MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ARCHITECTURE, CIVIL ENGINEERING AND DESIGN
COMPUTER TECHNOLOGIES OF CONSTRUCTION DEPARTMENT

TO ADMIT TO GUARD

Head of the Department

____________O.I. Lapenko

“_____” _____________ 2020

MASTER THESIS

(EXPLANATORY NOTE)

Topic: Evaluation of the stress-strain state of the metal frame structures of a high-rise building

Performed by: student of group FACD-205ma Rakovych Maksym Anatoliyovych
(student, group, last name, first name, patronymic)

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Kyiv 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АРХІТЕКТУРИ, БУДІВНИЦТВА ТА ДИЗАЙНУ
КАФЕДРА КОМП'ЮТЕРНИХ ТЕХНОЛОГІЙ БУДІВНИЦТВА

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач випускової кафедри

____________О.І. Лапенко

"_____" _____________2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ОСВІТНЬО-ПРОФЕСІЙНА ПРОГРАМА «ПРОМИСЛОВЕ І ЦИВІЛЬНЕ БУДІВНИЦТВО»

Тема: Оцінка напружено-деформованого стану конструкцій металевого каркасу висотної будівлі

Виконавець: студент групи ФАБД-205ма Ракович Максим Анатолійович
(студент, група, прізвище, ім'я, по батькові)

Керівник: Професор, доктор технічних наук кафедри комп'ютерних технологій будівництва Барабаш Марія Сергіївна
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Нормоконтролер: __________ Родченко О.В.____
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Київ 2020

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет архітектури, будівництва та дизайну
Кафедра комп'ютерних технологій будівництва
Спеціальність: 192 «Будівництво та цивільна інженерія»
Освітньо-професійна програми: «Промислове і цивільне будівництво»

ЗАТВЕРДЖУЮ
Завідувач кафедри
___________О.І. Лапенко
«____» __________ 2020 р.

ЗАВДАННЯ
на виконання дипломної роботи
Раковича Максима Анатолійовича
(П.І.Б. випускника)

1. Тема роботи «Оцінка напружено-деформованого стану конструкцій металевого каркасу висотної будівлі» затверджена наказом ректора від «_10_» ____11_____ 2020 р. №_2251__/_ст_.

2. Термін виконання роботи: з 05.10.2020 по 21.12.2020

3. Вихідні дані роботи: місце будівництва - Київ, офісна будівля, навантаження згідно ДБН "Навантаження і впливи", інженерно-геологічні, інженерно-геодезичні вишукування будівельної ділянки, район І - згідно ДБН "Будівельна кліматологія".

4. Зміст пояснювальної записки: Аналітичний огляд літератури за темою роботи, наукова частина, архітектурна частина (та графічний матеріал), конструктивна частина, охорона праці, охорона довкілля.

5. Перелік обов'язкового ілюстративного матеріалу: таблиці, рисунки, діаграми, графіки, креслення архітектурної частини та розрахунково-конструктивної частини.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Аналітичний огляд	5.10.2020	
2	Наукова частина	21.10.2020	
3	Архітектурна частина	09.11.2020	
4	Конструктивна частина	17.11.2020	
5	Основи та фундаменти	20.11.2020	
5	Охорона праці	20.11.2020	
6	Охорона довкілля	09.12.2020	
7	Оформлення пояснювальної записки	17.12.2020	

7. Консультація з окремих розділів:

Назва розділу	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Аналітичний огляд	Професор, доктор технічних наук кафедри комп'ютерних технологій будівництва Барабаш М.С.		
Архітектурна частина	Професор, доктор технічних наук кафедри комп'ютерних технологій будівництва Барабаш М.С.		
Конструктивна частина	Професор, доктор технічних наук кафедри комп'ютерних технологій будівництва Барабаш М.С.		
Основи та фундаменти	Професор, доктор технічних наук кафедри комп'ютерних технологій будівництва Барабаш М.С.		
Охорона праці	Коновалова О.В.		
Охорона навколишнього середовища	Радомська М.М.		

8. Дата видачі завдання: «_05_» ____10_____ 2020 р.

Керівник дипломної роботи: _____________ Барабаш М.С.

(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____________ Ракович М.А.

(підпис випускника) (П.І.Б.)

NATIONAL AVIATION UNIVERSITY
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Faculty of architecture, civil engineering and design
Computer technologies of construction department
Speciality: 192 «Building and Civil Engineering»
Educational Professional Program: Industrial and Civil Construction

APPROVE
Head of the Department
____________O.I. Lapenko
"_____" _____________ 2020

TASK
to perform the master thesis
Rakovych Maksym Anatoliyovych
(Surname, initials of the graduate)

1. The subject of the work: «Evaluation of the stress-strain state of the metal frame structures of a high-rise building» is approved by order of the rector from «_10_» _______11_____ 2020 №__2251___/_ст_.

2. Term of work performance: from 05.10.2020 to 21.12.2020.

3. Initial data of the work: construction site - Kyiv, office building, load according DBN "Loads and influences", engineering-geological, engineering-geodetic survays of the construction site, district I – according to DBN "Building climatology".

4. Content of the explanatory note: Analytical review of the literature on the topic of work, scientific part, architectural part (and graphic material), structural part, occupational safety, environment protection.

5. List of required illustrative material: tables, figures, diagrams, graphs, drawings of the architectural part and the calculation and structural part.

6. Calendar schedule

№	Task	Execution period	Signature of the head
1	Analytical review	08.10.2020	
2	Scientific part	09.11.2020	
3	Architectural part	09.11.2020	
4	Structural part	18.11.2020	
5	Bases and foundations	08.12.2020	
6	Occupational safety	20.11.2020	
7	Environment protection	09.12.2020	
8	Making an explanatory note	17.12.2020	

7. Consultation on separate chapters:

Chapter name	Consultant (position, surname, initials)	Date, signature	
		Task issued	Task exepted
Analytical review	Prof. Dr.-Ing., Department of computer technologies in construction, Barabash M. S.		
Scientific part	Prof. Dr.-Ing., Department of computer technologies in construction, Barabash M. S.		
Architectural part	Prof. Dr.-Ing., Department of computer technologies in construction, Barabash M. S.		
Structural part	Prof. Dr.-Ing., Department of computer technologies in construction, Barabash M. S.		
Bases and foundations	Prof. Dr.-Ing., Department of computer technologies in construction, Barabash M. S.		
Occupational safety	Konovalova O.V.		
Environment protection	Radomska M.M.		

8. Date of issue of the task: «_05_» ______10______ 2020

Scientific adviser: ______________ Barabash M. S.

(signature of the head) (surname, initials)

The task is accepted for execution: ______________ Rakovych M.A.

(signature of the graduate) (surname, initials)

Content

INTRODUCTION

The subject of diploma project «Evaluation of the stress-strain state of the metal frame structures of a high-rise building». Building which is designed in this project will be used for offices.

The purpose of diploma project is carrying of statical and dynamic calculation of buildings frame and so the calculations of the main structural elements of building such as: metal column, pile foundation with slab, main metal beam.

To calculate bearing capacity of elements in case of emergency such as progressive collapse.

To investigate the influence of numerical stiffness of nodes on bearing capacity of steel members of a high-rise building in case of emergency situation.

Chapter 1
ANALYTICAL REVIEW

1.1. GENERAL INFORMATION

Progressive collapse - a phenomenon in which there is a consistent, chain destruction of load-bearing structures, resulting in the collapse of the entire structure, or its parts, due to the initial isolated destruction

As a result of the expected initial local destruction, which leads to a change in the structural system, create a design to protect buildings and structures from progressive collapse, which is performed in an emergency design situation. To do this, calculate the indicators of the ultimate state, which is provided by the bearing capacity, deformation and stability of the deformation form of the structural system of the building and structure as individual elements of joints, except remote, in case of local destruction and as a whole.

Throughout the service life, the structure can be affected by extreme load conditions that significantly exceed the usual design assumptions, which can lead to catastrophic consequences.

The list of these loads includes shock, deformation and explosive loads.

Explosives (such as gas explosion, bomb explosion) and shock load (car collision, aircraft impact) are short-lived and high in intensity, resulting in unnatural structural reactions compared to more conventional dynamic loads such as earthquakes and wind. In addition, deformation loads include fire (which softens the metal) and subsidence of the foundation as a result of which the supporting soil moves down).

Given that these particularly anomalous load conditions have a low probability of occurrence, they are usually not taken into account in the design of structures due to economic factors and the inability to accurately predict extreme scenarios - human and natural factors.

Resistance to progressive collapse indicates that in the event of an emergency, dirt is destroyed in individual vertical load-bearing elements within one floor or floor area on one floor, but these initial collapses should not lead to the destruction of structures that were previously loaded with elements damaged in the result of the blow.

Assessment of the stability of the house as a result of progressive collapse are used only in the most dangerous schemes of settlement.

In the early 19th century, mankind began to study the problems of progressive collapse and look for methods to calculate it.

One of the key moments that led to the development of building codes in this direction was a terrible tragedy - the collapse of the towers of the World Trade Center (WTC) in New York. Each of the twin towers of World Trade Center 1 and 2 crashed on September 11, 2001. As a result of a Boeing 767 jet crashing into the tower at high speed; the accident caused structural damage directly on site impact and near it, as well as provoked a large fire inside the building; as a result, the structure near the impact zone has lost the ability to withstand the load; the building collapsed from above, losing its support; the weight and impact of the collapsed top of the tower caused the dips to progress to the ground.

Unequivocally, it was a "progressive destruction" in any way. But this cannot be called "disproportionate destruction." It was a very large displacement caused by a strong blow and fire. And in contrast to the case of the Murray building, simple changes in the design of the structure, which could significantly reduce the scale of the collapse, have not yet been found.

Increased traction for fire protection (almost three times greater than previously needed for buildings 25 to 130 meters (75 to 420 feet) high and seven times greater for buildings higher than 130 meters (420 feet)).

Requirements for field installation of fire insulation include:

The installation fully complies with the manufacturer's instructions;

bases (fire-retardant surfaces) are clean and do not contain any conditions that prevent adhesion;

tests are performed to confirm that the required adhesion is maintained for primed, painted or encapsulated steel surfaces;

the final state of fire insulation at full drying or hardening has no defects in the form of cracks, cavities, exfoliations, exfoliations or any influence of the basis.

All field inspections of fire insulation shall be carried out to ensure that the installed thickness, density and bond strength meet certain requirements, in addition to verifying that the bonding agent is used when the bond strength is less than required due to the effect of primed, painted or encapsulated steel surface. These inspections are carried out after the installation of mechanical, electrical, plumbing, sprinkler and ceiling systems.

Unambiguous adoption of the "structural boundaries" approach to the fire resistance rating, which assumes the presence of the highest degrees of fire resistance in all components of the primary structural structure, is usually required for columns. The primary structural frame provides for the presence of columns and other structural elements, including girders, beams, trusses and gaskets, which are directly connected to the columns, and support elements designed to withstand gravitational loads..

1.2. CALCULATION OF PROGRESSIVE COLLAPSE

Isolated collapse involves the collapse of a vertical structure of one floor of the house, which is limited to an area of 80 m2 (diameter 10 m):

- collapse of both walls, which have points of intersection, in areas from which (for example, from the corner of the house) to the nearest hole in each wall or to the next vertical section in the direction of the wall;
- collapse of a free column or one adjacent to certain sections of walls located on the same floor in the area of isolated collapse;
- collapse of a floor area of one floor in the zone of isolated destruction.

In all possible variants: the cross-sectional area of all removed vertical elements located at the cross-section of 80 m2 should not exceed 0.9 m2 for reinforced concrete elements and 0.7 m2 for reinforced concrete elements, 15% for rigid reinforcement;

It is obligatory to use the existing rules ensuring the correct calculation of the stability of the structure in the face of progressive collapse. It is also necessary to take into account the possibility of a building being destroyed if its supporting structures are designed from metal frames:especially if, in the event of the destruction of individual elements, it is necessary to identify the most dangerous places according to the accepted design scheme according to the possible risks. Calculations of the structure of the building are used as a system «foundation - foundation - construction» using software packages that take into account physical and geometric nonlinearity, As a result, the probability of results and reduced incremental costs of the material are effectively calculated.

The calculations are as follows:

Calculation of the whole diagram in a physically non-linear composition for permanent and temporary loads, emergency service;

- the strain-strain state we obtain as a result is the starting point for calculating the load from the removed element;

The calculation of the additional load of the removed elements is carried out in a physical and geometric non-linear setting. The load from removal of the elements corresponds to the efforts received at the previous calculation stage and is doubled dynamically. The strength test of the other components shall be carried out without regard to the longitudinal bending.

The methods used to ensure that a building, structure or individual structural element is resistant to local destruction during an extreme destructive action have a direct impact on it;

Modalities related to the development of so-called Standby Force Transfer Techniques after the isolated destruction of a separate structural element

Two sub-classes of methods are used:

Methods aimed at ensuring the continuity, overall integrity and plastic deformation of the structure under special impact by establishing the design minimum of the coupling straps (force binding method)

Methods based on the timely identification and limitation of the allowable area or volume of a building to be gradually destroyed during the isolated break-up of an individual structure and the design of a structural system capable of absorbing loads, operating within the volume of the collapsed building (alternative trajectory methods, AT - method). Provision should be made for a phased calculation for the protection of buildings against progressive collapse.

First of all, the stress-strain condition of the structures under optimal operating conditions has to be determined for the primary design scheme.

The stress-strain condition of the structures is then calculated for each secondary design design design, which develops at a specific limit during the isolated failure. During reconstruction, the stresses and deformations of the structures arising from operation shall be taken into account.

It is mandatory to calculate the load-bearing elements, in the event of failure of which a gradual breakdown of the structural system is possible. The Elements with the highest workloads, as well as those with additional workloads, are the ones that should be the most emphasized.

In calculating buildings and structures to protect against progressive collapse, it is necessary to consider individual isolated damage independently of other possible isolated damage.

In the calculation of buildings and structures, the actual material patterns of the structures and their joints should be taken into account (Stratification of brick during stretching: not perceiving tensile stresses at platform junction; fragile breakdown of structures and their interfaces, etc.)

The cinematic method of the theory of extreme equilibrium is used in calculating the protection against progressive collapse in order to ensure plastic work of the knocktur system in the maximum state.

When the structure (slabs, strings, beams, etc.) is significantly bent, its function must be considered as the work of the elements of the suspension system. However, it is necessary to calculate the constructive possibility of perceiving horizontal influence.

When an element is suddenly eliminated, the protection against progressive destruction is calculated by a dynamic or quasi-static method.

1.3. METHODS OF PREVENTING PROGRESSIVE COLLAPSE

There are, in general, three alternative approaches to designing structures to reduce their susceptibility to disproportionate collapse: ·

Redundancy or alternate load paths ·
Local resistance ·
Interconnection or continuity

1.2.1. Redundancy or Alternate Load Paths

The general structure is designed in such a way that, when one component fails, alternative ways of loading the component are activated, without a general phase-out. This method is dominated by simplicity and straightness. The most common applications involve the use of back-up structures, and the construction structure is capable of withstanding the loss of a single column without damage or structural change.

This requirement is sufficiently objective, easy to understand and productive. The main problem with redundancy is that the latter does not take into account the diversity of vulnerabilities.

It is an absolute fact that redundancy in one column, while each of them has a W8x35 size, does not provide this level of security, while each individual column has a built-in section of 2,000 pounds / feet. Therefore, an explosion that could have taken 2,000 pounds / a foot column would likely have destroyed several W8 columns, resulting in the redundancy of one column being irrational, which could have prevented and prevented its destruction.

It should be noted that codes and standards for which excess is required do not separate the two main cases; they treat each column as an element that is subject to the same possible destruction. In fact, it is much easier to develop the redundancy of a small and lightly loaded column, and reservation requirements can have the pitiful effect of encouraging structures with more small (and vulnerable) columns than fewer large columns. This could be a step in the wrong direction to protect against deliberate attacks.

