Saimaa University of Applied Sciences

Technology, Lappeenranta

Double Degree Programme in Civil and Construction Engineering

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Comparison of Russian norms (SNiPs) and European norms (Eurocodes) for road and railway bridges

Bachelor’s thesis 2012

ABSTRACT

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Saimaa University of Applied Sciences, Lappeenranta
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The main purpose of the study was to learn Russian and European building norms. Russian building norms are presented as SNiPs and European as Eurocodes, National Annexes and NCCI-series. The main reason for this study was to learn what are the main differences between Russian and European norms in the field of bridge engineering. The working process was organized with the help of Liikennevirasto.

In the theoretical part of the study the main issue was to learn the norms and to find out the main differences between the two types. Also, there was some calculation to see the differences. The information for the thesis was collected from different books, web links, by interviewing, but most of the information was taken from building norms SNiPs and Eurocodes in bridge engineering.

The results of the study show that there are big differences between Russian and European norms. At the end of the working process the table of safety factors was made. In short, there are differences between systems of norms in general, between calculation methods, the values of different parameters. The analyzes of the summary table and all the chapters confirm these differences.

Keywords: building codes, Eurocodes, SNiPs, bridge engineering, loads, traffic loads and safety factors.

CONTENTS

1 INTRODUCTION

Each country has its own norms for designing and constructing the different kinds of bridge structures. The main differences between building codes in Finland and in Russia will be described in this bachelor's thesis. The building codes used in Finland are Eurocodes, National Annexes and NCCI – series and in Russia SNiPs and GOSTs. So, the main goal of the thesis is to find out the main differences between Russian and European building norms concerning bridges.

The thesis is made for the organization Liikennevirasto. This is the Finnish Transport Agency. It is a government agency operating under the Ministry of Transport and Communications. It is responsible for maintaining and developing the standard of service in the transport system's traffic lanes overseen by the government. The main goals of this agency are:

- to promote the efficient functioning of the traffic system as a whole
- to improve transport safety
- to contribute to a balanced and sustainable development of the regions.

This study was chosen because of its relevance. These two countries, Finland and Russia, are situated very close to each other. That is why it is very important and useful to have global co-operation between these two countries. It is a good opportunity to exchange ideas, new technologies, new solutions of different problems and experience in building bridges for both, Russia and Finland. But for these reasons it is necessary to know what the main differences between their building codes are. Liikennevirasto is not an exception. It is interested in connections with Russia and in differences between building systems in Finland and Russia. Also, there is the question about changing over SNiPs to Eurocodes in Russia nowadays. This is very important for both countries because it will be easier to have co-operation in bridge field. For example, there will be opportunities to design bridge structures together or to use the experience of designing of foreigners colleagues. These are the main reasons for this topic of the thesis work.

Firstly, it can seem that the systems of Eurocodes and SNiPs are similar, but they have many differences. For example, they both are based on the limit state design system, but have different coefficients. Also, they both present regulations to define the principal objectives, principles and the overall structure of the regulation system in construction, requirements to instruments, maintenance, design, development, adoption and implementation. Both Eurocodes and SNiPs affect the design issues with almost all the major construction materials (concrete, steel, wood, stone / brick and aluminum), all major areas of structural design (basic design of structures, loads, fires, geotechnical engineering, earthquakes, etc.) as well as a wide range of types of structures and products (buildings, bridges, towers, masts, etc.). But Eurocodes are divided into different parts by the material issue and SNiPs by the structural design issues.

Differences between load parts on bridges, especially for traffic loads will be presented in this work. Also, the differences between the systems of combination of loads and their factors will be presented there.

2 LIMIT STATE DESIGNS

2.1 General about limit state design

European and Russian norms are based on the method of structural analysis on limit state design. Moreover, this method was adopted in Russian regulations before it was admitted to the Eurocodes. Building codes for structural design and production of these different structures from different materials determine the values of safety factors.

Limit state design (LSD) refers to a design method used in structural engineering. A limit state is a condition of a structure when the structure stops to satisfy the service requirement. So that, the structure loses the ability of resistance to external actions or gets a very big deformation or local failure. It should be stopped to use it in these conditions.

Limit state design requires the structure to satisfy two principal criteria: the ultimate limit state (ULS) and the serviceability limit state (SLS)

Any design process involves a number of assumptions. The loads to which a structure will be subjected must be estimated, the sizes of members to check must be chosen and the design criteria must be selected. All engineering design criteria have a common goal: that of ensuring a safe structure and ensuring the functionality of the structure.

2.1 Loads

Structural loads or actions are forces, deformations or accelerations applied to a structure or its components. Loads cause stresses, deformations and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled. Engineers often evaluate structural loads based upon published regulations, agreements, or specifications. Accepted technical standards are used for acceptance testing and inspection.

Loads may be dead loads, traffic loads, impact loads, thermal force, wind loads, seismic loads, ice loads, water level pressures, snow loads, forces due to curvature, forces on parapets, frictional resistance of expansion bearings, erection forces, and support settlements and so on.

There is some more information about loads:

-dead loads (permanent loads) are time-independent, gravity-dominated service loads. Examples of dead loads are the weights of structures, the ground pressure, prestress or permanent items that remain in place throughout the life of structure. Dead loads are typically static loads. The weight of structural parts and other effective unchanged forces to the structure such as fillings and coverings, earth pressure as well as load which is caused by water height under the water are considered as permanent loads.

-live loads (long-term and short-term loads) are gravity loads that vary in magnitude and location during normal operation of the structure. Examples of live loads are weight of persons, furniture, movable equipment, traffic loads (vehicle, railway, cycle and pedestrian). While some live loads (e.g. persons and furniture) are practically permanent and static, others (e.g. cranes and various types of machinery) are highly time dependent and dynamic. Since the magnitude, location and density of live load items are generally unknown in a particular case, the determination of live loads for design purposes is not simple.

For this reason, regulatory bodies sometimes prescribe the design live loads which are based on experience and proven practice. In Eurocodes the traffic loads for road bridges generally include the dynamic effect of the load.

-environmental loads (short-term and long-term loads) are loads that act as a result of weather, topography and other natural phenomena. Examples of environmental loads are snow loads, wind loads, ice load, thermal loads, loads from fluids and floods, etc. Most environmental loads are time dependent and repeated in some period, i.e. cyclic.

-accidental loads (*in SNiP they are called "special loads")* are arising from accidents such as collision, fire, seismic, explosion or dropped objects. Examples of accidental loads are impact forces, actions caused by derailed rail traffic, actions caused by ship traffic, etc. Accidental loads typically have dynamic or impact effect on structural behavior. Guidelines for predicting and accounting for accidental loads are more meager because of the unknown nature of accidents. But it is important to treat such loads in design, particularly where novel types of structures are involved, about which past experience may be lacking.

The maxima of the various types of loads mentioned above are not always applied simultaneously, but more than one load type normally coexists and interacts. Therefore, the structural design needs to account for the effect of phasing for defining the combined loads. Usually, this involves the consideration of multiple load combinations for design, each representing a load at its extreme value together with the accompanying values of other loads. Guidelines for relevant combinations of loads to be considered in design are usually specified by regulatory bodies or classification societies for particular types of structures.

Figure 2.1 shows which loads should be defined for calculating the bridge:

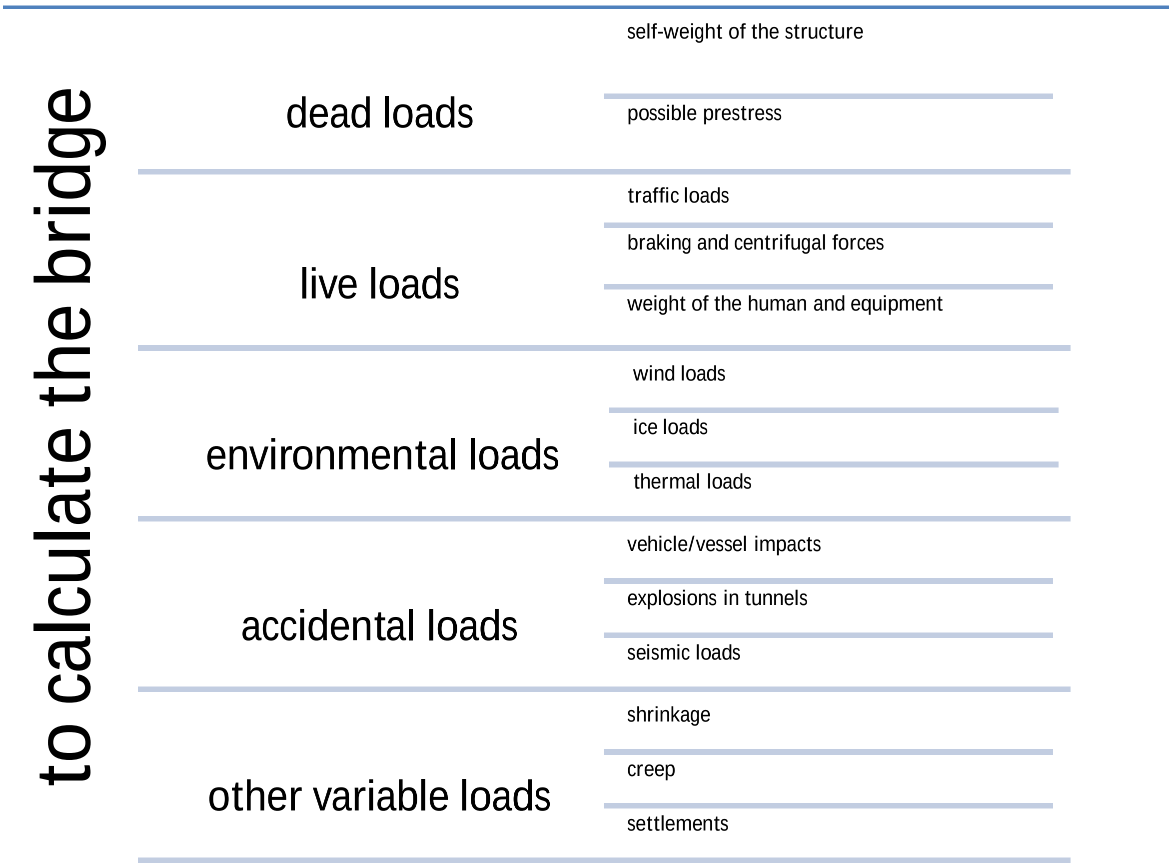


Figure 2.1 Loads for calculating the bridge

2.2 Safety factors

Safety factor is a term describing the structural capacity of a system beyond the expected loads or actual loads. Essentially, how much stronger the system is than it usually needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure's ability to carry load must be determined to a reasonable accuracy.

Many systems are purposefully built much stronger than needed for normal usage to allow for emergency situations, unexpected loads, misuse or degradation.

safety factors:

load factor (consequence factor)

material factor

- Load factor (γ-factor) is the factor which takes into account variation of the load and of the structural model (real structure and designed models). For example, for dead load in Eurocodes it varies from 1,15 to 1,35 and in *SNiP it varies from 1,1 to 2,0.*

- Consequence factor (K_{FI}/ y_n) depends of the consequence class. There are 3 classes in Eurocodes and *4 classes in SNiPs*. The values of consequence factor vary from 1,1 to 0,9 in Eurocodes and *from 1,2 to 0,8 in SNiPs.*

-Material factor (γ_m) takes into account variation of material strength and variation of sections, the possibility of an unfavorable deviation of a material or product property from its characteristic value. The value of material factor depends on the type of material and it can depend with the density the material. For example, for steel it varies 1…1,25 in Eurocodes and *1,05...1,165 in SNiPs.*

2.3 Combination factor

This factor is used when it should be taken into account the reduced probability of a number of loads which are acting simultaneously. Psi-factor (ψ) *(or in SNiP it is ŋ-factor)* is a combination factor which takes into account that all loads are not likely to occur at the same time with their maximum values. It also takes into account the period of time when this action is on the structure.

2.4 Ultimate Limit State (ULS)

Ultimate limit state includes the design that leads to the complete breakdown of constructions (buildings or constructions in general) or full (partial) loss of bearing capacity of buildings and constructions in general. A structure is deemed to satisfy the ultimate limit state criteria if all factored bending, shear and tensile or compressive stresses are below the factored resistance calculated for the section under consideration. The limit state criteria can also be set in terms of stress rather than load. Thus the structural element being analyzed (e.g. a beam or a column or other load bearing element, such as walls) is shown to be safe when the factored "Magnified" loads are less than their factored "Reduced" resistance.
Ultimate limit state is characterized with the following details:

- destruction of any nature (such as plastic, fragile, fatigue)
- loss of stability, resulting in the complete breakdown
- loss of sustainability
- quality change in the configuration
- other phenomenon which leads to stopping of ends the service life of the structure

2.5 Accidental limit state (ALS) and seismic design situation

Accidental limit state design is the design situation, which refer to exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion, impact or the consequences of localized failure. Also, there are the seismic design situations, which refer to conditions applicable to the structure when subjected to seismic events. The main safety functions of the structure that should not be compromised during any accident event or within a certain time period after the accident include:
- usability of escape ways;
- integrity of shelter areas and control spaces;
- global load-bearing capacity.

Therefore, the accidental limit state-based design criteria should be formulated so that the main safety functions mentioned above will work successfully, and the following are considered to adequate levels:
- energy dissipation related to structural crashworthiness;
- capacity of local strength members or structures;
- capacity of the global structure;
- allowable tensile strains to avoid tearing or rupture;
- endurance of fire protection.

2.6 Serviceability Limit State (SLS)

Serviceability limit state includes the design that prevents the normal use of the structures or reduces the lifetime of buildings (constructions) from the estimated. A structure is deemed to satisfy the serviceability limit state when the constituent elements do not deflect by more than certain limits laid down in the building codes, the floors fall within predetermined vibration criteria, in addition to other possible requirements as required by the applicable building code. In serviceability limit state (by Eurocodes) there are three different combinations: characteristic combination, frequent combination and quasi – permanent combination. Examples of further serviceability limit requirements may include crack widths in concrete, which typically must be kept below specified dimensions. A structure where the serviceability requirements are not met, e.g. the beams deflect by more than the serviceability limit state range, will not necessarily fail structurally. The purpose of SLS requirements is to ensure that people in the structure are not unnerved by large deflections of the floor, vibration caused by walking, sickened by excessive swaying of the building during high winds, or by a bridge swaying from side to side and to keep beam deflections low enough to ensure that brittle finishes on the ceiling above do not crack, affecting the appearance and longevity of the structure. Many of these limits depend on the finish materials (sheetrock, acoustical tile) selected by the architect, as such, the limits in the building codes on deflections are generally descriptive and leave the choice to the engineer of record (this may not be as true outside the U.S.).

Serviceability limit state is characterized with the following details:

- reaching of the limiting deformations of structure (for example, limiting the deflections, rotations), or limit deformation of the foundations;
- achievement of the limiting levels of vibrations of structures and foundations;
- developing the cracks;
- reaching the limiting crack width;
- loss of the form, which leads to unusable structure;
- other phenomenon which leads to prevent good service of the structure because of reducing its lifetime.

3 STRUCTURES OF EUROCODEs AND SNIPs

3.1 Structure of Eurocodes

Eurocodes are a set of European norms (EN) for the design of buildings and building products developed by Comité Européen de Normalisation (CEN).

Eurocodes are used by members of CEN such as Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom. Eurocodes may be used also outside CEN members like the old commonwealth countries. (Eurocode 0, 2004, p.1) Figure 3.1 shows 9 parts of Eurocodes.

Eurocodes

EN 1990	Basic of structural design
EN 1991	Actions on structures
EN 1992	Design of concrete structures
EN 1993	Design of steel structures
EN 1994	Design of composite steel and concrete structures
EN 1995	Design of timber structures
EN 1996	Design of masonry structures
EN 1997	Geotechnical structures
EN 1998	Design of structures for earthquake resistance
EN 1999	Design of aluminum structures

Figure 3.1 Eurocodes

The aims of Eurocodes:

- to provide general criteria and design methods that meet the necessary requirements of mechanical resistance, stability and fire resistance, including aspects of durability and economy;

- to provide a common understanding of the structural design process among the owners, managers, designers, manufacturers of building materials, contractors and operators;
- to get easier exchange of services in the building area between member countries;
- to get easier marketing and use of construction elements and nodes between the member countries;
- to get easier marketing and use of building materials and related products whose characteristics are used in the calculations for the design;
- to serve as a common basis for research and development in the construction industry;
- to provide a basis for common benefits for the design and software;
- to increase the competitiveness of European construction companies, contractors, designers and manufacturers of constructions and materials on the world market.

General assumptions of EN 1990 are:

-the choice of the structural system and the design of the structures is made by appropriately qualified and experienced personnel;

-execution is carried out by personnel having the appropriate skill and experience;

-adequate supervision and quality control is provided during execution of the work, i.e. in design offices, factories, plants and on site;

-the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;

-the structure will be adequately maintained;

-the structure will be used in accordance with the design assumptions.

Figure 3.2 shows the system of Eurocodes.

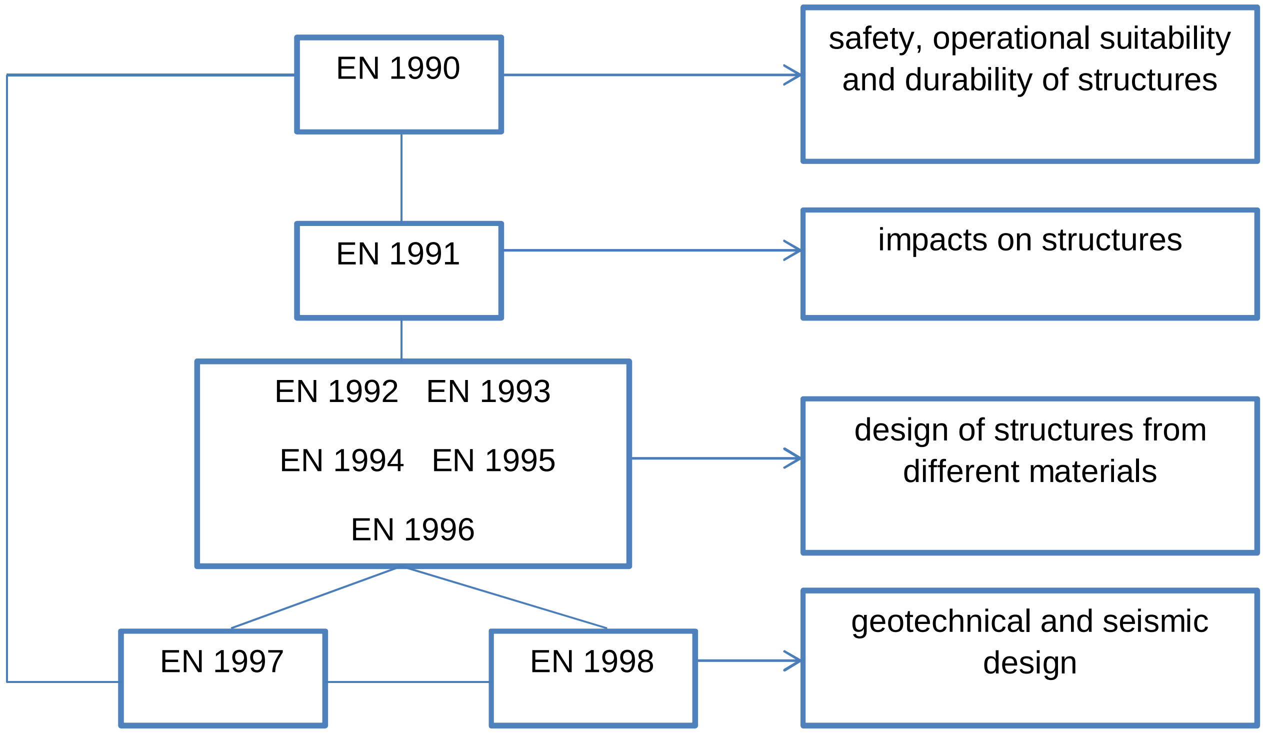


Figure 3.2 The system of Eurocodes.

The building codes in each European country consist of Eurocodes and National Annexes. Most countries (as Finland) have also prepared so-called NCCI-documents in order to help the designers to adopt a new system. These NCCI-documents are not contradicting Eurocodes (NCCI stands for "Non-Contradictory Complementary Information").

Eurocodes provide a set of recommended values, which can be replaced by parameters. These parameters are represented by classes, levels of requirements and indicators, as well as alternative methods.

National annexes arise from the need of each country to preserve its national sovereignty. The legal status of Eurocodes varies from country to country. Countries have the right to determine their own margins of safety, so the partial factors for actions and resistances appear in the Eurocodes in informative Notes, giving "recommended values" for what are called Nationally Determined Parameters (NDPs). There is a total of 1500 NDP's in all 58 parts of Eurocodes and about 250 NDP's concerning bridges. The reasons for using NDPs are the difference in environmental conditions (geographical, geological and climatic reasons) and safety conditions.

Most existing national codes include some provisions that are not in the Eurocodes. Provided that the material is consistent with the Eurocodes, it can be made a requirement in that country. It can be written in NCCI – series.

Finnish Transport Agency has created so called NCCI-series of documents for bridges. The series has 5 parts:

NCCI 1 – Basis of design, Loads and Load combinations

NCCI 2 – Concrete Structures

NCCI 4 – Steel and Composite Structures

NCCI 5 – Timber Structures

NCCI 7 – Geotechnical design.

The NCCI-series has been composed in a way that they explain the contents of Eurocode in a way that both Eurocode and Finnish National Annexes (NA) are taken into consideration. The series also include some local national design rules. The series is intended mainly for small and medium span bridges (but it can be applied to larger bridges), so it does not include all rules mentioned in Eurocodes.

3.2 Structure of SNiPs

Building Regulations (SNiPs) is a set adopted by the executive government regulations technical, economic and legal measures governing the implementation of urban planning and engineering studies, architectural design and construction. Also, in the Russian system of building norms there are different norms which are GOST and SP. (www.wikipedia.ru)

State standard (GOST) refers to a set of technical standards maintained by the Euro-Asian Council for Standardization, Metrology and Certification (EASC), a regional standard organization operating under the auspices of the Commonwealth of Independent States (CIS). All sorts of regulated standards are included, with examples ranging from charting rules for design documentation to recipes and nutritional facts of Soviet-era brand names.

Set of buildings rules (SP) is a document in the field of standardization, which contains technical rules and (or) description of the design (including research), production, construction, operation, installation, storage, transportation, sale and *disposal of products and which is applied on a voluntary basis in order to comply with the requirements of technical regulations. Figure 3.3 shows the system of SNiPs.*

SNiP	*Part 1*	*Organization, management and economics*
	Part 2	*Norms of structural design*
	Part 3	*Organization, production and acceptance of work*
	Part 4	*Estimated norms*
	Part 5	*Rates of material and labour resources*

Figure 3.3 SNiPs

Each part of SNiP is divided into individual chapters which are self-published. Provisions establishing a system of regulations, building vocabulary, classification of buildings and constructions, assignment rules modular sizes and tolerances in construction are included in the first part.

The second part consists of the regulatory requirements on different chapters: general questions of designing connected with the climate, geophysics, fire standards, building physics, loads and impacts, construction in seismic areas, etc.; the basis and foundations of buildings and structures; building construction, engineering equipment of buildings and external network; construction of transport; buildings and facilities, radio and television; hydraulic and energy facilities; design and construction of cities, towns and rural settlements; residential and public buildings and facilities; industry, production and auxiliary buildings; agricultural buildings, buildings and constructions; storage buildings and structures.

Part three includes requirements for the construction and the acceptance into service of finished objects; geodetic works in construction; occupational safety; the production and reception of works at erection of ground facilities, grounds *and foundations, building constructions; installing engineering and technological equipment of buildings, structures and external networks.*

Part four provides guidance on the development of computational and big estimated provisions for construction works; the estimated norms at erection of equipment; determining the estimated cost of materials, structures, maintenance of construction machinery; developing rules limited, etc. costs; determination of the total estimated cost of the construction.

SNiPs are reviewed periodically (chapter by chapter) and improved on the basis of the results of research in the field of construction, design excellence, construction and operation of buildings and constructions; the current head of the SNiPs adapted and supplemented.

Besides SNiPs there are other norms, rules and instructions concerning the questions about designing or building.

The aims of SNiPs:

-conformity of structures for its purpose and to create comfortable conditions for people's lives;

-safety of structures for people's lives and health in the process of production and maintenance;

-protection structures and people of the risk of emergencies;

-reliability and quality of structures and foundations, engineering systems, buildings;

-implementation of environmental requirements, rational using of natural, material, fuel, energy and labor resources.

SNiPs must contain the main organizational and methodological requirements aimed at ensuring the necessary level of quality construction products, the general technical requirements for engineering surveys for construction, design and construction, as well as the requirements for planning and building and structures, foundations and engineering's equipment systems.

