficient
Forms of oscillations η_k and the dynamic coefficient β_i

The seismicity of the construction area in points is adopted according to annexes and then the seismicity of the structure is clarified according to the construction site soil category.

For large transverse dimensions of the end supports on the facade, as well as for the calculation of massive intermediate supports across the bridge, in addition to the single unit movements listed, it is necessary to calculate also single displacements from the shear deformation of the support body

$$\delta_{kk}^{\dots} = \frac{1,2X_n}{G_0A_0} \quad (3.3)$$

Where G_0 is the shear modulus of the support body;

A_0 is the cross-sectional area of the support body.

When the load is concentrated at the point K, the total unit displacements are determined by formulas

$$\delta_{kk}^{\dots} = \frac{(1+\mu\lambda^3)h_{ii}^3}{3E_fI_f} \quad (3.4)$$

$$\mu = \frac{E_f I_f}{E_0 I_0} - 1 \quad (3.5)$$

$$\lambda = \frac{h_{\text{н}} - h_f}{h_{\text{н}}} \quad (3.6)$$

$$h_{\text{н}} = X_k;$$

Where $E_f I_f, E_0 I_0$ - bending stiffnesses of the foundation and the support body;

E_f, E_0 - moduli of elasticity of concrete foundation and support body;

h_f - height of the foundation.

The reduced (average height h_f) moment of inertia of the foundation is determined by the formula (when calculating along the axis of the bridge)

$$I_f = \frac{a_{f0} b_{f0}^3}{12}, \quad (3.7)$$

a_{f0}, b_{f0}^3 - reduced (average height h_f) dimensions of the foundation, determined respectively by the formulas

$$a_{f0} = \frac{(a_0 + 2c_1)h_1 + (a_0 + 2c_1 + 2c_2)h_2 + (a_0 + 2c_1 + 2c_2)h_3}{h_f} \quad (3.8)$$

$$b_{f0} = \frac{(b_0 + 2c_1)h_1 + (b_0 + 2c_1 + 2c_2)h_2 + (b_0 + 2c_1 + 2c_2)h_3}{h_f} \quad (3.9)$$

The total weight $Q_{\text{к.ред}}$ (k.red), reduced to the point K, is determined by the formula

$$Q_{\text{к.ред}} = \gamma_{f \text{ пп.с}} N_{\text{пп.с}} + \gamma_{f, \text{мп}} N_{\text{мп}} + \gamma_{f0} N_0 + \gamma_{ff} N_f \quad (3.10)$$

Where N_0, N_f - the normative weights of the body of the support and foundation;

$\gamma_{f \text{ пп.с}}, \gamma_{f, \text{мп}}, \gamma_{f0}, \gamma_{ff}$ are the reliability factors for the load, respectively, from the weight of the span structure $N_{\text{пп.с}}$, of the bridge bed $N_{\text{мп}}$, of the body and the support base N_0, N_f .

The standard weight of a reinforced concrete or metal span structure is determined by the formulas

$$N'_{\text{пр.с}} = V_{\text{жб}} \gamma_{\text{жб}} + N'_{\text{т.п}} + N'_{\text{о.ч}} \quad (3.11)$$

$$N'_{\text{пр.с}} = P_{\text{м}} l_{\text{п}} + N'_{\text{т.п}} + N'_{\text{о.ч}} \quad (3.12);$$

$$\gamma_{\text{жб}} = 25 \text{ кН/м}^3 \quad (3.13)$$

$P_{\text{м}}$ - load from the weight of span metal kN / m

$N'_{\text{т.п}}$ - normative weight of bilateral sidewalks with handrails

$$N'_{\text{т.п}} = P_{\text{т.п}} + l_{\text{п}} \quad (3.14)$$

$P_{\text{т.п}} = 5 \text{ кН/м}$ - the load from the weight of sidewalks with handrails.

$N'_{\text{о.ч}}$ - design weight of the set of support parts, kN, taken according to Table 3.1.1

Table 3.1.1

Design weight of the support set

$l_{\text{п}}, \text{ м}$	9.3-11.5	13.5-16.5	18.7	23.6-27.6	34.2
$N'_{\text{о.ч}}, \text{ кН}$	11	12	20	24	32
$,374 \text{ б} \times 4 h_{\text{о.ч}}, \text{ см}$	20	22	38.4	50.5	55.4
$h_{\text{м.п}}, \text{ см}$	10	11	25	27.5	39

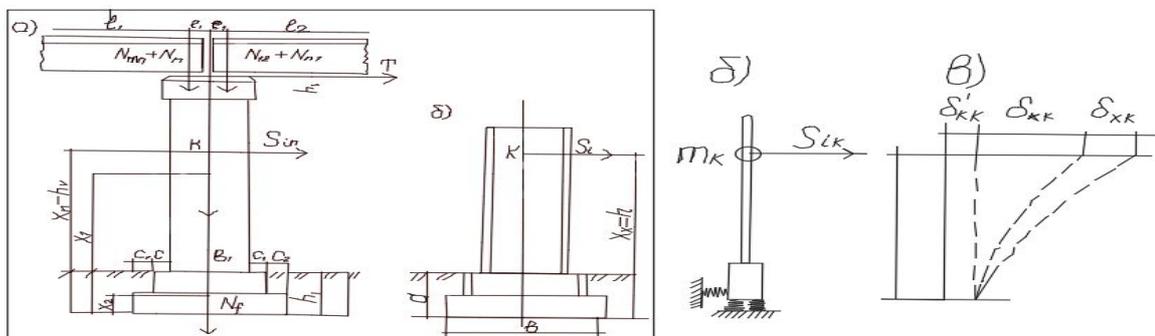


Figure 3.1.6 Calculation schemes for determining the seismic load directed along the axis of the overpass (bridge)

3.2. Basic equations of motion of support of bridges in earthquakes

Calculation of the intermediate support (appendix)

Collecting loads

Constant loads

1. The weight of the span structure is 23.6 m long: (3.15)

$$P_n = 82.9 * 10 = 829.0 \text{ts}; \text{ For } g_f > 1, P_{1p} = 829.0 * 1.1 = 911.9 \text{ mc} \quad (3.16)$$

Weight drainage pipe:

$$P_H = 0,3232 * 10 = 3,232 \text{ tc}; \text{ At } g_f > 1 P_{1p} = 3,232 * 1,1 = 3,5552 \text{ tons.} \quad (3.17)$$

Weight of reinforced concrete slabs:

$$P_H = 1,57 * 2,5 * 10 = 39,25 \text{ tc}; \text{ At } g_f > 1 P_{1p} = 39.25 * 1.1 = 43.175 \text{ tf.} \quad (3.18)$$

Weight reinforcement of paving slabs:

$$P_H = 0.211 \text{ tf}; \text{ For } g_f > 1, P_{1p} = 0.211 * 1.1 = 0.2321 \text{ tons.} \quad (3.19)$$

Weight of reinforced monochrome iris diaphragm B30

$$P_n = 0.14 * 2.5 * 10 = 3.5 \text{c at } g_f > 1.1 P_{1p} = 3.5 * 1.1 = 3.85 \text{ tf} \quad (3.20)$$

Weight of the beams:

$$P_n = 0.06 * 2.5 * 10 + 0.1406 * 10 = 2.906 \text{ts for } g_f > 1.1 P_{1p} = 3.1966 \text{ tf} \quad (3.21)$$

Weight of metal sheet overlapping the seam and metal railing

$$P_n = (0.2778 + 1.2355) * 10 = 15.133 \text{c for } g_f > 1.1 P_{1p} = 15.133 \text{ tf} \quad (3.22)$$

$$\text{The total weight of the span structure: } P_H = 893,232 \text{ tc} \quad (3.23)$$

At $g_f > 1,1 P_{1p} = 982,5552 \text{ tons.}$

The reference reaction from the intrinsic weight of the SS $L = 23.6 \text{ m}$

$A_n = 446.616 \text{ tons. } A_p = 491.2776 \text{ tf}$

Temporary loads

Vertical temporary load on one span

The reference reaction from the weight of the mobile load to p.s. $L = 23.6$ m on [52 p2.12] - Bridges and pipes and [47] - Loads and impacts

$V = 0,1 \times K = 0,1 \times 14 = 1,4$ tc / m, where $K = 14$ -class load

1) Normative reference reaction from a uniformly distributed load with 2 lanes:

The total reference response from a uniformly distributed load:

$$\Sigma A_{1H} = 16,8 + 10,08 = 26,88 \text{ tc}$$

2) Normative reference reaction from trolleys:

$$A_{2n} = (P + a / \lambda_p * P) * n = K * (1 + a / \lambda_p) * n = 14 \times (1 + 22,5/24) \times 2 = 54.25 \text{ tc.}$$