1.1.1. Local Resistance

In this case, the effect of progressive / disproportionate collapse is reduced by the use of so-called critical components that can be attacked, with additional resistance. This requires specific information about the nature of potential attacks. And it is very difficult to codify in a simple and objective way

1.1.1. Interconnection or Continuity

This method is a means of improving local resistance (or both). A study of a large number of recent building collapses found that the destruction had been avoided, or at least reduced, if the structural components had been more efficiently connected. This is the basis for the "integrity of the design" requirements in ACI 318 (ACI, 2002).

1.1.1. Ties

Load redistribution and element deflection are developed by the loss of the main structural element. These phenomena require the redistribution of loads throughout the structure through the main load areas.

The ability of the structure to distribute the load proportionally over these zones depends to a large extent on the relationship between the adjacent elements, which is called "communication" and links the integrated system in three directions along the main structural framing lines.

1.1.1. Ductility

In extreme situations, the main elements and their compounds will have to maintain their strength when major deformations occur (bends and rotations) and optimize load redistribution despite loss of key elements of the structure.

In the construction of structures to achieve plasticity, the manufacturers use high viscosity steel, which ensures overall and local stability of the structure and facilitates the creation of bonds between the elements exceeding the strength and viscosity of the main material.

In the manufacture of reinforced concrete and reinforced masonry structures, manufacturers achieve plasticity by ensuring sufficient reinforcement of reinforced steel, continuity of reinforcement by appropriate knee joints or mechanical strings, Maintenance of the overall stability of the structure and creation of links between the main elements which exceed the strength and viscosity of the base elements.

1.1.1. Adequate shear strength

Structural components which are in the affected area, such as perimeter beams or slabs, must be designed to withstand shifting loads exceeding the bending moment limit in the event of loss. The displacement must always exceed the bending capacity to stimulate the plastic response.

To prevent «rupture» after destructive landslides continuous upper and lower fittings are used, which are properly fixed in columns. This combination decreases the probability of progressive decay, as this plate-column assembly is supported by the membrane effect of the plate fittings.

1.1.1. Capacity for resisting load reversals

Primary structural elements (columns, runs, roof beams and side support system) and secondary structural elements (floor beams and slabs) shall be designed using the accepted standardized methods. Compliance with these requirements contributes to the ability of these elements to withstand loads in sensitive areas.

It is known that in framework structures the distance between columns should be limited. The large interval between the columns reduces the redistributive capacity, resulting in the design being unable to optimize the load distribution in the event of a column failure.

Chapter 2

SCIENTIFIC PART

2.1. General data about progressive collapse

The progressive collapse of a building occurs when local failure of one structural member that leads to the destruction of neighbor components and total damage that is not proportional to the original destruction.

The trouble of progressive collapse in building started when occured partial collapse of a Ronan Point building in the capital of GB - London. Following this the event, intensive research efforts led to the development of progressive collapse strategies and methods and led to the first progressive provisions on the collapse of British standards. Even modern ways are largely useful from approaches formed at that time. The second and third waves of progressive collapse are interested the building society emerged after the disproportionate disintegration of A.

Disproportional failure can be caused by various cases. There are such types of cases of emergency: explosions caused by gas or explosives; strikes of vehicles, ships or aircraft; earthquakes; human errors at the design or construction stage, etc. Prognostication this cases and not normal actions are very complicated and depend on many details. In terms of security, the disproportional failure is of partial importance as buildings and other important infrastructures are often the target of explosive terrorist attacks. A building must be able to prevent excessive spread its other members after local damage. However, to design huge building against a disproportional failure due to the explosive load is a rather complex problem due to some assumptions and some parameters: the number and type of explosive wave , distance from the structure where the explosive was detonated, whether the explosion affects the corner or central columns of the building, etc. These difficulties make them virtually non-existent provisions of national building codes and design standards to withstand explosion or indoor explosion made by explosives. the design is based on selected codes, standards and recommendations, mainly from the EU and the US.

As shown, previously developed design approaches for gradual mitigation are available are divided into indirect and direct. Indirect approaches are to apply prescriptions design rules (minimum requirements for strength, continuity, ductility, redundancy), contributing to resistance to progressive collapse. However, a progressive collapse behavior is not decided explicitly. These indirect design approaches apply problem by identifying and including in the building system the characteristics that increase reliability, without taking into account the loads or events that may provoke disproportionate collapse. On the other hand, direct approaches involve a design based on characteristics and consist of a specific method of local resistance (development of a “key elements ”for resistance to high enough pressure) and the method of alternative load path. The report also includes some real cases of progressive collapse, it contains a a representative view of research efforts in this area, as reported in international journals conferences and points to gaps in knowledge.

Analyzing such a building and checking whether progressive collapse can occur or not depends on many assumptions. For For example, the main unknowns are: how large the charge of the explosive (which peak pressure), how far from the building the explosive is detonated, and whether the explosion affects the angular load-bearing elements of the building or located in the middle of the sides of the building, etc.

These difficulties cause the absence of virtually no provisions in the state Codes and standards for the design of structures to withstand external or internal explosions explosions caused by explosives. Thus, instead of explicitly analyzing the structure to a specific explosive load, current norms, standards and recommendations recommend a threat independent design, ie design for an unknown reason, or the development of some elements (key elements) to withstand high enough pressure These early design approaches developed to gradually mitigate collapse can divided into indirect and direct approaches. Indirect approaches are to apply regulatory design rules (minimum requirements for strength, continuity, ductility, redundancy), providing resistance to progressive destruction; however progressive the coagulation behavior is clearly not considered. In other words, the indirect design approach solves the problem by identifying and incorporating strength-enhancing characteristics into building systems, without special consideration of loads or events that may cause a disproportionate collapse. Direct design approaches include a results-based approach and consist of specific local resistance method and the method of alternative loading path.

2.2. Terms and definitions

Terms of progressive collapse are common in various publications

may have a widr or narrower volume and are sometimes used with slightly different ones value. Therefore, the purpose of this chapter is to provide a list of terms with them definition.

Disproportional failure - progress of the initial local collapse from the element toelement, which in turn leads to the destruction of the whole structure or a not proportional large part of it (ASCE 7 [5]).

Disproportional failure - progress of local damage from the initial action, from member to member, which leads to the destruction of the entire building or a not proportional large part of it; known as progressive failure (NIST Best Practices [56]).

Progressive collapse - a situation where a local failure of the primary structure the component leads to the disintegration of adjacent members, which, in turn, leads to additional disintegration. Thus, the total damage is disproportionate to the original cause (GSA Guidelines [40]).

Progressive collapse - this term is indirectly mentioned EN 1990 [26], where the code considers the main positions to be met by the building: “The building should be calculated and executed in that way that it does not events such as explosion, blows or the result of human error not proportional to the original reason ". EN 1990 [26], 2.1 (4)

Reliability - the feature of the building to resist cases such as fire, explosions, the impact or results of human error without being damaged to some extent not proportional to the original cause (EN 1991-1-7 [28]).

Strength - the ability of a building or member to resist damage without premature and / or brittle destruction due to events such as explosions, impacts, fire or the consequences of human error, due to its energetic strength and viscosity (GSA Guidelines [40]).

Reliability - insensitivity of a design to local destructions where "insensitivity" and "local failure" should be quantified (Starosek and Haberland [69]). In this way, strength is a property of the building itself and does not depend on the possible causes of the start local collapse. 1991-1-7 [28] - which includes possible causes of the start malfunction. So wider the definition is close to the term collapse resistance, as defined below.

Resistance to failure - insensitivity of the building to accidental circumstances, representing low probability events and unforeseen events. Random circumstances should be assessed by the project objectives. There is resistance to collapse property that is affected by numerous conditions, including both structural features and possible causes of initial failure. (Starossek [65], Starossek and Haberland [69]).

The key element is the structural element on which the stability of the rest is ensured depends on the structure (EN 1991-1-7 [28]). The key element is the structural elements, the conditional removal of which can cause destruction unacceptably. Therefore, they must be designed for random loads, which are listed in several standards as 34 kPa (NIST Best Practices [56]). Localized failure - the part of the structure that is believed to have collapsed, or have been disabled due to an emergency situation (EN 1991-1-7 [28]). Continuity - refers to the continuous connection of members as well reinforcement of concrete members. Thus, continuity is an element resilience (Starossek and Haberland [69]). Damage tolerance - this term is compatible with the term strength used Lind [46]. In some other works, the value of damage tolerance is narrower and refers to the ability of the structure to withstand constant local deterioration as a result corrosion or the like (Starossek and Haberland [69]).

Plasticity - the ability of a member to resist big plastic deformation. Plasticity has a great influence on the disproportional failure and is is often listed as a factor that increases the strength of the structure (Starosek and Haberland [69]).

Plasticity - the ability of the structure to remain stable after large deformations (rotations and deflections). There are various tools for steel and reinforcement concrete structures to ensure sufficient ductility. Steel - using high steel viscosity, compounds that exceed the strength of the base material. Reinforced concrete structures - retention of reinforcing steel, continuity due to splicing of joints, maintaining overall structural stability and linking elements which exceed the strength and viscosity of the support elements, etc. (NIST Best Practices [56]).

Integrity - this term is mainly used in American standards such as ACI 318 [2], ASCE 7 [5], often in connection with regulatory requirements (as requirements for continuity, plasticity and redundancy).

Redundancy - structural redundancy refers to multiple availability load-bearing components or multiple load paths that may carry additional loads fault case. If one or more components fail, the structure remains able to redistribute the load and thus prevent failure of the entire system. Redundancy depends on the geometry of the structure and personality traits bearing elements (Frangopol and Curley [39]). This is not synonymous with the wordstatic uncertainty. Redundancy is mentioned as an important design factor strong structures and, therefore, prevention of progressive destruction (EN 1991-1-7 [28]). The redundancy concerns, in particular, the alternative loading method (Starossek and Haberland [69]).

Redundancy - the inclusion of unnecessary load paths in the vertical load carrier system to ensure the availability of alternative load routes in the case local failure of structural elements (NIST Best Practices [56]).

Vulnerability - describes the sensitivity of the structure to damage events. The structure is vulnerable if minor damage leads to disproportionate consequences.

Vulnerability is the opposite of reliability, and this is a property of the structural system(Starosek and Haberland [69]).

Connections - Loss of the main structural element usually leads to redistribution of loads and deviations of the elements. These processes require load transfer throughout the structure (vertically and horizontally) through the load paths. the ability of the structure to redistribute or transfer loads along these load paths is based largely on the relationship between neighboring members. It often referred to as "building linking" through Russia's integrated communications system three directions along the main lines of the structural frame. Fig. 3.4 taken from The DoD UFC Recommendations [20] illustrate the different types of ties that are typical built-in to ensure the integrity of the building structure (NIST Best Practices [56]).

Direct design for progressive collapse is a clear consideration of progressive folding in the design process through: an alternative method of the download path or specific local resistance method (ASCE 7 [5]).

Design for disproportional failure - implicit consideration of disproportional failure during design by ensuring best levels of strength and ductility (ASCE 7 [5]).

Specific local resistance method (key element method) - a method that seeks to provide sufficient strength to withstand rejection of accidents or misuse. In others In short, the critical load-bearing element is clearly designed to withstand the established load level (ASCE 7 [5]).

Alternative load path method - a method that allows local collapse, but seeks to provide alternative loading paths so that the damage is absorbed and large collapse prevention (ASCE 7 [5]).

Risk - a measure of a combination (usually a product) of probabilities or the frequency of occurrence of a particular danger and the magnitude of the consequences (EN 1991-1-7 [28]).

Consequences - a possible outcome of the event. The consequences can be expressed verbally or numerically in terms of loss of life, injuries, economic losses, ecology losses, losses for users and the public, etc. Both the immediate consequences and those that occur after a certain time (EN 1991-1-7 [28]).

Risk analysis - a systematic approach to the description and / or calculation of risk.

Risk analysis involves identifying adverse events as well as the causes and consequences of these events (EN 1991-1-7 [28]).

Risk assessment - comparison of the results of risk analysis with risk acceptance criteria and other decision criteria (EN 1991-1-7 [28]).

Risk management - systematic activities carried out by the organization in Russia in order to achieve and maintain a level of security that meets the defined objectives (EN 1991-1-7 [28]).

Risk acceptance criteria - these criteria are usually determined by the authorities to reflect the level of risk that is considered acceptable to people and society.

They correspond to the permissible limits of the probability of certain consequences adverse events and are expressed in annual frequencies (EN 1991-1-7 [28]). Deflagration - the spread of the combustion zone at a rate less than speed of sound in unreacted medium (EN 1991-1-7 [28]). Detonation - the spread of the combustion zone at a speed greater than the speed of sound in unreacted medium (EN 1991-1-7 [28]).

2.3. Review of procedures and strategies for progressive collapse design

2.3.1. British Standards

2.3.1.1. Load combinations

British standards recommend the design of bridges (alternative load method) applying load combinations as follows

$$D + W/3 + L/3 \qquad (2.3.1)$$

where: D - dead load, W - wind load, L - imposed load.

2.3.1.2. Horizontal ties

Steel structures

There must be steel elements made as horizontal screeds and their end joints is able to withstand the considered tensile load as follows:• internal ties

$$T_i = 0.5(1.4g_k + 1.6q_k)s_tL \text{ but not less than 75 kN,} \qquad (2.3.2)$$

where: g_k – the specified dead load per unit area of the floor or roof, q_k – the specified imposed floor or roof load per unit area, L – the span, s_t – the mean transverse spacing of the ties adjacent to that being checked.

$$T_e = 0.25(1.4g_k + 1.6q_k)s_tL \text{ but not less than 75 kN.} \qquad (2.3.3)$$

2.3.1.4. Design of bridging elements (alternate load path)

Steel structures

If the conditions for the bonding forces cannot be met, the building should be inspected in order to provide conditional deletion of the column (at each level, one) will not lead to a disproportionate collapse.

2.3.1.5. Key elements

Steel structures If the conditions for the tie forces are not satisfied and upon a column removal the building is suspected to total collapse or the area of the collapsed portion is greater than 15% or 70 m2 , then that column or element should be designed as a key element. The column or element is deemed as key element if it can resist the pressure of 34 kN/m2 .

2.3.2. Eurocodes

EN 1991-1-7 [28] contains provisions (strategies) for the design of structures against identified and unidentified emergency situations. However, as written in Eurocode, “EN 1991-1-7 does not specifically address emergency situations that have occurred external explosion. Thus, when designing a structure against a possible threat Terrorist attack, design must be carried out in accordance with the provisions indefinite random action. Some of the materials below are included in the rules and others in informative applications.