SNiPs must define:

-reliability of buildings and structures and their systems in calculated conditions of maintenance, strength and stability of structures and foundations;

-stability of buildings and structures and safety of people during the earthquakes, collapses, landslides and in other calculated conditions of bad nature impacts;

-stability of buildings and structures in maintenance process during the fire and in other calculated emergencies;
-protection of people's health in maintenance process, necessary warmth, light, moisture and acoustic conditions;
-maintenance characteristics and parameter process and rules of their placement, taking into account health, environmental and other regulations;
-reducing the consumption of fuel and energy and reducing the heat losses on buildings and structures.

3.3 Comparison of structures of Eurocodes and SNiPs

Both, European and Russian norms provide a set of regulations for designing and building the structures. They contain the regulations about different materials (concrete, steel, timber, masonry, composite, etc) and about different structures (houses, bridges, pipes, towers, etc) and, also, about structural design (basic design of structures, loads, fires, geotechnical engineering, earthquake designing, etc). Eurocodes are divided into parts by the material issue, and SNiPs are divided into parts by structural issues. They both have different structures, but in spite of this, have the same parts. Table 3.1 shows this comparison.

Table 3.1 Comparison of the names of Eurocodes and SNiPs.

Eurocodes	**the name**	**GOST, SNiP, SP**
EN 1990	Basic of structural design	GOST 27751-87
EN 1991	Design of actions	SNiP 2.01.07-85*
EN 1992	Design of concrete structures	SNiP 52-01-2003
EN 1993	Design of steel structures	SNiP II-23-81*
EN 1994	Design of composite steel and concrete structures	SP 52-101-2003
EN 1995	Design of timber structures	SNiP II-25-80
EN 1996	Design of masonry structures	SNiP II-22-81*
EN 1997	Geotechnical design	SNiP 2.02.01-83* SNiP 2.02.03-85

EN 1998	Design of structures for earthquake resistance	SNiP II-7-81*
EN 1999	Design of aluminum structures	SNiP 2.03.06-85

European norms for designing bridges have always number 2 in its names, like EN 1991-2 – “Actions on structures. Traffic loads on bridges”. Russian norms have one SNiP concerning the designing of bridges – SNiP 2.05.03-84* - “Designing of bridges and pipes”.

4. LOADS

In this thesis references are made both for NCCI-series and actual Eurocodes and, also, for SNiPs, GOSTs and SPs.

4.1 Dead loads

4.1.1 Dead loads in Eurocodes

Dead load on bridges includes the weight of structural materials (self-weight) and also the so-called superimposed dead loads (surfacing, finishes, etc.). The weight of the surfacing generally has a large variation during the life of a bridge and so particular care must be taken to assess its design value. It is customary to adopt a conservative estimate of initial thickness to determine the characteristic loading and then to apply a high partial factor.

It depends on the material. The weights of materials can be found from EN 1991-1-1 (tables of Annex A) and chapter A (table A.1) of NCCI 1.

Load factors can be found in tables G.4…G.6 and G.8 of NCCI 1 (tables A2.4(A)…A2.4(C) and A2.6 of EN 1990/A1) for ultimate limit state and serviceability limit state respectively. Load factors for accidental and seismic combinations of actions can be found in table A2.5 of EN1990/A1 and table G.7

of NCCI 1. Table G.6 of NCCI 1 (table A2.6(C) in EN1990/A1) is not used for bridges (it is used only in geotechnical slope stability checks).
In ultimate limit state the load factor for dead load is normally 1,15/0,9 (1,15 or 0,9 depending on which one is governing the design). Generally the so-called "one source rule" is adopted. That means that for loads that are coming from the same source (e.g. gravity, when thinking about self-weight) same factor is used.
Equation 6.10a (see table A2.4(B) in EN 1990/A1 and G.5 in NCCI 1) has load factors 1,35/0,9 for dead load (in this combination only dead load is considered). This combination can be governing when the bridge is really heavy compared to traffic loads (e.g. large concrete box girder bridge). The load factor for prestress is normally 1,1/0,9 (in some local checks 1,2 may be used). In accidental, seismic and serviceability limit state design the load factor for dead load (and prestress) is 1,0.

4.1.2 Dead loads in SNiPs

The information about self-weight of the structure can be found in chapter 2.4 of SNiP 2.05.03-84.*
The normative value of self-weight of the prefabricated structures should be defined from the standards, passports and working drawings of other structures – through project sizes and gravity of materials and grounds with taking into account its moisture in conditions of building and maintenance.
Load factors can be found from table 4.1 (according to table 8 in SNiP 2.05.03-84*):*

Table 4.1 Load factors for dead loads

loads and impacts	safety factor
All loads and impacts which are not in this table	1,1 (0,9)
the weight of bridge deck with the ballast covering for railway, subway and tram	1,3 (0,9)
the weight of the deck of bridge for tam at the concrete and reinforced concrete slabs	1,2 (0,9)
the weight of pavement for road and city bridges	1,1 (0,9)

the weight of the pavement of desk and footpaths for road bridges	1,3 (0,9)
the same in city bridges	1,5 (0,9)
the weight of wooden elements in bridges	2,0 (0,9)
the horizontal pressure from the weight of the embankment: -on the piers and abutments -on the parts of pipes	 1,4 (0,7) 1,3 (0,8)
the impact of shrinkage and creep of concrete	1,1 (0,9)
the impact of concrete settlements	1,5 (0,5)

4.1.3 Comparison of dead loads

Example values of the safety factors for the weight of structures are shown in table 4.2. The values show the difference in safety factors for steel and concrete structures between SNiP and EN 1991-1-1.

Table 4.2 Comparison of load factors between Eurocodes and SNiPs

	Eurocode	SNiP
safety factor	1,15	2,0…1,1

As it can be found from table 4.2, the values are different between Eurocodes and SNiPs.

4.2 Traffic loads

4.2.1 Traffic loads in Eurocodes

Traffic actions on road bridges and railway bridges consist of variable actions and actions for accidental design situations, which are represented by various models. There is a total of 4 load models (LM 1…LM 4) for road bridges and 4 load models (LM 71, SW/0, SW/2 and “unloaded train”) for rail bridges. There are some explanations about these load models.

4.2.1.1 Location of the load models on the bridge deck

Load models LM1…LM4 are assumed to act on the longitudinal direction of the bridge area, notional lane, the width of which is 3,0 meters. Number and placement of load lanes in the transverse direction of the bridge is chosen so that the dominant influence is achieved. The number of notional lanes is limited to the number, which fits to an area where vehicles have access (roadway and roadside verges). In special cases (for example, ramps in the area to a road junction, wide bridges of one driving lane road and etc) the number of lanes is specified for an individual project. For example, if the width of the bridge deck is between 5,4…6 meters, there will be 2 equally wide notional lanes. These will be the position of the load for Ultimate limit state and Serviceability limit state. (Transport Agency, 2010, p. 6)

4.2.1.2 Load models for road bridges

Firstly, there is information about vertical load models. More detailed information can be found in chapter 4.3 of EN 1991 – 2 and in chapter B 4.3 of NCCI 1.

Load model 1 (LM1) consists of a concentrated and uniformly distributed loads, which cover most of the effects of the traffic of lorries and cars. This load model is used for general and local verifications. LM1 consists of two partial systems:

-double-axle concentrated loads (tandem system: TS), each axle having the following weight: $\alpha_Q Q_k$, where α_Q – adjustment factor (for Finland equals 1,0)

- no more than one tandem system should be taken into account per notional lane
- only complete tandem system should be taken into account
- for the assessment of general effects, each tandem system should be assumed to travel centrally along the axes of notional lanes
- each axle of tandem system should be taken into account with two identical wheels, the load per wheel being therefore equal 0,5 $\alpha_Q Q_k$

- the contact surface of each wheel should be taken as square and of side 0,4 meter

- uniformly distributed loads (UDL system), having the following weight per square meter of notional lane $\alpha_Q q_k$, where α_Q – adjustment factor (for Finland equals 1.0). The uniformly distributed loads should be applied only in the unfavorable parts of the influence surface, longitudinally and transversally. The lane with the highest UDL is so-called "slow lane" for heavy traffic. The characteristic values of Q_{ik} and q_{ik} are presented in table 4.3 (according to table 4.2 in EN 1991-2 and table B.1 of NCCI 1). (Eurocode 1. Part 2, 2004, pp 35-38)

Table 4.3 LM1: characteristic values

Location	Tandem system TS	UDL system
	Axle loads Q_{ik} (kN)	q_{ik} (kN/m^2)
Lane number 1	300	9
Lane number 2	200	2,5
Lane number 3	100	2,5
Other lanes	0	5,5
Remaining area (q_{rk})	0	2,5

Normally the vehicle is situated in the middle of the lane, so the distance between tires is 1 meter, but the bridge should be checked for the situation when the distance is less than 1 meter. The location of LM1 is shown in figure 4.1.

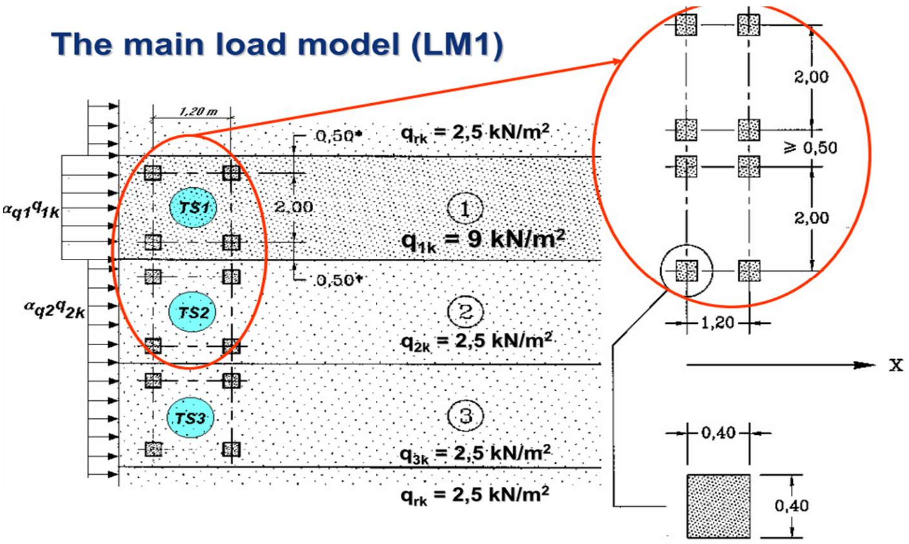


Figure 4.1 The location of LM1

Load model 2 (LM2) is a single axle load applied on specific tire contact areas which covers the dynamic effects of the normal traffic on short structural members. LM2 consists of a single axle load $\beta_Q Q_{ak}$ with Q_{ak} equal to 400 kN, dynamic amplification included, which should be applied at any location on the carriageway. The contact surface of each wheel should be taken into account as a rectangle of sides 0,35 meter and 0,6 meter. The values of β_Q equals 1 for public roads and can be 0,8 for the design of state help receiving private road bridges (see B.4.1of NCCI 1 and chapter 4.1(2) of EN 1991-2) in Finland. The location of LM2 is shown in figure 4.2. (Eurocode 1. Part 2, 2004, pp 38-39)

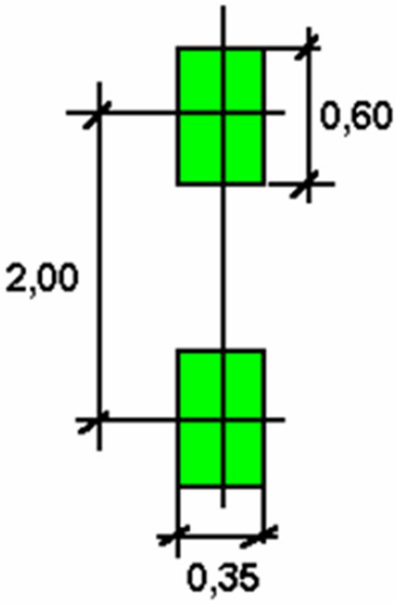


Figure 4.2 The location of LM2

Load model 3 (LM3) is located in one lane. This load model is used if the bridge locates in major transportation routes or the relevant authority has specified its use for the individual project. It is a set of assemblies of axle loads representing special vehicles (for example, industrial transport) which can travel on routes permitted for abnormal loads. This load is used for general and local verifications. This particular load model has been developed in Finland and it represents actual transportations happening in the Finnish road network. Eurocode also presents a set of special vehicles in Annex A of EN 1991-2. The location of LM3 is shown in figure 4.3.

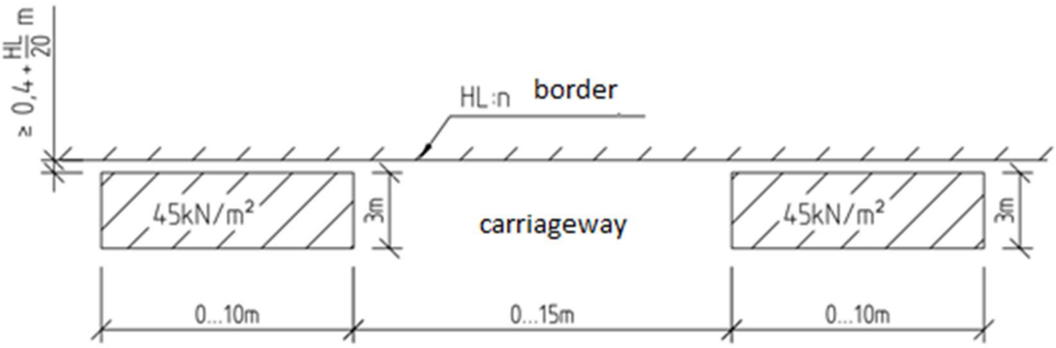


Figure 4.3 The location of LM 3

Load model 4 (LM4) is a load from crowd. LM4 consists of a uniformly distributed load equal to 5 kN/m^2, which is divided into the bridge, so that it creates a dominant effect. It is used for general verifications. It is situated everywhere on the bridge.

4.2.1.3 The horizontal forces of road traffic loads

Secondly, there is information about horizontal load models. More detailed information about them can be found in chapter 4.4 of EN 1991 – 2 and chapter B4.4 of NCCI 1.

Braking forces should be taken into account as a longitudinal force acting at the surfacing level of the carriageway. The load can be assumed to be equally distributed throughout the width of the carriageway. The characteristic value of Q_{lk}, limited to 500 kN for the total width of the bridge, should be calculated as a traction of the total maximum vertical loads corresponding to LM1.

Acceleration forces should be taken into account with the same magnitude as braking forces, but in the opposite direction.

Centrifugal forces Q_{tk} act at the finished carriageway level and radially to the axis of the carriageway as a point load at any deck cross section which is located within the radius *r*. The characteristic values of it obtained in table 4.3 of EN 1991-2 and table B2 of NCCI 1. Transverse braking force equal to 25% of the longitudinal braking or acceleration force should be considered to act simultaneously with Q_{lk} at the finished carriageway.

4.2.1.4 Load models for railway bridges

Thirdly, there is information about vertical load models for railway bridges. More information can be found in chapter 6.3 of EN 1991 – 2 and in chapter B 6.3 of NCCI 1.

Load model 71 (LM71) represents the static effect of vertical loading due to normal rail traffic, the permitted axle weight of vehicle is 22,5 tons. The location of LM71 is shown in figure 4.4 .

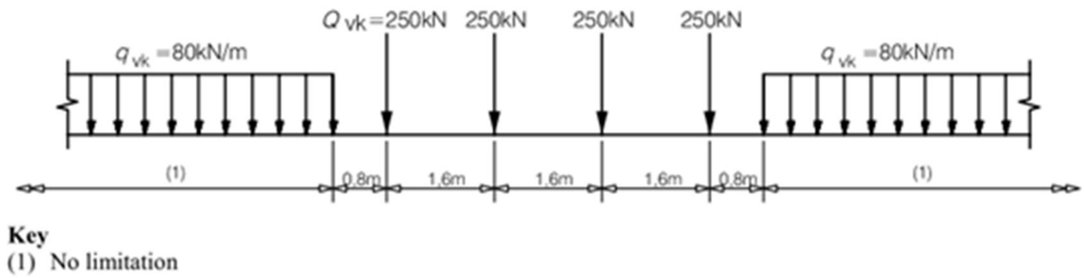


Figure 4.4 The location of LM 71

LM71 consists of four characteristic axle loads Q_{vk} and the characteristic value of vertical distributed load q_{vk}. Concentrated and vertical distributed loads are placed on the bridge so as to achieve a dominant influence. Vertical distributed load can be discontinuous and can influence in as many parts of any length. The characteristic values given in figure 6.1 shall be multiplied by a load classification factor α, on lines carrying rail traffic which is heavier or lighter than normal rail traffic. Load model LM71 is changed to correspond to this load when multiplying it by 35 tons equipment with the corresponding factor of α =1,46. Thus the obtained classified load models are marked with LM71-35 symbol. The following table shows load factor α and the classified values of the characteristic values of the LM71 (concentrated and distributed loads). Different countries use different values of α. For example, in Finland 1.46 is always used. The values of factor α and its classification are shown in table 4.3.

Table 4.4 The classification of load model LM71

Permitted axle weight of the equipment [kN]	The symbols of classified load models	Factor α	Concentrated load of the classified load models Q_v [kN]	Distributed load of the classified load models q_v [kN/m]
350	LM71-35	1,46	370	120
300	LM71-30	1,33	330	106
275	LM71-27,5	1,21	300	96
250	LM71-25	1,10	275	88
225	LM71-22,5	1,00	250	80
170	LM71-17	0,75	188	60

Load models SW/0 and SW/2 represent the static effect of vertical loading due to normal and heavy rail traffic on continuous beams respectively. The location of SW/0 is shown in figure 4.5. Table 4.4 shows the characteristics of SW/0 and SW/2.

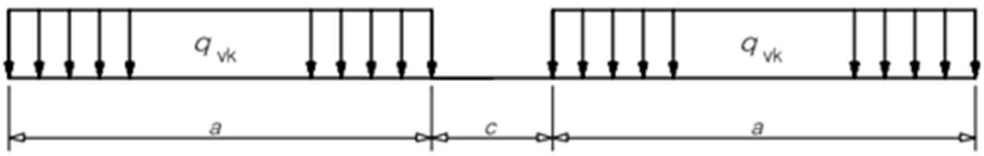


Figure 4.5 The location of SW/0

Table 4.5 Characteristic values for vertical loads for load models SW/0 and SW/2

Load model	**q_{vk}, [kN/m]**	**a, [m]**	**b, [m]**
SW/0	133	15,0	5,3
SW/2	150	25,0	7,0

These loads consist of two separate characteristic vertical distributed loads. The load model SW/0 is also classified. The classification is shown in table 4.5.

Table 4.6 The classification for SW/0

Permitted axle weight of the stocks [kN]	The symbols of classified load models	Factor α	Distributed load of the classified load models q_v [kN/m]
350	SW/0-35	1,46	195
300	SW/0-30	1,33	177
275	SW/0-27,5	1,21	161
250	SW/0-25	1,10	146
225	SW/0-22,5	1,00	133
170	SW/0-17	0,75	100

Load model "unloaded train" consists of vertical uniformly distributed load with a characteristic value of q_{vk}=10kN/m.

Load model HSLM represents the loading from passenger trains at speeds exceeding 200 km/h.

4.2.1.4. The horizontal forces of railway loads

More detailed information can be found in chapter 6.5 of EN 1991 – 2 and chapter B 6.5 of NCCI 1.

Centrifugal forces of train load describe the characteristic loads caused by the moving train in curved direction. The centrifugal force should always be with the vertical load. Centrifugal force is the function of the structure loading method, calculated classified load model LM71, vertical load (kN) (without the extra impact), radius of curve (m) and the objective speed (m/s) of truck part.

Nosing forces should be taken as a concentrated force acting horizontally, at the top of the rails perpendicularly to the center-line of track. The characteristic value of side nosing load is 100 kN. It is always combined with a vertical traffic load. This load is classified with the corresponding factor α =1,46.

Actions due to traction and braking act at the top of the rails in the longitudinal direction of the track. They should be considered as uniformly distributed over the corresponding influence length. The direction of the traction and braking forces should be taken into account of the permitted direction(s) of travel on each track.

4.2.1.5 Load groups

Loads from traffic (both vertical and horizontal) are grouped into so called load groups (see chapters 4.5 and 6.8 in EN1991-2 and chapters B 4.5 and B 6.8 in NCCI 1). These load groups are used when combining the loads (i.e. each load group is considered as a single load in combinations). There are 6 load groups which are presented in table 4.6 (according to table B.3 of NCCI 1).

Table 4.7 Classification of group models

<table>
<tr><th rowspan="4"></th><th colspan="8">CARRIAGEWAY</th><th rowspan="2">Footways & cycle tracks</th></tr>
<tr><th colspan="5">vertical forces</th><th colspan="3">horizontal forces</th></tr>
<tr><td colspan="2">LM1
TS and UDL</td><td>LM2
Single axle</td><td>LM3
Special force</td><td>LM4
Crowd loading</td><td colspan="3">Breaking & Centrifugal & acceleration forces transverse forces</td><td>Vertical forces only</td></tr>
<tr><td colspan="2">SFS-EN 1991-2_4.3.2</td><td>SFS-EN 1991-2_4.3.3</td><td>SFS-EN 1991-2_4.3.4</td><td>SFS-EN 1991-2_4.3.5</td><td colspan="3">SFS-EN 1991-2_4.4.1
SFS-EN 1991-2_4.4.2</td><td>SFS-EN 1991-2_5.3.2.1</td></tr>
<tr><td rowspan="2">gr1a</td><td colspan="2">Characteristic values</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2" colspan="2"></td><td rowspan="2"></td><td rowspan="2">Combination value
3 kN/m^2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>gr1b</td><td colspan="2"></td><td>Characteristic value
1</td><td></td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td rowspan="2">gr2</td><td colspan="2">Frequent values(ψ1)</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2" colspan="2">Characteristic value
1</td><td rowspan="2">Characteristic value
1</td><td rowspan="2"></td></tr>
<tr><td>0,75</td><td>0,4</td></tr>
<tr><td>gr3</td><td colspan="2"></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td>Characteristic value</td></tr>
</table>

							5 kN/m^2
gr4				Characteristic value 1			Characteristic value 5 kN/m^2
gr5			Characteristic value 1				

<u>group 1a (gr1a):</u>

- Vertical traffic load LM1 as its characteristic value;
- 3 kN/m^2 load of possible light traffic lane;
- Often dimensions main beams;
- Important for superstructure design;

The system of gr1a is shown in figure 4.6 .

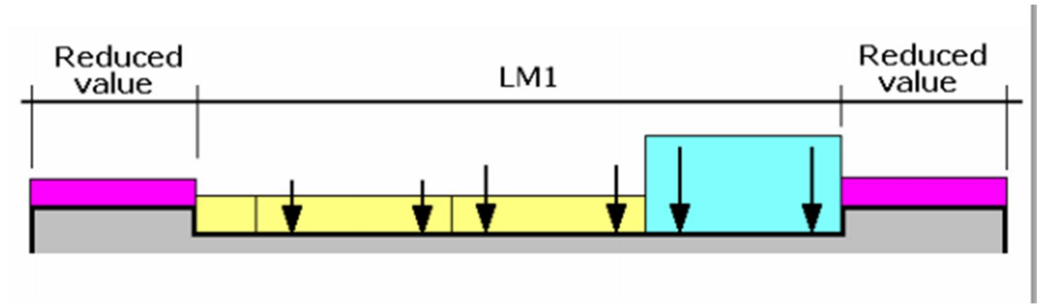


Figure 4.6 group1a

<u>group 1b (gr1b):</u>

- Vertical traffic load LM2 with its characteristic values;
- Possible dimensions on orthotropic deck, cantilever, etc;
- Important to e.g. secondary structures, orthotropic plates;

The system of gr1b is shown in figure 4.7.

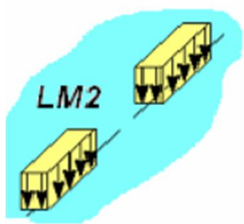


Figure 4.7 group1b

group2 (gr2):

- Vertical traffic load LM1 with its normal value (tandem forces multiplied by the value of 0.75 and uniformly distributed loads by the value of 0.40);
- Horizontal loads resulting from traffic with its characteristic value,
- Often dimensions substructures;
- Important for substructures, piling and etc.

The system of gr2 is shown in figure 4.8 .

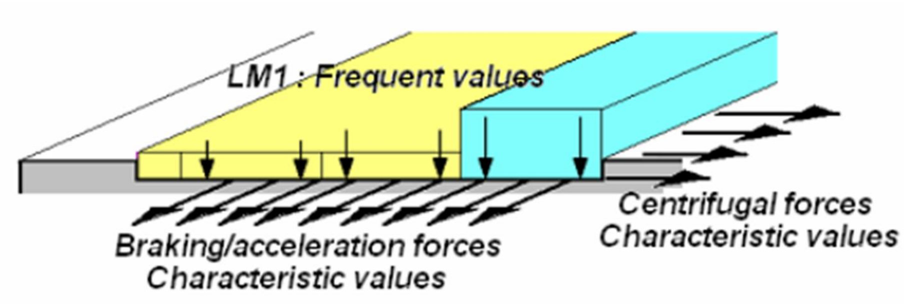


Figure 4.8 group2

gropu3 (gr3):

- Only light traffic lanes which are loaded by the surface load of 5 kN/m^2;
- Rarely dimensions.