The total normative reference reaction:

$$A_n = A_{1H} + A_{2H} = 26,88 + 54,25 = 81,13 \text{ tc.}$$

Coefficient of reliability at $\lambda_p = 23,3$ m:

$G_f = 1,2$ - for uniformly distributed load;

$G_f = 1,267$ - for the trolley;

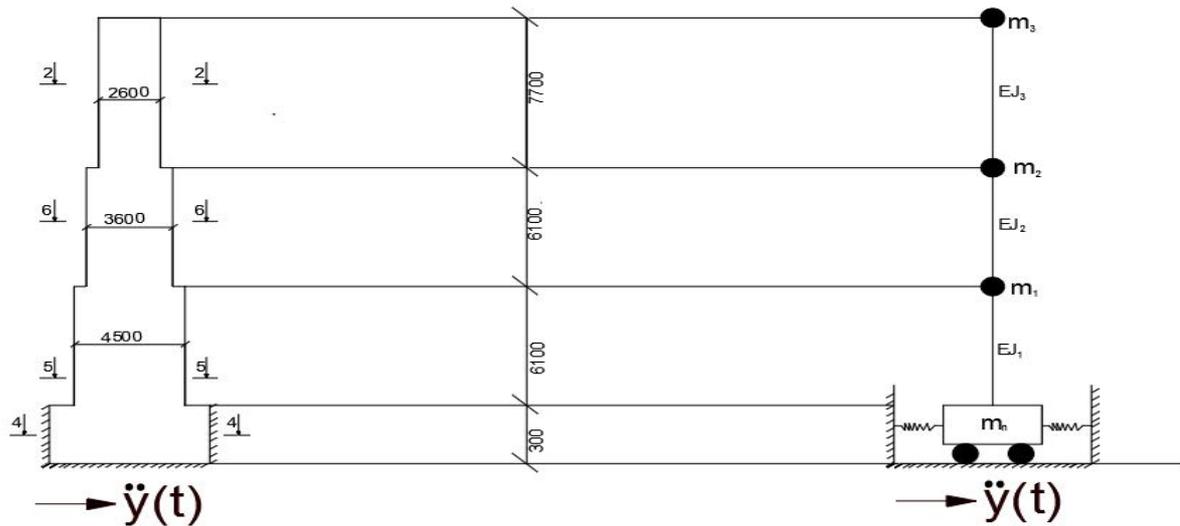
Dynamic coefficient:

$$1 + m = 1 + (45 - \lambda) / 135 = 1.16$$

The total calculated reference reaction from the uniformly distributed load and from the trucks:

$$A_p = A_{1p} + A_{2p} = (26.88 * 1.2 + 54.25 * 1.267) * 1.16 = 117.15 \text{ tons.}$$

Without a dynamic coefficient, $A_{pL} = 24 = 101.0$ tf



Calculation scheme of bridge supports of stepped cross section taking into account their interaction with the base mn-Moments of inertia

$$J_1 = \frac{4 \cdot 4.5^3}{12} = 30.375 \text{ M}^4$$

$$J_2 = \frac{3.6 \cdot 3.6^3}{12} = 13.99 \text{ M}^4 \quad (3.24)$$

$$J_3 = \frac{3 \cdot 2.6^3}{12} = 4.39 \text{ M}^4$$

Sectional areas

$$F_1 = 8 \text{ M}^2 = 18 \cdot 10^4 \text{ CM}^2$$

$$F_2 = 12,96 \text{ M}^2 = 12,96 \cdot 10^4 \text{ CM}^2 \quad (3.25)$$

$$F_3 = 7,8 \text{ M}^2 = 7,8 \cdot 10^4 \text{ CM}^2$$

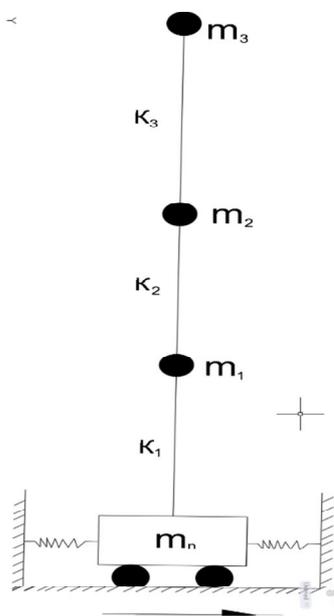
Modulus of elasticity of the support material (concrete)

$$E = 0,26 \cdot 10^6 \frac{\text{KГ}}{\text{CM}^2} \quad (3.26)$$

Poisson's ratio

$$\mu = 0,25 \quad (3.27)$$

Shear modulus



$$G = \frac{E}{2(1+\mu)} = 0.104 \text{ кгс /см}^2 \quad (3.28)$$

Weight of steps

$$m_n = (8.1 * 8.6 * 1.5 + 6.3 * 6.3 * 1.5) * 2000 \frac{\text{кг}}{\text{м}^3} = (104,49 + 59,53) * 2000 \frac{\text{кг}}{\text{м}^3} = 328040 \text{ кг} \quad (3.29)$$

$$m_1 = 4 * 4,5 * 6,1 * 2000 = 219600 \text{ кг}$$

$$m_2 = 3,6 * 3,6 * 6,1 * 2000 \frac{\text{кг}}{\text{м}^3} = 158112 \text{ кг} \quad (3.30)$$

$$m_3 = 2,6 * 3 * 7,7 * 2000 \frac{\text{кг}}{\text{м}^3} = 120120 \text{ кг}$$

Gravity forces of support legs

$$\begin{cases} Q_1 = m_1 * g = 2196000 \text{ Н} \\ Q_2 = m_2 * g = 1581120 \text{ Н} \\ Q_3 = m_3 * g = 1201200 \text{ Н} \\ Q_n = m_n * g = 3280400 \text{ Н} \end{cases} \quad (3.31)$$

$$\begin{cases} m_n = 328.04 \frac{\text{кгс c}^2}{\text{см}}; m_1 = 219.6 \frac{\text{кгс c}^2}{\text{см}}; \\ m_2 = 158.112 \frac{\text{кгс c}^2}{\text{см}}; m_3 = 120.12 \frac{\text{кгс c}^2}{\text{см}} \end{cases} \quad (3.32)$$

$$m_n = 328040 \frac{\text{Н c}^2}{\text{м}}; m_1 = 219600 \frac{\text{Н c}^2}{\text{м}}; m_2 = 158112 \frac{\text{Н c}^2}{\text{м}}; m_3 = 120120 \frac{\text{Н c}^2}{\text{м}}; \quad (3.33)$$

Vibrational movements of three-stage cantilevered shears in shear

K1, K2, K3-Shear rigidity

Relative shear strain

$$\gamma = \frac{\Delta S}{a} \quad (3.34)$$

Here

ΔS - Linear displacement of shear area; A - Distance between shifting boundaries

Shear stress at shear

$$\tau = \gamma * G \quad (3.35)$$

G-Shear modulus

$$G = \frac{E}{2(1+\mu)}; \quad (3.36)$$

Where

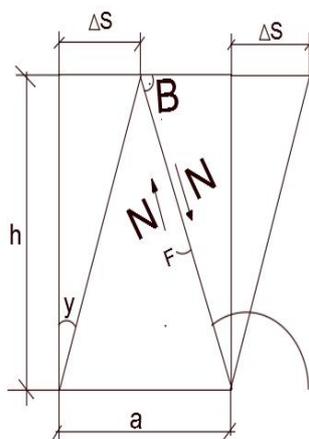
F-Sectional area under shear

N-cutting force

T-Horizontally acting seismic force. This force is proportional to the force of elasticity

$$N = T * \cos \beta \quad (3.37)$$

$$\frac{N}{F} = \tau - \text{Section stress} \quad (3.38)$$



$$\tau = \gamma * G \quad (3.39)$$

$$\frac{N}{F} = \gamma * G \quad (3.40)$$

$$\frac{T * \cos \beta}{F} = \frac{\Delta S}{a} * G \quad (3.41)$$

$$\frac{K * \Delta S * \cos \beta}{F} = \frac{\Delta S}{a} * G \quad (3.42)$$

$$K = \frac{F * G}{a \cos \beta} = \frac{F * G * \sqrt{h^2 + (a - \Delta S)^2}}{a(a - \Delta S)} \quad (3.43)$$

$$\cos \beta = \frac{(a - \Delta S)}{\sqrt{h^2 + (a - \Delta S)^2}} \quad (3.44)$$