According to EN 1991-1-7 [28] the strategies for emergency situations are illustrated in Fig. 3.1. Therefore, if an accidental action is identified we may try to

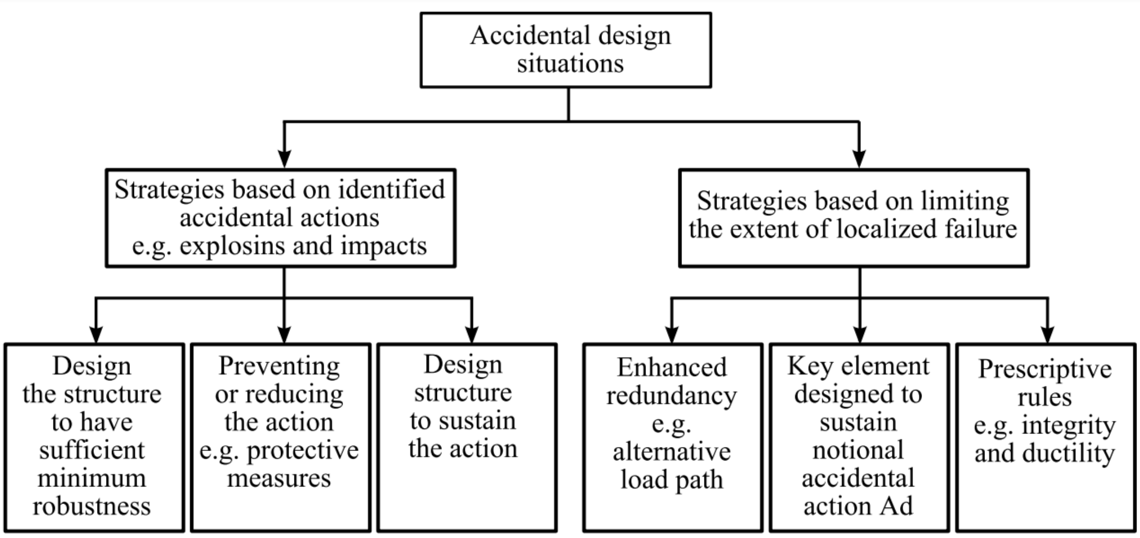


Figure 2.3.1. Strategies for accidental design situations

to prevent or reduce the effect of protective measures, we can design a design for sufficient stability or support of action. On the other hand, if we allow the local damage, the purpose of the design is either to enhance structural redundancy on an alternative load method or to ensure structural integrity and ductility. Potential damage can be avoided or limited by choosing one or more from the following actions:

• avoid, eliminate or reduce hazards that may be a design

subject,

• selection of a structural form that has a low sensitivity to the considered hazards,

• the choice of structural form and structure that can adequately survive the accidental removal of a single element or a limited part of the structure, or

occurrence of admissible localized damages,

• avoid, as far as possible, structural systems that can collapse without warning,

• linking structural elements together.

Strategies for random design situations depend on three consequences classes defined in EN 1990 [26]. These consequence classes (CC) include:

CC1 - low consequences of failure,

CC2 - average consequences of failure,

CC3 - high consequences of failure.

EN 1991 [27] defines random design situations for different consequences classes as follows:

CC1 - no special consideration required for random actions except which comply with the rules on stability and strength given in other Eurocodes (EN 1990 [26] to EN 1999 [36]), Eurocodes 15

CC2 - depending on the specific design conditions, simplified analysis for models of equivalent static actions can be adopted or design and detailing rules can be applied, CC3 - for a more detailed case study should be done the required level of reliability and depth of structural analysis. Risk evaluation, as well as an improved method of analysis (nonlinear dynamic analysis) may be required.

Annex A to EN 1991-1-7 [28] contains a classification of building types according to taking into account the classes of consequences. Simplified version of table A.1 EN 1991-1-7 [28] can be represented as follows:

CC1 - one-room houses not more than 4 floors, agricultural buildings, houses that are rarely occupied by people, etc .;

CC2a (lower risk group) - 5-storey one-room houses, hotels, apartments, flats, other residential buildings, offices not more than 4 floors, etc .;

CC2b (higher risk group) - hotels, apartments, flats and other residential buildings with more than 4 floors, but less than 15 floors, etc .;

CC3 - all buildings defined for classes CC2a and CC2b that exceed the limit on area or number of storeys, all houses occupied by a large number of people, stadiums for more than 5,000 spectators, buildings containing hazardous substances and processes, etc.

Based on this categorization, the following strategies are recommended:

a) for consequence class 1 buildings: as mentioned earlier, there is no specific project required procedure, in addition to the design and construction of buildings in Russia in accordance with the rules of other Eurocodes,

b) for buildings of impact class 2a (lower group): the additional procedure includes the use of appropriate effective horizontal screeds or effective fastening of suspended walls, as defined in 3.2.2,

c) for buildings of consequence class 2b (upper group):

• horizontal and vertical connections shall be provided as shown before;

• The building should be inspected for conditional removal of each support column and each column supporting beam or any nominal section.

load-bearing wall will not cause local damage greater than specified restrictions and not cause a complete collapse. Where is the conditional removal of such columns and sections of walls would lead to exceeding these limits for local damage, these elements should be reworked or designed as "key element"

d) for buildings of impact class 3: A systematic risk assessment of the building should be carried out taking into account both foreseeable and unforeseen hazards according to Annex B of EN 1991-1-7 [28].

Annex A to EN 1991-1-7 [28] provides rules and methods for the design of buildings to withstand the degree of localized destruction for an unknown reason. without disproportionate collapse.

2.3.2.1. Load combinations

Random actions shall be applied simultaneously in combination with constant and variable loads in accordance with (EN 1990 [26], 6.4.3.3).

Combination of actions for random design situations in the boundary states according to (EN 1990 [26], 6.4.3.3) is as follows

$$\sum_{j\geq 1} G_{k,j} + P + A_d + (\psi_{1,1} \text{ or } \psi_{2,1})Q_{k,1} + \sum_{i>1} \psi_{2,i}Q_{k,i} \qquad (3.5)$$

where: G – permanent load (dead load), P – relevant representative value of a prestressing action (see EN 1992 to EN 1996 and EN 1998 to EN 1999), Ad – design accidental action, Q – variable load (live load, snow load, wind load), ψ1 – factor for frequent value of a variable action, ψ2 – factor for quasi-permanent value of a variable action. Accidental action Ad should be taken as an explicit accidental action Ad for fire or impact or can refer to the situation after an accidental event. In this case Ad is equal to zero. Recommended values for ψ1 and ψ2, depending on the building categories, can be found in Table A1.1 of Annex A EN 1990 [26].

In the paragraph EN 1990 [26], 4.1.2 (8), it reads as follows “For accidental actions the design value Ad should be specified for individual projects based on EN 1991 [27] ”.

When analyzing a structure in a quasi-static way, the dynamic effects can be included by applying an equivalent dynamic amplification factor to the static actions, EN 1990 [26], 5.1.3 (3). However it is not specified in the Eurocodes what value for the dynamic amplification factor is recommended in the case of accidental actions.

Random actions that should be considered depend on measures taken to prevent or reduce the severity of the accidental action,

- the probability of occurrence of the detected accidental action,
- consequences of failure due to the detected accidental action,
- public perception,
- level of acceptable risk.

Localized failure due to accidental actions may be acceptable if it is not to threaten stability of all design, and also the general bearing loading the design capacity is maintained and allows the necessary emergency measures to be taken for be accepted.

Measures should be taken to reduce the risk of accidental actions and such measures should include one of the following strategies: prevention of action from occurrence, protecting the structure from the consequences of accident action by reducing the effect of the action on the structure, ensuring that the structure has sufficient strength.

2.3.2.2. Horizontal ties

For frame structures - continuous internal connections, including their end connections, must be able to withstand the design tensile load of the quantity

$$T_i = 0.8(g_k + \psi q_k)sL \quad \text{or} \quad 75\,\text{kN}$$

s – the spacing of ties, L – the span of the tie, ψ – the relevant factor in the expression for combination of action effects for the accidental design situation

2.3.2.3. Vertical ties

All vertical screeds (for frame and wall structures) must be continuous from

foundations to roof level. For frame structures, vertical screeds must be able to withstand a random structure tensile force equal to the largest design vertical response of constant and variable load applied to a column from one floor. It should be noted that this is an accident the design load should not act simultaneously with constant and variable actions which may affect the design.

2.3.2.4. Key elements

For building structures, the key element must withstand accidental design action the ad is applied in horizontal and vertical directions (one direction at a time).

2.3.2.5. Risk assessment

For category CC3 of buildings, Eurocode EN 1991-1-7 [28] requires a risk assessment for a building. Risk is defined as a measure of the combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence and is expressed as

$$R = \sum_{i=1}^{N_H} p(H_i) \sum_{j}^{N_D} \sum_{k=1}^{N_S} p(D_j|H_i) \cdot p(S_k|D_j) \cdot C(S_k), \tag{3.11}$$

where NH – number of different hazards, ND – number of ways the hazards may damage the structure, NS – number of adverse states (Sk) into which the damage structure can be discretised, C(Sk) – consequences of an adverse state, P(Hi) – probability of occurrence (within a reference time interval) of the i-th hazard, p(Dj |Hi) – the conditional probability of the j-th damage state of the structure given the i-th hazard and p(Sk|Dj) – the conditional probability of the k-th adverse overall structural performance S given j-th damage state.

2.3.2.6. Dynamic design against impact

Annex C to EN 1991-1-7 [28] provides guidance on approximate dynamics

design of structures for accidental impact of road vehicles, railway vehicles and ships based on simplified or empirical models.

First, we consider the general theory of the dynamics of shocks, where shocks are idealized and grouped into two types, namely strong shocks (energy is dissipated by object that affects) and soft shocks (the structure absorbs the impact energy due to deformation of the structure). As for strong blows, EN 1991-1-7 formulates the expression for the maximum resulting dynamic interaction force (F) in the object function

impact velocity (vr), equivalent elastic stiffness of the object (k) and mass affecting object (m). This maximum dynamic force of interaction is intended for the outer surface of the structure, while for the structure itself can have dynamic effects should be greater and should be included using the dynamic gain.

For soft blows, the same formula can be used for maximum dynamic interaction force however, for k it is necessary to take the rigidity of the structure. There are also formulated provisions that the structure must have sufficient ductility to be able to absorb total kinetic energy by plastic deformation.

The second part of Annex C EN 1991-1-7 deals with specific provisions on the impact of road vehicles and vessels containing formulas or meanings impact velocities (vr) and approximate design values for dynamic interaction forces (Fd) depending on various factors, such as: where the vehicles are moving, weight of vehicles, distance of vehicles from lanes, size and weight of vessels, whether vessels travel by inland or sea waterways, etc.

2.3.2.7. Internal explosions

Annex D EN 1991-1-7 [28] contains instructions on how to deal with:

• explosion of dust in rooms, ships and bunkers,

• explosions of natural gas,

• explosions in automobile and railway tunnels.

For dust explosion in rooms, vessels and hoppers EN 1991-1-7 contains:

• material parameters KSt (which characterize the limited behavior of the explosion) for the most common types of dust and,

• formula for the ventilation area of cubic, elongated rooms, vessels and hoppers, as as well as for rectangular fences.

For natural gas explosions, EN 1991-1-7 contains formulas of nominal equivalent static pressure, because the load the structure must withstand.

For explosions in road and railway tunnels, EN 1991-1-7 contains the expression for pressure time function in cases of detonation and deflagration.

2.3.3. ASCE 7-05

The American Society of Civil Engineers, ASCE 7 [5] discusses the overall design specifications to reduce the potential for progressive collapse, however, are specific the requirements are given. Similarly, no US building code provides for a specific design requirements for gradual collapse.

The commentary to ASCE 7 [5] contains a detailed discussion of the overall structural integrity. It contains a list of possible methods of progressive design of such landslides as a direct and indirect approach to design. Approaches to direct design include an alternative load path method and a specific local resistance method, while indirect design The approach is based on the implicit consideration of progressive collapse resistance from the outside ensuring a minimum level of strength, continuity and ductility Like Eurocodes and British standards, there are no provisions on what dynamic reinforcement the coefficient should be used when equivalent static methods are used.

2.3.3.1. Load combinations

ASCE 7 [5] determines the following combinations of loads:

• for a specific method of local resistance

$$1.2D + A_k + (0.5L \text{ or } 0.2S) \quad \text{or} \tag{3.12}$$
$$(0.9 \text{ or } 1.2)D + A_k + 0.2W_n, \tag{3.13}$$

for the alternative load path method (checking whether residual bearing capacity remains conditional deletion of the selected bearing element)

$$(0.9 \text{ or } 1.2)D + (0.5L \text{ or } 0.2S) + 0.2W_n, \tag{3.14}$$

where: D – dead load, L – live load, Wn – wind load, S – snow load, Ak – load effect resulting from an extraordinary event to be specified by the authority having jurisdiction.

2.3.5.2. Linear Static Analysis Procedure

In linear static analysis, the following steps are performed. this should be noted that a second-order analysis or P-необхід is required.

1. To analyze alternative paths for load-bearing elements that do not have adequate vertical bonding force, pull the element out of the structural model according to the specific

material requirements. For the analysis of alternative ways MLOP and HLOP structures remove the column or load-bearing wall.

2. Apply the load.

3. After the analysis, compare the expected elements and forces of connection and deformation with the given acceptance criteria. in general in Table 3-1 of UFC 4-023-03. To demonstrate compliance eligibility criteria, software package with modules that perform construction code checks can be used, provided that the modules can be adapted to check the criteria in Table 3-1. Make sure that all code positions related to the specific mounting material compactness, bending-axial interaction, etc.

4. If none of the structural elements or connections violates the eligibility criteria, the analysis is complete and satisfactory resistance to progressive destruction was demonstrated. If any of the structural elements or connections are broken eligibility criteria, follow the procedure below:

a) Change the geometry or properties of the model material (ie remove elements and / or insert hinges and constants).

b) If it was shown that the element failed, redistribute the load on the element.

c) Re-analyze this modified model and the applied load, starting from the unloaded / undeformed state.

d) At the end of the re-analysis, evaluate the resulting damaged condition and compare with the limitations of the damage. If damage limits are violated, redesign and re-analyze the structure starting from step 1. If the loss limits are as follows not disturbed, compare the obtained internal forces and deformations of each element and relationship to eligibility criteria

e) If any of the eligibility criteria are violated in the new analysis, repeat this process (steps (a) - (e)) until the harm limitation is violated or not no more violations of the eligibility criteria. If the limits of losses are as follows violated, redesign and re-analyze the design starting from step 1. If the limits of damages are not violated, and no new elements violate acceptability criteria, then the design is adequate.

2.3.5.3. Nonlinear Static Analysis Procedure

In nonlinear static analysis, the following steps are performed.

1. To analyze alternative paths for load-bearing elements that do not have adequate vertical bonding force, pull the element out of the structural model according to the specific material requirements. For the analysis of alternative ways MLOP and HLOP structures, remove the column or load-bearing wall.

2. Apply a load using a load history that starts from zero and increases to final values. Apply at least 10 load steps to achieve the total load. Software must be able to gradually increase the load and achieve iteratively convergence before moving on to the next load gain.

3. During the analysis, compare the intended element and the connection forces and deformations against the eligibility criteria, which are generally shown in Table 3-1 of UFC 4-023-03. To demonstrate eligibility, a software package with building code modules checks can be used if the modules can be adapted to check the criterion in Table 3-1. Make sure that all code positions related to the specific mounting material compactness, bending-axial interaction, etc.

4. If none of the structural elements or connections violates the eligibility criteria during the download process the analysis is complete and has satisfactory resistance to a progressive collapse was demonstrated. If any of the structural elements or connections violate the eligibility criteria, perform the following procedure:

a) At a time in the download history when an item or connection fails

eligibility criteria, delete an item or connection.

b) If it was shown that the element failed, redistribute the load on the element.

c) Restart the analysis from the point in the download history where the item is located or the connection failed and the model was changed. Increase the load to the maximum load is reached or until another element or connection is broken eligibility criteria.

d) At each point where the analysis is stopped, check the estimated damage state against the limits of losses. If damage limits are violated, redesign and re-analyze the structure starting from step 1.

e) If the limits of damage are not violated and the total load is applied, the design is adequate. If the damage limit is not violated, but one of eligibility criteria were violated on re-analysis, repeat this process (steps (a) - (e)) until the total load or damage is applied boundaries are violated.

2.3.5.4. Nonlinear Dynamic Analysis Procedure

1. Distribute the weight of the structure throughout the model realistically; lump masses are prohibited, unless they are mechanical equipment pumps, architectural features and similar items. Distribute the mass along the beams and the column as a mass per unit length; for tiles and floors represent the mass as mass per unit area. If any part of the structure is represented by a solid body elements, distribute the mass as mass per unit volume.

2. Before removing the load-bearing element, bring the model to static equilibrium under loads; the process of achieving equilibrium under the action of gravitational loads will depend on the analysis technique.