The system of gr3 is shown in figure 4.9.

Figure 4.9 group3

group4 (gr4):

- Light traffic lanes loaded by surface load of 5 kN/m^2;
- Other lanes loaded by crowd load of 5 kN/m^2,
- Rarely dimensions.

The system of gr4 is shown in figure 4.10.

Figure 4.10 group4

<u>group5 (gr5):</u>

- Load model LM3 is over heavy special load with its characteristic value;
- Possible measures the structures in the ULS;
- Important for superstructure design;
- See terms and conditions of section B.4.3.4.

  The system of gr5 is shown in figure 4.11 .

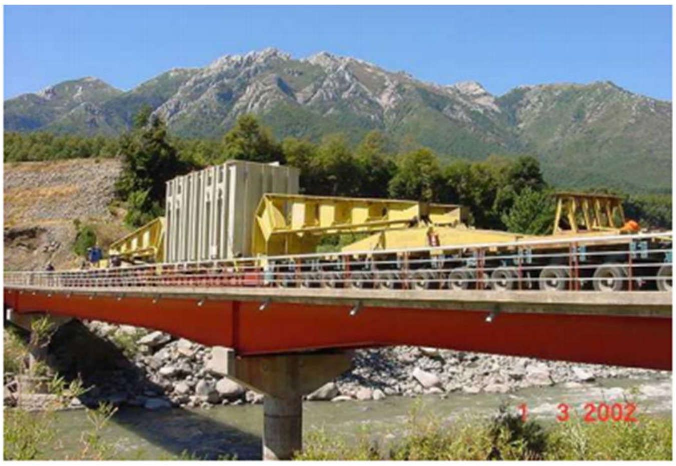


Figure 4.11 group5

(Transport Agency, 2010, pp 11-13)

Load groups gr1a, gr2, gr5 are the most important for bridge designing. Different factors for road and railway bridges are shown in table 4.7

Table 4.8 The values of factors for traffic loads in Eurocodes

Factors	for railroad bridges	for road bridges
safety factor	1,45 (however load factor is 1,2 for SW/2).	1,35
combination factor ψ_0	0,8	0,75/0,4
combination factor ψ_1	0,8/0,7/0,6 (depending on the number of tracks)	0,75/0,4
combination factor ψ_2	0	0/0,3 (axle load/UDL).

4.2.2 Traffic loads in SNiPs

The values of load depend on the class of the load (K) which is defined from GOST 52748: for permanent structures K=14, for wooden bridges K=11, for structures under reconstruction K≥11 or it should be defined by the client. For railroad for capital structures K=14 and for wooden bridges K=10. But the schemes for load models with load class K=14 is different, because one of them is for road bridges and the other is for railway bridges.

4.2.2.1 Location of the load models on the bridge deck

There are some rules for positions of load model AK on the bridge deck in SNiP:

1) *two ways of load situation on the bridge deck*
- *first – unfavorable position of load lines, not more than traffic lanes (without safety lanes) and crowd on the footpaths;*
- *second – unfavorable position of two load lines on the whole carriageway (with safety lanes) and unloaded footpaths (on the bridge with one lane – one line of load).*
2) *the axels of extreme load lines of load AK should be no closer than 1,5 meters from the extreme of carriageway in the first way and from barrier of traffic lane.*
3) *the number of load lines should be no more than the number of traffic lanes.*

4) when calculating the structure on the Ultimate limit state should be taken into account the both ways of situation of load and for the Serviceability limit state – only the first way.

4.2.2.2 Load models for road bridges

Firstly, there is information about vertical loads for road bridges. More detailed information can be found in chapter 2.12, 2.13 of SNiP 2.05.03-84.*

AK is a set of bands each of which consists of vehicle with two axles and uniformly distributed load. The load on each axle is P=9,81K (10kN) kN and the uniformly distributed load is ϑ=0,98K kN/m. If there is more than one lane, the load should be multiplied on the coefficient s_1, which equals to 1,0 for axle loads and 0,6 for uniformly distributed load. The location of AK is shown in figure 4.12

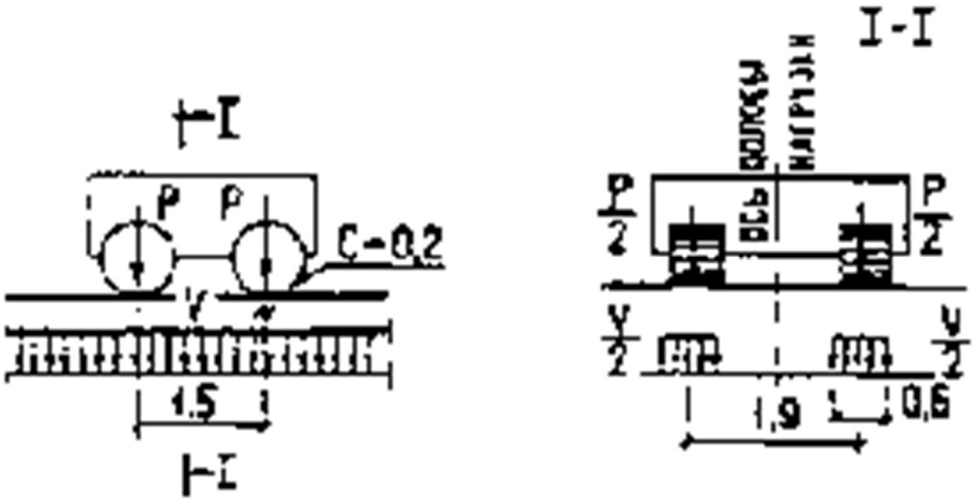


Figure 4.12 The location of AK

HK is the load from the heavy vehicles and tracked vehicles (НГ). It is presented as 4-axle truck with the load 18K on each axle. The location of HK is shown in figure 4.13 . Now HK-100 is used.

Note: for calculating the bridges for HK, the verification on double HK loads should be made. They should be made with the distance of 12 meters (between the last axle of the first truck and the first axle of the last truck). Also, reduction factor should be taken into account, it equals 0,75.

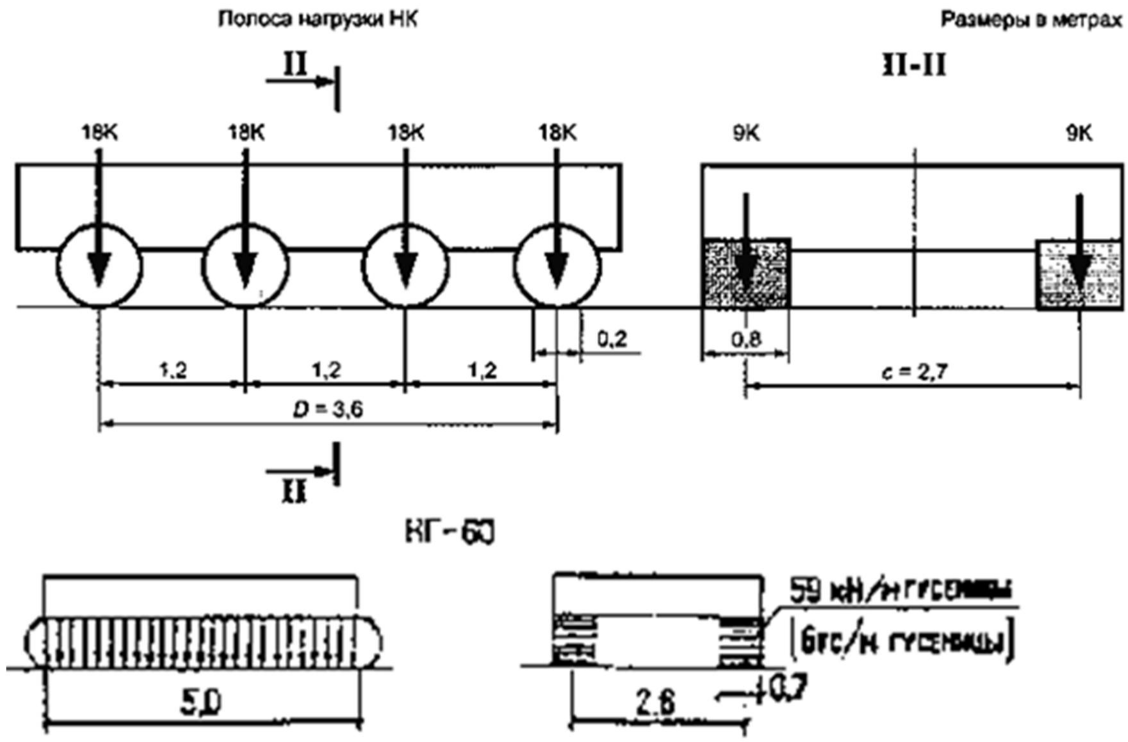


Figure 4.13 The location of HK and HГ

4.2.2.3 Load models for railway bridges

Secondly, there is information about load models for railway bridges. More detailed information can be found in chapter 2.11 of SNiP 2.05.03-84.*

CK is the load for railway traffic load. The load is given as a uniformly distributed line of equivalent load v kN/m, with different values depending on the length and shape of influence line. The characteristic values can be found in Table 4.9 according to table 1 in Annex 5 of SNiP 2.05.03-84.*

Table 4.9 Characteristic value for load model CK

loading length λ, m	equivalent load ν, kN/m (t/m) , for			
	К = 1		К = 14	
	α = 0	α = 0,5	α = 0	α = 0,5
1	49,03 (5,000)	49,03 (5,000)	686,5 (70,00)	686,5 (70,00)
1,5	39,15 (3,992)	34,25 (3,493)	548,1 (55,89)	479,5 (48,90)
2	30,55 (3,115)	26,73 (2,726)	427,7 (43,61)	374,2 (38,16)

loading length λ, m	equivalent load ν, kN/m (t/m) , for			
	К = 1		К = 14	
	α = 0	α = 0,5	α = 0	α = 0,5
3	24,16 (2,464)	21,14 (2,156)	338,3 (34,50)	296,0 (30,18)
4	21,69 (2,212)	18,99 (1,936)	303,7 (30,97)	265,8 (27,10)
5	20,37 (2,077)	17,82 (1,817)	285,2 (29,08)	249,5 (25,44)
6	19,50 (1,988)	17,06 (1,740)	272,9 (27,83)	238,8 (24,35)
7	18,84 (1,921)	16,48 (1,681)	263,7 (26,89)	230,7 (23,53)
8	18,32 (1,868)	16,02 (1,634)	256,4 (26,15)	224,4 (22,88)
9	17,87 (1,822)	15,63 (1,594)	250,2 (25,51)	218,9 (22,32)
10	17,47 (1,781)	15,28 (1,558)	244,5 (24,93)	214,0 (21,82)
12	16,78 (1,711)	14,68 (1,497)	234,9 (23,95)	205,5 (20,96)
14	16,19 (1,651)	14,16 (1,444)	226,6 (23,11)	198,3 (20,22)
16	15,66 (1,597)	13,71 (1,398)	219,3 (22,36)	191,8 (19,56)
18	15,19 (1,549)	13,30 (1,356)	212,7 (21,69)	186,0 (18,97)
20	14,76 (1,505)	12,92 (1,317)	206,6 (21,07)	180,8 (18,44)
25	13,85 (1,412)	12,12 (1,236)	193,9 (19,77)	169,7 (17,30)
30	13,10 (1,336)	11,46 (1,169)	183,4 (18,70)	160,5 (16,37)
35	12,50 (1,275)	10,94 (1,116)	175,0 (17,85)	153,2 (15,62)
40	12,01 (1,225)	10,51 (1,072)	168,2 (17,15)	147,2 (15,01)
45	11,61 (1,184)	10,16 (1,036)	162,6 (16,58)	142,2 (14,50)
50	11,29 (1,151)	9,875 (1,007)	158,0 (16,11)	138,3 (14,10)
60	10,80 (1,101)	9,807 (1,000)	151,1 (15,41)	137,3 (14,00)
70	10,47 (1,068)	9,807 (1,000)	146,6 (14,95)	137,3 (14,00)
80	10,26 (1,046)	9,807 (1,000)	143,6 (14,64)	137,3 (14,00)
90	10,10 (1,030)	9,807 (1,000)	141,4 (14,42)	137,3 (14,00)
100	10,00 (1,020)	9,807 (1,000)	140,0 (14,28)	137,3 (14,00)
110	9,944 (1,014)	9,807 (1,000)	139,3 (14,20)	137,3 (14,00)
120	9,895 (1,009)	9,807 (1,000)	138,6 (14,13)	137,3 (14,00)
130	9,865 (1,006)	9,807 (1,000)	138,1 (14,08)	137,3 (14,00)
140	9,846 (1,004)	9,807 (1,000)	137,9 (14,06)	137,3 (14,00)
150 and more	9,807 (1,000)	9,807 (1,000)	137,3 (14,00)	137,3 (14,00)

a - projection of the smallest distance from the top to the end of the loading, which can be found by equation 4.1

$$\alpha = \frac{a}{\lambda} \qquad (4.1)$$

α – relative position of the top of loading
Figure 4.14 shows the loading.

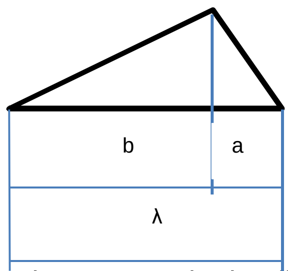


Figure 4.14 The loading of railway bridge

The weight of the unloaded train should be taken as 13,7 kN/m. Also, there is factor $\varepsilon \leq 1$, which is taken into account only with advanced cars and no heavy cars. It should be used wneh calculating for durability, for opening the cracks in concrete structures, for defining the deflections of the deck and moving of piers, when loading more than one lane.
The values of ε can be found from the table 4.10 (according to the table 9 in chapter 2.11 of SNiP 2.05.03-84).*

Table 4.10 The values of ε

length of loading, m	***5 and less***	***from 10 to 25***	***50 and more***
factor ε	*1,00*	*0,85*	*1,00*

<u>The load of metro-tracks.</u> It is a load consisting of estimated train length with 4-axle load equal to 147kN on each axle. The location for loads of metro-tracks is shown in figure 4.15.

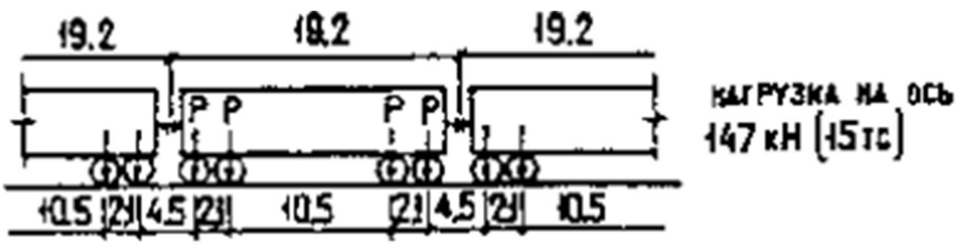


Figure 4.15 The location of load from metro-tracks.

4.2.2.4 Horizontal forces for road and railroad bridges

Also, in SNiP there are horizontal forces which are centrifugal forces, impact forces, braking and traction forces. More detailed information about these forces can be found in chapters 2.18 – 2.20 of SNiP 2.05.03-84.*

Centrifugal forces are used when a bridge is situated on the curves. So, this force should be taken from each lane like the uniformly distributed load with volume v_h or point load F_h. The value of this force depends on the type of the road and radius of the curve. It can be calculated by using formulas 12-16 from chapter 2.18 of SNiP 2.05.03-84.*

Impact forces should be taken independent from the number of lanes on the bridge. It should be taken as an uniformly distributed load with the volume of 0,59K kN/m for the railway bridges, 0,39K kN/m for the road bridges.

Braking and traction forces depend on the type of calculating the elements. For example, for calculating the superstructure and piers of the bridge, the braking and traction forces should be taken as a part (%) of the traffic loads. For railway traffic, metro is 10%; for road traffic 50% (but it should not be less than 7,8K kN and no more than 24,5K kN, K can be found in item 4.2.2 of this work). For calculating expansion joints the value of these forces depends on the category of the road: for city road it equal to 6, 86K kN.

Safety factors for traffic loads in SNiP should be taken from different tables. Intable 4.11 safety factors for road bridges are presented.

Table 4.11 Safety factors for road loads

load	***safety factor***
double axles	*1,50*
uniformly distributed	*1,15*
HK	*1,10*

For railway load CK should be taken from table 4.11 according to table 13 of chapter 2.23 of SNiP 2.05.03-84*. It depends on the load length. The table is shown below.*

Table 4.12 Safety factors for railroad loads

load /impact	***safety factor***		
	load length, m		
	0	***50***	***150 and more***
vertical	*1,30*	*1,15*	*1,10*
horizontal	*1,20*	*1,10*	*1,10*

There is one more factor on which traffic loads should be multiplied. This is (1+μ). It depends on the type of bridge and the type of material. More detailed information about it is in chapter 2.22 of SNiP 2.05.03-84*. For example, for loads AK and HK it equals:*

- for the axle load AK for the calculation carriageway – 1,4;

- for the axle load AK for the calculation of steel bridges – 1,4;

- for the axle load AK for the calculation of concrete bridges – 1,3;

- for the axle load AK for the calculation of wood bridges – 1,0;

- for the uniformly distributed load AK – 1,0;

- for the load HK – 1,0.

4.2.3 Calculation

There were made the decision to include a small example of calculation simple bridge beam on traffic loads to look what differences between values of the maximum moment and maximum shear force will be. The maximum moments was found in the center part of the beam. The shear forces were found in the cross-section from one meter from the left support. The beams are calculated on load model LM1 by Eurocode and A14 by SNiP. The length of the beam is 15 meters and the width is 10 meters (3 lanes for 3 meters and 1 safety lane for 1 meter). It is calculated for Ultimate (ULS) and Serviceability (SLS) limit states.

4.2.3.1 Calculation by Eurocodes

The design scheme and loads are presented in figure 4.16 and 4.17 below. Figure 4.16 shows the design scheme for calculating the maximum moment in the center of the beam. Figure 4.17 shows the design scheme for calculating the maximum shear force near the support. There is the separate calculation for maximum moment for uniformly distributed load and for axle loads.

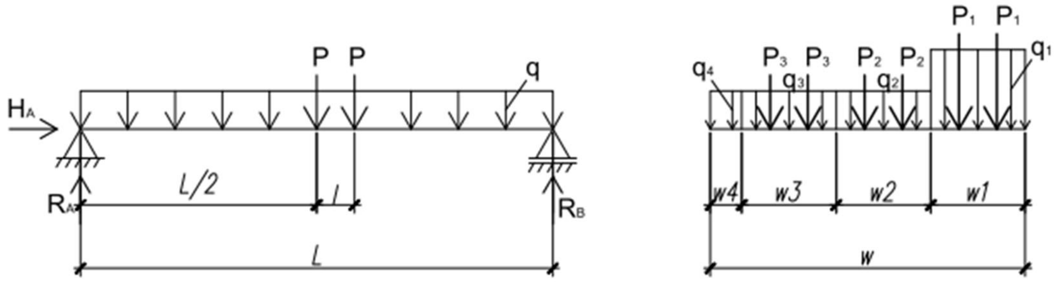


Figure 4.16 The design scheme of the beam for calculating bending moment

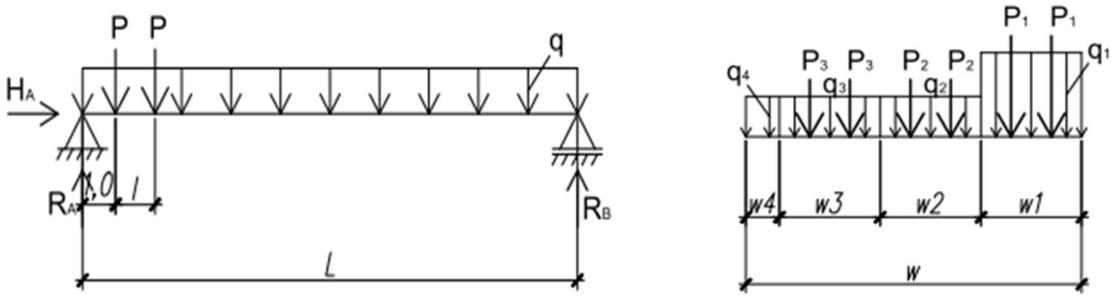


Figure 4.17 The design scheme of the beam for calculating shear force

Calculation:

1) basic data

a. $q_1 = 9$ kN/m^2, $q_2 = 2{,}5$ kN/m^2 , $q_3 = 2{,}5$ kN/m^2, $q_4 = 2{,}5$ kN/m^2 ;

b. $P_1 = 150$ kN, $P_2 = 100$ kN, P_3=50 kN;

c. L = 15,0 m, l = 1,2 m, w=10,0 m, $w_1 = w_2 = w_3 = 3{,}0$ m, $w_4 = 1{,}0$ m;

2) calculate traffic loads

a. $q = q_1 * w_1 + q_2 * w_2 + q_3 * w_3 + q_4 * w_4 = 9*3+2{,}5*3+2{,}5*3+2{,}5*1 = 44{,}5$ kN/m

b. $P = P_1*2+ P_2*2+ P_3*2 = 150*2+100*2+50*2 = 600$ kN

3) maximum moments:

a. maximum moment for uniformly distributed load

$\sum Ma = 0$

$R_B*L - q*(L/2)*L = 0$

$R_B = \frac{44,5*7,5*15}{15} = 333,75$ kN

$\sum Mb = 0$

$-R_A*L + q*(L/2)*L = 0$

$R_A = \frac{44,5*7,5*15}{15} = 333,75$ kN

$\sum y = 0$

$R_A + R_B - q*L = 0$

333,75 +333,75 - 44,5*15 = 0

0=0 !!!

$M^q = \frac{q*L^2}{8} = \frac{44,5*15^2}{8} = 1251,56\ kN/m$

b. maximum moment for axles loads

$\sum Ma = 0$

$R_B*L – P*((L/2)+l) – P*(L/2) = 0$

$R_B = \frac{600*\left(\frac{15}{2}+1,2\right)+600*(15/2)}{15} = 648$ kN

$\sum Mb = 0$

$-R_A*L + P*((L/2)-l) + P*(L/2) = 0$

$R_A = \frac{600*\left(\frac{15}{2}-1,2\right)+600*(15/2)}{15} = 552$kN

$\sum y = 0$

$R_A + R_B – P – P = 0$

552 + 648 – 600 – 600 = 0

0=0 !!!

$M^{axl} = R_A*(L/2) = 552*(15/2) = 4140$ kN/m

$$\sum M = M^q + M^{axl} = 1251,56 + 4140 = 5391,56\ kN/m$$

4) <u>shear forces:</u>

a. shear force for uniformly distributed load

$\sum Ma = 0$

R_B*L - q*(L/2)*L = 0

$R_B = \frac{44,5*7,5*15}{15} = 333,75$ kN

$\sum Mb = 0$

-R_A*L + q*(L/2)*L = 0

$R_A = \frac{44,5*7,5*15}{15} = 333,75$ kN

$\sum y = 0$

R_A +R_B - q*L = 0

333,75 + 333,75 - 44,5*15 = 0

0=0 !!!

$Q^q = R_A$ - q*1,0 = 333,75 - 44,5*1,0 = 289,25 kN

b. maximum moment for axles loads

$\sum Ma = 0$

R_B*L – P*(1,0+l) – P*1,0=0

$R_B=\frac{600*(1,0+1,2)+600*1,0}{15} = 128\ kN$

$\sum Mb = 0$

-R_A*L + P*(L-1,0) + P *(L-1,0-l) = 0

$R_A = \frac{600*(15-1,0)+600*(15-1,0-1,2)}{15} = 1072$kN

$\sum y = 0$

$R_A + R_B$ – P – P = 0

1072 + 128 – 600 – 600 = 0

0=0 !!!

$Q^{axl} = R_A = 1072$ kN

$$\sum Q = Q^q + Q^{axl} = 289,25 + 1072 = 1361,25\ kN/m$$

So, the results are:

M_{max}=5391,56 kNm

Q_{max}=1361,25 kN

4.2.3.2 Calculation by SNiPs

The design scheme and loads are presented in figure 4.18 and 4.19 for calculating the maximum moment and maximum shear force accordingly.