Stiffness in the shift of each stage in the following form

Crosscut sections

$$F_1 = 7.58 * 4 = 30.32 \text{ M}^2$$

$$F_2 = 7.1 * 3.6 = 25.56 \text{ M}^2 \quad (3.45)$$

$$F_3 = 8.1 * 3 = 24.3 \text{ M}^2$$

$$a_1 = 4.5 \text{ M}; a_2 = 3.6 \text{ M}; a_3 = 2.6 \text{ M} \quad (3.46)$$

$$h_1 = 6.1 \text{ M}; h_2 = 6.1 \text{ M}; h_3 = 7.7 \text{ M} \quad (3.47)$$

$$l_1 = \sqrt{6.1^2 + 4.5^2} = 7.58 \text{ M}$$

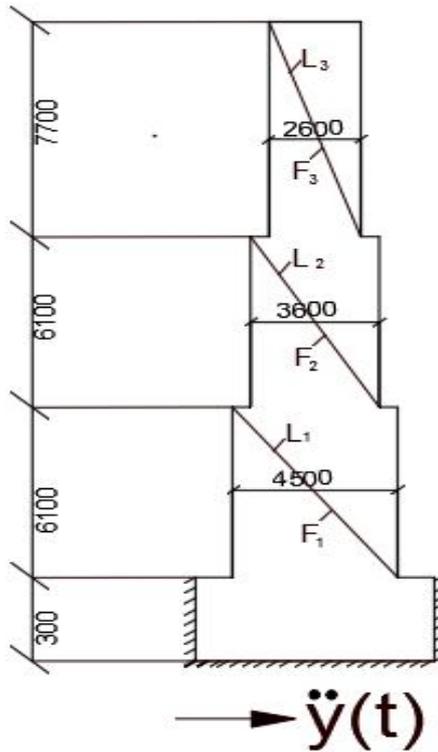
$$l_2 = \sqrt{6.1^2 + 3.6^2} = 7.1 \text{ M} \quad (3.48)$$

$$l_3 = \sqrt{7.7^2 + 2.6^2} = 8.1 \text{ M}$$

$$K_1 = \frac{F_1 * G \sqrt{(a_1 - (y_1 - y_n))^2 + h_1^2}}{a_1(a_1 - (y_1 - y_n))}$$

$$K_2 = \frac{F_2 * G \sqrt{(a_2 - (y_2 - y_1))^2 + h_2^2}}{a_2(a_2 - (y_2 - y_1))} \quad (3.49)$$

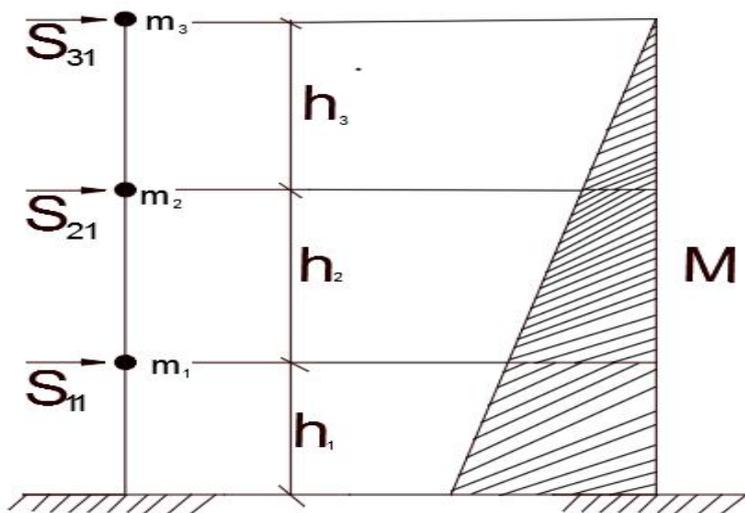
$$K_3 = \frac{F_3 * G \sqrt{(a_3 - (y_3 - y_2))^2 + h_3^2}}{a_3(a_3 - (y_3 - y_2))}$$



The equation of oscillatory motion of a single-stage cantilever rod under shear

$$\begin{cases} -K_1(y_n - y_1) - R = m_n(\ddot{y}_0 + \ddot{y}_n) \\ K_1(y_n - y_1) - K_2(y_1 - y_2) = m_1(\ddot{y}_0 + \ddot{y}_1) \\ K_2(y_1 - y_2) - K_3(y_2 - y_3) = m_2(\ddot{y}_0 + \ddot{y}_2) \\ K_3(y_2 - y_3) = m_3(\ddot{y}_0 + \ddot{y}_3) \end{cases} \quad (3.50)$$

Where - y_1, y_2, y_3 are the time displacements



Seismic action of the stepped support

$$S_{i\rho} = m_i * \rho_i^2 * y_i \quad (3.51)$$

y_i -move the step; ρ_i -frequency (on the console); m_i - steps mass

y_i - displacement $R=k_x y_n$

$$S_{31}h_3$$

$$S_{31}(h_3 + h_2) + S_{21}h_2 \quad (3.52)$$

$$S_{31}(h_3 + h_2 + h_1) + S_{21}(h_1 + h_2) + S_{11}h_1$$

$$\sigma = \frac{M_{max}}{W} \leq [\sigma]; \quad (3.53)$$

$$W = \frac{J}{h_0}; \quad (3.54)$$

$$W = J / h_0;$$

Oscillation of three-stage bridge supports in bending.

The equations of oscillations in bending.

$$\begin{cases} -R = m_n(\ddot{y}_0 + \ddot{y}_n) \\ y_1 - y_n = -\delta_{11}m_1(\ddot{y}_0 + \ddot{y}_1) - \delta_{12}m_2(\ddot{y}_0 + \ddot{y}_2) - \delta_{13}m_3(\ddot{y}_0 + \ddot{y}_3) \\ y_2 - y_n = -\delta_{21}m_1(\ddot{y}_0 + \ddot{y}_1) - \delta_{22}m_2(\ddot{y}_0 + \ddot{y}_2) - \delta_{23}m_3(\ddot{y}_0 + \ddot{y}_3) \\ y_3 - y_n = -\delta_{31}m_1(\ddot{y}_0 + \ddot{y}_1) - \delta_{32}m_2(\ddot{y}_0 + \ddot{y}_2) - \delta_{33}m_3(\ddot{y}_0 + \ddot{y}_3) \end{cases} \quad (3.55)$$

The displacement of bridge supports under dynamic influences is determined by the Simpson formula.

$$\delta_{ii} = \frac{l}{6EJ}(a_1a_2 + 4b_1b_2 + c_1c_2) \quad (3.56)$$

Determine the force of interaction of the foundations of the support with the surrounding soil

$$R = k_x * y_n \quad (3.57)$$

$$k_x = C_x F_n + C_x F_\delta + C_z F_{СИК,ТОМОН} \quad (3.58)$$

$$C_x = 0.7C_z \quad (3.59)$$

Where

y_n - moving foundations relative to the ground

C_z - compressive elastic soil coefficient $2 \div 7 \text{ kgf} / \text{cm}^2$

F_n -The foundation area of the foundations of the Yuzaki

F_δ -Area of the side of the foundation

$F_{push.side}$ -compressible foundation area

If the design resistance of the soil (loam) is $2 \text{ kg} / \text{sm}^2$, $C_z = 4000 \text{ tf} / \text{m}^3$