3. When stabilizing the model, immediately remove the corresponding bearing element. To analyze alternative paths for load-bearing elements that do not have sufficient vertical binding force, remove the element according to material-specific requirements. To analyze alternative ways of MLOP and HLOP constructions, remove the column or load-bearing wall.

4. Continue the dynamic analysis until the structure becomes stable and stable conditions (ie the history of moving the model reaches almost constant values, with very small fluctuations and all material and geometric nonlinear processes stopped).

5. During or after the analysis, compare the intended element and the communication forces and distortions regarding eligibility criteria, which are generally shown in Table 3-1 of UFC 4-023-03. Demonstrate compliance with acceptability criteria, a software package with modules that perform building code verification can use modules that can be adapted to check the criteria in the table 3-1. Make sure that all material-specific code positions for mounting, compactness, bending-axial interaction, etc.

6. If none of the structural elements or joints violates the criteria of acceptability during the dynamic movement of the structure, the analysis is completed and satisfactory resistance to progressive collapse has been demonstrated. If any of structural elements or connections violate the criteria of acceptability, perform following procedure:

a) At a time in the download history when an item or connection fails eligibility criteria, instantly remove an item or connection from model.

b) If it was shown that the element failed, redistribute the load on the element.

c) Restart the analysis from the point in the download history where the item is located or the connection failed and the model was changed. Continue the analysis until the structural model is stabilized either to the violation of another element or connection eligibility criteria.

d) for each moment when the analysis is stopped due to violation of the element eligibility criteria, check the limits of damage. If the limits of losses are as follows violate, stop the analysis and redesign and re-analyze the structure, starting with step 1.

e) If the limits of losses are not violated and the structural model is stabilized, the design is adequate. If the damage limit is not violated, but one of eligibility criteria were violated on re-analysis, repeat this process (steps A to E) until the structure reaches a stable state or the limits of damage are violated.

2.3.5.7. Modeling of plastic hinges

For linear static analysis, if the calculated torque is greater than the nominal one torque strength and tested that the element is able to form plastic hinge, insert an equivalent plastic hinge into the model by inserting a discrete hinge in the member at a distance from the end of the member and add two constant moments, one on each side of the new loop in the appropriate direction for the current moment.

The magnitude of the constant moments is equal to a certain plastic moment element capacity. Instructions are given to determine the plastic hinge recommended

Example: the collapse of the Takomi Narrow Bridge.

2.3.6. Collapse of the domino type.

The list of signs that characterize the collapse of the domino type is as follows:

• initial overturning of one element

• the fall of this element by the angular motion of the rigid body around the lower edge

• conversion of potential energy into kinetic energy

• a sharp slowdown of the element by sudden activation discrete other elements; the horizontal force induced by this event is both static and dynamic origin, as it is the result of both tilt and movement of the slow element

• overturning other elements due to the horizontal load from the slow element

• progression of collapse in the horizontal direction

2.3.7. Collapse of the sectional type.

This can be described in the context of a beam or beam under the axial tension. When there is a cut in the area of the beam, the internal forces must be transmitted by the residual cross section. This type of collapse usually cannot can be called a progressive collapse, but rapid destruction. However, it is included in a list of typologies for the use of similarities and analogies.

2.3.8. Collapse of unstable type.

Collapse of unstable type is characterized by the following signs:

• initial failure of elements that stabilize the load-bearing elements during compression

• instability of elements at compression which cease to be stabilized

• sudden failure of these destabilized elements due to minor disturbances

• progression of failure

2.3.9. Mixed type of collapse.

Other types of progressive collapse mechanisms that cannot be easily distinguished and described and / or can be a combination the previous five types fall into a progressive collapse of the mixed type. As an example This type of progressive collapse of Starosek [66] gives a partial collapse of Russia Alfred P. Murray Federal Building (Oklahoma City, 1995) and Heng Ju Grand Bridge (Seoul, 1992).

These types of progressive collapse can be classified according to their main features. Therefore, lightning and section decays can be grouped in redistribution class, because the remaining structure must redistribute the forces of the failed elements. Pancake and domino collapse are characterized by being major the amount of potential energy is converted into kinetic energy. So they can be grouped by stroke class. Finally, the type of instability and mixed type is destroyed form their own classes that have no common features.

2.4. Calculation in accord with Building code ДБН-В.2.2-24-2009

2.4.1 Basic data.

2.4.1.1 Resistance to progressive collapse means that in the event of an emergency, mud collapses of individual vertical load-bearing elements within one floor or floor area one floor, but these initial collapses should not lead to the collapse or destruction of structures, to which the load previously perceived by the elements damaged by emergency impact is transferred.

To assess the resilience of a house against progressive collapse, only the most more dangerous settlement schemes of collapse.

2.4.1.2 As a local (hypothetical) collapse should be considered the collapse (removal) of vertical structures of one (any) floor of the house, limited around the area up to 80 m2 (diameter 10 m):

- collapse (removal) of two intersecting walls in areas from the place of their intersection (for example, from corner of the house) to the nearest hole in each wall or to the next vertical intersection with the wall of the direction;

- collapse (removal) of a separate column (pylon) or column (pylon) with adjacent areas walls located on one floor in the area of local collapse;

- collapse of the floor area of one floor in the area of local collapse.

In all: cases, the cross-sectional area of all removed vertical elements located on section of 80 m2, should not exceed 0.9 m2 for reinforced concrete elements, for fibroconcrete elements 0.7 m2, for rigid fittings 15%;

- overlapping on the specified area.

2.4.1.3 When calculating the construction of buildings for resistance to progressive collapse should be guided current regulations. The following method of calculating the structures for resistance to progressive collapse of the relative is fed to houses with a reinforced concrete framework.

Destruction of houses, load-bearing structures of which are designed with a metal frame, should be considered according to special scenarios, in which the destruction (removal) of individual elements should be assigned in the most more dangerous places depending on the accepted constructive scheme according to estimations of possible risks .

2.4.1.4 It is recommended to calculate the construction of the house as a system "foundation - foundation - structure" with using software packages that allow you to take into account the physical and geometric nonlinearity that provides the greatest probability of results of calculation and decrease in additional material expenses.

It is recommended to perform the calculation according to the following scheme:

- calculation of all scheme in physically nonlinear statement on constant and temporary loadings is carried out.

- emergency services;

- the obtained stress-strain state is the starting point for calculating the load from the element deleted;

- calculation of additional load from the removed elements is carried out in physical and geometric nonlinear formulation. The load from removing the elements corresponds to the forces that are received in them at the previous stage of calculation and increased by a coefficient of dynamism of 1.2. Strength test the remaining elements are performed without taking into account the longitudinal bending.

2.4.2 Calculation of load and resistance of materials

2.4.2.1 The calculation of strength and stability is carried out on the emergency combination of loads and impacts that includes permanent and long-term temporary loads, as well as the impact on the construction of the house of local hypotheses. economic collapse in accordance with E.1.2. Local collapse can be located anywhere in the house.

2.4.2.2 Loads are accepted in accordance with applicable regulations (DBN B.1.2-2 p. 4.18 and 4.19).

2.4.2.3 The design characteristics of the strength and deformability of materials are taken as such that equalize their normative value in accordance with the current design standards of reinforced concrete and steel structures.

2.4.3 Calculation of structures of high-rise buildings for resistance to progressive collspse.

2.4.3.1 Calculation of the house in case of local collapse of load-bearing structures is carried out only for boundary conditions of the first group. The movement of structures and the opening of cracks in them in the considered emergencies are not limited.

2.4.3.2 The calculation of the spatial model of the house must be carried out taking into account the physical and geometric nonlinearity. It is recommended to use a spatial calculation model. The model may to hide elements which under normal operating conditions are non-bearing (for example, hinged external wall panels, reinforced concrete fences of balconies, etc.), and in the presence of local influences take active participation in the redistribution of efforts in the elements of the constructive system. The estimated model of the house should take into account the possibility of removal (collapse) of individual vertical structural elements corresponding to but up to 1.3. The design model of the house should be calculated separately taking into account each (one) from local landslides.

2.4.3.3 In some cases, it is advisable to consider the operation of the floors over the removed column (pylon, with large deflections as a hanging reinforced concrete shell, taking into account the membrane effects that spoken by the physical and geometric nonlinearity of her work.

2.4.3.4 Each floor of a high-rise building shall be designed to take into account the weight of the covering of the top floor (constant and long loading with coefficient of dynamism k = 1.5) on the area80 m2.

2.4.4 Design requirements

2.4.4.1 The stability of a high-rise building against progressive collapse should be ensured by the most economical strong means:

- rational constructive and planning decision of the house taking into account the possibility of occurrence the considered emergency situation;

- constructive measures that ensure the integrity of structures;

- the use of materials and design solutions that ensure the development of structural elements. actions and their joints of plastic deformations;

- construction of technical floors in the form of a spatial system - plates of box section, able to withstand loads that are due to the removal of vertical elements located between technical floors.

2.4.4.2 Effective operation of elms that prevent progressive collapse is due to ensuring their plasticity in the limit state so that they are not excluded from work and allowed without development of the necessary deformations. To meet this requirement, the elm must be designed from plastic sheet or reinforcing steel, and the strength of the anchoring of the reinforcement should be greater than the effort calls for its destruction.

2.4.4.3 Connection of prefabricated elements with monolithic structures that prevent progressive ollapse of buildings, should be designed uneven, with an element whose limit state is provided bakes the largest plastic deformation of the joint, should be the least strong. To fulfill this condition, it is recommended to calculate the connection for a force that is 1.5 times greater bearing capacity of the connecting elements. It is necessary to pay special attention to the actual accuracy design solutions of plastic elements.

2.4.4.4 To increase the effectiveness of resistance to the progressive collapse of the house, it is recommended:

- superstructure jumpers, acting as shear elms, be designed so that they are destroyed by bending, and not from the action of transverse force;

- key joints in prefabricated monolithic structures should be designed so that the strength of individual keys on the cut was 1.5 times greater than their flexural strength;

- to ensure the adequacy of the length of the armature anchoring during its operation as a shear;

- support sections of beams and crossbars, as well as nodes of their connections with columns (walls, pylons) must have lateral strength is 1.5 times higher than their bearing capacity in bending in span, taking into account plastic properties.

2.4.4.5 The minimum cross-sectional area of both longitudinal and transverse reinforcement in reinforced concrete floors them and the coating is determined by calculation and must be at least 0.25% of the cross-sectional area of concrete.

In this case, the valve must be continuous and joined in accordance with the requirements of current regulations. motivational documents for the design of reinforced concrete structures.

2.5. Calculation in accord with Building code СП 385.1325800.2018

2.5.1. Calculation in dynamic setting

Dynamic calculation in a nonlinear formulation in the time domain should be performed in software packages that implement the method finite elements and direct time integration schemes (explicit or implicit) equations of dynamics.

The calculation is made taking into account the significant effects of physical, geometric and structural nonlinearities in the destruction / collapse of individual parts of structures.

The design scheme should take into account both general and local

imperfections in the structure, including the deflection of elements along the length, deviation of the geometry of sections according to the standards for design and manufacture when modeling with shell and volumetric elements type.

The applied material models should work correctly for stages of plastic deformation, cracking and fracture for rod and shell finite elements, implement procedures for assessing the bearing capacity for the requirements of regulatory documents. For solid finite elements, models should be used correctly reflecting the work of the material with a complex triaxial stress-strain state according to strength and deformation criteria. Deformation diagrams are accepted on the basis of normative documents, codes of practice, GOSTs or laboratory tests for appropriate justification. Depending on the types of finite elements used for metal structures, it is necessary to use (if there are no straight other instructions of the developers of software systems):

- engineering diagram of deformation presented in

SP16.13330, for bar finite elements;

- corrected deformation diagram in true

stresses and strains for shell and volumetric finite elements.

For reinforced concrete materials, deformation diagrams according to SP63.13330 are used.

In addition to the deformation diagram for volumetric finite elements, the corresponding yield and fracture surfaces for the triaxial stress-strain state, reflecting the actual behavior of the material for the stages cracking, plastic work and fracture.

The parameters of dynamic hardening and hardening of structural materials are taken into account on the basis of data from special technical specifications, laboratory tests of materials or relevant experience of scientific and technical support for reference materials. These parameters in the bearing capacity margin are allowed not to be taken into account.The design of structures is carried out in three stages:

Stage 1. Obtaining the correct stress-strain state of the structure at the time before the element failure. Payment is performed either in a static setting, or in a dynamic nonlinear setting with a gradual linear loading for a time interval sufficient to neutralize dynamic effects, or with increased damping.

Stage 2. Initiating impact. Removal of a structural element in a dynamic nonlinear formulation for a time interval equal to 1/10 of the main period of natural oscillations of the removed element

with an appropriate design justification, the specified values may be corrected.

Stage 3. Dynamic analysis of a structure with a removed element in a nonlinear formulation by methods of direct integration of the equations dynamics in time in explicit or implicit formulations with standard damping parameters. Recommended values are presented in

As the basic criteria for failure of elements at the stage of dynamic calculation, two groups can be distinguished: deformation and strength. Requirements for limitation of main or equivalent stresses corresponding to points of the material destruction surface, as well as the fulfillment of the requirements of regulatory documents and codes of design rules for bar and shell elements along normal and inclined sections. Constraints are applied as deformation criteria by principal or equivalent deformations.

Stability of elements when split into several elements by span (at least 4–6) and introduction of local imperfections is allowed do not check. Elements that have lost their bearing capacity or stability, when compliance with strength and deformation criteria, it is allowed not exclude from the design model at the stage of dynamic calculation, taking into account the ability to limitedly transfer efforts through them. Joints of structural elements, if they are not explicitly included in the design model, must be tested for strength in accordance with the design standards for the forces arising in them.

The deformation process can go along two calculated branches:

- stabilization of the system after initiating action, or after the failure of a number of elements;

- sequential failure of groups of elements, leading to a complete collapse of the entire structure.

The following are recommended as stabilization criteria:

- stabilization of displacements throughout the system after the process of dynamic deformation for a significant period of time;

- stabilization of efforts in the elements;

- stabilization of plastic deformations at a level below critical;

- the drop in the kinetic energy of the entire system to zero values over a significant time interval.

The time interval of dynamic calculation should be increased when the growth of deformations, efforts and displacements in time;

2.6. Calculation of stiffness of nodes of high-rise building

The named method is used in the IDEA StatiCa Connection program, which offers designers a reliable and proven tool for engineering analysis, calculation and verification according to the standards of steel structure units.

Today it is difficult to imagine the calculation of any design without the use of modern software and computer systems (hereinafter PVC). With the development of information technology, the functionality of PVCs is expanding, allowing you to solve more complex problems, including taking into account physical, geometric and structural nonlinearity. The wide possibilities of PVC make it possible to create models of buildings and structures that are as close as possible to reality - taking into account the rigidity of the connections of elements, the nonlinear work of the material, etc.

In most cases, excessive detailing of the design scheme and taking into account various types of nonlinearity are unjustified. The time spent on preparing the calculation scheme and the calculation itself is not justified by the excessive accuracy of the results obtained.

In order to avoid excessive detail in the calculation of buildings and structures, various simplifications of the calculation scheme are used. For example, all linearly extended structures - beams, columns - are modeled by bar elements; flat elements - plates and walls - with plate elements or just loads. The conjugation of the elements with each other and the structures with the base are also described simplistically. The actual dimensions of the joints are not taken into account, as well as their stiffness. All nodes are conditionally divided into "rigid" (transmitting rotational forces) and "articulated" (not receiving moments).

In clause 5.1.1 of section 5 of Eurocode 1993-1-8-2009, it is noted that the calculation should take into account the influence of the work of the joints on the distribution of internal forces and moments in the structure. The same section provides a slightly broader classification of nodes according to the type of model — they are divided into articulated, rigid, and semi-rigid nodes. Often when compiling a design diagram of a building or structure, the design of the nodes is not known in advance. It is worked out after the calculation is completed. Therefore, it may happen that a node that was previously considered rigid, after construction will be semi-rigid, which, in turn, will lead to a redistribution of efforts. Thus, the efforts by which the diameters of the bolts, the legs of the welds and the thickness of the stiffeners were selected can change. For this reason, the process has to be repeated several times.