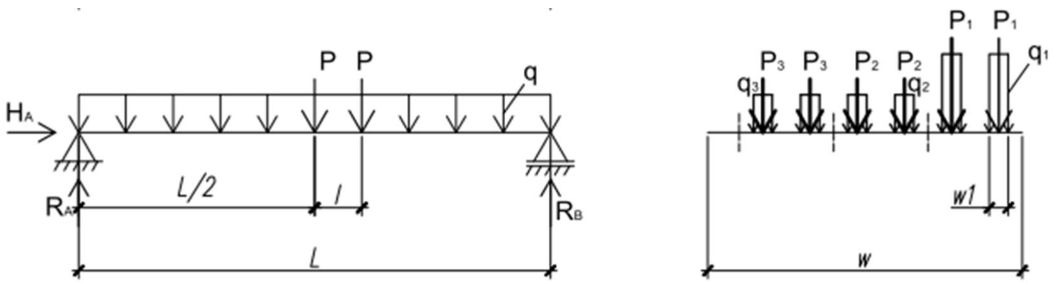


Figure 4.18 The design scheme of the beam for calculating bending moment

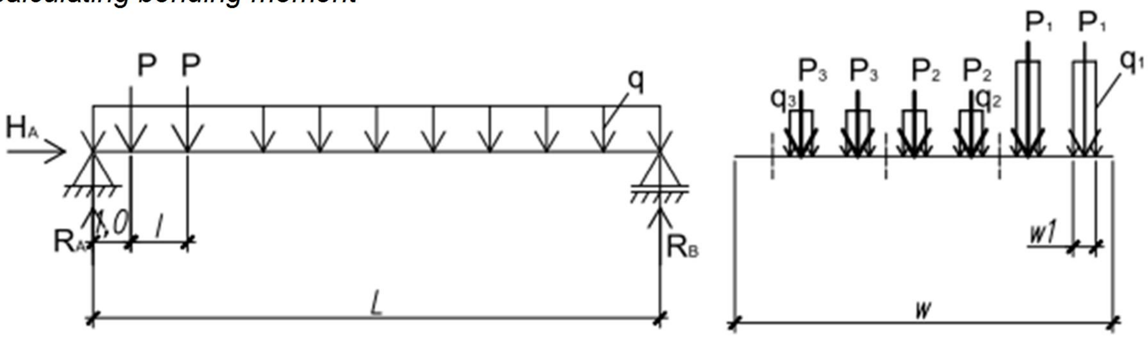


Figure 4.19 The design scheme of the beam for calculating shear force

Calculation part:

1) *basic data*
   a. $K = 14$
   b. $q = 0{,}98*K = 0{,}98*14 = 13{,}72$ kN/m

      $P = 9{,}81*K = 9{,}81*14 = 137{,}34$ kN
   c. $s_1 = 0{,}6$ for q and $s_1 = 0$ for P
   d. $q_1 = 13{,}72$ kN/m^2, $q_2 = (13{,}72* s_1)$ kN/m^2 , $q_3 = (13{,}72* s_1)$ kN/m^2;
   e. $P_1 = 68{,}67$ kN, $P_2 = 68{,}67$ kN, $P_3 = 68{,}67$ kN;
   f. $L = 15{,}0$ m, $l = 1{,}5$ m, $w = 10{,}0$ m, $w_1 = 0{,}6$ m;
2) *calculate traffic loads*
   a. $q = q_1* w_1 + q_2* w_2 + q_3* w_3 = 13{,}72*0{,}6 + (13{,}72*0{,}6)*0{,}6 + +(13{,}72*0{,}6)*0{,}6 = 18{,}108$ kN/m
   b. $P = P_1*2 + P_2*2 + P_3*2 = 68{,}67*2 + 68{,}67*2 + 68{,}67*2 = 412{,}02$ kN

3)maximum moments:

a. *maximum moment for uniformly distributed load*

$\sum Ma = 0$

$R_B*L - q*(L/2)*L = 0$

$R_B = \frac{18,108*7,5*15}{15} = 135,81\ kN$

$\sum Mb = 0$

$-R_A*L + q*(L/2)*L = 0$

$R_A = \frac{18,108*7,5*15}{15} = 135,81\ kN$

$\sum y = 0$

$R_A + R_B - q*L = 0$

*135,81 + 135,81 - 18,108*15 = 0*

0=0 !!!

$M^q = \frac{q*L^2}{8} = \frac{18,108*15^2}{8} = 509,29\ kN/m$

b. *maximum moment for axles loads*

$\sum Ma = 0$

$R_B*L – P*((L/2)+l) – P*(L/2) = 0$

$R_B = \frac{412,02*\left(\frac{15}{2}+1,5\right)+412,02*(15/2)}{15} = 453,22\ kN$

$\sum Mb = 0$

$-R_A*L + P*((L/2)-l) + P*(L/2) = 0$

$R_A = \frac{412,02*\left(\frac{15}{2}-1,5\right)+412,02*(15/2)}{15} = 370,82 kN$

$\sum y = 0$

$R_A + R_B – P - P=0$

370,82 + 453,22 - 412,02 - 412,02 = 0

0=0 !!!

$M^{axl} = R_A*(L/2) = 370,82*(15/2) = 2781,15\ kN/m$

$$\sum M = M^q + M^{axl} = 509,29 + 2781,15 = 3290,44\ kN/m$$

4)shear forces:

a. *shear force for uniformly distributed load*

$\sum Ma = 0$

$R_B*L - q*(L/2)*L=0$

$R_B=\frac{18,108*7,5*15}{15} = 135,81\ kN$

$\sum Mb = 0$

$-R_A*L + q*(L/2)*L=0$

$R_A=\frac{18,108*7,5*15}{15} = 135,81\ kN$

$\sum y = 0$

$R_A+R_B-q*L=0$

*135,81+135,81-18,108*15=0*

0=0 !!!

$Q^q=R_A-q*1,0=135,81-18,108*1,0=117,702\ kN$

b. *maximum moment for axles loads*

$\sum Ma = 0$

$R_B*L – P*(1,0+l) – P*1,0=0$

$R_B=\frac{412,02*(1,0+1,5)+412,02*1,0}{15} = 96,138\ kN$

$\sum Mb = 0$

$-R_A*L + P*(L-1,0) + P *(L-1,0-l)=0$

$R_B=\frac{412,02*(15-1,0)+412,02*(15-1,0-1,5)}{15} = 727,9\ kN$

$\sum y = 0$

$R_A+R_B-P-P=0$

727,9+96,138-412,02-412,02=0

0=0 !!!

$Q^{axl}= R_A=727,9\ kN$

$$\sum Q = Q^q + Q^{axl} = 117,702 + 727,9 = 845,6\ kN/m$$

So, the results are:

$M_{max} = 3290,44kNm$

$Q_{max} = 845,6kN$

4.2.4 Comparison of traffic loads

To compare traffic loads by SNiPs and Eurocodes is very difficult, because they have different models with different values of loads and impacts. For example, there is only one load model on rail traffic in SNiP (but it includes all load models of Eurocode in one except of HSLM), but in Eurocode – 4 load models. Also, load groups in SNiP are not so clear by presented as in Eurocode. Also, there is a big difference between the positions of load models on the bridge deck. Firstly, in Eurocode there is one rule for loading the bridge deck for ULS and for SLS, but for SNiP there is the difference because two ways of loading should be used for ultimate limit state and one way of loading for serviceability limit state. Also, there is the difference because of the number of load lines and the difference concerning the crowd on the footpaths. The load in Eurocode is depending on the width of the bridge deck, but the load in SNiP is depending on the number of lanes.

Safety factors cannot be compared because their values depend on the situation and on the project. But in general, the values of safety factors are a little bit higher for railway bridges in Eurocode than in SNiP, and about the same for road bridges.

According to the calculation part there can be found that the values of maximum moments and shear forces are bigger when calculating with Eurocode.

Eurocode:	*SNiP:*
M_{max}=5391,56 kNm	M_{max} = 3290,44 kNm
Q_{max}=1361,25 kN	Q_{max} = 845,6 kN

4.3 Wind loads

4.3.1 Wind loads in Eurocodes

The wind loads can be found from EN 1991-1- 4 and chapter C of NCCI 1. Wind actions on bridges produce forces in the x, y and z directions as shown in figure 4.20, where:
x-direction is the direction parallel to the deck width, perpendicular to the span;
y-direction is the direction along the span;
z-direction is the direction perpendicular to the deck.

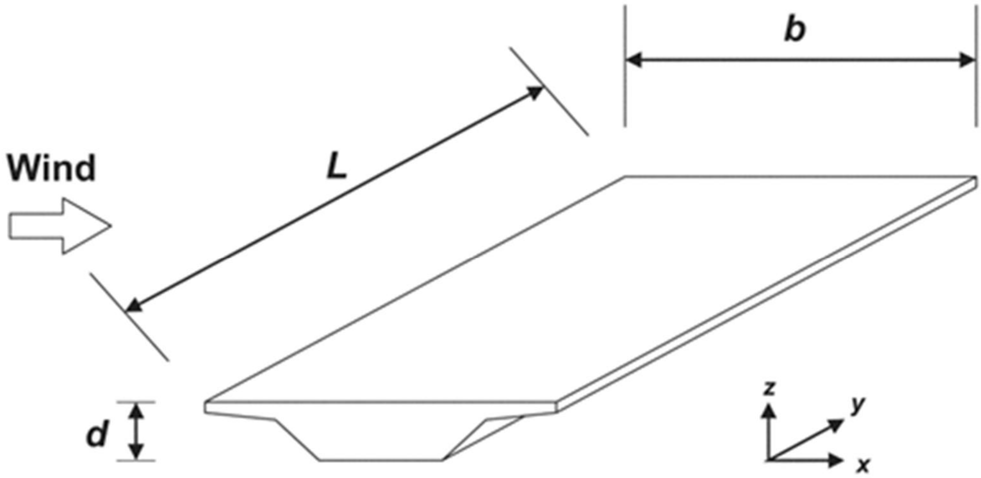
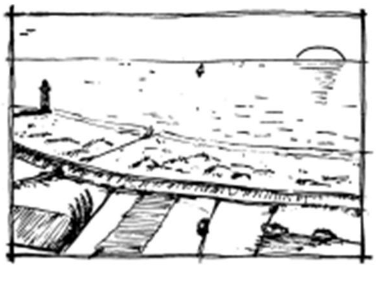


Figure 4.20 Directions of wind actions on the bridge

Longitudinal winds of bridges are 25% from transverse wind loads for beam and slab bridges, 50% from the transverse wind loads for the truss bridges unless otherwise specified for an individual project.
Assuming a value of 23 m/s the fundamental value of the basic wind velocity is $v_{b,0}$. The fundamental value of the basic wind velocity corresponds to the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in terrain category II. To calculate the wind load the following tables should be used. For large bridges and unusual conditions wind forces have to be calculated separately according to EN 1991-1- 4. The velocity and volume of the wind load depend on the terrain classes:

0 - sea, coastal area exposed to the open area;

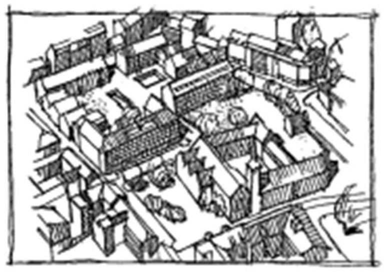


I - lakes or areas with negligible (незначительный) vegetation and without obstacles;

II - area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights;

III - area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain and permanent forest);

IV - area in which at least 15% of the surface is covered with buildings and their average height exceeds 15 m.



(Eurocode 1. Part 4, p 157)

The wind pressure (q [kN/m^2]) should be taken from table 4.12 (according to the table C.1 of NCCI 1 and table in NA of EN 199–1-4 in section 8.3.2/1) against bridge when the fundamental value of the basic wind velocity is 23 m/s.

Table 4.13 The values of wind pressures

Terrain class	0		I		**II**		III		IV	
b/d_{tot}	$z_c \leq 20m$	$z_c = 50m$	$z_c \leq 20m$	$z_c = 50m$	**$z_c \leq 20m$**	**$z_c = 50m$**	$z_c \leq 20m$	$z_c = 50m$	$z_c \leq 20m$	$z_c = 50m$
≤0,5	3,58	4,18	254	3,02	**2,23**	**2,75**	1,73	2,28	1,30	1,86
≥4[a]	1,94	2,26	1,37	1,64	**1,21**	**1,49**	0,94	1,24	0,71	1,01
≥5[b]	1,49	1,74	1,06	1,26	**0,93**	**1,15**	0,72	0,95	0,54	0,77

[a] Concerns bridge, where the rails are open, i.e. more than 50% of the projected area of the rail is opened.

[b] Concerns bridge, where at the same time presented traffic load or rails are closed

where b = width of the bridge deck

d_{tot} = height of the bridge deck

z_c = distance of the center of the gravity of the bridge deck from the ground

In general, the values of the terrain category II can be used, unless the relevant authority specifies for an individual project.

The impact area ($A_{ref,x}$) of the transverse wind load should be taken from the table 4.13 (according to table C.2 of NCCI 1 and table 8.1 of EN 1991-1-4).

Table 4.14 The impact area

	from one side	from both sides
Open rail (>50% open):	d + 0,3 [m]	d + 0,6 [m]
Zipped rail:	$d + d_1$ [m]	$d + 2 \times d_1$ [m]
With traffic:	$d + d^*$ [m]	

d = height of the bridge deck, d_1 = height of the zipped rail, d* = height of the traffic

Height of the road traffic on the bridge deck is assumed to be d^*=2,0 m and the height of railway traffic is assumed to be d^*=4,0 m in which d_{tot} measurement is calculated.
Different factors for road and railway bridges are shown in table 4.14.

Table 4.15 The values of safety factors for wind loads

Factors	for railroad bridges	for road bridges
safety factor	1,5	
combination factor ψ_0	0,75	0,6
combination factor ψ_1	0,5	0,2
combination factor ψ_2	0	0

The wind load is calculated separately for the case of empty bridge when it occurs simultaneously with traffic load. In Finnish NA for En 1991-1-4 the same basic wind velocity of 23 m/s is used also for the case when traffic is simultaneously on the deck (this is not the case in all countries). One must remember that this table is formulated only for small and medium span bridges constructed in normal environmental conditions.

4.3.2 Wind loads in SNiPs

The information about the wind loads can be found in chapter 6 in SNiP 2.01.07-85 and chapter 2.24 in SNiP 2.05.03-84*. The wind load should be determined as the sum of the average and pulsating components. The normative value of the vertical wind load should be defined by equation 4.1:*

$$W_n=W_m+W_p\ , \quad (4.1)$$

where

-W_m is the average wind load,can be defined by equation 4.1

-W_p is vibrating load, can be defined by equation 4.2

$$W_m=w_0*k*c_w, \quad (4.2\ )$$

where

-w_0 is normative wind value taking by SNiP 2.01.07-85. It depends on the area where the structure is located. Figure 4.15 shows which city belongs to which*

wind area and table 4.21shows normative wind values for different wind areas (according to table 5 of chapter 6 in SNiP 2.01.07-85). (SNiP 2.05.03-84*, 1996, pp 39-40)*

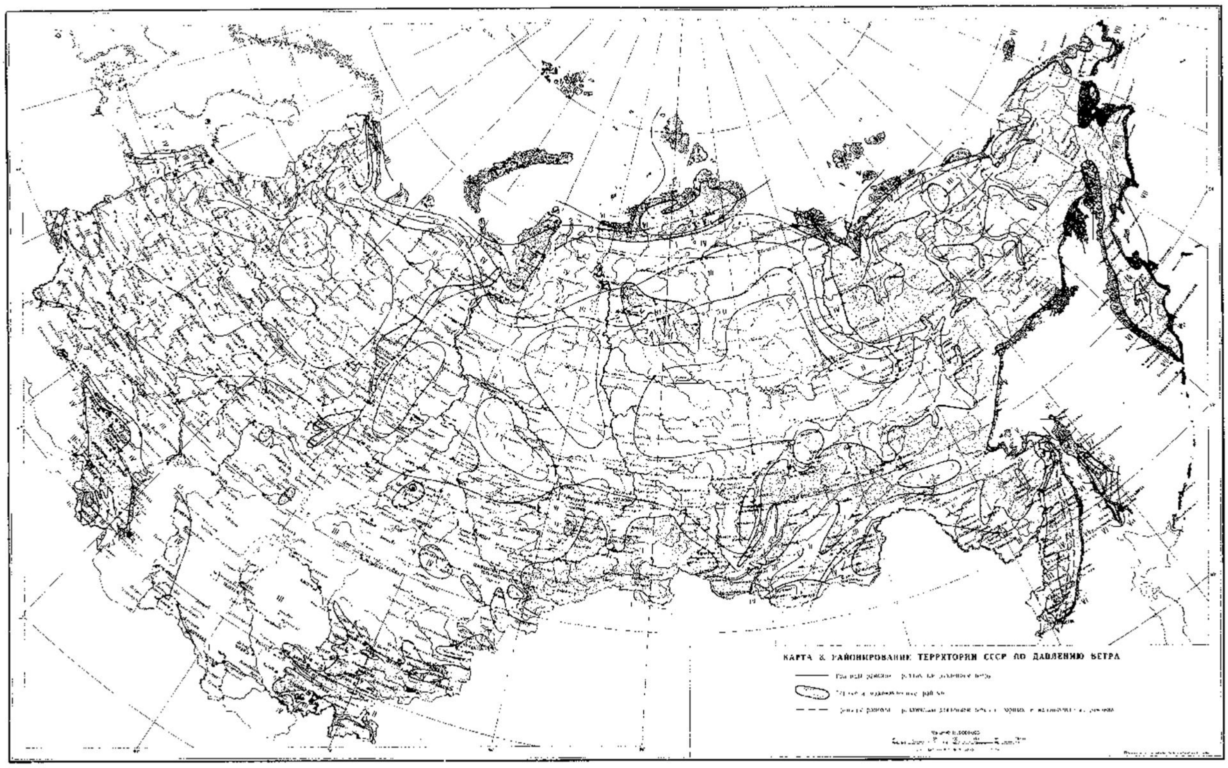


Figure 4.21 The map of the wind areas.

Table 4.16 The values of normative wind values

Wind areas (taken from the map 3)	*Ia*	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*
w_0, kPa (kgs/m^2)	*0,17 (17)*	*0,23 (23)*	*0,30 (30)*	*0,38 (38)*	*0,48 (48)*	*0,60 (60)*	*0,73 (73)*	*0,85 (85)*

For example, Saint – Petersburg is situated in the II wind area and has w_0=0,30kPa.

k – factor, taking into account changes of wind pressure on height, taking by SNiP 2.02.07-85. It depends on the area where the structure is located. The values of k-factor are shown in table 4.17 according to table 6 of chapter 6 in SNiP 2.01.07-85*.*

Table 4.17 The values of k-factor

Height z, m	*coefficient k for the types of area*		
	A	*B*	*C*
≤ 5	*0,75*	*0,5*	*0,4*
10	*1,0*	*0,65*	*0,4*
20	*1,25*	*0,85*	*0,55*
40	*1,5*	*1,1*	*0,8*
60	*1,7*	*1,3*	*1,0*
80	*1,85*	*1,45*	*1,15*
100	*2,0*	*1,6*	*1,25*
150	*2,25*	*1,9*	*1,55*
200	*2,45*	*2,1*	*1,8*
250	*2,65*	*2,3*	*2,0*
300	*2,75*	*2,5*	*2,2*
350	*2,75*	*2,75*	*2,35*
≥ 480	*2,75*	*2,75*	*2,75*

A, B, C are the areas of wind loads:

A - opened beaches of the seas, lakes and water reservoirs, deserts, steppes and tundra,

B - city areas, forest massive and other area covered with obstacles with height more than 10 meters,

C - city area with structures (height is more than 25 meters)

c_w *– aerodynamic factor of frontal resistance of bridge structures and railway trucks, taken from appendix 9 of SNiP 2.05.03-84**

$$W_p=w_m*\zeta*L*\vartheta, \quad (4.3)$$

where

w_m *is an average wind load*

ζ *is a dynamic factor, taken by SNiP 2.01.07-85*. It depends on the area where the structure is located. The values of dynamic factor are shown in table 4.18 according to table 7 of chapter 6 in SNiP 2.01.07-85*.*

Table 4.18 The values of dynamic factor

Height z, m	dynamic factor ζ for the types of area		
	A	B	C
≤ 5	0,85	1,22	1,78
10	0,76	1,06	1,78
20	0,69	0,92	1,50
40	0,62	0,80	1,26
60	0,58	0,74	1,14
80	0,56	0,70	1,06
100	0,54	0,67	1,00
150	0,51	0,62	0,90
200	0,49	0,58	0,84
250	0,47	0,56	0,80
300	0,46	0,54	0,76
350	0,46	0,52	0,73
≥ 480	0,46	0,50	0,68

L is a fluctuating factor of wind pressure on the height z

ϑ is a coefficient of spatial correlation of pressure vibrations of the construction of the estimated surface. It depends on the length of the span and height of the pier.

The horizontal transverse wind load should be defined as density of wind load multiplied on "wind surface".

Load factors are defined by table 17 in SNiP 2.05.03-84. The values of ψ-factors are defined by Annex 2 of SNiP 2.05.03-84*.*

Different factors for road and railway bridges are shown in table 4.19.

Table 4.19 The values of load factors for wind loads in SNiP

Factors	**for railroad bridges**	**for road bridges**
safety factor	1,0/1,4 (building phase / maintenance phase of bridge)	
combination factor η	0,5/0,7/0,8 (depends on	0,25/0,5 (depends on the

	the load combination).	*load combination).*

4.3.3 Comparison of wind loads

Example values of the design wind pressure and safety factors are shown in the table 4.20. The values are given on level 10 meters for Saint – Petersburg (for locality type B), corresponding terrain category III of EN 1991-1-4.

Table 4.20 Comparison for wind loads between Eurocode and SNiP

	terrain category III (EN 1991-1-4)	**Saint – Petersburg (SNiP)**
wind pressure	0,94	0,22
safety factor	1,5	1,0/1,4

As it can be found from table 4.20, the value of wind pressure is much higher according to Eurocode than to SNiP. The value of safety factor is higher in Eurocode, than in SNiP. Also, there are different methods of calculating wind loads. Wind loads are determined as peak wind loads in Eurocode and as wind pressure in SNiP.

4.4 Thermal loads

4.4.1 Thermal loads in Eurocodes

Information about thermal load can be found in EN 1991-1-5 and chapter D of NCCI 1. The free expansion or contraction of a structure due to changes in temperature may be restrained by its form of construction. Where any portion of the structure is not free to expand or contract under the variation of temperature, allowance should be made for the stresses resulting from this condition. Apart from stresses in structure the thermal forces also affect the design of bearings and expansion joints. For the purpose of the design, temperature loadings are adopted from the country specific maps and tables.

In SFS-EN 1991-1-5 bridge decks are grouped into three categories:

Type 1 – steel deck – steel box girder, steel truss or plate girder;

Type 2 – composite deck;

Type 3 – concrete deck – concrete slab, concrete beam and concrete box girder.

For calculating the thermal load uniform bridge temperature should be used. The maximum temperatures of the bridges are concerning temperatures that are warmer than the measured temperatures in the air shadow 16^{o}C for steel bridges, 4^{o}C for composite bridges and 2^{o}C for concrete bridges. Similarly, the minimum temperatures of the bridge are lower 3^{o}C for the steel bridge and for composite beam bridges 4^{o}C, and for concrete bridges 8^{o}C higher than the minimum air temperatures. Figures 4.22 and 4.23 show the needed information for thermal loads. (NCCI-1, 2010, p 44)

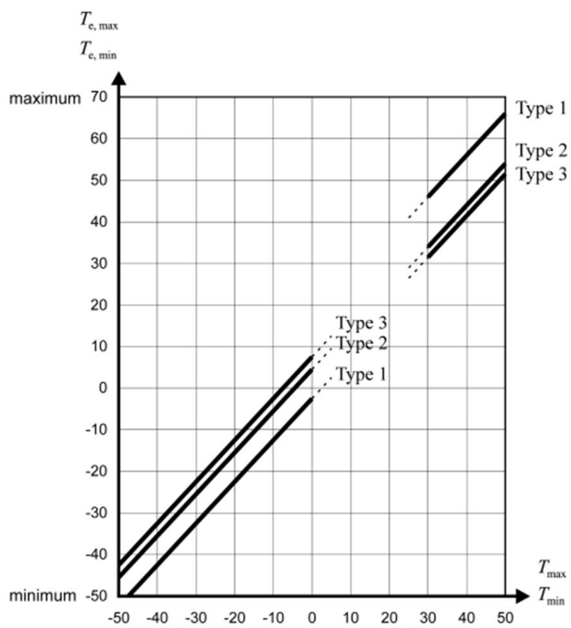


Figure 4.22. Correlation between minimum/maximum shade air temperature (T_{min}/T_{max}) and minimum/maximum uniform bridge temperature component ($T_{e.min}$/$T_{e.max}$).