$$k_x = C_z(0,7a_nb_n + 0,7 * 2 * h_na_n + h_nb_n) \quad (3.60)$$

$$a_n = 8,6 \text{ m}$$

$$b_n = 8,1 \text{ m} \quad (3.61)$$

$$h_n = 1,5 \text{ m}$$

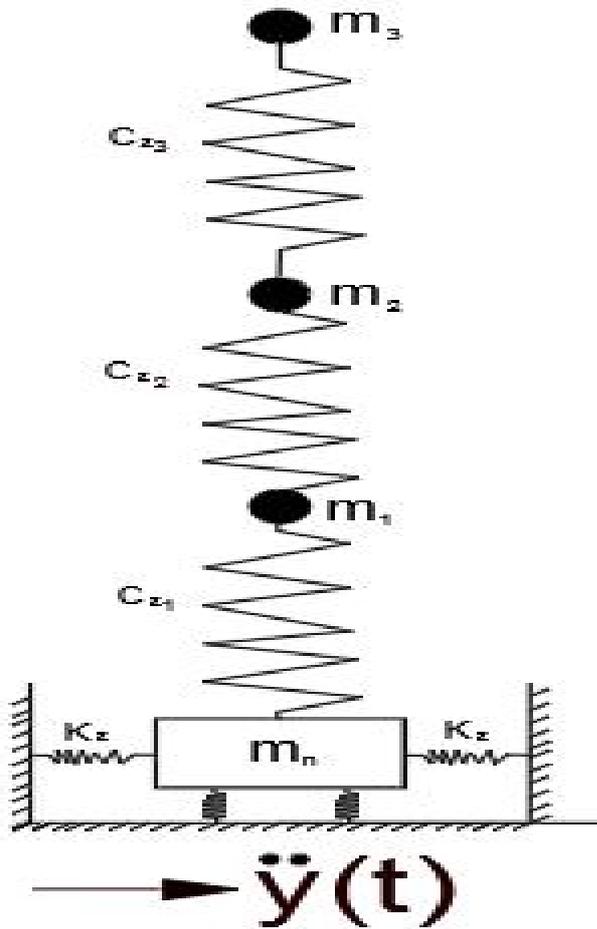
$$\begin{aligned} k_x &= 4000(0,7 * 8,6 * 8,1 + 0,7 * 2(1,5 * 8,1 + 1,5 * 6,3) + (1,5 * 8,6 + 1,5 * \\ &6,3)) = 4000(48,672 + 1,4(12,15 + 9,45) + (12,9 + 9,45)) = \\ &4000(48,672 + 30,24 + 22,35) = 405048 \end{aligned} \quad (3.62)$$

$$k_x = 4,05 * 10^7 \text{ N/sm} \quad (3.63)$$

From the equation, we calculate the intermixings using the Simpson formula

$$\begin{aligned} \delta_{11} &= \frac{6.1 * 10^2}{6 * 0.26 * 10^6 * 30.375 * 10^8} (3.05 * 3.05 * 10^4 * 4 + 6.1 * 6.1 * 10^4) \\ &= 9.58 * 10^{-9} \text{ sm} / \text{N} \end{aligned} \quad (3.64)$$

$$\begin{aligned} \delta_{12} &= \frac{6.1 * 10^2}{6 * 0.26 * 10^6 * 30.375 * 10^8} (0 * 0.61 * 10^2 + 4 * 3.05 * 9.15 * 10^4 + 6.1 * 12.2 * 10^4) \\ &= 2.39 * 10^{-8} \text{ sm} / \text{N} \end{aligned} \quad (3.65)$$



$$\delta_{13} = \frac{6.1 \cdot 10^2}{6 \cdot 0.26 \cdot 10^6 \cdot 30.375 \cdot 10^8} (0 \cdot 13.8 \cdot 10^2 + 4 \cdot 3.05 \cdot 16.85 \cdot 10^4 + 6.1 \cdot 19.9 \cdot 10^4) \quad (3.66)$$

$$= 4.21 \cdot 10^{-8} \text{ sm / N}$$

$$\delta_{22} = \frac{6.1 \cdot 10^2}{6 \cdot 0.26 \cdot 10^6 \cdot 13.99 \cdot 10^8} (3.05 \cdot 3.05 \cdot 10^4 \cdot 4 + 6.1 \cdot 6.1 \cdot 10^4) +$$

$$+ \frac{6.1 \cdot 10^2}{6 \cdot 0.26 \cdot 10^6 \cdot 30.375 \cdot 10^8} (6.1 \cdot 6.1 \cdot 10^4 + 4 \cdot 9.15 \cdot 9.15 \cdot 10^4 + 12.2 \cdot 12.2 \cdot 10^4) = \quad (3.67)$$

$$= 8.78 \cdot 10^{-8} \text{ sm / N}$$

$$\delta_{23} = \frac{6.1 \cdot 10^2}{6 \cdot 0.26 \cdot 10^6 \cdot 30.375 \cdot 10^8} (0 \cdot 7.7 \cdot 10^2 + 4 \cdot 3.05 \cdot 10.75 \cdot 10^4 + 6.1 \cdot 13.8 \cdot 10^4) +$$

$$+ \frac{6.1 \cdot 10^2}{6 \cdot 0.26 \cdot 10^6 \cdot 30.375 \cdot 10^8} (6.1 \cdot 13.6 \cdot 10^4 + 4 \cdot 9.15 \cdot 16.85 \cdot 10^4 + 12.2 \cdot 19.9 \cdot 10^4) \quad (3.68)$$

$$= 1.81 \cdot 10^{-7}$$

$$\begin{aligned}
\delta_{33} &= \frac{7.7 * 10^2}{6 * 0.26 * 10^6 * 4.39 * 10^8} (4 * 3.85 * 3.85 * 10^4 + 7.7 * 7.7 * 10^4) + \\
&+ \frac{6.1 * 10^2}{6 * 0.26 * 10^6 * 13.99 * 10^8} (7.7 * 7.7 * 10^4 + 4 * 1075 * 10.75 * 10^4 + 13.6 * 13.6 * 10^4) * \\
&\frac{6.1 * 10^2}{6 * 0.26 * 10^6 * 30.375 * 10^8} (13.6 * 13.6 * 10^4 + 4 * 16.85 * 16.85 * 10^4 + 19.9 * 19.9 * 10^4) = \\
&= 5 * 10^{-7}
\end{aligned} \quad (3.69)$$

Equations of the vertical oscillatory motion of a three-stage cantilever rod.

The equations of the vertical oscillatory dipping of a three-step cantilever rod

$$\begin{cases} -C_{Z_1}(Z_n - Z_1) - k_Z * Z_n = m_n(\ddot{Z}_0 + \ddot{Z}_n) \\ C_{Z_1}(Z_n - Z_1) - C_{Z_2}(Z_1 - Z_2) = m_1(\ddot{Z}_0 + \ddot{Z}_1) \\ C_{Z_2}(Z_1 - Z_2) - C_{Z_3}(Z_2 - Z_3) = m_2(\ddot{Z}_0 + \ddot{Z}_2) \\ C_{Z_3}(Z_2 - Z_3) = m_3(\ddot{Z}_0 + \ddot{Z}_3) \end{cases} \quad (3.70)$$

Solve equation (3.70) and determine C_{Zi}

$$(\ddot{y}_0(t) * 0,7) = \ddot{Z}_0(t) \quad (3.71)$$

$$C_Z = \frac{EF}{h} \quad (3.72)$$

$$C_{Z_1} = \frac{EF_1}{h_1} = \frac{0,26 * 10^6 * 18 * 10^4}{610} = 76,72 * 10^6 \frac{\text{KГC}}{\text{CM}}$$

$$C_{Z_2} = \frac{EF_2}{h_2} = \frac{0,26 * 10^6 * 12,96 * 10^4}{610} = 55,24 * 10^6 \frac{\text{KГC}}{\text{CM}} \quad (3.73)$$

$$C_{Z_3} = \frac{EF_3}{h_3} = \frac{0,26 * 10^6 * 7,8 * 10^4}{610} = 33,24 * 10^6 \frac{\text{KГC}}{\text{CM}}$$

Oscillations in the bending of a stepped support (hard base).

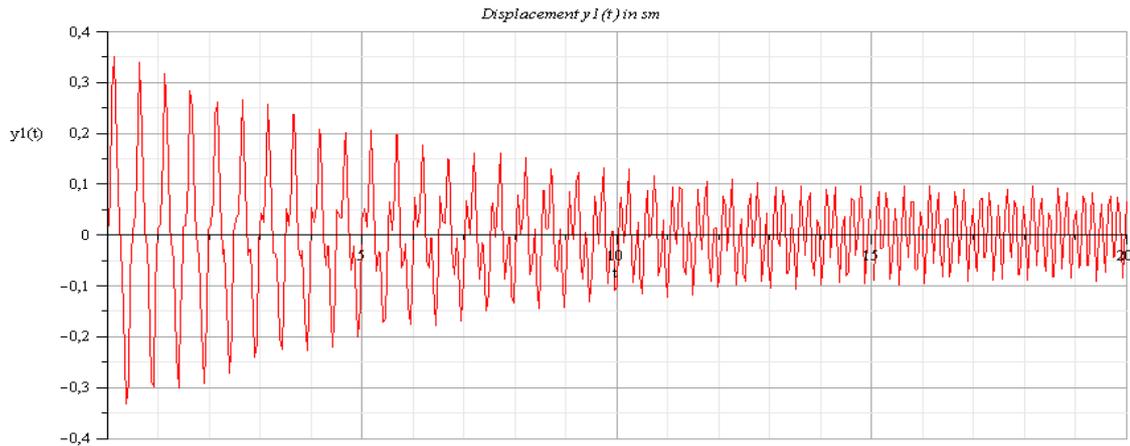


Fig. 3.2.1 Displacement the first floor (hard base).