Even in the case of simple circuits with a small number of structural elements, the process can take a lot of time - each node must be properly designed to absorb the received efforts. The use of standard solutions (series, manuals) can simplify the process, however, when calculating structures of complex shape, detailed elaboration of non-standard units is often required.

The calculation of standard units can be performed manually - for them there are various manuals, series and regulatory documents. Non-standard units always require the preparation of a complex high-tech model that describes its behavior in the structure. Usually, the calculation is carried out using PVCs that implement the FEM in its pure form.

When compiling a node model, as a rule, the following questions arise:

2.6.1. Material behavior

In the transition from the calculation of the model of the entire structure to the calculation of nodes, local effects — the places of changes in the cross section, the points of application of concentrated loads, and the location of the holes — have an increasing influence on the operation of the structure. It is also necessary to take into account the nonlinear work of the material, since the neglect of local plastic deformations leads to an excessive consumption of the material. For steel, as a rule, the Prandtl diagram is used - elastic-perfectly-plastic.

2.6.2. Weld Model Description

The method for setting these elements in the calculation scheme directly affects the results. Welds are often replaced by absolutely rigid bodies connecting parts or simply by combining movements. In both the first and second cases, the real stiffness of the weld is not taken into account. The most accurate way is to simulate welding using volumetric or flat finite elements, however, in the case of non-standard nodes, this can cause certain difficulties in constructing a finite element mesh.

2.6.3. Bolt model

The most common bolt models are the space rod and the elastic bond between the two nodes. In this setting, you can evaluate the effort in the bolts and compare their deviation from the allowable effort. However, this simplification does not take into account various factors of a local scale - crushing the plates by the body of the bolt, squeezing the part under the washer, etc. To solve this problem, volume elements can be used, but this will significantly complicate the scheme and increase the calculation time.

2.6.4. Assessment of effort and stress

When modeling welds by combining movements, evaluation of their strength becomes impossible. Although it is in them that plastic deformations often develop. If the welds are defined by volumetric elements, then to assess the bearing capacity of the weld, it is necessary to analyze a large amount of data - the values of normal and tangential stresses in each finite element.

2.6.5. Accounting for constructive nonlinearity and local effects

With a large number of contacting surfaces, contact modeling becomes a difficult task. This requires specifying special finite elements that work only on compression. This is also true for the contact areas of the washer and plate in the bolted joint.

The way to solve all these questions directly affects the correctness of the results. The models used should reflect the actual behavior of the components of the assembly. There are no clear recommendations in the Russian standards on the use of models, the designation of the stiffness of elements and the ultimate level of plastic deformations in a node. In this case, you have to be guided by the general provisions of mechanics. To obtain reliable and reliable results, it is necessary to verify and validate design models by comparing them with the results of field tests.

2.6.6. Foreign practice of calculating steel nodes.

Component Finite Element Method

In the foreign practice of calculating the joints of steel structures, the component method (hereinafter referred to as KM) is widely used. Its essence lies in the fact that the node is considered as a set of elements connected with each other - components. For a given node according to certain rules, a computational model is constructed consisting of elastic bonds and bar elements that perceive longitudinal, transverse, bending and torsional deformations.

As a result of the calculation, each component contains forces and stresses that can later be used for the necessary unit tests (for strength, stability, etc.) in accordance with the required design standards.

The component method is used as the main method in European regulatory documents (EN 1993-1-8-2009). It greatly simplifies the process of calculating typical nodes - for them a single component model can be used, the elements of which will have different physical and mechanical characteristics, but the same relative position. With small changes in the topology of the node, its component model will also have to be changed. This fact is the main disadvantage of this method - it has significant limitations when calculating nodes of arbitrary shape.

The finite element method (hereinafter - the FEM) is devoid of this drawback, which allows solving almost any problems that engineers face, from linear calculations of flat frames and beams to static loads to dynamic nonlinear calculations of complex systems in a three-dimensional formulation. The complex, sometimes irregular shape of the computational domain in this case does not have much significance - it is divided into simple components -

straight rods, plates, tetrahedra, etc., whose operation is described by well-known physical laws and geometric equations.

If the CM is supplemented by the FEM, this will allow us to model nodes that are not limited to standard templates, and the stiffness of individual components will be calculated automatically based on their geometric and mechanical properties. This idea belongs to Professor František Wilde, Head of the Department of Steel and Wood Structures of the Czech Technical University in Prague.

Initially, this technique was developed by the Department of Steel and Wood Structures of the Faculty of Civil Engineering of the Czech Technical University in Prague and the Faculty of Metal and Wood Structures of the Technological University in Brno as part of a grant for research work. To calculate the nodes, an approach was needed that combines the basic provisions of the CM and the versatility of the FEM. Later it received the name of the component finite element method - KMKE (in the original - Component Based Finite Element Method, CBFEM).

2.6.7. The node model in KMKE has the following advantages:

2.6.7.1. Versatility

KMKE is suitable for most joints of various configurations - supporting and frame units, coating units and other units common in engineering practice.

Convenience and speed with the model

The results of the usual calculations can be obtained in less time compared to other approaches.

2.6.7.2. Visibility

KMKE model gives a modern engineer a sufficient amount of information about the behavior of the unit, its stress-strain state and utilization rates of individual components, as well as the results of general checks.

A little later, IDEA StatiCa became interested in the development of the university, and KMKE was laid as the basis for the new IDEA StatiCa software designed for calculation and verification of steel structure units according to the norms.

2.6.7.3. Material model

To describe the behavior of the material, as a rule, the following models are used: elastic-ideally-plastic, ideally-elastic with hardening and the true dependence of stress on deformation. IDEA StatiCa for steel uses the Prandtl diagram with a slight upward slope of the branch responsible for flow (shown in gray in Figure 3-1). The criterion for the onset of the limiting state is associated with the achievement of the main longitudinal deformation of the maximum value.

Plates and elements. Finite element mesh

The walls and shelves of elements, stiffening ribs, vut, etc. are modeled by three- and four-node finite elements of the shells with 6 degrees of freedom in each node (3 translational and 3 rotational). Each element has 5 integration points across the thickness, in each of which, as a result of the calculation, the normal and tangential stresses are determined and the moment of the moment of yield is monitored.

The finite element mesh generation of an individual plate is independent of other plates. The configuration of the FE mesh is affected by the location of bolts, holes, and cutouts. The breakdown occurs automatically according to the specified parameters - the maximum and minimum size of the FE (default 50 mm and 10 mm, respectively).

2.6.7.4. Contact surfaces

Contact zones between the plates significantly affect the distribution of stress between the elements of the site. The solver automatically determines the nodes of the design circuit, penetrating into adjacent plates, and calculates the distribution of contact stresses between these nodes and plates. This allows you to create contact zones with different grids on the plates .

2.6.7.5. Welds

To simulate welds, special elastoplastic volumetric elements are used, taking into account the position of the seam, its orientation and dimensions. The moment of the onset of fluidity is monitored by the magnitude of the stresses in the section of the weld (in the volumetric FE of the weld). This model shows the true values of stresses that are directly used for checks .

2.6.7.6. Conventional bolts

Bolts are modeled by non-linear elastic bonds that perceive tension and shear. In the vicinity of the hole, only compressive forces are transmitted from the bolt to the plate. This is done using special interpolation inserts between the nodes of the bolt body and the nodes of the edges of the holes. The bolt holes are assigned round by default, but can also be oval - in this case, the bolts can freely move along the long side without perceiving lateral forces in this direction. After the calculation, tensile and shear forces are displayed in each bolt.

2.6.7.7. Pretension Bolts

The tensile behavior of such bolts is similar to conventional bolts, taking into account the tightening force. The shear force in the joints with prestressed bolts is perceived not by crushing the plates, but by friction between them (bolt-contact). At IDEA StatiCa, frictional joints are checked for perception of shear by bolt contact. If slippage is observed, prestressed bolts do not pass deformation tests.

Using IDEA StatiCa, you can perform node calculation in the following modes:

2.6.7.8. Determination of VAT node

After performing this calculation, IDEA StatiCa displays the isopole of stresses in all plates, the forces in all bolts and the utilization rates of individual components (bolts, anchors, welds) according to the specified design standards.

Calculation of the site for stability

In the course of this calculation, the critical load is calculated - stability margin factors are derived from the first six forms.

2.6.7.9. Calculation of the stiffness of the attachment of the element

This mode allows you to determine the rotational and longitudinal stiffness of the attachment of individual elements to the node. Based on the results of the calculation, we can conclude about what the node is in reality - rigid, articulated or semi-rigid.

2.6.7.10. Calculation of the node at the limit moment

Allows you to calculate taking into account the formation of a plastic hinge in one of the elements.

2.6.7.11. Calculation of the bearing capacity of the node

In the course of this calculation, the ultimate load is determined, which can be perceived by the node. The criterion is the formation of ultimate plastic deformation or utilization of components in excess of 100%.

2.7. Calculation of frame taking into account numerical stiffness of nodes

As the initial point of calculation of nodes was taken such "rigid" node:

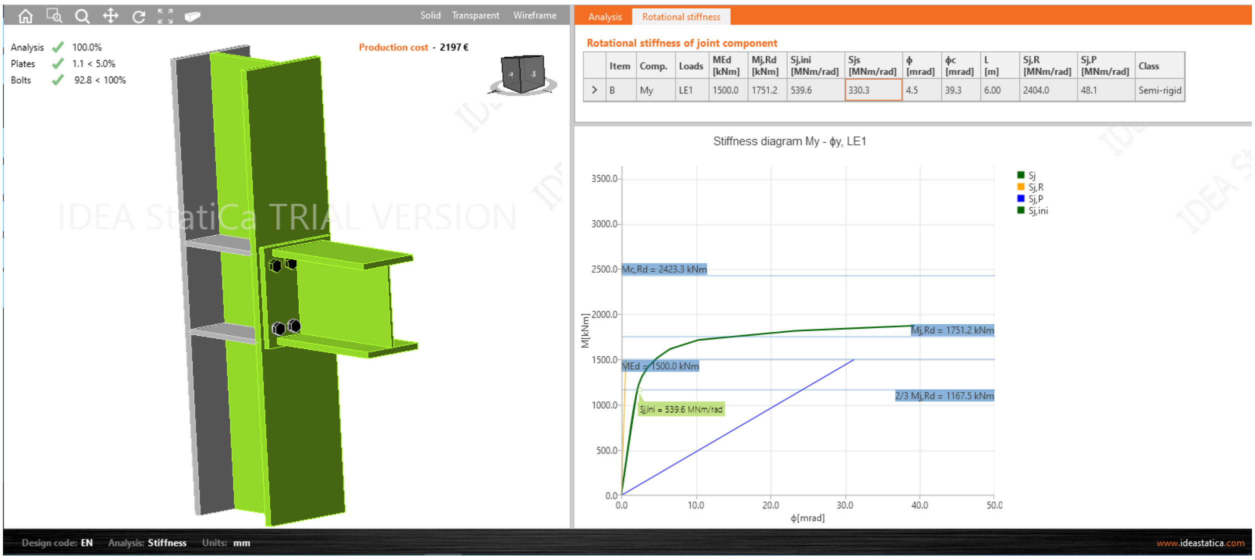


Fig. 2.7.1. Connection of main beam and column.

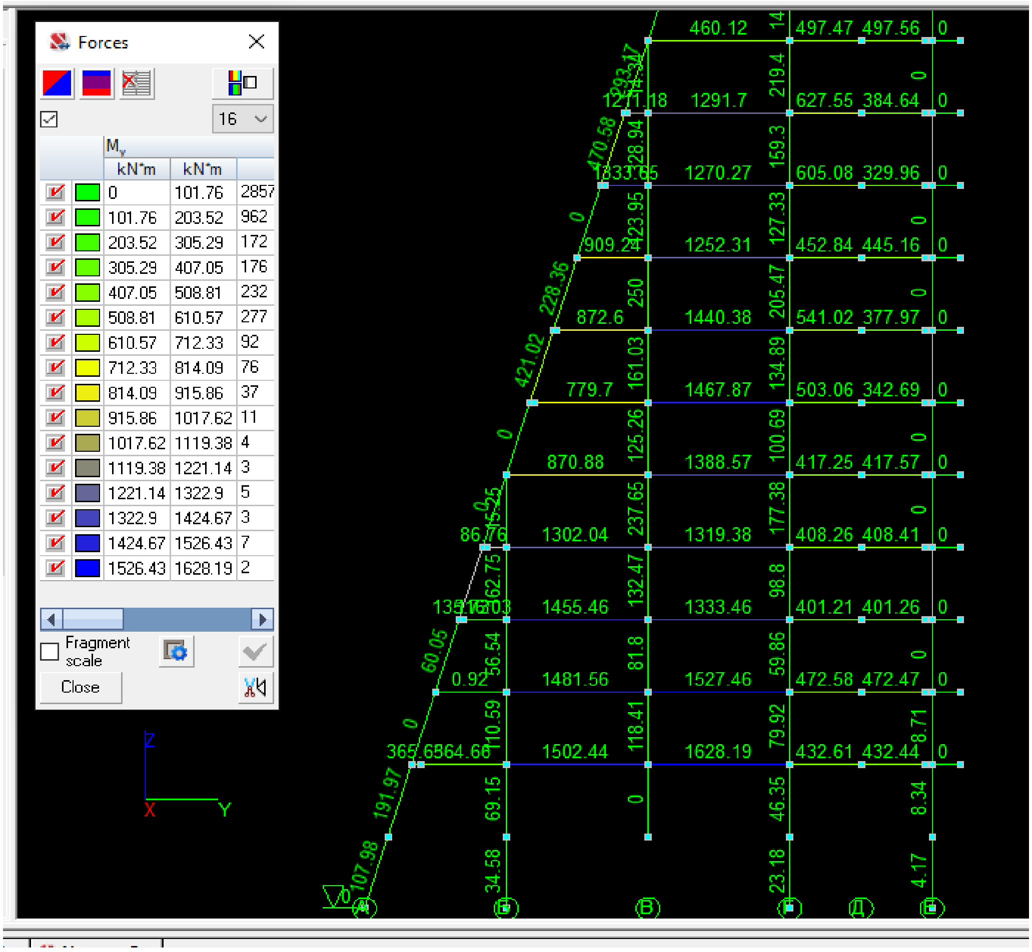


Fig. 2.7.2. Bending moments in structural elements of scheme with absolutely rigid connections of main beams and columns.