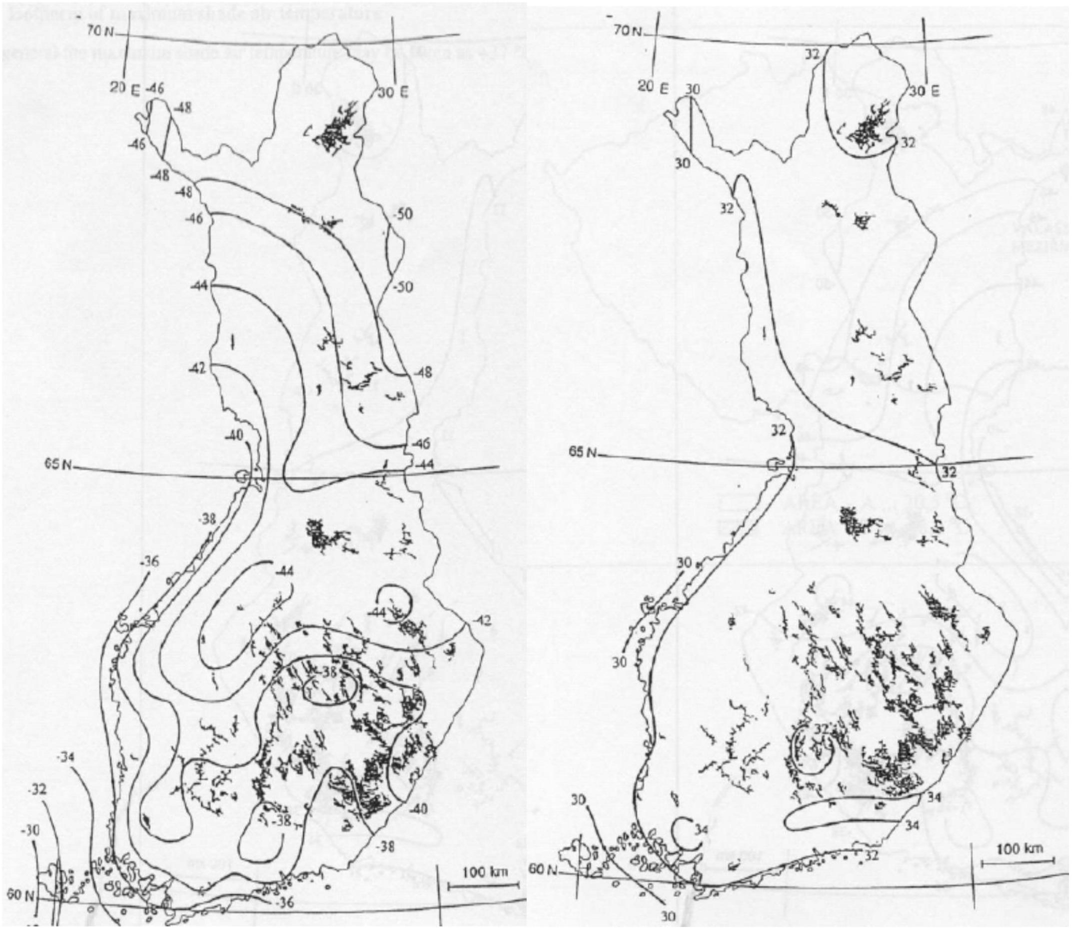


Figure 4.23   The extreme values of temperatures in Finland

For example, in Lappeenranta the extreme values of temperature are -40^{o}C in winter and +34^{o}C in summer.

Over a prescribed time period warming and cooling of a bridge deck’s upper surface will result in a maximum heating (top surface warmer) and a maximum cooling (bottom surface warmer) temperature variation. This is more important for designing the bridge, than when all the surface of bridge is warming. This is written in chapter 6.1.4 of EN 1991-1-5 and in chapter D of NCCI 1. The vertical temperature differences may produce effects within a structure due to:

-restraint of free curvature due to the form of the structure (e.g. portal frame, continuous beams and etc);

-friction at rotational effects ;

-non-linear geometric effects (2nd order effects).

There are two methods for calculating vertical thermal components: linear and non-linear. Linear method is normally used in Finland. The linear vertical temperature difference can be determined from table 4.21(corresponding table 6.1 of EN 1991-1-5 and table D1 of NCCI 1).

Table 4.21 Linear vertical temperature changes

Type of Decks:	Top warmer $\Delta T_{M,heat}$ (°C)	Bottom warmer $\Delta T_{M,cool}$ (°C)
Type 1: Steel deck	18	13
Type 2: Composite deck	15	18
Type 3: Concrete deck: - concrete box girder - concrete beam - concrete slab	 10 15 15	 5 8 8

The present values of table 4.21 are based on the 50 mm surfacing thickness. In table 6.2 of EN 1991-1-5 (corresponding table D2 of NCCI 1) correction factor k_{sur} for the different surfacing thicknesses has been presented.
Different factors for road and railway bridges are shown in table 4.22.

Table 4.22 The values of load factors for thermal loads in Eurocode

Factors	**for railroad bridges**	**for road bridges**
safety factor	1,5	
combination factor ψ_0	0,6	0,6
combination factor ψ_1	0,6	0,6
combination factor ψ_2	0,5	0,5

4.4.2 Thermal loads in SNiPs

The information about thermal loads can be found in chapter 8 in SNiP 2.01.07-85 and in chapter 2.27 in SNiP 2.05.03-84*.*

The normal thermal load should be taken into account when the bridge is calculated on the displacement, when forces are defined externally statically in terminate system are defined and for the elements of composite superstructures. The thermal load is defined as the average temperature of the coldest 5 days in a winter and with the availability 0,98. And in summer as the average of the month and the daily amplitude. Thermal load depend on the area where the structure is situated. It is defined by the temperature maps. For example, there are maps of the average temperature in January and in July in figures 4.24 and 4.25. For example, in Saint – Petersburg the average temperature in January is -10 C^{o} and in July 15 C^{o}.

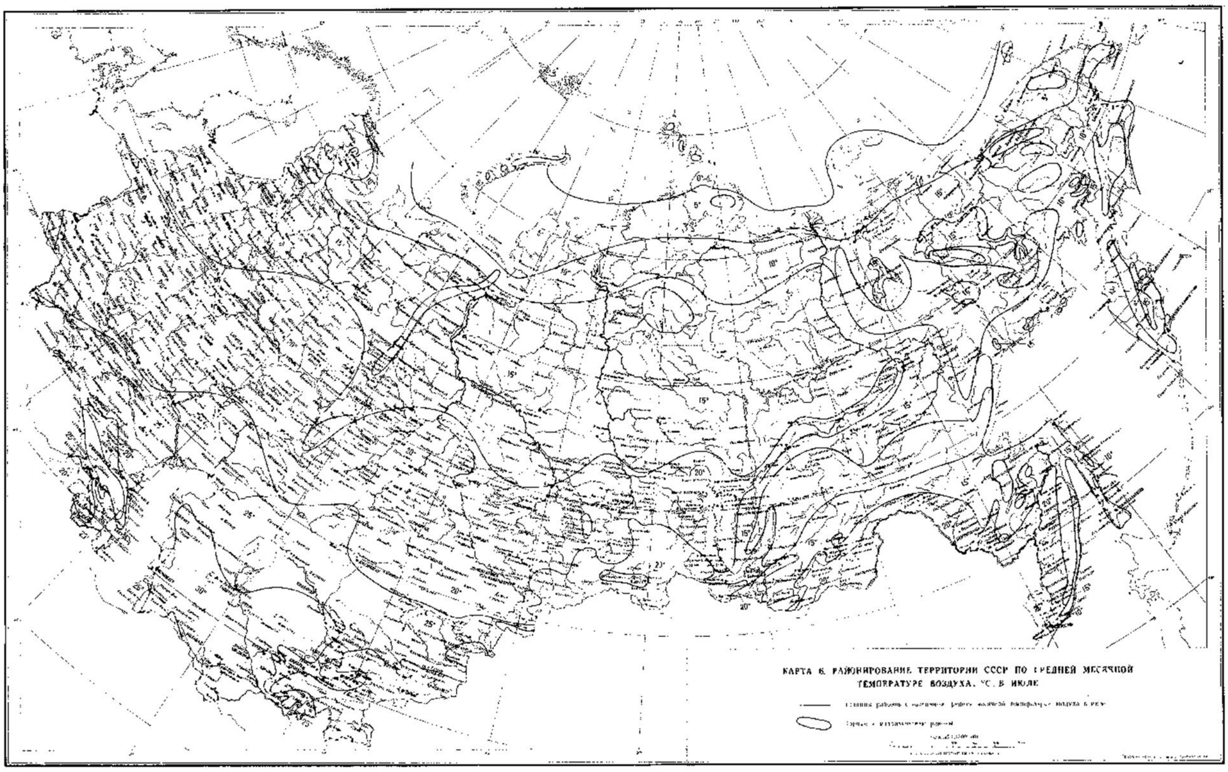


Figure 4.24 The map of the average values of temperatures in July

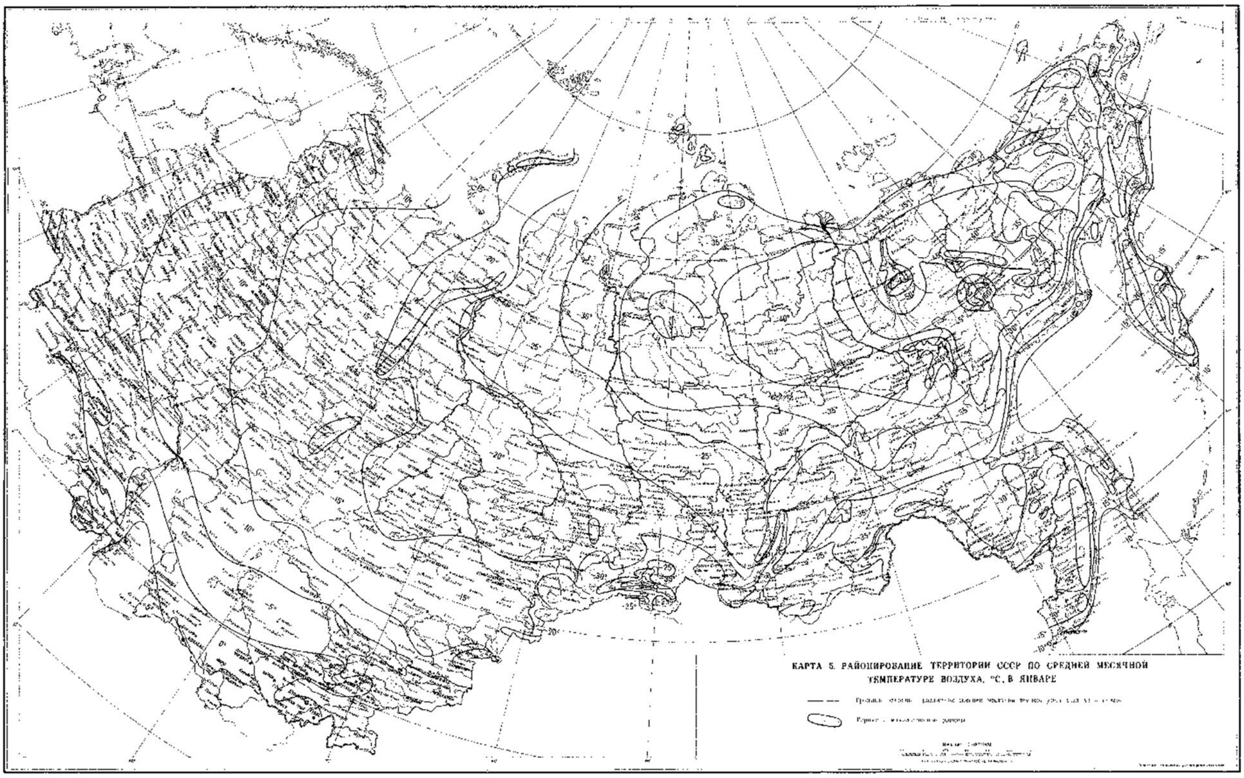


Figure 4.25 The map of the average values of temperatures in January

The extreme values of temperatures in Saint – Petersburg are: the minimum temperature is -35,9C^{o} and the maximum is 37,1C^{o}.

Different factors for road and railway bridges are shown in table 4.23.

Table 4.23 The values of load factors for thermal loads in SNiP

Factors	***for railroad bridges***	***for road bridges***
safety factor	*1,2*	
combination factor η	*0,7/0,8 (depends on the load combination).*	

4.4.2 Comparison of thermal loads

Examples of extreme temperatures and safety factors are shown in the table 4.24. The values are given for Saint – Petersburg (SNiP) and Lappeenranta (EN 1991-1-5).

Table 4.24 Comparison of different parameters for thermal loads between Eurocode and SNiP

	Lappeenranta (EN 1991-1-5)	**Saint – Petersburg (SNiP)**
maximum temperature	+34C^o	+37,1C^o
minimum temperature	-40C^o	-35,9C^o
safety factor	1,5	1,2

As it can be found from table 4.24, the values are higher in Finland. Also, In Russia thermal loads are calculated by using average temperatures, but in Finland extreme temperatures.

4.5 Ice loads

4.5.1 Ice loads in Eurocodes

The scope of Eurocodes does not include ice loads. The ice loads used in Finland are explained in NCCI 1 chapter H.1

The bridge structure is designed for the ice loads by taking into account local conditions and structure design. In normal icy conditions, the ice loads of the bridges can be determined as follows. Ice loads against the structures are expected to affect in a horizontal direction to the water level. Bridge piers are subjected to ice load P_1, which is primarily caused by the temperature change of permanent ice cover, and ice load P_2, which is caused by the current pressure on the fixed ice cover. Load P_1 is supposed to affect in horizontal direction against the side surface of column and load P_2 to the flow direction. These ice loads are not expected to act simultaneously. This all is shown in figure 4.26. (NCCI-1, 2010, p 64)

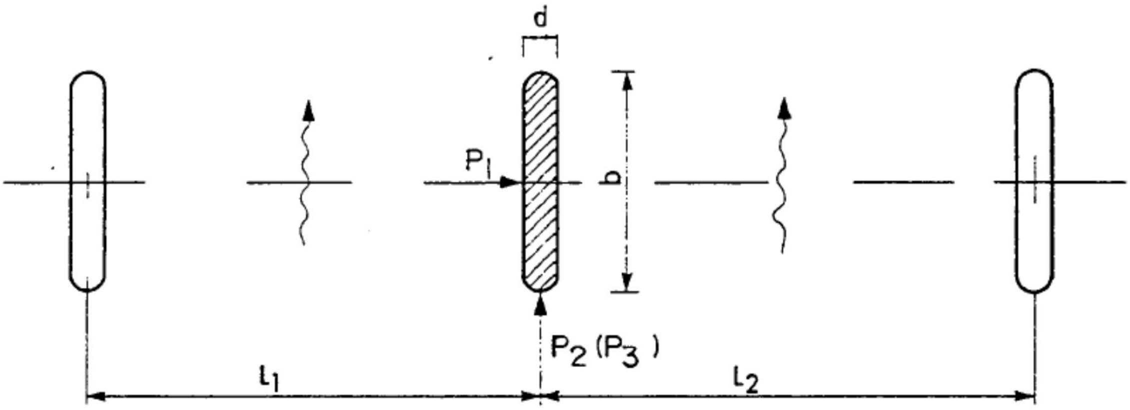


Figure 4.26 Influenced ice loads to the bridge pier.

Different factors for road and railway bridges are shown in table 4.25.

Table 4.25 The values of load factors for ice loads in Eurocode

Factors	for railroad bridges	for road bridges
safety factor	1,5	
combination factor ψ_0	0,7	0,7
combination factor ψ_1	0,5	0,5
combination factor ψ_2	0,2	0,2

4.5.2 Ice loads in SNiPs

The information about ice loads can be found in chapter 7 of SNiP 2.01.07-85 and annex 10 in SNiP 2.05.03-84*.*

The ice load on bridge's piers should be defined based on the initial data of ice conditions in the area where the structure is situated for the period when the ice load is maximum. The ice load depends on the area where the structure is situated and the shape of the pier. For example, table 4.26 shows the ice areas of Russia (according to table 1 of Annex 10 in SNiP 2.5.03-84).*

Table 4.26 The ice areas of Russia

№ of the area	*borders of the area*	*climatic coefficient K_n*
I	*to the south of the line Vibourg – Smolensk – Kamishin – Aktubinsk - Balhash*	*1*
II	*to the south of the line Arxangelsk – Kirov – Ufa – Kustanai – Karaganda – Yst'-Kamenogorsk*	*1,25*
III	*to the south of the line Vorkuta – Hanti-Mansiisk – Krasnozrsk – Ylan-Yde – Nikolaevsk-na-Amure*	*1,75*
IV	*to the north of the line Vorkuta Hanti-Mansiisk – Krasnozrsk – Ylan-Yde – Nikolaevsk-na-Amure*	*2*

Table 4.27 (according to the table 2 of Annex 10 in SNiP 2.05.03-84) shows the coefficients of the shape of the pier..*

Table 4.27 The values of shape factors for ice loads

coefficient	*Shape factor for the piers which has in the plan the shape of*							
	polygon	*rectangle*	*triangle with an angle of taper in plan, deg*					
			45	*60*	*75*	*90*	*120*	*150*
ψ_1	*0,90*	*1,00*	*0,54*	*0,59*	*0,64*	*0,69*	*0,77*	*1,00*
ψ_2	*2,4*	*2,7*	*0,2*	*0,5*	*0,8*	*1,0*	*1,3*	*2,7*

Different factors for road and railway bridges are shown in table 4.28.

Table 4.28 The values of load factors for ice loads in SNiP

Factors	***for railroad bridges***	***for road bridges***
safety factor	*1,2*	
combination factor η	*0,7*	

4.5.2 Comparison of ice loads

Examples of values of safety factors are shown in table 4.29.

Table 4.29 Comparison of safety factors for ice loads between Eurocode and SNiP

	Eurocode	**SNiP**
safety factor	1,5	1,2

As it can be found from table 4.29, the value of safety factor is higher in Eurocode, than in SNiP.

4.6 Seismic loads

4.6.1 Seismic loads in Eurocodes

The information about seismic loads can be found in EN 1998, especially in En 1998-2 – seismic load for bridges. Seismic loading is one of the basic concepts of earthquake engineering. If a bridge is situated in an earthquake prone region, the earthquake or seismic forces are given consideration in structural design. Seismic loading depends, primarily, on:

- Anticipated earthquake’s parameters at the site - known as seismic hazard
- Geotechnical parameters of the site
- Structure’s parameters
- Characteristics of the anticipated gravity waves from tsunami (if applicable).

Sometimes, seismic load exceeds ability of a structure to resist it without being broken, partially or completely.

Earthquakes cause vertical and horizontal forces in the structure that will be proportional to the weight of structure. Both horizontal and vertical components have to be taken into account for the design of a bridge structure. Because of Finnish geographical location seismic loads are not considered in Finland.

The load safety factors and ψ -values for different loads can be found from table A2.5 of EN 1990/A1and table G.7 of NCCI 1.

The safety factor for seismic load is 1,0. The ψ_2 -value is used for all other simultaneous loads. Table 4.30 shows the values of combination factors in seismic design situation.

Table 4.30 The values of combination factors in Eurocode

factors	for railway bridges	for road bridges
safety factor	1,0	
combination factor for traffic loads	0	0/0,3
combination factor for wind loads	0	0
combination factor for thermal loads	0,5	0,5
combination factor for ice loads	0,2	0,2

4.6.2 Seismic loads in SNiPs

The information about seismic loads can be found in chapter 4 of SNiP II-7-81 "Design in the seismic areas" and chapter 2.31 of SNiP 2.05.03-84*.*

When designing in seismic areas the following criteria should be considered:

- *use materials, structures and structural systems which cause the minimum values of seismic load;*
- *use symmetrical systems, uniformdistribution of rigidity and mass, load on the overlapping;*
- *provide a good monolithic of the structure*
- *take into account the density of seismic impact (in points) and frequency of seismic*
- *Buildings and structures should be calculated on seismic load only when they are situated in the area where seismic activity is 7, 8 or 9 points. (SNiP II-7-81*, 2011, pp 4-9).*

  These areas can be defined from the seismic map which is in figure 4.27.

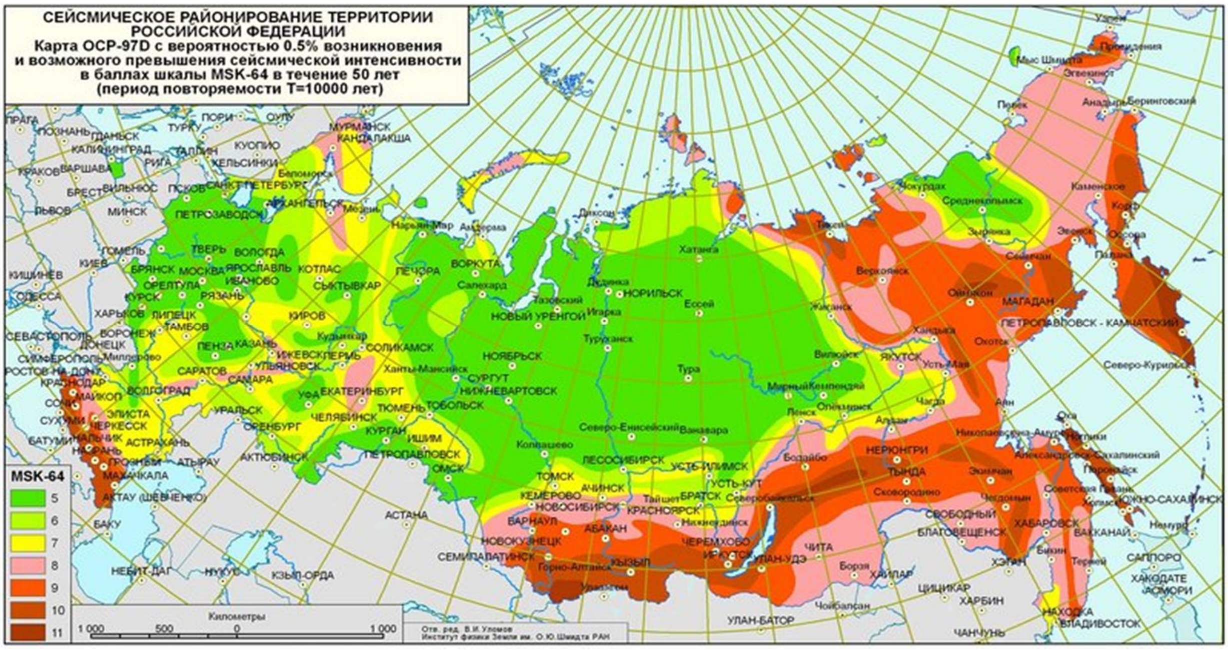


Figure 4.27 The map of seismic activity

For example, in Saint – Petersburg structures should not be calculated on seismic load because its seismic activity is 5. But if the bridge is situated in the seismic activity area, the beam systems with split and continuous spans are better. Table 4.31 shows the values of combination factors in seismic design situation.

Table 4.31 The values of combination factors in SNiP

factors	**for railway bridges**	**for road bridges**
safety factor	1,2	
combination factor for traffic loads	0,7	0,3
combination factor for wind loads	1	1
combination factor for thermal loads	1	1
combination factor for ice loads	1	1

4.6.2 Comparison of seismic loads

Examples of values of safety factors are shown in table 4.32.

Table 4.32 Comparison of load factors for seismic loads between Eurocode and SNiP

factors	for railway bridges by Eurocode	for railway bridges by SNiP	for road bridges by Eurocode	for road bridges by SNiP
safety factor	1,0	1,2	1,0	1,2
combination factor for traffic loads	0	0,7	0/0,3	0,3
combination factor for wind loads	0	1	0	1
combination factor for thermal loads	0,5	1	0,5	1
combination factor for ice loads	0,2	1	0,2	1

As it can be found from table 4.32, the values of safety and combination factors are higher in SNiP, than in Eurocode. Also, both in Lappeenranta and Saint – Petersburg, bridges are not calculated for seismic loads, because they are situated in not dangerous areas.

4.7 Accidental loads

4.7.1 Accidental loads in Eurocodes

Accidental loads can be found from EN 1991-1-7 and from chapter F of NCCI 1. NCCI 1 presents 5 accidental loads which are: road vehicle impact on supporting substructures, road vehicle impact on superstructures, accidental actions caused by derailed rail traffic (both derailed train on deck and collision of derailed train to other structures) and accidental actions caused by ship traffic. But more detailed will be presented accidental actions caused by ship traffic which is in chapter 4.6 of EN 1991-1-7 and chapter 4.8 of NCCI 1.

Accidental actions due to collisions from ships should be determined taking into account the following things:

-the type of waterway

-the flood conditions

-the type and draught of vessels and their impact behavior

-the type of the structures and their energy dissipation characteristics.

The vessel types of sea areas and inland shipping routes are provided by the received shipping data specific waterways by relevant authorities, unless the relevant authorities are not specified the features of vessels for an individual project. The severity classes of ship collision, acceptable level of risk as well as the classification of waterways are specified by the relevant authorities for the individual project.

In Finland Eurocodes are not used for ship impact directly (ships in Eurocode are so different). Normally the load is defined for individual project. Typically it is 1,5…4,0 MN.