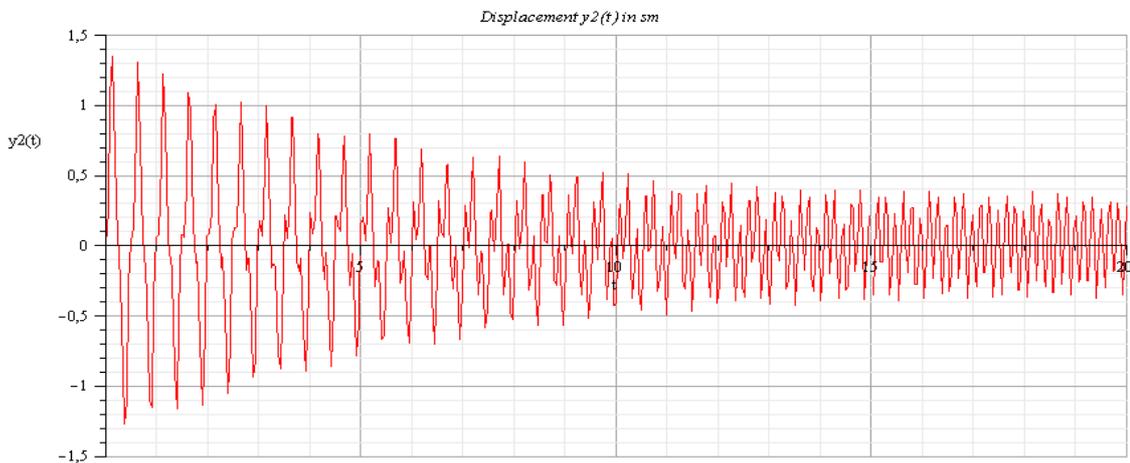


Fig. 3.2.2 Displacement the second floor (hard base).

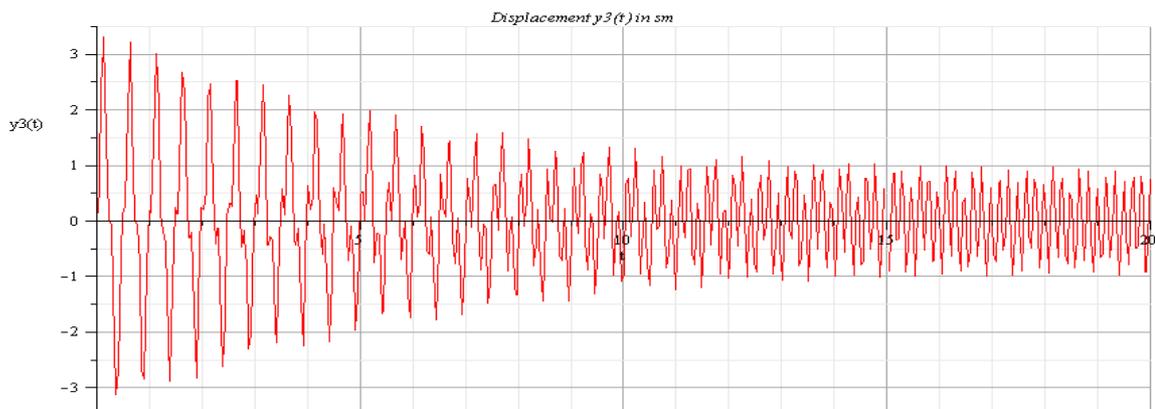


Fig. 3.2.3 Displacement the third floor (hard base).

Oscillations in the bending of a stepped column (elastic base).

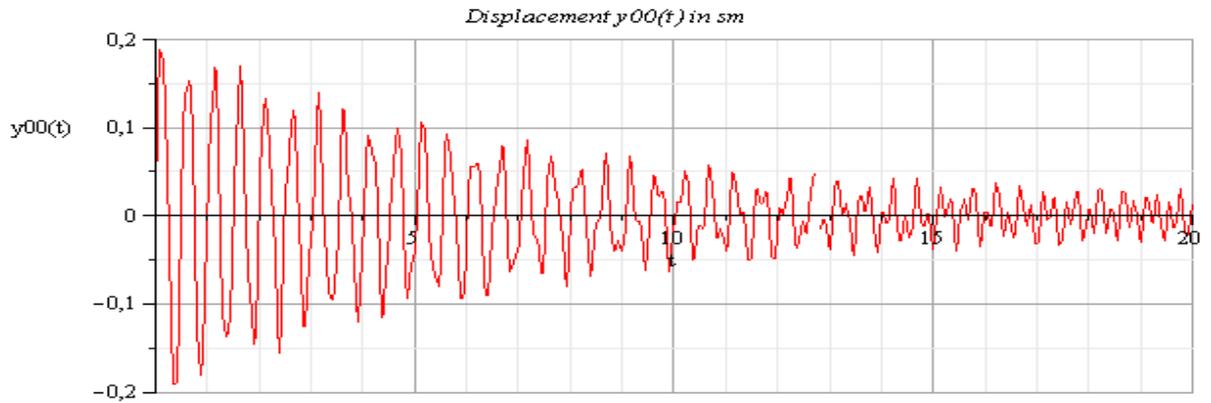


Fig 3.2.4 Displacement the third (elastic base)

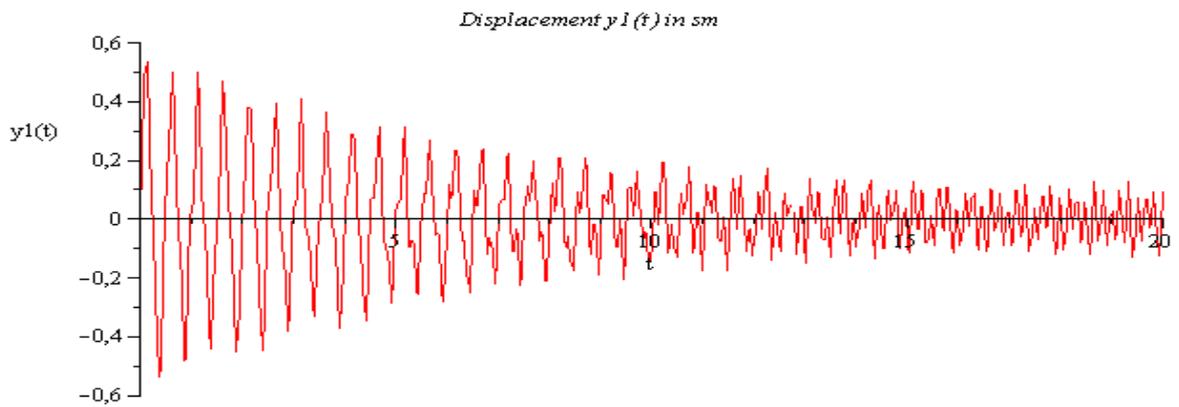


Fig. 3.2.5 Displacement the third floor (elastic base)

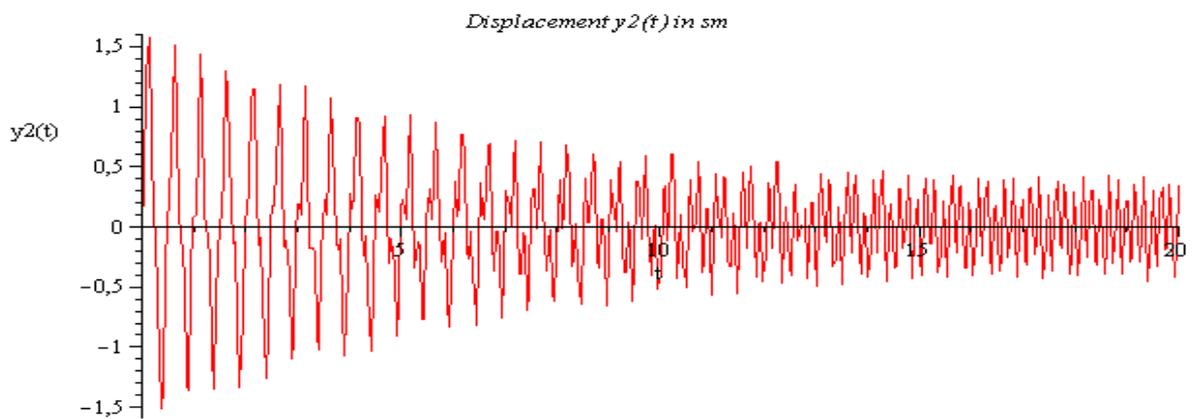


Fig. 3.2.6 Displacement the third floor (elastic base)