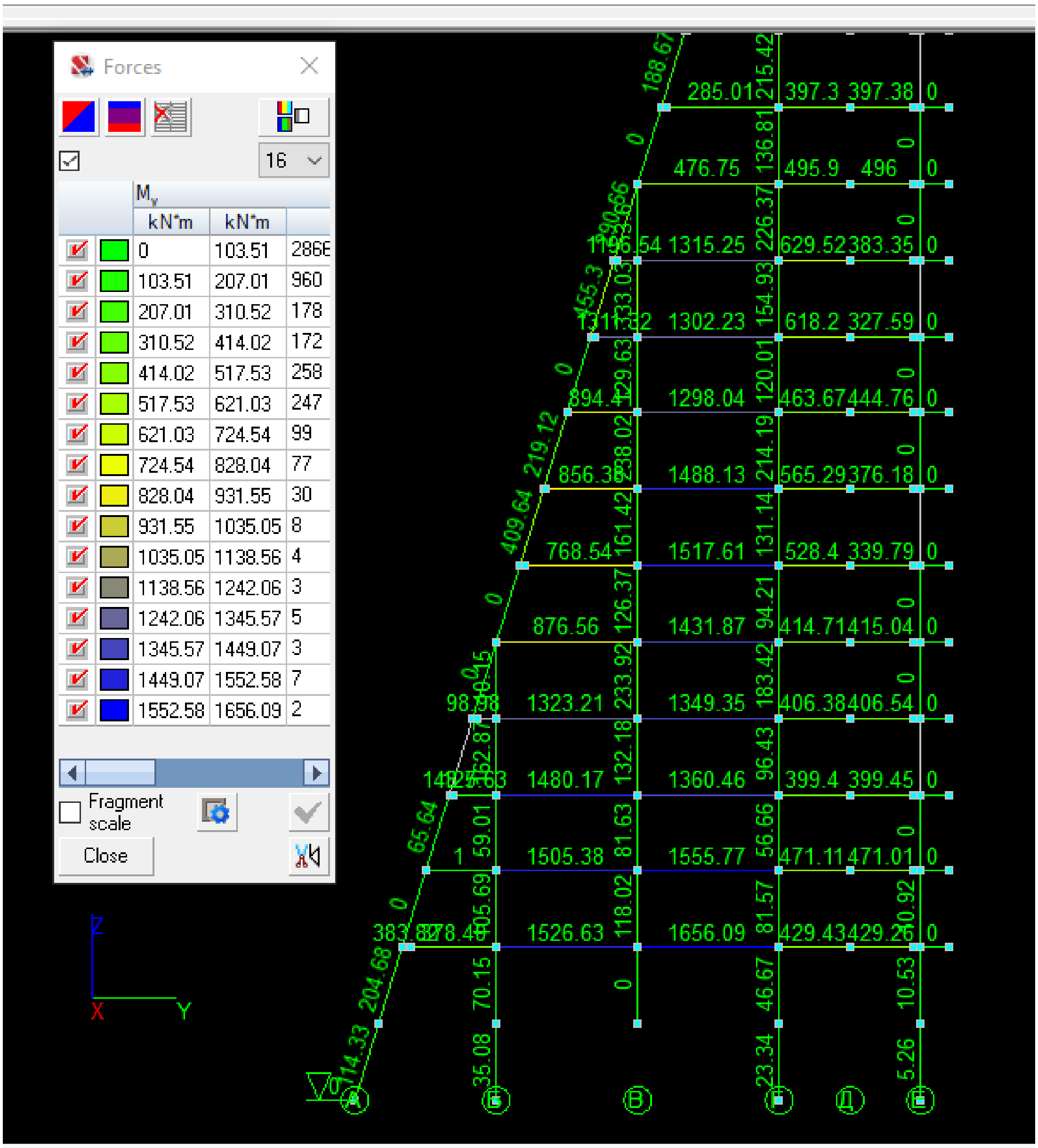


Fig. 2.7.3. Bending moments in structural elements of scheme with semi-rigid (with numerical stiffness) connections of main beams and columns.

To solve this problem of increasing of bending moments it is proposed to use next type of connection beam+column, which has higher stiffness, and can imitate almost absolutely rigid node.

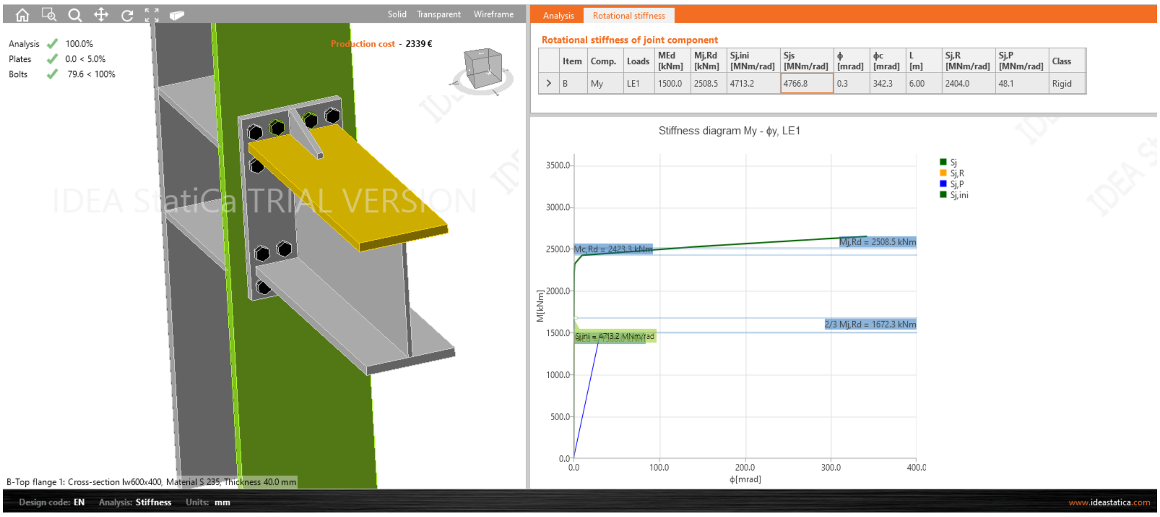


Fig. 2.7.4. Almost absolutely rigid connection of main beam and column.

Chapter 3

ARCHITECTURAL PART

3.1. General data

3.1.2 Type of construction - new construction.

3.1.3 Purpose of the building - Office building.

3.1.4 Construction area - Kyiv:

- 5th district according to the characteristic value of snow load;

- 1st district according to the characteristic value of wind pressure, type of terrain III.

3.1.5 The level of clean floor of the 1st floor is taken as a conditional mark of 0.000.

3.1.6 The service life of the building is 100 years, according to DBN B.1.2-2: 2006, Annex B.

3.1.7 The own weight of enclosing constructions is accepted according to drawings of the AR brand, see arch. 3.

3.1.8 This technical documentation is made in accordance with current norms, rules and standards in force at the time of its transfer to the customer.

3.1.9 It is forbidden to fix the equipment not provided by the project to the load-bearing structures of the warehouse frame.

3.2. Volume planning decision

3.2.1 The office building is located in the axes "1-9" x "A-E", dimensions 62x40m. The building is warm, the wall is made of glass facades, the roof is flat. The building is 15-storey, designed according to the frame structural scheme. Frames are designed from columns and crossbars of I-beam section. The building has 4 spans of 10 m, the pitch of the frames is variable, up to 10 m. The columns of the frame are hinged to the foundation. The mark of the top of the building is +81,000.

The overall stability of the frame is ensured by a rigid connection of the columns with the main beams of the floor and pavement, a system of vertical ties located around the perimeter of the building, and the work of the pavement disk formed by profiled flooring and reinforced concrete slab.

3.2.2 Columns are made of steel and have I-section.

3.2.3 Ties are made of square cross-section pipes and welded I-beams.

3.2.4 Roof beams are made of welded I-beams.

Chapter 4

STRUCTURAL PART

4.1. Structural decision

4.1.1. Foundation
Was chosen pile foundation with slab grout.

4.1.2. Columns
Columns are metal, and have I-section.

4.1.3. Beams
Were chosen I-beams of composed cross-section main and secondary beams.

4.1.4. Floor slab
Floor slab was designed as monolithic on the profiled steel sheet which will be used as leave-in-place formwork.

4.1.5. Walls
The walls of building are made from energy efficient multiple glazing.

Table 4.1.1.

Table of loads						
Type of load		Composition	Normative value, kN/m^2	γ_f	Calculated value, kN/m2	Notes
Constant, P_d	Roof	Membrane	0.05	1.20	0.06	
		Thermal insulation t=250mm, g=2kN/m3	0.50	1.20	0.60	
		Bearing profile sheet H57-750-0.8	0.10	1.05	0.105	
		Total	0.65		0.77	
		with γ_n=1,25	0.81		**0.96**	
Constant, Pd	Load on floor	Ceramic tile 10mm g=18kN/m3	0.18	1.20	0.22	
		Glue 4mm g=18kN/m3	0.07	1.30	0.09	
		Cement screed (t=60mm)	1.08	1.30	1.40	
		Monolithic slab on the profiled steel sheet 140mm (t av=105мм)	2.63	1.10	2.89	
		profiled steel sheet H60, t=0,7mm	0.10	1.05	0.11	
		Total	4.06		4.709	
		with γ_n=1,25	5.075		**5.89**	
Constant, Pd	Walls	multiple glazing	0.50	1.05	0.53	
		purlins	0.10	1.05	0.11	
		Total	0.60		0.63	
		with γ_n=1,25	0.75		**0.79**	
Longterm, Pt	Servise load on floor	Weight of people	4.00	1.30	5.20	
		with γn=1,25	5.00		**6.50**	
Longterm, Pt	Servise load on floor	Equipment	1.00	1.30	1.30	
		with γ_n=1,25	1.25		**1.63**	
Short-term, Pt	Snow load	5-th region, T=100 years	1.55	1.14	1.77	
		with γ_n=1,25	1.94		**2.21**	
Short-term, Pt	Snow load	T=100 years. 1st region. III type of terrain	0.38	1.14	0.43	
		with γ_n=1,25	0.48		**0.54**	
Special	Srismic load	Soil category by seismic properties			II	
		Seismicity of the construction site			6 points	