Impact by ships against solid structures on inland waterways should normally be considered as hard impact, with the kinetic energy being dissipated by elastic or plastic deformation of the ship itself. In the absence of a dynamic analysis, table 4.33 (corresponding to the table C.3 in EN 1991-1-7) gives indicative values of the forces due to ship impact on inland waterways. But a risk analysis is needed when there is a risk about large ship collisions.

Table 4.33 Indicative values for the dynamic forces due to ship impact on inland waterways.

CEMT[a] Class	**Reference type of ship**	**Length / (m)**	**Mass *m* (ton)[b]**	**Force F_{dx}[c] (kN)**	**Force F_{dy}[c] (kN)**
I		30-50	200-400	2000	1000
II		50-60	400-650	3000	1500
III	"Gustav Köning"	60-80	650-1000	4000	2000
IV	Class "Europe"	80-90	1000-1500	5000	2500

Va	Big ship	90-110	1500-3000	8000	3500
Vb	Tow +2 barges	110-180	3000-6000	10000	4000
VIa	Tow + 2 barges	110-180	3000-6000	10000	4000
VIb	Tow + 4 barges	110-190	6000-12000	14000	5000
Vic	Tow + 6 barges	190-280	10000-18000	17000	8000
VII	Tow + 9 Barges	300	14000-27000	20000	10000

[a] CEMT: European Conference of Ministers of Transport, classification proposed 19 June 1992, approved by the Council of European Union 29 October 1993

[b] The mass *m* in tons (1 ton=1000kg) includes the total mass of the vessel, including the ship structure, the cargo and the fuel. It is often referred to as the displacement tonnage.

[c] The forces F_{dx} and F_{dy} include the effect of hydrodynamic mass and are based on background calculations, using expected conditions for every waterway class.

The factors are shown in table 4.34. More detailed information about load factors can be found in tables G.7 (chapter G 3.2) and table 2 in Annexes 1A and 1B of NCCI 1.

Table 4.34 The values of load factors for ship collisions

factors	for railroad bridges	for road bridges
safety factor	1,0	
combination factor ψ_1	0,8/0,7/0,6[1)2)] for traffic loads	0,75/0,4[3)] for traffic loads
combination factor ψ_2	for all other loads	

Notes:

[1)] The factor depends on the number of the loaded tracks I as follows: i=1=> $\psi 1=0,7$, when i=2 and 0,6 when i≥3

[2)] If otherwise not decided based on a specific project (eg, track-yard), in the accidental combination the traffic loads on the bridges can be halved

[3)] In accidental combination traffic load model LM1 is taken into account in one lane (with a frequent value)

4.7.2 Accidental loads in SNiPs

Accidental loads, especially ship impacts, can be found from chapter 2.26 of SNiP 2.05.03-84. Load from ship impacts and collisions should be taken as pointed longitudinal and transverse force. It, also, should be limited depending on the waterway class with the values, which are in table 4.35 (according to table 15 of chapter 2.26 in SNiP 2.05.03-84*).*

Table 4.35 The values of load from ship collisions in SNiP

waterway class	***Load from ship collisions, kN***			
	along the bridge span		*transverse the bridge span*	
	shipping	*no shipping*	*upper side*	*lower side*
I	*1570*	*780*	*1960*	*1570*
II	*1130*	*640*	*1420*	*1130*
III	*1030*	*540*	*1275*	*1030*
IV	*880*	*490*	*1130*	*880*
V	*390*	*245*	*490*	*390*
VI	*245*	*147*	*295*	*245*
VII	*147*	*98*	*245*	*147*

The load from ship collisions should be calculated on the pier on the high 2 meters from the estimated level of shipping.
Different factors for road and railway bridges are shown in table 4.36.

Table 4.36 The values of load factors in SNiP

Factors	***for railroad bridges***	***for road bridges***
safety factor	*1,2*	
combination factor η	*0,7/0,8/1,0 (depends on the load combination)*	

4.7.3 Comparison of accidental loads

Examples of values of safety factors are shown in table 4.37.

Table 4.37 Comparison of safety factors for accidental loads between Eurocode and SNiP

	Eurocode	**SNiP**
safety factor	1,5	1,2

As it can be found from table 4.37, the value of safety factor is higher in Eurocode, than in SNiP.

As it can be found from tables 4.33 and 4.35 the values from ship collisions are very different: in Eurocode they are bigger. For example, the maximum value of ship load transverse the bridge equals 1960 kN in SNiP and 10 000 kN in Eurocode.

5 LOAD COMBINATIONS

A combination of actions is a set of design values used for the verification of structural reliability for a limit state under the simultaneous influence of different actions. A load combination results when more than one load type acts on the structure. Design codes usually specify a variety of load combinations together with load factors for each load type in order to ensure the safety of the structure under different maximum expected loading scenarios.

Effects of actions that cannot exist simultaneously due physical or frictional reasons should not be considered together in combinations of actions.

5.1 Load combinations in Eurocodes

The information about the load combinations can be found in Annex 2 of EN 1990 and in the chapter G of NCCI 1. The load combinations of the ultimate and serviceability limit state are formed by the help of table G4-G8 (corresponding tables A2.4…A2.6 are in the standard). The used combination factors in the combination have been presented in tables G1…G3 (corresponding tables A2.1…A2.3 are in the standard)

5.1.1 Combination rules

There are some combination rules for road, railway bridges and, also, for accidental design situation, which are in EN 1990/A1 Annex A2 in the paragraph A2.2.2, A2.2.4 and A 2.2.5.

The rules are:

- for road bridges:
  - LM2 and the concentrated load Q_{fwk} (see 5.3.2.2 in EN 1991-2: 10 kN acting on the surface of sides 0,10 m) on footways need to be combined with any variable non traffic action;
  - neither snow nor wind loads need to be combined with:
    - braking and acceleration forces of the centrifugal forces or the associated group of loads gr 2;
    - loads on footways and cycle tracks or with the associated group of load gr3;
    - crowd loading (LM4) or the associated group of loads gr 4;
  - snow loads need to be combined with LM1 and LM2 or with the associated groups of loads gr1a and gr 1b unless otherwise specified for particular geographical areas;
  - wind actions and thermal actions need to be taken into account simultaneously unless otherwise specified for local climatic conditions.
- for railway bridges:
  - snow loads need to be taken into account in any combination for persistent design situations nor for any transient design situation after the completion of the bridge unless otherwise specified for particular geographical areas and certain types of railway and pedestrian bridges;
  - the combinations of actions to be taken into account when traffic actions and wind actions act simultaneously should include:
    - vertical rail traffic actions including dynamic factor, horizontal rail traffic actions and wind forces with each action being considered as the leading action of the combination of actions one at time;

        - vertical rail traffic actions excluding dynamic factor and lateral rail traffic actions from the “unloaded train” defined in EN 1991-2 (6.3.4) with wind forces for checking stability;
    - actions due to aerodynamic effects of rail traffic (see EN 1991-2, 6.6) and wind actions should be combined together. Each action should be considered individually as a leading variable action;
    - where groups of loads are not used for rail traffic loading, rail traffic loading should be considered as a single multi – directional variable action with individual components of rail traffic actions to be taken as maximum unfavorable and minimum favorable values as appropriate.
- for accidental design situations:
    - where the action for an accidental design situation needs to be taken into account, no other accidental action or wind action or snow load need be taken into account in the same combination;
    - for an accidental design situation concerning impact from traffic (road od railroad) under the bridge, the loads due to the traffic on the bridge should be taken into account in the combinations as accompanying actions with their frequent value;
    - for railway bridges, for an accidental design situation concerning actions caused by a derailed train on the bridge , rail traffic actions on the other tracks should be taken into account as accompanying actions in the combinations with their combination value;
    - accidental design situations involving ship collisions against bridges should be identified. (EN 1990A1/annex2, 2005, pp 9-12).

All above rules (+ other rules of Annex 2 not repeated here) have been included into combination tables of NCCI 1.

5.1.2 Combination and consequence factors

Combination factors

Combination factors are used when it more than one loads or impacts should be taken into account. There are 3 different serviceability situations for combination factors in Eurocode: Characteristic, frequent and quasi – permanent combination.

Characteristic combination means that is calculated the load which can be once for the cycle of life time the structure, frequent – in some period (for example, once in 1 year) and quasi – permanent is the constant load. The combination value is used for the verification of ultimate limit states and irreversible serviceability limit state (e.g. stress limits for concrete). The frequent value is used for verifications of reversible serviceability limit states (e.g. deflection limits). The quasi-permanent value is used for the verification of ultimate limit states involving accidental actions and for the verification of reversible serviceability limit states. Quasi-permanent values are also used for the calculation of long-term effects. All combination factors can be found in tables 5.1 and 5.2 of this section, according to tables A2.1...A2.3 of EN 1990/A1 Annex A2 and to tables G1…G3 of NCCI 1.

Table 5.1 Combination factors for road bridges

	Load			ψ^0 Combination	ψ^1 Frequent	ψ^2 Quasi-permanent
gr1a	TRAFFIC LOADS	gr1a	ts (LM1)	0,75	0,75	-
			UDL (LM1) <2>	0,4	0,4	- 0,3
			Footway and cycle tracks (3kN/m)	0,4	0,4	-
gr1b		gr1b	Single axle (LM2)	-	0,75	-
gr2		gr2	LM1 + Horizontal forces	-	-	-
gr3		gr3	Footway and cycle track loads	-	-	-
gr4		gr4	Crowd loading	-	0,75	-
gr5		gr5	Special vehicle (LM3)	-	-	-
F_{wk}	WIND FORCES	– F_{wk}, Persistent design situations		0,6	0,2	-
		– F_{wk}, Execution		0,8	-	-
F^*_{wk}		– F^*_w, Together with traffic load		1	-	-
T_k	THERMAL ACTIONS <3>	(see application guidance)		- 0,6	0,6	0,5
BF	BEARING FRICTION	(see application guidance)		0,6	0,5	0,4
IL	ICE LOAD	(see application guidance)		0,7	0,5	0,2
S	SUPPORT SETTLEMENT	(see application guidance)		permanent		
W	WATER LEVEL	W – permanent water level (MW)		permanent		
dW		– high/low water (between HW- and NW)		1	0,7	0,5
TLEP	TRAFFIC LOAD EARTH PRESSURE <1>	(EN 1991-2 NA, 4.9.1 (1))		0,75 0,4	0,75 0,4	-
SL1	SNOW LOAD	$Q_{Sn,k}$ – During execution		0,8	-	-
SL2		– Together with traffic load		0,8	0,5	0,2
Q_c	CONSTRUCTION LOADS	Q_c		1	-	1

<1> Traffic load earth pressure:

- When no tandem load exists at the bridge deck: psi-values for gr1a axle load is used for traffic load earth pressure (0,75/0,75/0)

- When tandem load exists at the bridge deck: psi-values for gr1a UDL load is used for traffic load earth pressure(0,4/0,4/0)

<2>The quasi-permanent value (ψ_2) of gr1a for bridges loacating in public road is 0,3 and for private road bridges receiving aid of state is 0.

<3>The selection of the combined value (ψ0) for thermal actions: see application instructions of specific materials.

Table 5.2 Combination factors for railway bridges

Actions			ψ_0	ψ_1	ψ_2 4)
Individual components of traffic actions 5)	LM 71		0,80	1)	0
	SW/0		0,80	1)	0
	SW/2		0	1,00	0
	Unloaded train		1,00	–	–
	HSLM		1,00	1,00	0
	Traction and braking Centrifugal forces Interaction forces due to deformation under vertical traffic loads		Individual components of traffic actions in design situations where the traffic loads are considered as a single (multi-directional) leading action and not as groups of loads should use the same values of ψ factors as those adopted for the associated vertical loads		
	Nosing forces		1,00	0,80	0
	Non public footpaths loads		0,80	0,50	0
	Real trains		1,00	1,00	0
	Horizontal earth pressure due to traffic load surcharge		0,80	1)	0
	Aerodynamic effects		0,80	0,50	0
Main traffic actions (groups of loads)	gr11 (LM71 + SW/0)	Max. vertical 1 with max. longitudinal	0,80	0,80	0
	gr12 (LM71 + SW/0)	Max. vertical 2 with max. transverse			
	gr13 (Braking/traction)	Max. longitudinal			
	gr14 (Centrifugal/nosing)	Max. lateral			
	gr15 (Unloaded train)	Lateral stability with "unloaded train"			
	gr16 (SW/2)	SW/2 with max. longitudinal			
	gr17 (SW/2)	SW/2 with max. transverse			
	gr21 (LM71 + SW/0)	Max. vertical 1 with max. longitudinal	0,80	0,70	0
	gr22 (LM71 + SW/0)	Max. vertical 2 with max transverse			
	gr23 (Braking/traction)	Max. longitudinal			
	gr24 (Centrifugal/nosing)	Max. lateral			
	gr26 (SW/2)	SW/2 with max. longitudinal			
	gr27 (SW2)	SW/2 with max. transverse			
	gr31 (LM71 + SW/0)	Additional load cases	0,80	0,60	0
Other operating actions	Aerodynamic effects		0,80	0,50	0
	General maintenance loading for non public footpaths		0,80	0,50	0
Wind forces 2)	F_{Wk}		0,75	0,50	0
	F_W^{**}		1,00	0	0
Table continued on next page					

Consequence factor

Consequence factor (K_{FI}) depends on the consequence class which can be CC3/CC2/CC1 by Eurocode. For Finnish bridges it is always CC2, but sometimes CC3. The final decision is made by the client. The designer may propose a consequence class to the client. All information about consequence factor can be found in Annex B of EN 1990 and in table 5.3 (according to table B1) and the values can be found in table 5.4 (according to table B3).

Table 5.3 Definition of consequence classes

Consequences Class	Description	Examples of buildings and civil engineering works
CC3	**High** consequence for loss of human life, or economic, social or environmental consequences **very great**	Grandstands, public buildings where consequences of failure are high (e.g. a concert hall)
CC2	**Medium** consequence for loss of human life, economic, social or environmental consequences **considerable**	Residential and office buildings, public buildings where consequences of failure are medium (e.g. an office building)
CC1	**Low** consequence for loss of human life, and economic, social or environmental consequences **small or negligible**	Agricultural buildings where people do not normally enter (e.g. storage buildings), greenhouses

Table 5.4 The values for K_{FI}

K_{FI} factor for actions	Reliability class		
	RC1	RC2	RC3
K_{FI}	0,9	1,0	1,1

NOTE: In particular, for class RC3, other measures as described in this Annex are normally preferred to using K_{FI} factors. K_{FI} should be applied only to unfavourable actions.

5.1.3 Combination equations

The design values of actions for ultimate limit states in the persistent and transient design situations are obtained from table 5.5 presented in this section. These tables correspond to tables A2.4(A)…A2.4(C) of EN 1990/A1 Annex A2 and to the tables G4…G6 presented in NCCI 1.

Static equilibrium for bridges should be verified using table x.x (according to table A2.4(A)-SET A EQU of EN 1990/A1 Annex A2 and table G4 of NCCI 1).

Table 5.5 Design combination for ultimate limit state

	Permanent Actions		*Prestress*		*Leading variable action*	*Accompanying variable actions*
Equation 6.10	*1,15 / 0,9*	*G*	*1,1 / 0,9*	*P*	*1,35*(road traffic actions)* *1,35*(light traffic actions)* *1,45*(rail traffic actions)*	*1,50*$\psi_{0,j}$ *(accompanying variable actions)*
	or					

	1,15 / 0,9	*G*	*1,1 / 0,9*	*P*	*1,50*(accompanying variable actions)*	*1,35*$\psi_{0,j}$*(road traffic actions)* *1,35*$\psi_{0,j}$ *(light traffic actions)* *1,45*$\psi_{0,j}$ *(rail traffic actions)* *1,50*$\psi_{0,j}$ *(accompanying variable actions)*

- the partial safety factor of prestress is 1,30, when checking external prestressing force in connection with occurring stability limit and the increase of prestressing force may be unfavorable;
- special cases (the use of counter weight, the rise of bearings, etc), see the recommendation of the standard;
- combination factors are in tables 5.5;
- the design equation 5.1 .

$$E_d = K_{FI} \cdot 1{,}15 \cdot G_{kj,\sup} + 0{,}9 \cdot G_{kj,\inf} + K_{FI} \cdot \gamma_P \cdot P + K_{FI} \cdot \gamma_{Q,1} \cdot Q_{k,1} + \sum \left(K_{FI} \cdot \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \right)$$
(5.1)

Resistance of structural members should be verified using table 5.6 (according to table A2.4(B) – Set B STR/GEO of EN 1990/A1 Annex A2 and table G5 of NCCI 1).

Table 5.6 Design combination for ultimate limit state

	Permanent Actions		*Prestress*		*Leading variable action*	*Accompanying variable actions*
Equation 6.10a	*1,35 / 0,9*	*G*	*1,10 / 0,9*	*P*		
	or					
	1,15 / 0,9	*G*	*1,10 / 0,9*	*P*	*1,35*(road traffic actions)* *1,35*(light traffic actions)*	*1,50*$\psi_{0,j}$ *(accompanying variable actions)*

Equation 6.10b					*1,45*(rail traffic actions)*	
	or					
	1,15 / 0,9	*G*	*1,10 / 0,9*	*P*	*1,50*(accompanying variable actions)*	*1,35**$\psi_{0,j}$**(road traffic actions)* *1,35**$\psi_{0,j}$ **(light traffic actions)* *1,45/1,2**$\psi_{0,j}$ **(rail traffic actions)* *+ 1,50**$\psi_{0,j}$ **(accompanying variable actions)*

-expressions 6.10a and 6.10b are used in Finland;

-expressions 6.10a contents only permanent actions;

-support settlement is assimilated to the permanent action;

-the partial safety factor of earth pressure of the traffic actions is 1,50/0;

-in the linear analysis the partial factor of support settlement is 1,20/0 and in non-linear analysis is 1,30/0;

-the partial factor of prestress is 1,20 when verifying the local effects of tension fore(e.g. anchorage area), see SFS-EN 1992-1-1 section 2.4.2.2(3);

-combination factors in tables 5.6;

-the design equation 5.2:

$$E_d = K_{FI} \cdot 1{,}35 \cdot G_{kj,\sup} + 0{,}90 \cdot G_{kj,\inf} + K_{FI} \cdot \gamma_P \cdot P \quad (5.2)$$

-the design formula 5.3:

$$E_d = K_{FI} \cdot 1{,}15 \cdot G_{kj,\sup} + 0{,}90 \cdot G_{kj,\inf} + K_{FI} \cdot \gamma_P \cdot P + K_{FI} \cdot \gamma_{Q,1} \cdot Q_{k,1} + \sum \left(K_{FI} \cdot \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i} \right)$$

(5.3)

The design values for actions for the accidental and seismic design situations are presented in table 5.7, in accordance with table A2.5 of EN 1990/A1 Annex A2 and table G7 of NCCI 1.

Table 5.7 Design combination for accidental and seismic design situations

		Permanent actions		*Prestress*		*Accidental- or seismic action*	*Accompanying variable actions*
Accidental force	*6.11 a/b*	*1,00*	*G*	*1,00*	*P*	A_d *(accidental force)*	$\psi_{1,j}$ *(traffic action), $\psi_{2,j}$* (accompanying variable actions)*
Seismic force	*6.12 a/b*	*1,00*	*G*	*1,00*	*P*	A_{Ed} *(Seismic force)*	$\psi_{2,j}$* *(accompanying variable actions)*

-in the accidental design combinations for the leading variable action its normal value ψ_1 will be given in case of traffic loads, otherwise the long – term value of ψ_2. For the other variable actions the long – term value of ψ_2 will be given;
-for road bridges the traffic loads exist in only one lane;
-if not otherwise decided for an individual project, for the railway bridges the traffic action can be halved in the accidental combinations;
-the National Authority may impose separately earthquake scenarios;
-the design formula 5.4:

$$E_d = 1{,}0 \cdot G_{kj,\sup} + 1{,}0 \cdot G_{kj,\inf} + P + A + \left(\psi_{1,1} \vee \psi_{2,1}\right) \cdot Q_{k,1} + \sum \left(\psi_{2,i} \cdot Q_{k,i}\right)$$

(5.4)

The design values of actions in serviceability limit state are obtained from table 5.8, according to table A2.6 of EN 1990/A1 Annex A2 and table G 8 of NCCI 1.

Table 5.8 Design combination for serviceability limit state

	Permanent Actions		*Prestress*		*Leading variable action*	*Accompanying variable actions*
Characteristic	*1,00*	*G*	*1,00*	*P*	*(leading variable actions)*	$\psi_{0,,j}$ *(accompanying variable actions)*
Frequent	*1,00*	*G*	*1,00*	*P*	$\psi_{1,1}$ * (leading variable actions)	$\psi_{2,j}$ *(accompanying variable actions)
Quasi-permanent	*1,00*	*G*	*1,00*	*P*	$\psi_{2,1}$ * (leading variable actions)	$\psi_{2,j}$ *(accompanying variable actions)

-the review of tasks for the different serviceability limit state has been defined in the application instruction of specific material;

-the design formula 5.5:

$$E_d = 1{,}0 \cdot G_{kj,\sup} + 1{,}0 \cdot G_{kj,\inf} + P + Q_{k,1} + \sum \left(\psi_{0,i} \cdot Q_{k,i} \right) \quad (5.5)$$

-the design formula 5.6:

$$E_d = 1{,}0 \cdot G_{kj,\sup} + 1{,}0 \cdot G_{kj,\inf} + P + \psi_{1,1} \cdot Q_{k,1} + \sum \left(\psi_{2,i} \cdot Q_{k,i} \right) \quad (5.6)$$

-the design formula 5.7:

$$E_d = 1{,}0 \cdot G_{kj,\sup} + 1{,}0 \cdot G_{kj,\inf} + P + \sum \left(\psi_{2,i} \cdot Q_{k,i} \right) \quad (5.7)$$

(from NCCI 1)

5.1.4 Explanations of NCCI 1 combination tables

In NCCI 1 there are some combination tables with the help of which it can be found the values of combination factors very easy. The using of these tables for road bridges for ULS will be considered in this thesis.

The following traffic loads are not usually dominant actions when dimensioning the main structure:

-single axle load (LM2) grb1;

-footway and cycle axle track loads (gr3);

-crowd loading (gr4).

So, these actions can be omitted from load combination equation.

These following actions are missing in the Eurocode and they have been added according to the Finnish National Annex:

- Bearing Friction (BF)
- Ice load (IL)
- Support settlement (S)
- Traffic load earth pressure (TLEP)

Also, the notation of the loads:

- gr 1…gr5 – load groups
- F_{wk} – wind load
- T_k – thermal load

Combination of use ULS…ULS_0…ULS_11. Figure 5.1 according to table 1 of Annex 1A of NCCI 1. All explanations of load combination tables are shown in figures 5.1 – 5.6.

ROAD BRIDGES - ULTIMATE LIMIT STATE - Set A: A2.4 (A), Set B: A2.4 (B)

				LEADING VARIABLE LOADS OF THE LOAD COMBINATION ((6.10b)										
				COMBINATION FORMULAS ULS 1 - ULS 11										
				1	2	3	4	5	6	7	8	9	10	11
			0	gr1a	gr1b	gr2	gr3	gr4	gr5	F_{wk}	T_k	BF	IL	TLEP
			6.10a	LM1	LM2	LM1+horiz.	light	crowd loading	LM3	Wind	Temperature	Bearing friction	Ice load	Traffic load E.P
SET A (EQU)	Self wieght		1,35	1,15 / 0,9										
SET B (STR/EQU)	Prestress		1,1 / 0,9 4)	1,1 / 0,9 4)										
SET A (EQU) & SET B (STR/EQU)	gr1a (LM1)	Ts	-	1,35	- -	- -	- -	- -	- -	- -	x 0,75	x 0,75	x 0,75	x 0,75
		UDL	-		- -	- -	- -	- -	- -	- -	1,35 x 0,4	1,35 x 0,4	1,35 x 0,4	1,35 x 0,4
		Light	-		- -	- -	- -	- -	- -	- -	x 0,4	x 0,4	x 0,4	x 0,4
	gr1b (LM2)		-	- -	1,35	- -	- -	- -	- -	- -	- -	- -	- -	- -
	gr2(LM1+Horizontal)		-	- -	- -	1,35	- -	- -	- -	- -	- -	- -	- -	- -
	gr3 (Light)		-	- -	- -	- -	1,35	- -	- -	- -	- -	- -	- -	- -
	gr4 (Crowd loading)		-	- -	- -	- -	- -	1,35	- -	- -	- -	- -	- -	- -
	gr5 (LM3)		-	- -	- -	- -	- -	- -	1,35	- -	- -	- -	- -	- -
	F_{wk} 1)		-	1,5 x 0,6	- -	- -	- -	- -	- -	1,5	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6
	T_k 2)		-	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	- -	1,5 x 0,6	1,5	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6
	BF		-	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5	1,5 x 0,6	1,5 x 0,6
	IL		-	1,5 x 0,7	- -	1,5 x 0,7	1,5 x 0,7	1,5 x 0,7	- -	1,5 x 0,7	1,5 x 0,7	1,5 x 0,7	1,5	1,5 x 0,7
	S 2)		1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
	TLEP		-	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	- -	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5

1) Wind load note: The wind load is separately calculated for the case of empty bridge and case where it occurs simultaneously with the traffic load.