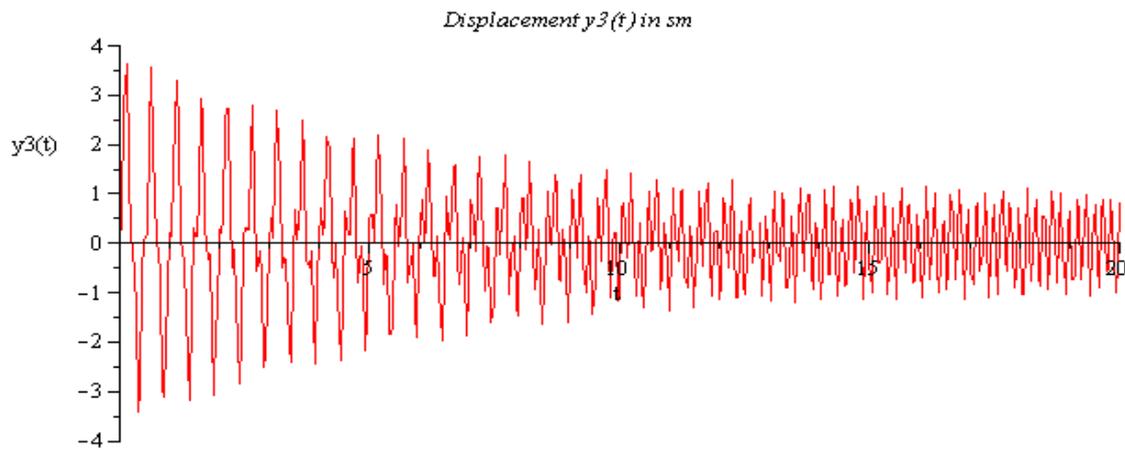


Fig. 3.2.7 Displacement the third floor (elastic base)

Oscillations in bending (in Fig.3.2.1-3.2.2-3.2.3). The displacement of the support stages in time is given. By results, it can be seen that a significant shift is observed at the highest part. Figures 3.2.4-3.2.5-3.2.6-3.2.7 show changes in the support of the stepped bridge of the elastic principle with respect to time. Based on the results obtained, it can be seen that the elastic base of the support bridge is relatively shortened, and the amplitude of the time fluctuates.

3.3. Influence of the observance of the support base of bridges and their influence on the frequency of oscillations

Reference specification and selection of the design scheme for a two-mass absorber.

At present, the volume of theoretical studies on the effectiveness of DVA in relation to bridges is very limited. Meanwhile, the use of DGC for the purpose of seismic protection of bridges has a number of specific features. One of them is that when used as a DHA, it is possible to increase the quenching mass of DHA. The mass of the span structure in most cases is comparable to the reduced mass of the support, and in some cases may exceed it by several times. In this connection, it becomes necessary to study the effect of such a significant increase in the quenching mass of DHA.

At the same time, the evaluation of the efficiency of DHA of any mass (small, commensurable and large) should be carried out by comparison with reference systems. The criterion of efficiency is the reduction in the support of seismic loads [61].

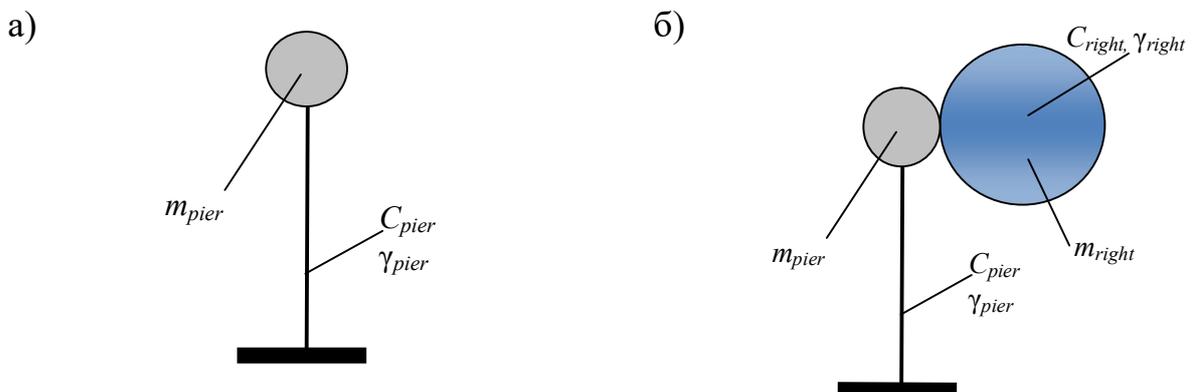
When studying the efficiency of dynamic absorbers of seismic vibrations in the bridge, the following DGA systems were considered as reference:

1. System without absorber, i.e., support without DHA (Figure 2.5, a).
2. A system in which the span structure is rigidly attached to the support (Figure 2.5, b).

As the system under investigation, a scheme with a dynamic absorber in the form of an additional mass, was connected with the support by an elastic coupling (Figure 2.5, c) was chosen.

System "b" is, in fact, similar to the first, with the difference that as the oscillating mass is the total mass of the support and the span structure, rigidly connected with each other.

To calculate the supports using DVA (system "B"), and two-mass system was adopted. In this case, one of the masses is the mass of DHA, and the other is the mass of the protected structure (supports). The design support schemes with DHA and without DHA are shown in Fig. 2.5.



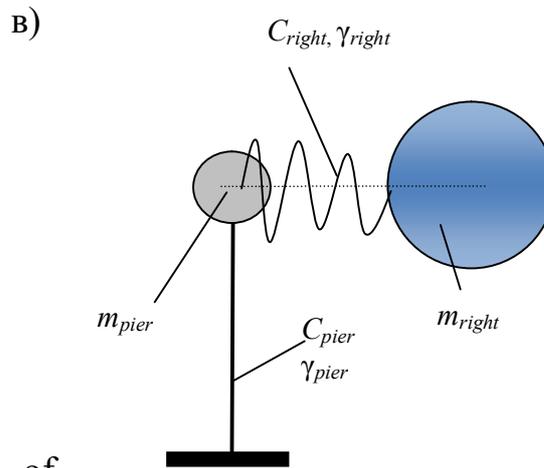


Fig. 2.5. Scheme of supports associated with a span structure:

A) system without absorber;

B) a system in which the absorber is rigidly attached to it, i.e. The mass of the system is increased by the amount of absorber mass;

C) a system with DHA, i.e. The span structure, connected with the support by an elastic connection.

On the basis of the above analyzes, the author in the next section of this chapter has carried out an investigation of the equations for the two-mass system given in (Figure 2.5, c) with the optimum tuning of the stiffnesses of the compliant DHA compounds.

Study of the equations of a two-mass system for the optimal adjustment of the stiffnesses of compliant DHA compounds.

In the first part of this chapter, we consider a two-mass system, shown in Fig. 2.6.

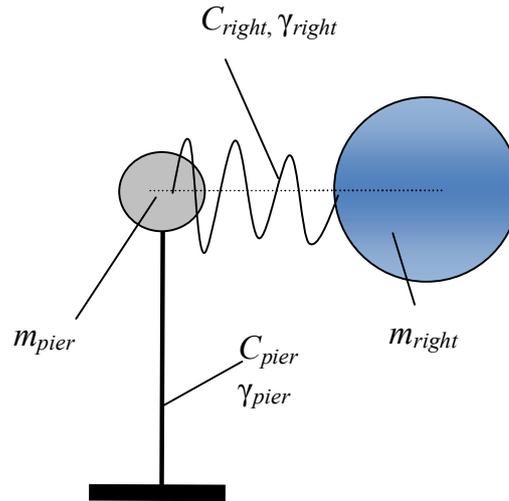


Fig. 2.6. The design scheme of a two-mass system

The proposed scheme lists the parameters:

C_{right} - the stiffness of the absorber (intermediate part);

C_{pier} - stiffness of the support (end part);

m_{right} - mass of absorber (intermediate part);

m_{pier} - mass of the support (end part);

γ_{right} - attenuation factor of the absorber (intermediate part);

γ_{pier} is the attenuation coefficient of the support (end part).