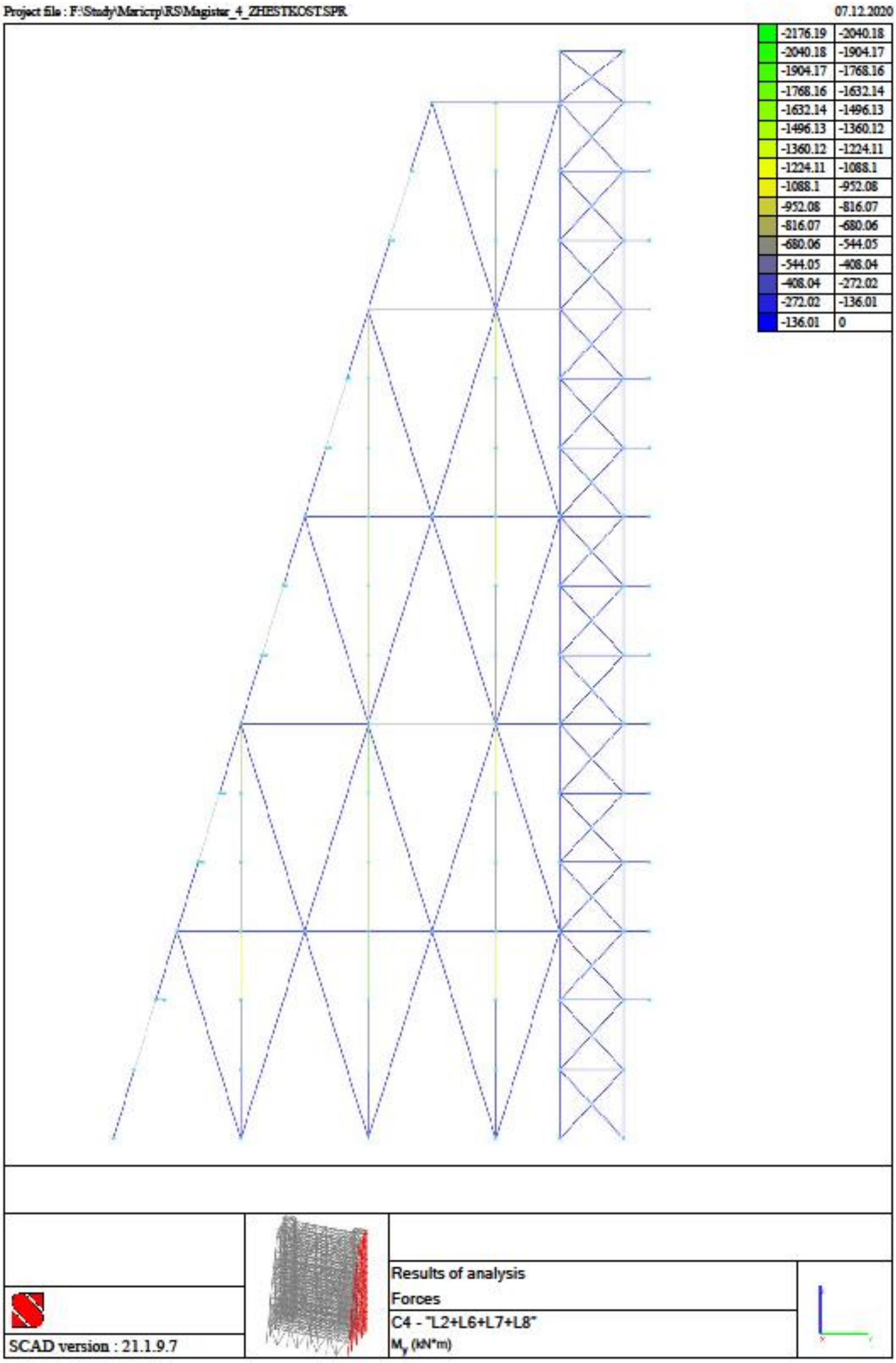


Fig. 4.1.1. Scale of bending moments in steel frame

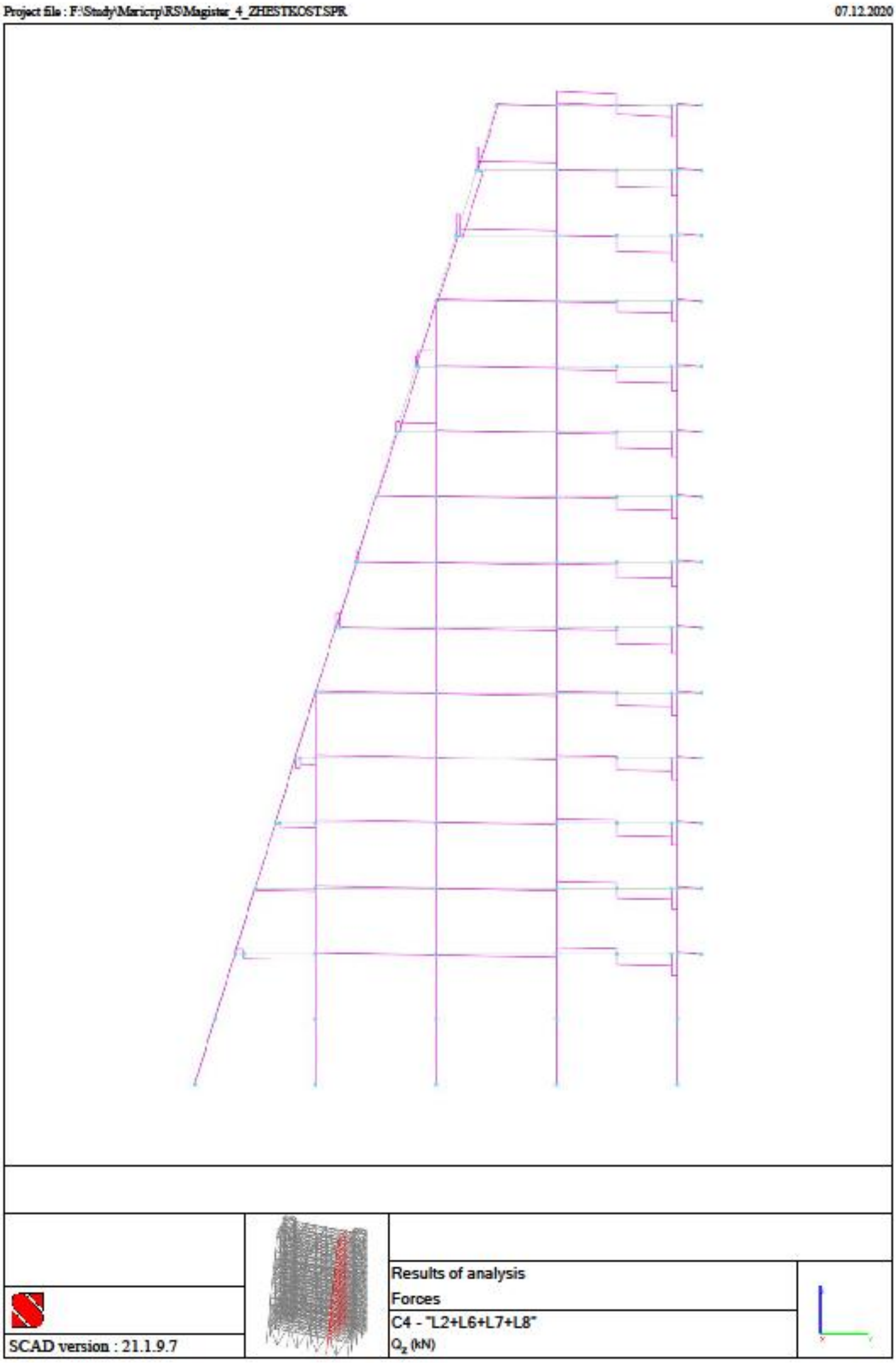


Fig. 4.1.2. Result of analysis. Q_z

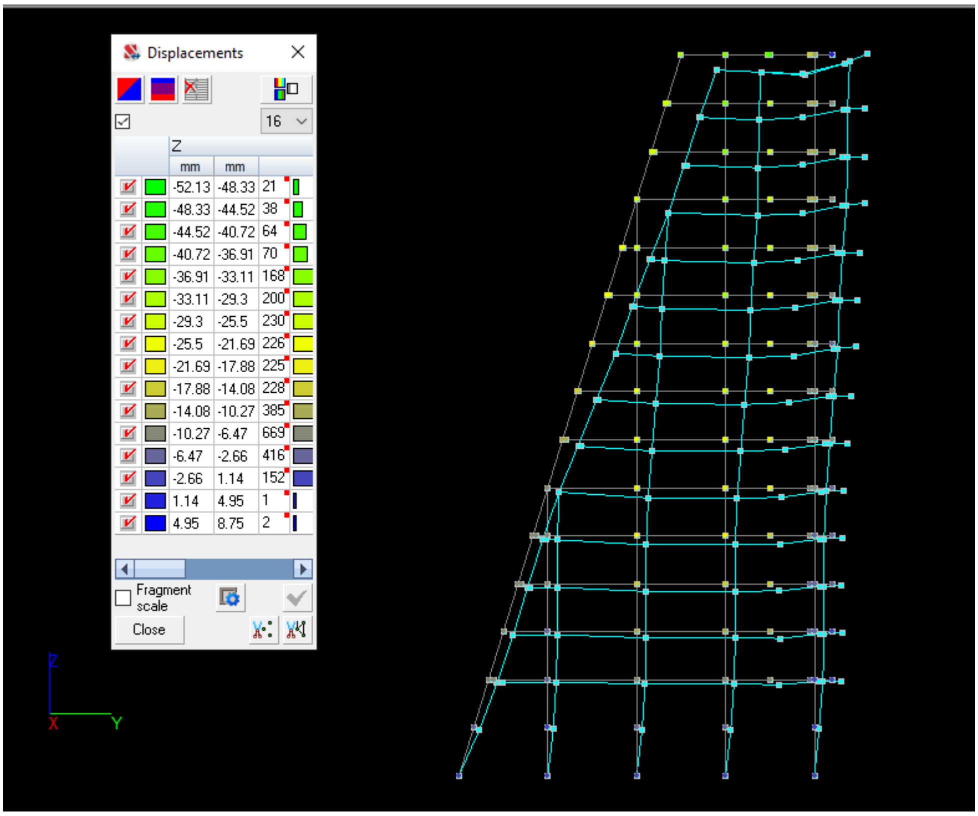


Fig. 4.1.3. Displacement of steel frame under loads.

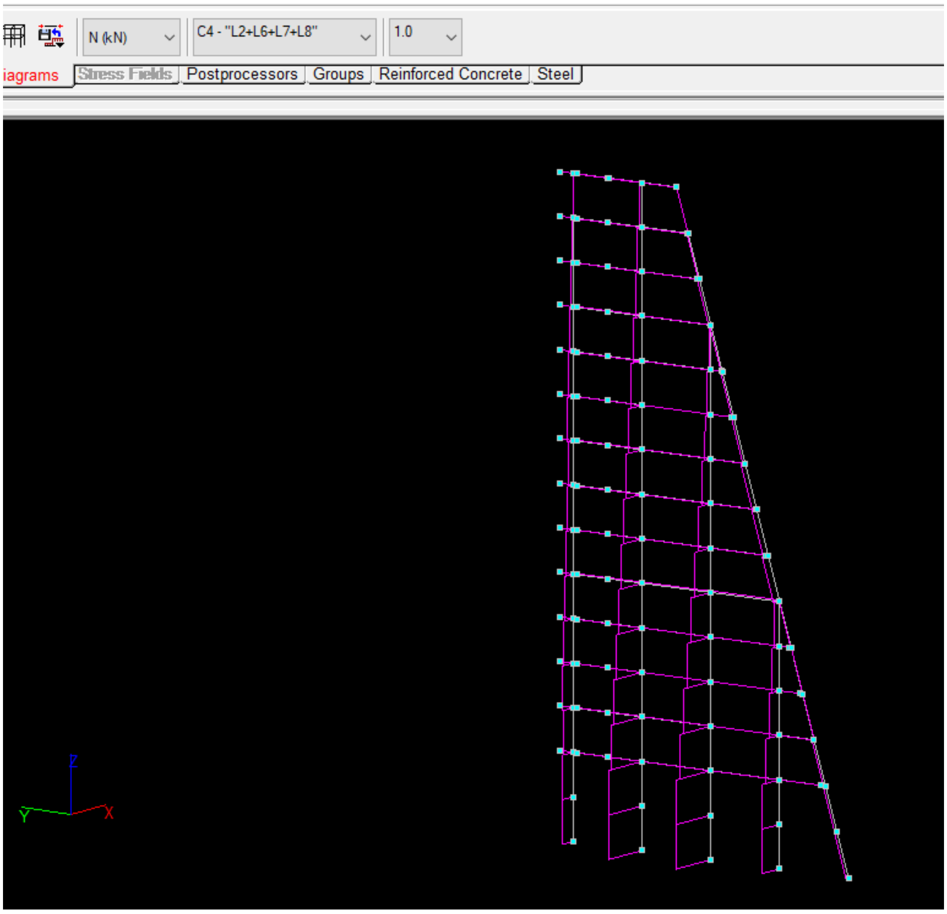


Fig. 4.1.4. Diagram of shear force.

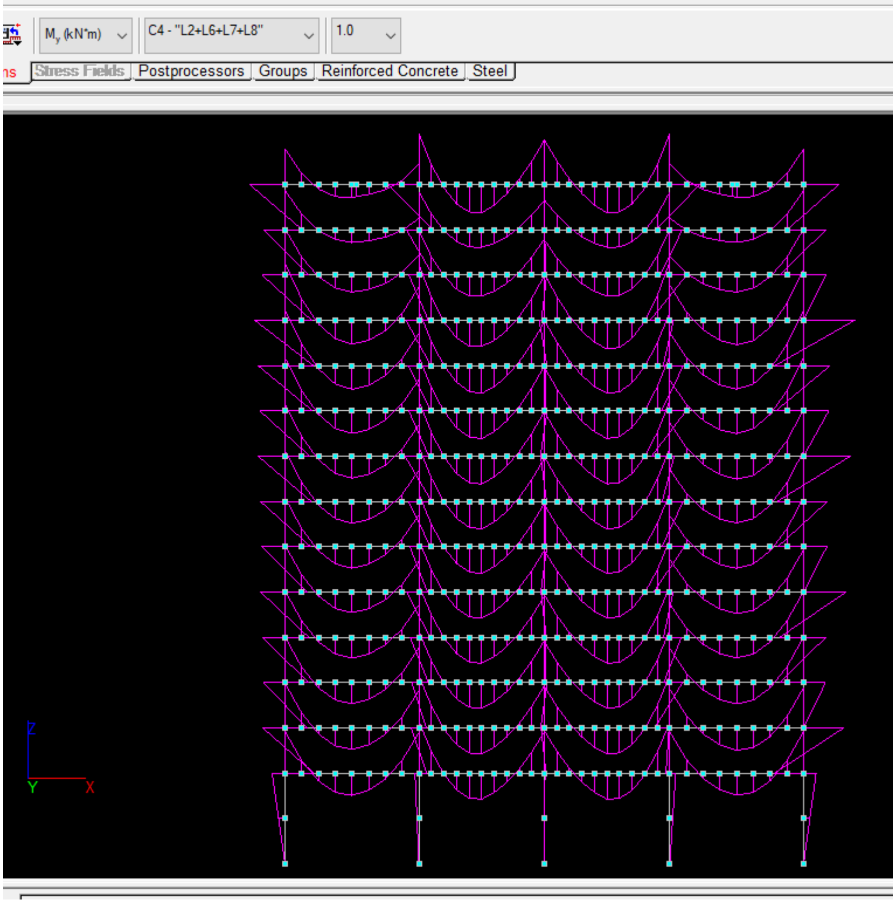


Fig. 4.1.5. Diagram of bending moments.

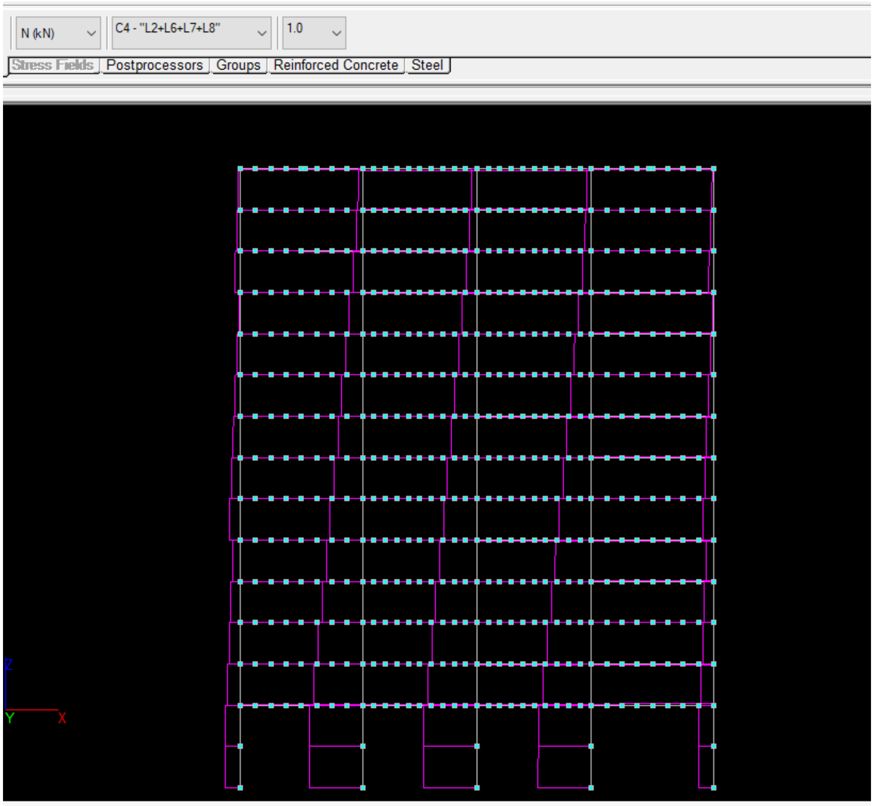


Fig. 4.1.6. Diagram of shear force.

Table 4.1.2.

[Element No. 151] Design Combinations (of the Progressive Collapse) in the Element

Section	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X
		kN	kN*m	kN*m	kN	kN*m	kN	kN/m
0.95*L2+0.95*L6+0.87*L7+0.67*L8								
1	Design values	-12315.33	0.18	0	-14.27	0	9.07	0
1	Design long-term	-12315.33	0.18	0	-14.27	0	9.07	0
2	Design values	-12298.34	0.18	-38.52	-14.27	-24.5	9.07	0
2	Design long-term	-12298.34	0.18	-38.52	-14.27	-24.5	9.07	0
3	Design values	-12281.36	0.18	-77.03	-14.27	-49	9.07	0
3	Design long-term	-12281.36	0.18	-77.03	-14.27	-49	9.07	0

Table 4.1.3.

[Element No. 85] Design Combinations (of the Progressive Collapse) in the Element

Section	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X
		kN	kN*m	kN*m	kN	kN*m	kN	kN/m
0.95*L2+0.95*L6+0.87*L7+0.67*L8								
1	Design values	-12277.32	0.13	0	-1.23	0	18.43	0
1	Design long-term	-12277.32	0.13	0	-1.23	0	18.43	0
2	Design values	-12260.33	0.13	-3.33	-1.23	-49.75	18.43	0
2	Design long-term	-12260.33	0.13	-3.33	-1.23	-49.75	18.43	0
3	Design values	-12243.34	0.13	-6.65	-1.23	-99.51	18.43	0
3	Design long-term	-12243.34	0.13	-6.65	-1.23	-99.51	18.43	0

Table 4.1.4.

[Element No. 352] Design Combinations (of the Progressive Collapse) in the Element

Section	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X
		kN	kN*m	kN*m	kN	kN*m	kN	kN/m
0.95*L2+0.95*L6+0.87*L7+0.67*L8								
1	Design values	-3568.45	-0.57	0	29.13	0	0.28	0
1	Design long-term	-3568.45	-0.57	0	29.13	0	0.28	0
2	Design values	-3551.46	-0.57	78.66	29.13	-0.75	0.28	0
2	Design long-term	-3551.46	-0.57	78.66	29.13	-0.75	0.28	0
3	Design values	-3534.48	-0.57	157.32	29.13	-1.49	0.28	0
3	Design long-term	-3534.48	-0.57	157.32	29.13	-1.49	0.28	0

Table 4.1.5.