2) T load/ S can be omitted from the ULS combination if the structure has sufficient deformation capacity (see specific material's application guides)

3) The stability 1,30 [EN 1992-1-1: 2.4.2.2 (2) NB])

4) The local effects 1,20 [EN 1992-1-1: 2.4.2.2 (3) NB])

- Combining coefficient of passive pressure according to the causing load and safety factor according to permanent load

-Effects of the water surface position are combined with the dead load so that dominant

= Leading variable load

Figure 5.1 Load combinations table for road bridges. Ultimate limit state.

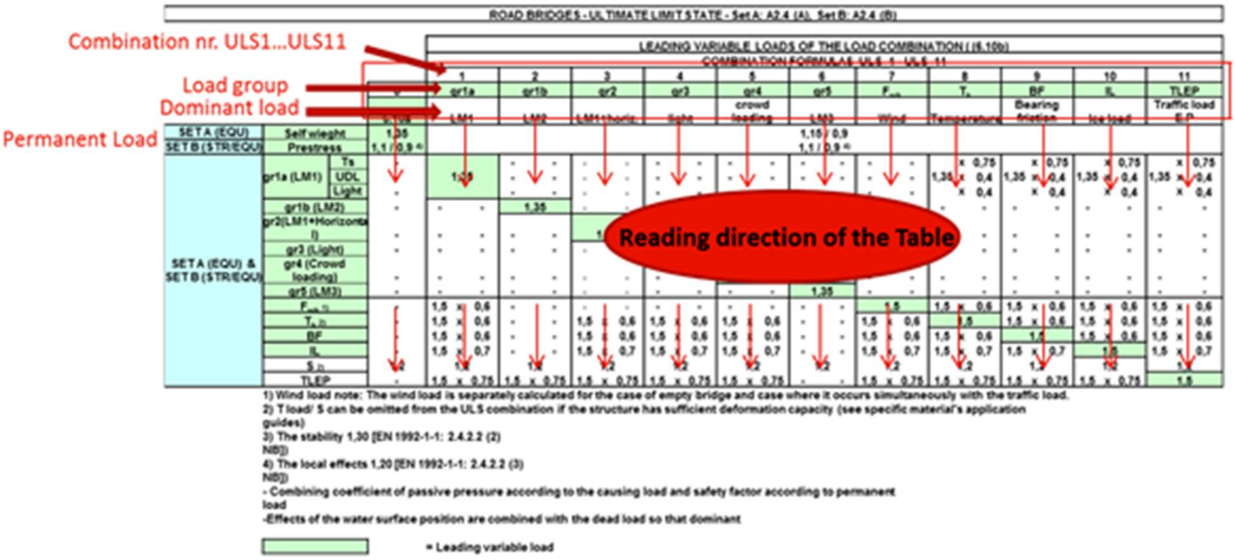


Figure 5.2 Explanation of load combination table for road bridges.

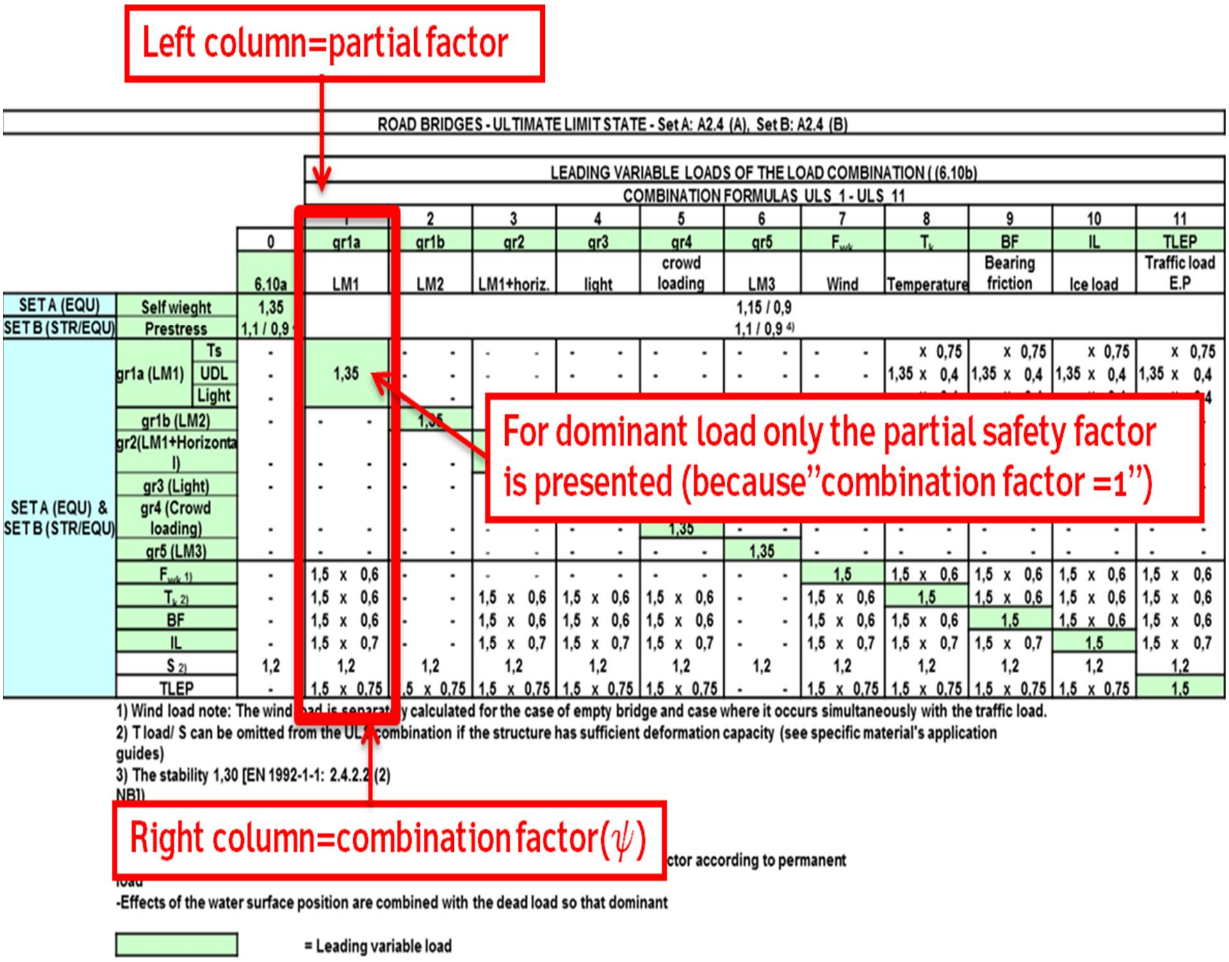


Figure 5.3 Explanation of load combination table for road bridges.

Needed combinations

- o sometimes it is not necessary to check all possible combinations (up to ”engineering judgement”);
- o generally, pedestrian and cycle lanes are not critical for design;
  - ➢ ULS_4(gr3) and ULS_5(gr4) usually necessary;
- o often, the designer can come to conclusion that LM2 is not required in the design;
  - ➢ ULS-2(gr1b) is unnecessary;
- o often, the designer can conclude that formula 6.10a (only permanent load, with safety load factor 1.35) is not required in the design;
  - ➢ ULS_0 (6.10a) is unnecessary;
- o often there is no ice load;
  - ➢ ULS_10 is unnecessary;
  - ➢ often , the designer can conclude that thermal load, traffic load, traffic load earth pressure and bearing friction are not critical for the design as a leading action;
  - ➢ ULS_8(T_k), ULS_9(BF) and ULS_11(TLEP) are unnecessary;

ROAD BRIDGES - ULTIMATE LIMIT STATE - Set A: A2.4 (A), Set B: A2.4 (B)

				LEADING VARIABLE LOADS OF THE LOAD COMBINATION ((6.10b) COMBINATION FORMULAS ULS 1 - ULS 11										
				1	2	3	4	5	6	7	8	9	10	11
			0	gr1a	gr1b	gr2	gr3	gr4	gr5	F_{wk}	T_k	BF	IL	TLEP
			6.10a	LM1	LM2	LM1+horiz.	light	crowd loading	LM3	Wind	Temperature	Bearing friction	Ice load	Traffic load E.P
SET A (EQU)	Self wieght		1,35						1,15 / 0,9					
SET B (STR/EQU)	Prestress		1,1 / 0,9 4)						1,1 / 0,9 4)					
SET A (EQU) & SET B (STR/EQU)	gr1a (LM1)	Ts	-	1,35	- -	- -	- -	- -	- -	- -	x 0,75	x 0,75	x 0,75	x 0,75
		UDL	-		- -	- -	- -	- -	- -	- -	1,35 x 0,4	1,35 x 0,4	1,35 x 0,4	1,35 x 0,4
		Light	-		- -	- -	- -	- -	- -	- -	x 0,4	x 0,4	x 0,4	x 0,4
	gr1b (LM2)		-	- -	1,35	- -	- -	- -	- -	- -	- -	- -	- -	- -
	gr2(LM1+Horizontal)		-	- -	- -	1,35	- -	- -	- -	- -	- -	- -	- -	- -
	gr3 (Light)		-	- -	- -	- -	1,35	- -	- -	- -	- -	- -	- -	- -
	gr4 (Crowd loading)		-	- -	- -	- -	- -	1,35	- -	- -	- -	- -	- -	- -
	gr5 (LM3)		-	- -	- -	- -	- -	- -	1,35	- -	- -	- -	- -	- -
	F_{wk} 1)		-	1,5 x 0,6	- -	- -	- -	- -	- -	1,5	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6
	T_k 2)		-	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	- -	1,5 x 0,6	1,5	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6
	BF		-	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5 x 0,6	- -	1,5 x 0,6	1,5 x 0,6	1,5	1,5 x 0,6	1,5 x 0,6
	IL		-	1,5 x 0,7	- -	1,5 x 0,7	1,5 x 0,7	1,5 x 0,7	- -	1,5 x 0,7	1,5 x 0,7	1,5 x 0,7	1,5	1,5 x 0,7
	S 2)		1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
	TLEP		-	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	- -	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5 x 0,75	1,5

1) Wind load note: The wind load is separately calculated for the case of empty bridge and case where it occurs simultaneously with the traffic load.
2) T load/ S can be omitted from the ULS combination if the structure has sufficient deformation capacity (see specific material's application guides)
3) The stability 1,30 [EN 1992-1-1: 2.4.2.2 (2) NB])
4) The local effects 1,20 [EN 1992-1-1: 2.4.2.2 (3) NB])
- Combining coefficient of passive pressure according to the causing load and safety factor according to permanent load
-Effects of the water surface position are combined with the dead load so that dominant

= Leading variable load

Figure 5.4 Explanation of load combination table for road bridges.

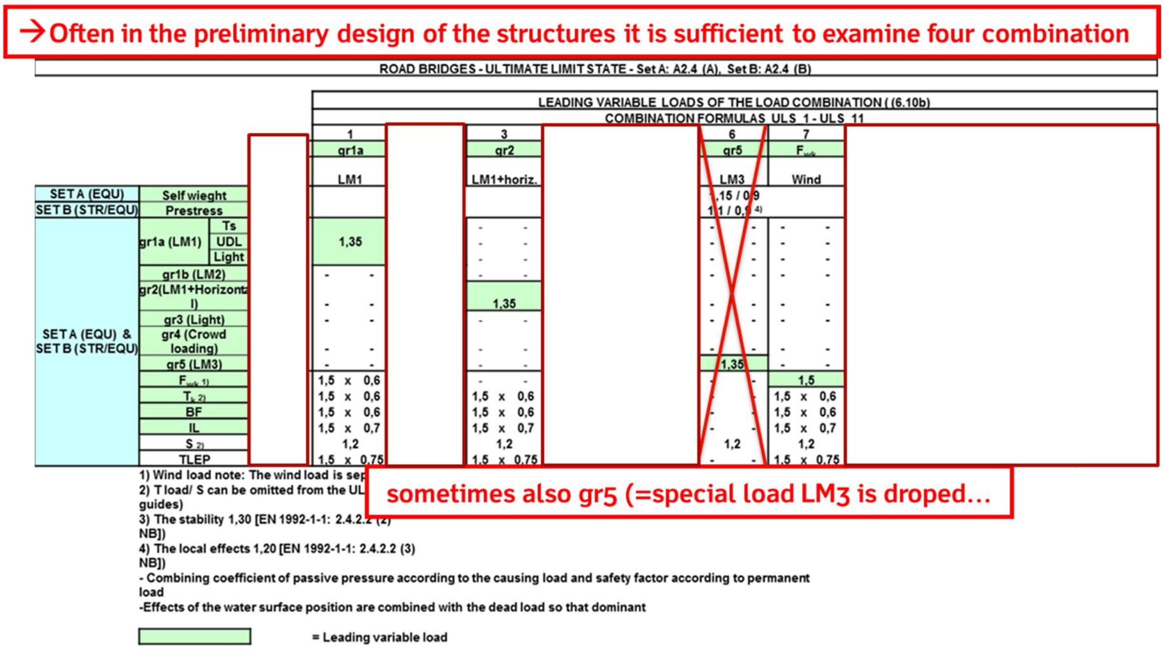


Figure 5.5 Explanation of load combination table for road bridges.

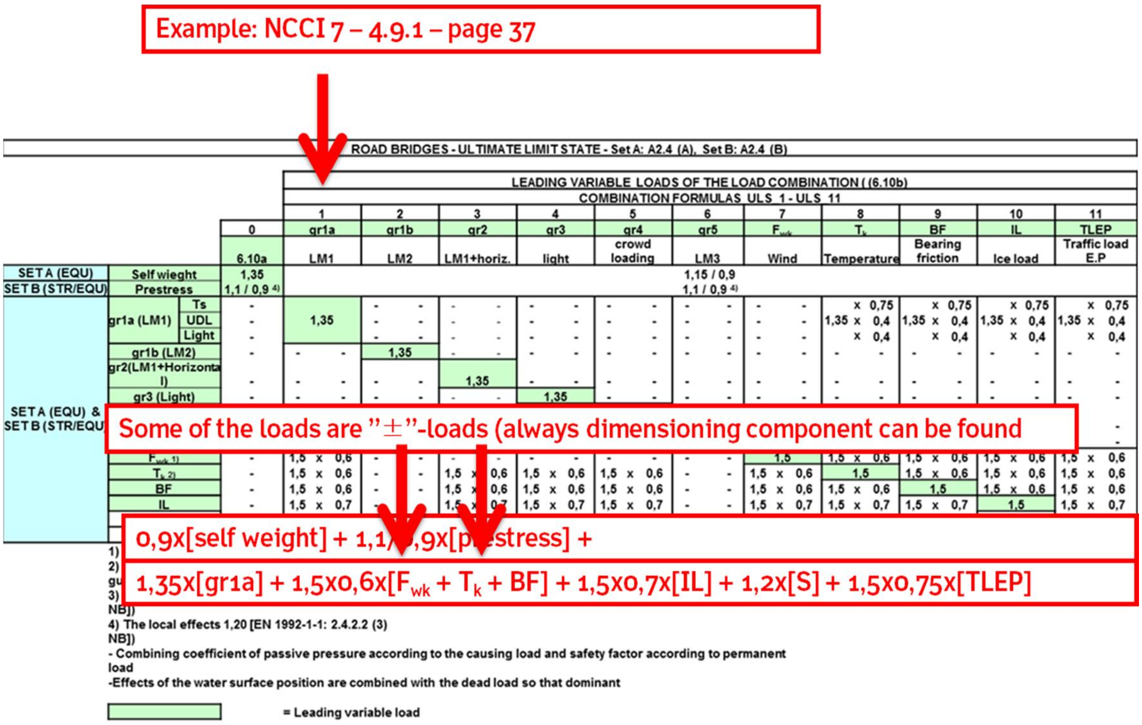


Figure 5.6 Explanation of load combination table for road bridges.

5.2 Load combinations in SNiP

The information about the load combinations can be found in chapter 2 of SNiP 2.05.03-84.*

5.2.1 Combination rules

In SNiP there are 2 groups of combination loads: the main combination and the special combination. The bridge structures should be calculated on the loads and impacts taken by table 9, according to table 5 of SNiP 2.05.03-84*.*

Table 5.9 Load combinations in SNiP

№ of load	***name of load***	*number of the load which are not in combination with the given load*
A. permanent		
1	*self – weight*	*-*
2	*prestress*	*-*
3	*soil's pressure*	*-*
4	*hydrostatic pressures*	*-*
5	*shrinkage and creep*	*-*
6	*effects of the ground settlement*	*-*
B. temporary (from the stock and pedestrians)		
7	*vertical loads*	*16,17*
8	*soil's pressure from stock*	*16,17*
9	*horizontal loads from centrifugal force*	*10,16,17*
10	*horizontal transverse impacts from the stock*	*9,11,12,16-18*
11	*horizontal longitudinal load from braking and acceleration forces*	*10,13,14,16,17*
Other actions		
12	*wind loads*	*10,14,18*
13	*ice loads*	*11,14,16,18*
14	*ship impacts*	*11-13,15-18*
15	*thermal loads*	*14,18*
16	*impact of frost heaving*	*7-11,13,14,18*
17	*construction loads*	*7-11,14,18*
18	*seismic loads*	*10,12-17*

5.2.2 Combination and consequence factors

Combination factor

The factor η is combination factor which is used when it is needed to combine different loads. The factor η is the same as the factor ψ in Eurocodes, but it doesn't depend on the return period. It depends on the reducing the probability of the joint events. It depends on the variation of the combination and may be found from the tables of Appendix 2 in SNiP 2.05.03-84. It varies from 0,25 to 1. There is no clear separation into combination, frequent and quasi – permanent combinations in Russian norms. These terms are already taken into account in the table of combination factors in Appendix 2* of SNiP 2.05.03-84*. So, there is not the need for thinking which group to take for calculating. But some of the combinations are for calculating piers and some of them are for calculating superstructures.*

There are some combination rules for factors in SNiP:

- *combination factors should be taken as*
    - *1,0 for permanent loads №1-6, for load №17 and for the weight of unloaded train for railroad;*
    - *1,0 for the taken into account only one of temporary loads or groups of associated loads № 7-9;*
    - *for taken into account two or more temporary loads (suspended considering the group load №7-9 for one load) – for one of the temporary load – 0,8 and for the others – 0,7;*
    - *combination factor for the load № 12 in all combinations with load №7 depending on the type of stock is:*
        - *for railway transport or metro – 0,5/1,0 (depends on the wind pressure);*
        - *for road transport or tram – 0,25;*
    - *combination factor equals 0,5 for load № 12 for road and railway bridges in the case when several load are acting and when there is no load № 7;*
    - *combination factors should be the same for loads №7-9 and no more than for load № 7 for load № 11 in all combinations;*

- *combination factors should be 0,8 for the load № 18 together with the load № 7 and its associated and for other temporary load*
    - *for railway bridges – 0,7;*
    - *for road bridges 0,3;*
- *also, the values of all combination factors are in the table in Annex 2* of SNiP 2.05.03-84*. (from SNiP 2.05.03-84*).*

The values of loads and impacts is taken with the coefficients from table 5.10 (according to table 6 of SNiP 2.05.03-84). Factors y_f is taken from tables 8*, 13, 14 and 17* from chapter 2 of SNiP 2.05.03-84* and 1+μ is taken from chapter 2.22* of SNiP 2.05.03-84*. Tables 5.11 show the values of combination factors for different load combinations in SNiP (according to table in Annex 2* of SNiP 2.05.03-84*).(SNiP 2.05.03-84*, 1996, pp 23-25)*

Table 5.10 Table of coefficients for the values of loads and impacts

limit state	type of calculating	coefficients	
		all loads, except moving vertical load	moving vertical load
I	a. all calculating except in points "b-d"	y_f	y_f, $1+\mu$
	b. on the endurance	$y_f=1$	$y_f=1$, $1+(2/3)\mu$
	c. on stability	y_f	y_f***
	d. seismic situation	y_f**	y_f
II	all calculating	$y_f=1$	$y_f=1$

*** seismic load should be taken with safety factor equals 1*

**** for the unloaded train of railroad and metro $y_f=1$*

Table 5.11 The values of combination factors for temporary loads and impacts

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination					
		№7 (temporary vertical loads)	№8 (soil's pressure from stock)	№9 (centrifugal force)	№10 (transverse impacts from stock)	№11 (bracking and acceleration force)	№12 (wind load)
1	2	3	4	5	6	7	8
7 и 8	9	1	1	1	-	-	-
	10*	1	1	-	1	-	-
	9, 11, 12 и 15	0,8	0,8	0,8	-	0,7	0,5 0,25
	9, 12, 13, 15 и S	0,8	0,8	0,8	-	-	0,5 0,25
	10, 13, 15 и S	0,8	0,8	-	0,7	-	-
	10 и 14	0,8	0,8	-	0,7	-	-
	11, 12 и 15	0,8	0,8	-	-	0,7	0,5 0,25
	12, 13 и 15	0,8	0,8	-	-	-	0,5 0,25
9	11, 12 и 15	0,8	0,8	0,8	-	0,7	0,5 0,25
	12, 13, 15 и S	0,8	0,8	0,8	-	-	0,5 0,25
	14	0,8	0,8	0,8	-	-	-
10*	7, 8, 13, 15 и S	0,7	0,7	-	0,8	-	-
	7, 8 и 14	0,7	0,7	-	0,8	-	-
11	7-9, 12 и 15	0,8	0,8	0,8	-	0,8	0,5 0,25
12*	7-9	0,7	0,7	0,7	-	-	0,5 0,25
	7, 8, 11 и 15	0,7	0,7	-	-	0,7	0,5 0,25
	7-9, 13, 15 и S	0,7	0,7	0,7	-	-	0,5 0,25
	13, 15, 17 и S	-	-	-	-	-	0,8 0,5

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination					
		№7 (temporary vertical loads)	№8 (soil's pressure from stock)	№9 (centrifugal force)	№10 (transverse impacts from stock)	№11 (bracking and acceleration force)	№12 (wind load)
1	2	3	4	5	6	7	8
	15-17 и S	-	-	-	-	-	0,8 0,5
13	-	-	-	-	-	-	-
	7-9, 12, 15 и S	0,7	0,7	0,7	-	-	0,5 0,25
	7, 8, 10, 15 и S	0,7	0,7	-	0,7	-	-
	12, 15 и S	-	-	-	-	-	0,7 0,5
14	-	-	-	-	-	-	-
	7-9	0,7	0,7	0,7	-	-	-
	7, 8 и 10	0,7	0,7	-	0,7	-	-
15	-	-	-	-	-	-	-
	7-9, 11 и 12	0,7	0,7	0,7	-	0,7	0,5 0,25
	7-9, 12, 13 и S	0,7	0,7	0,7	-	-	0,5 0,25
	7, 8, 10, 13 и S	0,7	0,7	-	0,7	-	-
	12, 13, 17 и S	-	-	-	-	-	0,7 0,5
	12, 16, 17 и S	-	-	-	-	-	0,7 0,5
16	-	-	-	-	-	-	-
	12, 15, 17 и S	-	-	-	-	-	0,7 0,5
17	-	-	-	-	-	-	-
	12, 13, 15 и S	-	-	-	-	-	0,7 0,5
	12, 15, 16 и S	-	-	-	-	-	0,7 0,5
18***	7-9, 11 и S	0,7	0,7	0,7	-	0,7	-

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination					
		№7 (temporary vertical loads)	№8 (soil's pressure from stock)	№9 (centrifugal force)	№10 (transverse impacts from stock)	№11 (bracking and acceleration force)	№12 (wind load)
1	2	3	4	5	6	7	8
		0,3	0,3	-		-	
S	-	-	-	-	-	-	-
	7-9, 12, 13, 15	0,7	0,7	0,7	-	-	0,5 0,25
	7, 8, 10, 13, 15	0,7	0,7	-	0,7	-	-
	12, 13, 15, 17	-	-	-	-	-	0,7 0,5
	12, 15-17	-	-	-	-	-	0,7 0,5

The end of table 5.11

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination						
		№ 13 (ice load)	№14 (ship impacts)	№15 (thermal loads)	№16 (impact of frost heaving)	№17 (construction loads)	№18 (seismic loads)	S (friction or shear strenght in the supporting parts)
1	2	9	10	11	12	13	14	15
7 и 8	9	-	-	-	-	-	-	-
	10*	-	-	-	-	-	-	-
	9, 11, 12 и 15	-	-	0,7	-	-	-	-
	9, 12, 13, 15 и S	0,7	-	0,7	-	-	-	0,7
	10, 13, 15 и S	0,7	-	0,7	-	-	-	0,7
	10 и 14	-	0,7	-	-	-	-	-
	11, 12 и 15	-	-	0,7	-	-	-	-
	12, 13 и 15	0,7	-	0,7	-	-	-	-
9	11, 12 и 15	-	-	0,7	-	-	-	-

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination						
		№ 13 (ice load)	№14 (ship impacts)	№15 (thermal loads)	№16 (impact of frost heaving)	№17 (construction loads)	№18 (seismic loads)	S (friction or shear strenght in the supporting parts)
1	2	9	10	11	12	13	14	15
	12, 13, 15 и S	0,7	-	0,7	-	-	-	0,7
	14	-	0,7	-	-	-	-	-
10*	7, 8, 13, 15 и S	0,7	-	0,7	-	-	-	0,7
	7, 8 и 14	-	0,7	-	-	-	-	-
11	7-9, 12 и 15	-	-	0,7	-	-	-	-
12*	7-9	-	-	-	-	-	-	-
	7, 8, 11 и 15	-	-	0,7	-	-	-	-
	7-9, 13, 15 и S	0,7	-	0,7	-	-	-	0,7
	13, 15, 17 и S	0,7	-	0,7	-	1	-	0,7
	15-17 и S	-	-	0,7	0,7	1	-	0,7
13	-	1	-	-	-	-	-	-
	7-9, 12, 15 и S	0,7	-	0,7	-	-	-	0,7
	7, 8, 10, 15 и S	0,7	-	0,7	-	-	-	0,7
	12, 15 и S	0,7	-	0,7	-	-	-	0,7
14	-	-	1	-	-	-	-	-
	7-9	-	0,8	-	-	-	-	-
	7, 8 и 10	-	0,8	-	-	-	-	-
15	-	-	-	1	-	-	-	-
	7-9, 11 и 12	-	-	0,8	-	-	-	-
	7-9, 12, 13 и S	0,7	-	0,8	-	-	-	0,7
	7, 8, 10, 13 и S	0,7	-	0,8	-	-	-	0,7
	12, 13, 17 и S	0,7	-	0,8	-	1	-	0,7
	12, 16, 17 и S	-	-	0,8	0,7	1	-	0,7
16	-	-	-	-	1	-	-	-
	12, 15, 17 и S	-	-	0,7	0,8	1	-	0,7
17	-	-	-	-	-	1	-	-
	12, 13, 15 и S	0,7	-	0,7	-	1	-	0,7

number of load (impact), which is most unfavorable for the calculation	number of loads combination, acting simultaneously or separate with the most unfavorable	factor η for the different loads combination						
		№ 13 (ice load)	№14 (ship impacts)	№15 (thermal loads)	№16 (impact of frost heaving)	№17 (construction loads)	№18 (seismic loads)	S (friction or shear strenght in the supporting parts)
1	2	9	10	11	12	13	14	15
	12, 15, 16 и S	-	-	0,7	0,7	1	-	0,7
18***	7-9, 11 и S	-	-	-	-	-	0,8	0,7
S	- 7-9, 12, 13, 15 7, 8, 10, 13, 15 12, 13, 15, 17 12, 15-17	- 0,7 0,7 0,7 -	- - - - -	- 0,7 0,7 0,7 0,7	- - - - 0,7	- - - 1 1	- - - - -	1 0,8 0,8 0,8 0,8

**when the bridge is situated on the curvatures of big radius the load №10 should be taken as accompanying with the loads №7 and №8.*

*** combination factor for the load № 12 in all combinations with load №7 depending on the type of stock is:*

- *for railway transport or metro – 0,5/1,0 (depends on the wind pressure);*
- *for road transport or tram – 0,25;*

**** combination factors should be 0,8 for the load № 18 together with the load № 7 and its associated and for other temporary load:*

- *for railway bridges – 0,7;*
- *for road bridges 0,3;*

Note: the values for railway bridges are above the line and for road bridges are under the line.