In the notation adopted, the diagonal matrix of the masses of the system takes the form

$$M = \begin{vmatrix} m_{right} & 0 \\ 0 & m_{pier} \end{vmatrix} \quad (3.74)$$

From the above scheme, we construct a rigidity matrix

$$R = \begin{vmatrix} C_{\text{right}} & -C_{\text{right}} \\ -C_{\text{right}} & C_{\text{right}} + C_{\text{pier}} \end{vmatrix} \quad (3.75)$$

We take the mass relations in the form

$$\mu = \frac{m_{\text{pier}}}{m_{\text{right}}} \quad (3.76)$$

Let's designate partial frequencies of oscillations of a support (an end part)

$$k_0 = \sqrt{\frac{C_{\text{pier}}}{m_{\text{pier}}}} \quad (3.77)$$

And the partial frequency of oscillations of the absorber of the intermediate part

$$k_2 = \sqrt{\frac{C_{\text{right}}}{m_{\text{right}}}} \quad (3.78)$$

The ratio of the eigenfrequencies of the fundamental pitch of the oscillations of the absorber and the support (the end part) is denoted in the form

$$f = \left(\frac{k_2}{k_0} \right) \quad (3.79)$$

In earthquake-proof construction, when analyzing real structures, it is necessary to take into account the damping parameters for each structural element. The most convenient method for constructing the equations of oscillations of multimass damped systems is the ES method. Sorokina.

To do this, consider the amplitude-frequency characteristics (AFC) of a seismically isolated system with allowance for damping [80].

The derivation of the equations of motion of the two-mass system under consideration is available in the courses of theoretical mechanics and seismic stability theory [23, 25, 38, 42, etc.]. In matrix form, the system of oscillation equations with damping takes the form

$$\mathbf{M}\dot{\mathbf{H}} + \mathbf{R}\mathbf{H} + \mathbf{B}\dot{\mathbf{H}} = -\mathbf{M}\ddot{\mathbf{Y}}_0, \quad (3.80)$$

Where $\mathbf{M} = \begin{bmatrix} m_1 & & \\ & m_2 & \\ & & \dots m_n \end{bmatrix}$ is the diagonal matrix of inertia,

$$\mathbf{R} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nn} \end{bmatrix} \quad \text{stiffness matrix; (3.81)}$$

$$\mathbf{B} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \quad (3.82)$$

- matrix of viscous damping of the system, made up of dissipation coefficients.

$\mathbf{H} = \{h_1, h_2, \dots, h_n\}$ is the vector of generalized coordinates;

$\dot{\mathbf{H}} = \{\dot{h}_1, \dot{h}_2, \dots, \dot{h}_n\}$ - vector of generalized velocities;

$$\ddot{\mathbf{y}}_0 - \text{vector of kinematic perturbations, } \ddot{\mathbf{y}}_0 = V_p \cdot \ddot{y}_0 \quad (3.83)$$

\ddot{y}_0 - acceleration of the base;

$V_p = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ - the vector of the projections of the effects on the directions of generalized coordinates.

Certain difficulties in the construction of the system (3.82) cause the determination of the damping coefficients.

The basis for determining the coefficients of damping is the generalized hypothesis of E.C. Sorokin, according to which the forces of resistance are proportional to the rigidity of the elements of the system. In accordance with the hypothesis of E.S. Sorokin's forces of resistance F_i , acting on the mass m_i , are represented as:

$$F_i = \sum_{j=1}^n b_{ij}^{(c)} y_j^* = \sum_{j=1}^n c_{ij} \gamma_{ij} y_j^* \quad (3.84)$$

Here are the damping coefficients according to E.C. Sorokin,

$b_{ij}^{(c)}$ - coefficient of inelastic resistance in the element connecting masses m_i and m_j ;

y_j^* Is a function conjugate to y_j [23, 25].

The problem of taking damping into account is that the hypothesis of E.S. Sorokin makes it easy to form a damping matrix B_c . This matrix is constructed in exactly the same way as the rigidity matrix with the replacement of the rigidity of the elements c_{ij} by the products $c_{ij} \square_{ij}$. However, the analysis of the equations of oscillations in the form of E.S. Sorokina causes difficulties of a fundamental nature [37].

The basis of this method is the hypothesis of the proportionality of the stiffness matrix and the hysteresis damping matrix B_c :

$$\mathbf{B}_c = \gamma \mathbf{R}, \quad (3.85)$$

For a two-mass system, we write formula (2.14) as follows

$$\mathbf{B}_c = \begin{pmatrix} C_{\text{right}} \cdot \gamma_z & -C_{\text{right}} \cdot \gamma_z \\ -C_{\text{right}} \cdot \gamma_z & C_{\text{right}} \cdot \gamma_z + C_{\text{pier}} \cdot \gamma \end{pmatrix} \quad (3.86)$$

Where, c and C are respectively the stiffnesses of the absorber and the supports with the coefficients of the inelastic resistance of the absorber and the support - u .

The solution of equation (2.11) has the form:

$$\mathbf{H} = \mathbf{a}_c \cos \omega t + \mathbf{a}_s \sin \omega t \quad (3.87)$$

To assess the effect of tuning inaccuracies on the performance of the absorber, the amplitude-frequency characteristics (AFC) of the oscillations of the span structure and the support were investigated. The AFCs were constructed by known methods using formulas

The amplitude of the oscillations was calculated from

$$U_s(\omega) = \sqrt{\mathbf{a}_s(\omega)^2 + \mathbf{a}_c(\omega)^2} \quad (3.88)$$

Where a_c and a_s are the desired amplitude vectors, respectively, with cosine and sine,

$$\mathbf{a}_s = \left[(\mathbf{R} - \mathbf{M} \cdot \omega^2) \cdot \mathbf{B}_c^{-1} \cdot (\mathbf{R} - \mathbf{M} \cdot \omega^2) + \mathbf{B}_c \right]^{-1} \cdot \mathbf{M} \cdot V_p \cdot A \cdot g \quad (3.89)$$

$$\mathbf{a}_c = (\mathbf{R} - \mathbf{M} \cdot \omega^2)^{-1} \cdot \mathbf{B}_c \cdot \mathbf{a}_s \quad (390)$$

\mathbf{R} , \mathbf{M} , and \mathbf{B}_c are, respectively, the stiffness, inertia, and damping matrices for the system under consideration.

3.4. Application of ANSYS to calculate three-stage bridge supports for seismic actions

At present, in analyzing structures and their elements, in addition to the traditional problem of determining the stress-strain state, problems of determining the resource of structures are increasingly being considered [54, 55]. One of the issues that need to be studied is the issue of conditions for the destruction of structures. To date, in the numerical methods for solving the problem of mechanics of a deformed solid, two basic approaches to solving this problem develop. The first approach is the modeling of the development of defects (pores, cracks, etc.), taking into account the change in boundary conditions in the structural element in question and the reconstruction of the grid with a change in the size of the defect [56-61]. The second approach is to assess the degree of material damage in structural elements, provided that defects and their growth are not explicitly considered [62-65]. According to the publications devoted to the application of the first approach [57, 66-67], this approach is individual for each specific problem and leads to writing of own software or macros in existing finite element analysis systems (ANSYS, NASTRAN, etc.). Its application requires from the user the level of knowledge of a research scientist who has experience

in the numerical modeling of problems of crack growth. The second approach does not allow for

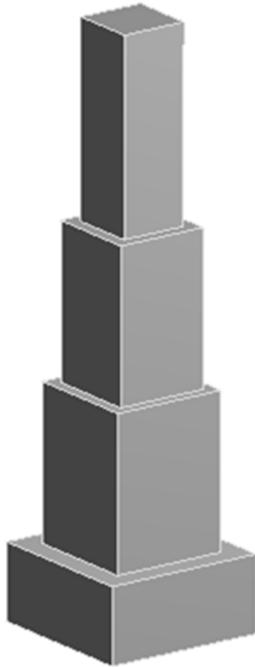


Fig. 3.4.1 General view of the simulated system

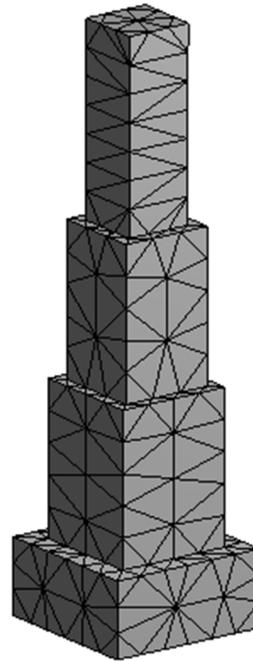


Fig. 3.4.2. Scheme of a 3-dimensional rod end element

The three-stage support is modeled in the form of a console, i.e. The lower side of the support is rigidly fixed (Figure 3.4.3).

In the calculations, the following values of the loads were adopted (Figure 3.4.4.):

- the weight of the support structures, in accordance with the assigned types of stiffness (according to the accepted geometric characteristics of the cross sections and the density of the material);
- temporary uniformly distributed linear load;
- seismic alternating load with concentrated masses (including own weight of structures) collected from the relevant cargo areas.

$$F = 96452 \text{ N}$$

$$A = 2 \text{ m / s}^2$$

B: Static Structural
Fixed Support
Time: 1, s

■ Fixed Support

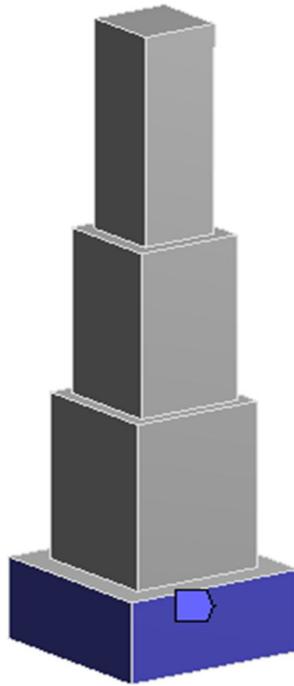


Fig. 3.4.4. The general load of the bridge support

B: Static Structural
Force
Time: 1, s

■ Force: 96452 N
Components: 0,;0,;-96452 N

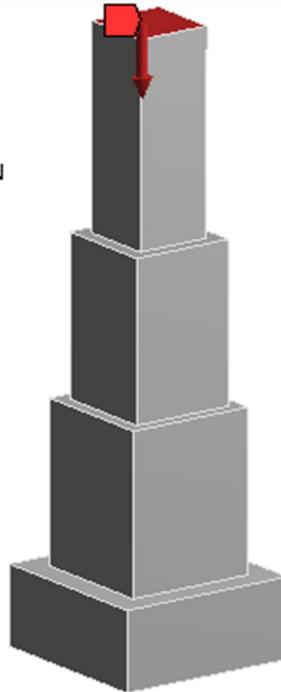


Fig. 3.4.4. The general load of the bridge support

As a result of the calculation of the system, the data on the processing of dynamic (seismic) effects, deformation (displacements in Figure 3.4.5), stresses (p. 6) in the elements of the system, the calculated combinations of forces in the

elements along the sections, according to the accepted geometric dimensions, And types of rigidity (Figure 3.4.5-3.4.6).

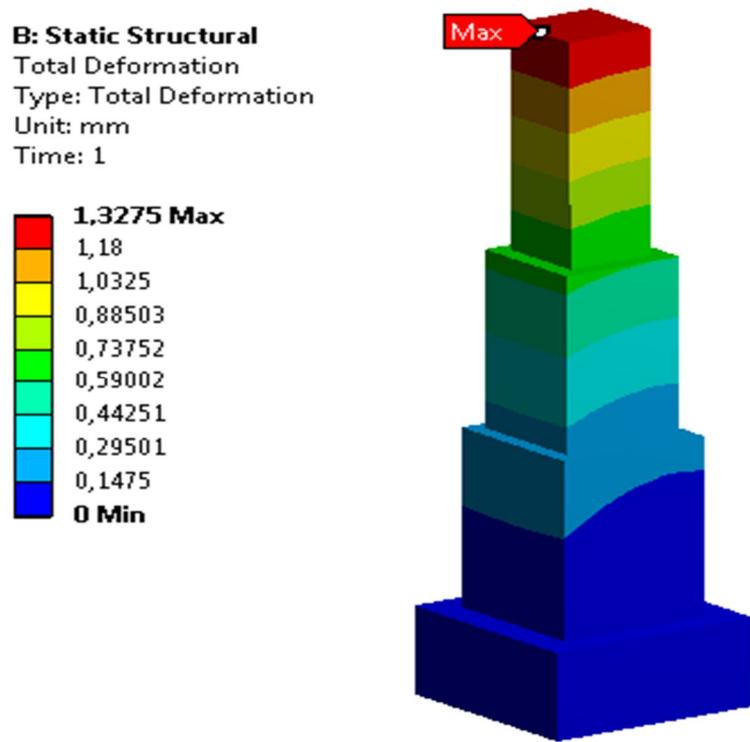


Fig. 3.4.5. Changing the deformation of the bridge support.

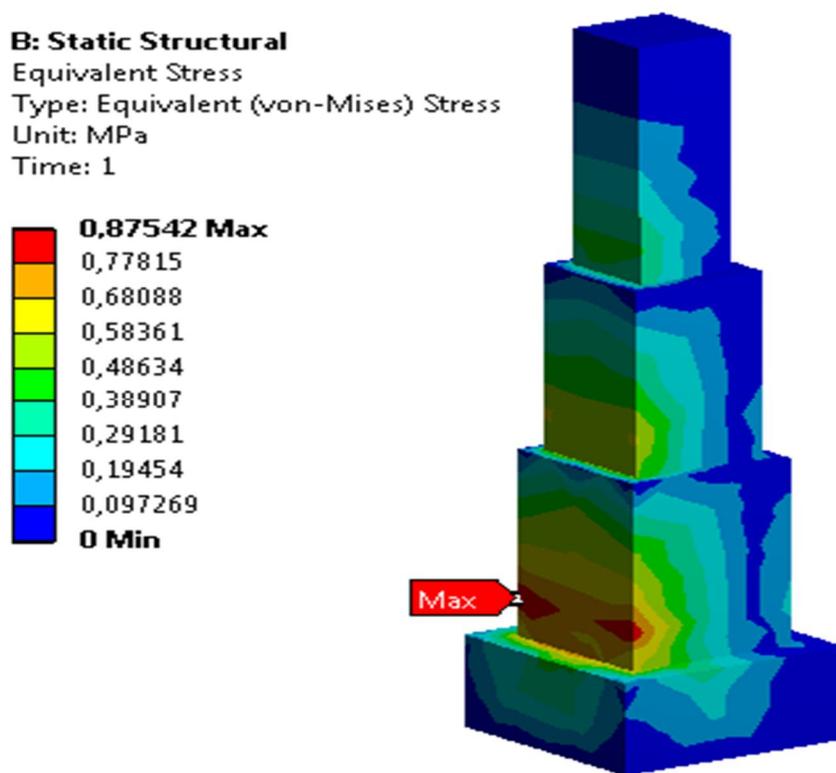


Fig. 3.4.6. Change in bridge support stresses

It can be seen from the figures that the deformation is higher from above, and the maximum stress is reached at the bottom.

3.5. Conclusions on the chapter

1. The obtained estimates make it possible to significantly simplify the task of designing seismic protection devices for bridges, since they give the designer a wide opportunity in choosing the dimensions and rigidity of the designed elements of seismic protection devices.
2. An investigation of this chapter considered a two-mass system with rigid fixation of the end part (at the end). It should be noted that its solution is recommended for the case when the bridge is located in a steep gorge, the intermediate supports are high and flexible, and the end supports are rather rigid. This decision has, of course, scientific novelty.
3. Using ANSYS, the stress-strain state of the three-stage bridge support was studied, the distribution of deformations and stresses in the support was obtained. This solution can be not only effective, but the only possible way, because, as a result, with increasing rigidity, strength increases,

Conclusion

In our country, special attention is paid to the development of transport infrastructure, roads and railways, which ensure Uzbekistan's access to the world market. As is known, the territory of the Republic of Uzbekistan is a seismically dangerous zone, therefore, taking into account the modern growth of traffic flow, bridge structures should develop accordingly.

In the thesis, a detailed analysis of the past strong earthquakes of the CIS countries and foreign countries is made, special attention is focused on earthquakes of recent years, such as earthquakes in Uzbekistan, CIS and far abroad countries. The most important aspects and factors influencing the seismic stability of bridge structures have been determined in the aftermath of earthquakes, and typical damage is established on the basis of these materials in the most vulnerable places of the bridge. It was revealed that the most vulnerable part of the bridge is a support, in connection with this the thesis is devoted to the calculation of the support of road bridges under seismic loads.

The materials of the last World Conference on Earthquake Engineering were studied. The analysis of materials on the support of bridges under the influence of strong earthquakes on them is made.

Specific tasks are being solved. Stress-strain states of stepped bridge supports under linear interaction with the soil are investigated. Dangerous points of occurrence of the maximum normal voltage are determined when seismic loads are applied to the bridge supports.

The results obtained are a natural development of the seismodynamic theory of bridge structures and can be used by designers and engineers of bridge structures as raw materials. In addition, the development of the theory of seismic resistance of bridge structures, and ensuring the seismic safety of life support systems - is certainly relevant for our country, and carrying out preventive work on the safety of the operation of transport facilities will ensure the safety of the population and the preservation of material values.

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