Consequence factor

The consequence factor (y_n) depends on the importance class of the structure. These can be found in GOST P54257-2010. There are 4 classes of consequence factors, which depend on the level of responsibility of structures, *characterized by social, environmental and economic consequence of damage and destruction. The values of consequence factors are shown in table 5.12.*

Table 5.12 The minimum values of the consequence factors.

The level of responsibility	***The minimum values***
1a	*1,2*
1б	*1,1*
2	*1,0*
3	*0,8*

Classification of the level of responsibility:

1. *- 1a - particularly high level of responsibility:*
   - *structures of the using of nuclear energy;*
   - *hydraulic structures of the 1st and 2nd classes*
   - *communication structures, which are the most dangerous;*
   - *power lines and other transmission facilities energized 330 kV and more;*
   - *structures of space infrastructures;*
   - *structures of aviation infrastructure;*
   - *seaports, except of the special seaports, which are useful for sports and pleasure crafts;*
   - *dangerous production facilities on which are:*
     - *obtaining, using, processing, storing, transporting dangerous materials in very big amounts;*
     - *obtaining the melts of ferrous and nonferrous metals*
     - *mining operation is underway*
     - *enrichment of minerals*
   - *structures with spans more than 100 meters;*
   - *structures of life support of the cities;*
   - *structures of hydro- and heat energy with volume more than 1000MW.*
2. *- 1б – high level of responsibility:*
   - *buildings of main museums, state archives, administrative authorities; storage buildings of national and cultural values;*

- *entertainment facilities, building of health care, commercial enterprises with a mass of people;*
- *structures of the railway transport;*
- *subways;*
- *structures with spans more than 60 meters;*
- *buildings of universities, schools, kindergartens;*
- *residential and administrative buildings with height more than 75 meters;*
- *masts and tower structures of communication and broadcasting, pipes with height more than 100 meters;*
- *bridges, tunnels, pipelines on the road of high category or with the length more than 500 meters;*
- *structures of hydro- and heat energy with volume more than 150MW.*

Note: Structure with the high consequence class of the design which uses fundamentally new design solutions which do not pass the practice of construction and operation, should be added to the particularly level of consequence.

3. *– 2 – normal level of responsibility:*
   - *residential buildings with high less than 75 meters and other buildings and structures (which are net included in classes 1a,1б and 3);*
   - *main objects of mechanical engineering, recycling and other industries;*
   - *bridges and tunnels with length less than 500 meters.*
4. *– 3 – low level of responsibility:*
   - *greenhouses, movable buildings, storages for temporary things;*
   - *cabins for personnel, other structures and building with limited using of people and life time.*

(GOST 54257, 2010, pp 8-10)

For bridges, it is always the first or the second one. The class and the value of y_n should be defined by Chief designer with the client or in the special technical conditions.

5.2.3 Combination equations

The main equation for ULS and SLS in SNiP is

$$S_{расч} = \sum_i S_{расч,i} \leq S_{пред}\,, \qquad (5.8)$$

where

$S_{расч}$ *– the load effect, can be calculated by equation (5.9)*

$S_{пред}$ *- the limit load effect.*

The values of load effect can be found by characteristic values multiplying with the different factors:

$$S_{расч,\,i} = \gamma_n\ \gamma_t\ \gamma_{f,i}\ (1+\mu)\ \ \psi_i\ \ S_{норм,\,i}\,, \qquad (5.9),\ where$$

γ_n - *consequence factor (choosing from the previous section)*

γ_t - *factor which take into account load's increasing from vehicles and should be only with traffic loads:*
1,1 – for structures of massive piers and columnar piers
1,0 – for the another elements ;

$\gamma_{f,\,i}$ - *load factor (choosing from the tables of chapter 4 of this thesis);*

$1+\mu$ - *dynamic factor (added only for traffic loads) (choosing from chapter 2.22* of SNiP 2.05.03-84*);*

$\psi_l\,(\eta)$ - *combination factor (choosing from table 5.10 of the previous section);*

$S_{норм,\,i}$ - *value of the i characteristic load or impact.*

5.3 Calculation part

There are examples of calculating of beam to show the differences between the results of using combination rules in Eurocodes and in SNiPs. It is very simple beam, the same as was calculated it part 4.2. So, all values are taken from that part of this thesis. The length of the beam is 15 meters, the width is 10 meters, the high is 1,0 meter. The carriageway consists of 3 layers: concrete, pavement and extra-layer. It is taken only dead load (self-weight) and traffic loads (LM1 and A14). The design scheme is shown in figure 5.7 and the carriageway is shown in figure 5.8 below.

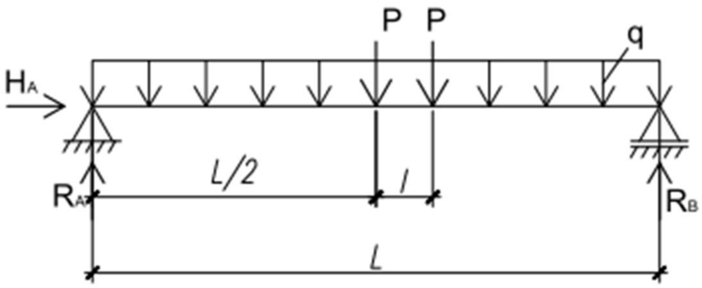


Figure 5.7 The design scheme of the beam

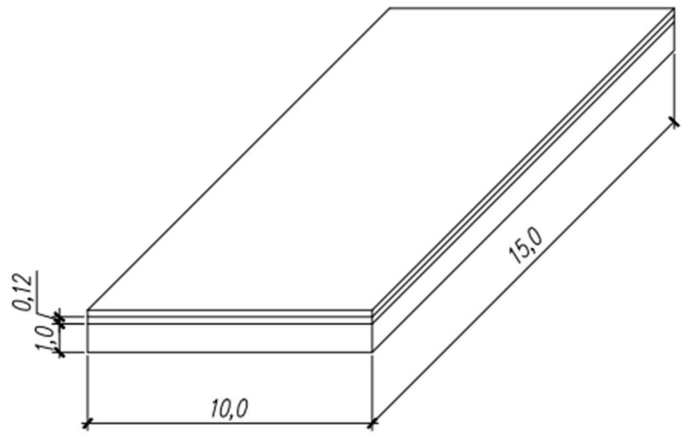


Figure 5.8 The carriageway

5.3.1 Calculation by Eurocodes

1) basic data:

a. densities:

- γ_b = 25 kN/m^3 for concrete slab
- g_1 = 2,5 kN/m^2 for pavement
- g_2 = 1 kN/m^2 for extra-layer

b. loads and maximum moments:

- G = γ_b*S + g_1*S + g_2*S = 25*(10*1,0) + 2,5*(10*1,0) + 1*(10*1) = 285 kN/m
- $M^G = \frac{q*L^2}{8} = \frac{285*15^2}{8}$ = 8015,63kN/m
- M^q = 1251,56 kNm

- M^{axl} = 4140 kNm

c. Ultimate limit state (two cases):

$M_d = \gamma_G * \psi_G * M^G + \gamma_{LM1,q} * \psi_{LM1,q} * M^q + \gamma_{LM1,P} * \psi_{LM1,P} * M^{axl}$

1. $\gamma_G = 1,15$; $\psi_G = 1,0$;

$\gamma_{LM\,1} = 1,35$; $\psi_{LM1} = 1,0$;

$M_{d,ULS}$ = 1,15*1,0*8015,63 + 1,35*1,0*(1251,56 + 4140) = 16496,58 kNm

2. $\gamma_G = 1,35$; $\psi_G = 1,0$;

$\gamma_{LM1} = 0$;

$M_{d,ULS}$ = 1,35*1,0*8015,63 + 0*(1251,56 + 4140) = 10821,10 kNm

d. Serviceability limit state (three cases)

$M_d = \gamma_G * \psi_G * M^G + \gamma_{LM1,q} * \psi_{LM1,q} * M^q + \gamma_{LM1,P} * \psi_{LM1,P} * M^{axl}$

1. characteristic combination:

$\gamma_G = 1,0$; $\psi_G = 1,0$;

$\gamma_{LM1,q} = 1,0$; $\psi_{LM1,q} = 1,0$;

$\gamma_{LM1,P} = 1,0$; $\psi_{LM1,P} = 1,0$;

$M_{d,SLS}$ = 1,0*1,0*8015,63 + 1,0*1,0*1251,56 + 1,0*1,0*4140 = 13407,19kNm

2. frequent combination:

$\gamma_G = 1,0$; $\psi_G = 1,0$;

$\gamma_{LM1,q} = 0,75$; $\psi_{LM1,q} = 1,0$;

$\gamma_{LM1,P} = 0,4$; $\psi_{LM1,P} = 1,0$;

$M_{d,SLS}$ = 1,0*1,0*8015,63 + 0,75*1,0*1251,56 + 0,4*1,0*4140 = 10610,3kNm

3. quasi-permanent combination:

$\gamma_G = 1,0$; $\psi_G = 1,0$;

$\gamma_{LM1,q} = 0$;

$\gamma_{LM1,P} = 0,3$; $\psi_{LM1,P} = 1,0$;

$M_{d.SLS}$ = 1,0*1,0*8015,63 + 0*1251,56 + 0,3*1,0*4140 = 9257,63 kNm

5.3.2 Calculation by SNiPs

1) *<u>basic data:</u>*

a. *densities:*

- γ_b = 25 kN/m^3 *for concrete slab*
- γ_m = 1,3 *for concrete slab*
- g_1 = 2,5 kN/m^2 *for pavement*
- g_2 = 1 kN/m^2 *for extra-layer (in this thesis they are taken the same as in Eurocode to make the comparison more clear)*

b. loads and maximum moments:

- $G = \gamma_b*S*\gamma_m + g_1*S + g_2*S = 25*(10*1,0)*1,3 + 2,5*(10*1,0) + 1*(10*1) = 360\ kN/m$
- $M^G = \frac{q*L^2}{8} = \frac{360*15^2}{8} = 10125\ kN/m$
- $M^q = 509,29\ kNm$
- $M^{axl} = 2781,15\ kNm$

c. Ultimate limit state:

$M_{ULS} = y_n*y_t*y_f*M^G + y_n*y_t*y_f*(1+\mu)*\psi*M^{axl} + y_n*y_t*y_f*(1+\mu)*\psi*M^q$

- $\gamma_t = 1,0$
- $\gamma_n = 1,0$
- $\gamma_{f,G} = 1,1$; $\gamma_{f,q} = 1,50$; $\gamma_{f,axl} = 1,15$;
- $\psi = 1,0$ *for traffic loads in combination with dead load*
- $(1+\mu) = 1,0$ *for uniformly distributed load*
- $(1+\mu) = 1,3$ *for axle load*

$M_{ULS} = 1,0*1,0*1,1*10125 + 1,0*1,0*1,15*1,3*1,0*2781,15 + 1,0*1,0*1,50*1,0*1,0*509,29 = 16059,25\ kNm$

d. Serviceability limit state:

$M_{ULS} = y_n*y_t*y_f*M^G + y_n*y_t*y_f*(1+\mu)*\psi*M^{axl} + y_n*y_t*y_f*(1+\mu)*\psi*M^q$

- $\gamma_t = 1,0$
- $\gamma_n = 1,0$
- $\gamma_{f,G} = 1,0$; $\gamma_{f,q} = 1,0$; $\gamma_{f,axl} = 1,0$;
- $\psi = 1,0$ *for traffic loads in combination with dead load*
- $(1+\mu) = 1,0$ *for uniformly distributed load*
- $(1+\mu) = 1,0$ *for axle load*

$M_{ULS} = 1,0*1,0*1,0*10125 + 1,0*1,0*1,0*1,0*1,0*2781,15 + 1,0*1,0*1,0*1,0**1,0*509,29 = 13415,44\ kNm$

5.4 Comparison of load combinations

European and Russian norms have loads combinations. The main difference of them is about the system. Both norms are using different factors, like load, consequence and combination factors, but the amount of equations is different. There are 3 different equations for calculating load combinations in Eurocode: for ultimate limit states, serviceability limit states and accidental/seismic design situations, but in SNiP the equation is, actually, one. SNiP is solving this problem with the help of factor's systems. They are different for each situation.
According to the calculation part, there are differences between values of loads. But the main difference is that there is different amount of the values according to Ultimate limit state and Serviceability limit state. The results are shown in table 5.12 below.

Table 5.13 The results of calculation part

<table>
<tr><th></th><th>Eurocode</th><th>SNiP</th></tr>
<tr><td rowspan="2">Ultimate limit state</td><td>16496,58 kNm</td><td rowspan="2">16059,25 kNm</td></tr>
<tr><td>10821,10 kNm</td></tr>
<tr><td rowspan="3">Serviceability limit state</td><td>13407,19 kNm</td><td rowspan="3">13415,44 kNm</td></tr>
<tr><td>10610,3 kNm</td></tr>
<tr><td>9257,63 kNm</td></tr>
</table>

From table 5.12 can be found that the values of loads in Eurocode and SNiP are about the same.

6 CONCLUSIONS AND ANALYZING

At the end of this work some results about differences between Russian and European norms were made.
Firstly, their systems and structures are compared.
Both of them are based on the limit states design system, so, that they have Ultimate limit state and Serviceability limit state, but there is also accidental limit

state design in Eurocodes. Accidental and seismic design situations are treated in a separate SNiP.

Both of them contain the rules about the different structures (buildings, bridges, towers, masts and etc), different materials (concrete, steel, wood, stone/brick and aluminum) and major areas of structural design (basic design of structures, loads, fires, geotechnical engineering, earthquakes and etc). But Eurocodes is divided into parts by types of material and SNiPs in structural issue. That is why if you need to calculate a concrete bridge structure by Eurocodes, you should take a lot of Eurocodes: EN 1990, EN 1991, EN 1992-2 and etc. This is at least 5 parts of Eurocodes which are about 1000 pages. You should take a less amount of SNiPs to calculate a concrete bridge: only SNiP 2.05.03-84* “Bridges and pipes” which is about 350 pages and you will have most of the needed information in it. It is easier and more comfortable.

Also, the parts of the system of Eurocodes are National Annexes and Finnish NCCI-series. This system is very useful and comfortable. For example, if somebody from another country using Eurucodes wants to design a bridge in Finland, he needs just to get the Finnish coefficients from National Annex (or NCCI-series) and use the same code and program he is used to. But if somebody from another country wants to design the bridge in Russia, he should read SNiPs from the beginning and only then begin to design. NCCI-series is a good idea for combining the rules of Eurocode and rules from each country in one normative document.

Secondly, the part of loads for bridge structures is compared. In general, the system is the same.

Both, Eurocodes and SNiPs have the same loads for designing bridges. The values of these loads are different, the way of calculating the loads is sometimes different, too. For example, there is the difference between load models in Eurocodes and SNiPs. Four load models for road bridges and four load models for railway bridges are presented in Eurocode. Three load models for road bridges and one load model for railway bridges are considered in SNiP.

In both of the norms are using the system of different factors, such as load safety factors, consequence factors, combination factors and others. The main difference is between the values of these factors. Table 6.1 with values of different factors is presented below:

Table 6.1 Comparison of the values of safety factors between Eurocodes and SNiPs

<table>
<tr><th colspan="2" rowspan="3">factors

loads</th><th colspan="2">load factors
y_f</th><th colspan="4">combination factors
ψ / η</th><th colspan="2">Consequence factors
K_{Fl}/y_n</th></tr>
<tr><th rowspan="2">EN</th><th rowspan="2">SNiP</th><th colspan="3">EN</th><th rowspan="2">SNiP</th><th rowspan="2">EN</th><th rowspan="2">SNiP</th></tr>
<tr><th>ψ_0</th><th>ψ_1</th><th>ψ_2</th></tr>
<tr><td colspan="2">dead load</td><td>1,15/0,9</td><td>1,05 – 1,3</td><td>-</td><td>-</td><td>-</td><td>-</td><td rowspan="9">1,0/1,1</td><td rowspan="9">1,0/1,1/1,2</td></tr>
<tr><td rowspan="2">traffic load</td><td>road</td><td>1,35</td><td>1,2 – 1,5</td><td>0,75/0,4</td><td>0,75/0,4</td><td>0/0,3</td><td rowspan="2">1,0/0,8</td></tr>
<tr><td>rail</td><td>1,45/1,2</td><td>1,1 – 1,3</td><td>0,8</td><td>0,8/0,7/0,6</td><td>0</td></tr>
<tr><td rowspan="2">wind load</td><td>road</td><td rowspan="2">1,5</td><td rowspan="2">1,0/1,4</td><td>0,6</td><td>0,2</td><td>0</td><td>0,25/0,5</td></tr>
<tr><td>rail</td><td>0,75</td><td>0,5</td><td>0</td><td>0,5/0,7/0,8</td></tr>
<tr><td colspan="2">thermal load</td><td>1,5</td><td>1,2</td><td>0,6</td><td>0,5</td><td>0,5</td><td>0,7/0,8</td></tr>
<tr><td colspan="2">ice load</td><td>1,5</td><td>1,2</td><td>0,7</td><td>0,5</td><td>0,2</td><td>0,7</td></tr>
<tr><td rowspan="2">accidental load</td><td>road</td><td rowspan="2">1,0</td><td rowspan="2">1,2</td><td rowspan="2">-</td><td>0,75/0,4</td><td rowspan="2">for all other loads</td><td rowspan="2">0,7/0,8/1,0</td></tr>
<tr><td>rail</td><td>0,8/0,7/0,6</td></tr>
</table>

As it can be found from table 6.1, firstly, there are 3 combination factors in Eurocodes, at the same time in SNiPs there is only 1. Secondly, the values of load factors and combination factors are higher in Eurocodes than in SNiPs. But the values of consequence factors are the same in Eurocodes and SNiPs.

Third, load combination is compared.

Both, Eurocodes and SNiPs have load combinations. The system of different equation is using for calculating load combinations for Ultimate limit state, Accidental limit state and Serviceability limit state in Eurocode. The system of different coefficients is using for calculating load combinations in SNiP.

At last, it should be good to mention that there is a question about changeover to Eurocodes in Russia. Nobody designed and calculated yet in Russia with Eurocodes that is why, firstly, it will be experimental design of structures. At the end of this it will be decided what annexes should be developed more and if it is more expensive or cheaper to design by Eurocodes. There are already developed National annexes for EN 1990, EN 1991 (all parts), EN 1992-1, EN 1993-1, EN 1994-1 at this moment. In this year is planned to develop National annex for EN 1992-2, EN 1993-2 and EN 1994-2.

7 FIGURES

8 TABLES

9 LIST OF REFERENCES

<u>A printed book:</u>

Finnish Standards Association SFS, 2004, Eurocode 0. Basis of structural design.

Finnish Standards Association SFS, 2005, Eurocode 0/A1 Annex A2. Basis of structural design. Application for bridges.

Finnish Standards Association SFS, 2002, Eurocode 1. Actions on structures. Part 1-1: General actions. Densities, self-weight, imposed loads for buildings.

Finnish Standards Association SFS, 2004, Eurocode 1. Actions on structures. Part 2: Traffic loads on bridges.

Finnish Standards Association SFS, 2005, Eurocode 1. Actions on structures. General Actions. Part 1- 4: Wind actions.

Finnish Standards Association SFS, 2004, Eurocode 1. Actions on structures. Part 1- 5: General actions. Thermal actions.

Finnish Standards Association SFS, 2007, Eurocode 1. Actions on structures. Part 1- 7: General actions. Accidental actions.

Finnish Standards Association SFS, 2006, Eurocode 8. Design of structures for earthquake resistance. Part 2: Bridges.

Transport Agency, Bridge design Unit, 2010, NCCI-1

Salamahina P.M., 2008 Engineering roads in transport building. Moscow: Academic.

Russian transport academy, 2008, GOST 52748 Designing the road of general use, Moscow.

2010, GOST 27751-88 Reliability of building structures and grounds, Moscow.

ОАО НИЦ «Строительство», 2010, GOST 54257 Reliability of constructions and foundations. Basic principles and requirements, Moscow

МВЭС России, ГУГПС МВД РФ, 2003, SNiP 2.01.07-85* Loads and impacts, Moscow.

Главгосэкспертиза России, 1996, SNiP 2.05.03-84* Designing of bridge and pipes, Moscow.

General department of standardization, technical regulations and certifications, 1994, SNiP 10.01.94* System of normative documents in construction. Basic principles, Moscow.

MIN Stroi of Russia, 2011, SNiP II-7-81* Designing of seismic areas, Moscow.

GosDuma, 2004, Code of town planning in Russia, Moscow.

Saifi Hosai, 2011, Special assignment. Load combination in road bridges, Helsinki.

Report: Ministry of Regional Development of the Russian Federation on "Harmonization of Russian and European systems of normative documents in construction"

2006, SCDOT bridge design manual: loads and loads factors.

Internet sources:

Ivanov A., 2001, Academic, *http://dic.academic.ru/dic.nsf/bse/136506/%D0%A1%D1%82%D1%80%D0%BE%D0%B8%D1%82%D0%B5%D0%BB%D1%8C%D0%BD%D1%8B%D0%B5 17.02.2012* (Accessed sicne 15.02.2012 to 20.02.2012)

Roger P. Johnson, 2007, Scielo http://www.scielo.br/scielo.php?pid=s0370-44672007000200007&script=sci_arttext (Accessed on 16.02.2012)

Wikipedia – free encyclopedia, www.wikipedia.ru (Accessed since 17.02.2012 to 1.05.2012)