[Element No. 644] Design Combinations in the Element

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
3	20	Design values	185.8	1.3	-1160.77	-388.31	33.87	-8.53	0	L2+0.9*L5+L6+0.95*L7
3	14	Design values	214.24	1.38	-1137.99	-389.43	56.6	-20.19	0	L2+L6+L7
3	14	Design long-term	214.24	1.38	-1137.99	-389.43	56.6	-20.19	0	L2+L6+L7
3	20	Design long-term	197.22	1.32	-1134.7	-383.89	44.72	-14.17	0	L2+0.45*L5+L6+0.95*L7
3	20	Characteristic values	180.95	1.27	-1134.53	-379.23	32.16	-7.93	0	0.9523*L2+0.9*L5+0.9523*L6+0.95*L7
3	2	Design values	252.05	1.2	-1119.11	-382.84	9.74	-4.38	0	L2+0.9*L3+L6+0.95*L7
3	17	Design values	252.33	1.2	-1116.16	-382.14	9.75	-4.4	0	L2+0.9*L3+L6+0.95*L7+0.9*L8
3	2	Design long-term	230.34	1.27	-1113.87	-381.16	32.65	-12.09	0	L2+0.45*L3+L6+0.95*L7
3	17	Design long-term	230.48	1.27	-1112.4	-380.81	32.66	-12.1	0	L2+0.45*L3+L6+0.95*L7+0.45*L8
3	14	Characteristic values	209.38	1.35	-1111.75	-380.35	54.89	-19.59	0	0.9523*L2+0.9523*L6+L7
3	14	Characteristic long-term	209.38	1.35	-1111.75	-380.35	54.89	-19.59	0	0.9523*L2+0.9523*L6+L7
3	20	Characteristic long-term	192.36	1.29	-1108.47	-374.82	43.01	-13.57	0	0.9523*L2+0.45*L5+0.9523*L6+0.95*L7
3	4	Design long-term	209.24	1.41	-1104.85	-378.06	78.83	-27.63	0	0.45*L1+L2+L6+0.95*L7
3	10	Design long-term	209.38	1.41	-1103.38	-377.71	78.84	-27.64	0	0.45*L1+L2+L6+0.95*L7+0.45*L8
3	4	Design values	209.85	1.48	-1101.07	-376.64	102.09	-35.46	0	0.9*L1+L2+L6+0.95*L7
3	10	Design values	210.13	1.49	-1098.13	-375.94	102.1	-35.47	0	0.9*L1+L2+L6+0.95*L7+0.9*L8
3	2	Characteristic values	247.2	1.17	-1092.87	-373.77	8.02	-3.78	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7
3	17	Characteristic values	247.47	1.17	-1089.92	-373.07	8.04	-3.8	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7+0.9*L8
3	2	Characteristic long-	225.	1.24	-	-	30.94	-	0	0.9523*L2+0.45*L3+0.9523*L6+

Section	Criterion	Type of combination	N	Mk	My	Qz	Mz	Qy	rX	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
		term	48		1087.63	372.09		11.49		0.95*L7
3	17	Characteristic long-term	225.62	1.24	-1086.16	-371.74	30.95	-11.5	0	0.9523*L2+0.45*L3+0.9523*L6+0.95*L7+0.45*L8
3	4	Characteristic long-term	204.38	1.38	-1078.62	-368.99	77.11	-27.03	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7
3	10	Characteristic long-term	204.52	1.38	-1077.14	-368.64	77.12	-27.04	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7+0.45*L8
3	4	Characteristic values	205	1.45	-1074.83	-367.57	100.37	-34.86	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7
3	2	Design values with seismic loads	189.71	1.08	-1074.36	-347.64	-9.89	14.83	0	0.9*L2+0.9*L6+0.8*L7-L9
3	10	Characteristic values	205.27	1.46	-1071.89	-366.86	100.39	-34.87	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7+0.9*L8
3	2	Characteristic values	185.34	1.05	-1050.74	-339.47	-11.44	15.37	0	0.8571*L2+0.8571*L6+0.8*L7-L9
3	17	Design values with seismic loads	197.44	1.01	-972.83	-333.36	-4.53	0.43	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L10
3	2	Design long-term	181.59	1.17	-965.49	-330.6	48.89	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L9
3	4	Design long-term	181.59	1.17	-965.49	-330.6	48.89	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L10
3	10	Design long-term	181.67	1.17	-964.67	-330.4	48.89	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L9
3	17	Design long-term	181.67	1.17	-964.67	-330.4	48.89	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L10
3	4	Design values with seismic loads	165.9	1.33	-956.51	-327.44	102.31	-35.26	0	0.9*L2+0.9*L6+0.8*L7-L10
3	17	Characteristic values	193.06	0.98	-949.21	-325.19	-6.07	0.97	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8+L10
3	2	Characteristic long-term	177.22	1.14	-941.87	-322.43	47.34	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L9
3	4	Characteristic long-term	177.22	1.14	-941.87	-322.43	47.34	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L10
3	10	Characteristic long-term	177.3	1.14	-941.06	-322.23	47.35	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L9
3	17	Characteristic long-term	177.3	1.14	-941.06	-322.23	47.35	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L10
3	4	Characteristic values	161.53	1.3	-932.9	-319.27	100.76	-34.72	0	0.8571*L2+0.8571*L6+0.8*L7-L10

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
3	10	Design values with seismic loads	173.63	1.26	-854.98	-313.16	107.67	-49.66	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L9
3	10	Characteristic values	169.26	1.23	-831.37	-304.99	106.13	-49.12	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8+L9
2	20	Design values	185.8	1.3	-774.09	-385.05	25.34	-8.53	0	L2+0.9*L5+L6+0.95*L7
2	20	Characteristic values	180.95	1.27	-756.85	-376.13	24.23	-7.93	0	0.9523*L2+0.9*L5+0.9523*L6+0.95*L7
2	20	Design long-term	197.22	1.32	-752.44	-380.64	30.55	-14.17	0	L2+0.45*L5+L6+0.95*L7
2	14	Design values	214.24	1.38	-750.19	-386.17	36.42	-20.19	0	L2+L6+L7
2	14	Design long-term	214.24	1.38	-750.19	-386.17	36.42	-20.19	0	L2+L6+L7
2	2	Design values	252.05	1.2	-737.89	-379.59	5.35	-4.38	0	L2+0.9*L3+L6+0.95*L7
2	17	Design values	252.33	1.2	-735.65	-378.89	5.35	-4.4	0	L2+0.9*L3+L6+0.95*L7+0.9*L8
2	20	Characteristic long-term	192.36	1.29	-735.19	-371.72	29.44	-13.57	0	0.9523*L2+0.45*L5+0.9523*L6+0.95*L7
2	2	Design long-term	230.34	1.27	-734.33	-377.91	20.56	-12.09	0	L2+0.45*L3+L6+0.95*L7
2	17	Design long-term	230.48	1.27	-733.21	-377.56	20.56	-12.1	0	L2+0.45*L3+L6+0.95*L7+0.45*L8
2	14	Characteristic values	209.38	1.35	-732.95	-377.25	35.3	-19.59	0	0.9523*L2+0.9523*L6+L7
2	14	Characteristic long-term	209.38	1.35	-732.95	-377.25	35.3	-19.59	0	0.9523*L2+0.9523*L6+L7
2	4	Design long-term	209.24	1.41	-728.42	-374.81	51.2	-27.63	0	0.45*L1+L2+L6+0.95*L7
2	2	Design values with seismic loads	189.71	1.08	-728.18	-344.71	4.77	14.83	0	0.9*L2+0.9*L6+0.8*L7-L9
2	10	Design long-term	209.38	1.41	-727.3	-374.46	51.2	-27.64	0	0.45*L1+L2+L6+0.95*L7+0.45*L8
2	4	Design values	209.85	1.48	-726.06	-373.39	66.63	-35.46	0	0.9*L1+L2+L6+0.95*L7
2	10	Design values	210.13	1.49	-723.82	-372.68	66.63	-35.47	0	0.9*L1+L2+L6+0.95*L7+0.9*L8
2	2	Characteristic values	247.2	1.17	-720.6	-370.	4.24	-3.78	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7

Section	Criterion	Type of combination	N kN	M_k kN*m	M_y kN*m	Q_z kN	M_z kN*m	Q_y kN	rX kN/m	Formula
					5	67				
2	17	Characteristic values	247.47	1.17	-718.41	-369.97	4.24	-3.8	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7+0.9*L8
2	2	Characteristic long-term	225.48	1.24	-717.09	-368.99	19.44	-11.49	0	0.9523*L2+0.45*L3+0.9523*L6+0.95*L7
2	17	Characteristic long-term	225.62	1.24	-715.97	-368.64	19.44	-11.5	0	0.9523*L2+0.45*L3+0.9523*L6+0.95*L7+0.45*L8
2	2	Characteristic values	185.34	1.05	-712.67	-336.69	3.76	15.37	0	0.8571*L2+0.8571*L6+0.8*L7-L9
2	4	Characteristic long-term	204.38	1.38	-711.18	-365.89	50.08	-27.03	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7
2	10	Characteristic long-term	204.52	1.38	-710.06	-365.54	50.08	-27.04	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7+0.45*L8
2	4	Characteristic values	205	1.45	-708.82	-364.47	65.51	-34.86	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7
2	10	Characteristic values	205.27	1.46	-706.58	-363.77	65.51	-34.87	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7+0.9*L8
2	541	Design values with seismic loads	197.28	1.01	-642.18	-330.82	-4.13	0.44	0	0.9*L2+0.9*L6+0.8*L7+L10
2	17	Design values with seismic loads	197.44	1.01	-640.93	-330.43	-4.13	0.43	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L10
2	2	Design long-term	181.59	1.17	-636.36	-327.67	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L9
2	4	Design long-term	181.59	1.17	-636.36	-327.67	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L10
2	541	Design long-term	181.59	1.17	-636.36	-327.67	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L10
2	10	Design long-term	181.67	1.17	-635.73	-327.47	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L9
2	17	Design long-term	181.67	1.17	-635.73	-327.47	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L10
2	23	Design long-term	181.67	1.17	-635.73	-327.47	31.48	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L10
2	4	Design values with seismic loads	165.9	1.33	-630.53	-324.51	67.08	-35.26	0	0.9*L2+0.9*L6+0.8*L7-L10
2	23	Design values with seismic loads	166.05	1.33	-629.29	-324.12	67.09	-35.27	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8-L10
2	541	Characteristic values	192.91	0.98	-626.66	-322.8	-5.14	0.98	0	0.8571*L2+0.8571*L6+0.8*L7+L10
2	17	Characteristic values	193.	0.98	-	-	-5.14	0.97	0	0.8571*L2+0.8571*L6+0.8*L7+0.

Section	Criterion	Type of combination	N kN	M_k kN*m	M_y kN*m	Q_z kN	M_z kN*m	Q_y kN	rX kN/m	Formula
			06		625.42	322.41				5*L8+L10
2	2	Characteristic long-term	177.22	1.14	-620.84	-319.64	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L9
2	4	Characteristic long-term	177.22	1.14	-620.84	-319.64	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L10
2	541	Characteristic long-term	177.22	1.14	-620.84	-319.64	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L10
2	10	Characteristic long-term	177.3	1.14	-620.22	-319.45	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L9
2	17	Characteristic long-term	177.3	1.14	-620.22	-319.45	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L10
2	23	Characteristic long-term	177.3	1.14	-620.22	-319.45	30.47	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L10
2	4	Characteristic values	161.53	1.3	-615.02	-316.48	66.08	-34.72	0	0.8571*L2+0.8571*L6+0.8*L7-L10
2	23	Characteristic values	161.68	1.3	-613.77	-316.09	66.08	-34.73	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8-L10
3	18	Design values	76.63	0.62	-608.91	-200.35	11.92	-0.07	0	L2+L5+L6
3	9	Design values with seismic loads	99.9	0.51	-604.75	-188.54	-26.35	20.9	0	0.9*L2+0.9*L6-L9
3	18	Characteristic values	71.77	0.59	-582.67	-191.28	10.21	0.53	0	0.9523*L2+L5+0.9523*L6
3	9	Characteristic values	95.53	0.48	-581.14	-180.37	-27.89	21.44	0	0.8571*L2+0.8571*L6-L9
3	18	Design long-term	89.31	0.64	-579.95	-195.45	23.98	-6.34	0	L2+0.5*L5+L6
3	9	Design values	150.24	0.51	-562.62	-194.28	-14.9	4.54	0	L2+L3+L6
3	3	Design values	145.69	0.53	-558.51	-193.2	-9.79	2.81	0	L2+0.9*L3+L6+0.9*L8
3	9	Design long-term	126.11	0.59	-556.8	-192.41	10.57	-4.03	0	L2+0.5*L3+L6
3	3	Design long-term	123.84	0.6	-554.75	-191.87	13.12	-4.9	0	L2+0.45*L3+L6+0.45*L8
3	18	Characteristic long-term	84.45	0.61	-553.71	-186.37	22.26	-5.74	0	0.9523*L2+0.5*L5+0.9523*L6
3	1	Design long-term	102.74	0.74	-545.73	-188.77	59.3	-20.44	0	0.45*L1+L2+L6+0.45*L8

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
2	10	Design values with seismic loads	173.63	1.26	-543.28	-310.23	58.18	-49.66	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L9
3	1	Design values	103.49	0.81	-540.47	-187	82.56	-28.27	0	0.9*L1+L2+L6+0.9*L8
3	9	Characteristic values	145.38	0.48	-536.38	-185.21	-16.61	5.14	0	0.9523*L2+L3+0.9523*L6
3	3	Characteristic values	140.83	0.5	-532.27	-184.13	-11.5	3.41	0	0.9523*L2+0.9*L3+0.9523*L6+0.9*L8
3	9	Characteristic long-term	121.25	0.56	-530.56	-183.34	8.85	-3.43	0	0.9523*L2+0.5*L3+0.9523*L6
3	3	Characteristic long-term	118.98	0.57	-528.51	-182.8	11.41	-4.3	0	0.9523*L2+0.45*L3+0.9523*L6+0.45*L8
2	10	Characteristic values	169.26	1.23	-527.76	-302.2	57.18	-49.12	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8+L9
3	13	Design long-term	113.88	0.69	-524.07	-185.99	46.58	-18.41	0	L2+0.45*L4+L6+0.45*L8
3	1	Characteristic long-term	97.88	0.71	-519.49	-179.7	57.58	-19.84	0	0.45*L1+0.9523*L2+0.9523*L6+0.45*L8
3	1	Characteristic values	98.63	0.78	-514.24	-177.93	80.85	-27.67	0	0.9*L1+0.9523*L2+0.9523*L6+0.9*L8
3	3	Design values with seismic loads	107.63	0.44	-503.22	-174.26	-20.98	6.5	0	0.9*L2+0.9*L6+0.5*L8+L10
3	13	Characteristic long-term	109.02	0.66	-497.83	-176.92	44.87	-17.81	0	0.9523*L2+0.45*L4+0.9523*L6+0.45*L8
3	13	Design values	125.78	0.71	-497.16	-181.44	57.13	-24.22	0	L2+0.9*L4+L6+0.9*L8
3	9	Design long-term	91.79	0.6	-495.88	-171.49	32.43	-11.34	0	0.9*L2+0.9*L6+0*L9
3	18	Design long-term	91.79	0.6	-495.88	-171.49	32.43	-11.34	0	0.9*L2+0.9*L6+0*L10
3	1	Design long-term	91.86	0.6	-495.07	-171.29	32.44	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L9
3	3	Design long-term	91.86	0.6	-495.07	-171.29	32.44	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L10
3	18	Design values with seismic loads	76.09	0.76	-486.91	-168.33	85.85	-29.19	0	0.9*L2+0.9*L6-L10
3	3	Characteristic values	103.26	0.42	-479.61	-166.09	-22.52	7.04	0	0.8571*L2+0.8571*L6+0.5*L8+L10
3	9	Characteristic long-term	87.42	0.57	-472.2	-163.	30.89	-10.8	0	0.8571*L2+0.8571*L6+0*L9

Section	Criterion	Type of combination	N kN	M_k kN*m	M_y kN*m	Q_z kN	M_z kN*m	Q_y kN	r_X kN/m	Formula
					7	32				
3	18	Characteristic long-term	87.42	0.57	-472.27	-163.32	30.89	-10.8	0	0.8571*L2+0.8571*L6+0*L10
3	1	Characteristic long-term	87.49	0.57	-471.45	-163.13	30.89	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L9
3	3	Characteristic long-term	87.49	0.57	-471.45	-163.13	30.89	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L10
3	13	Characteristic values	120.92	0.68	-470.92	-172.37	55.42	-23.62	0	0.9523*L2+0.9*L4+0.9523*L6+0.9*L8
3	18	Characteristic values	71.72	0.73	-463.3	-160.17	84.31	-28.65	0	0.8571*L2+0.8571*L6-L10
2	9	Design values with seismic loads	99.9	0.51	-417.69	-185.61	-5.62	20.9	0	0.9*L2+0.9*L6-L9
2	18	Design values	76.63	0.62	-410.19	-197.1	11.85	-0.07	0	L2+L5+L6
2	9	Characteristic values	95.53	0.48	-402.17	-177.58	-6.62	21.44	0	0.8571*L2+0.8571*L6-L9
2	18	Characteristic values	71.77	0.59	-392.95	-188.18	10.73	0.53	0	0.9523*L2+L5+0.9523*L6
1	20	Design values	185.8	1.3	-390.67	-381.8	16.81	-8.53	0	L2+0.9*L5+L6+0.95*L7
2	18	Design long-term	89.31	0.64	-386.13	-192.19	17.64	-6.34	0	L2+0.5*L5+L6
3	1	Design values with seismic loads	83.82	0.69	-385.38	-154.05	91.22	-43.59	0	0.9*L2+0.9*L6+0.5*L8+L9
1	4	Design values with seismic loads	189.71	1.08	-384.94	-341.79	20.78	14.83	0	0.9*L2+0.9*L6+0.8*L7-L9
1	20	Characteristic values	180.95	1.27	-382.27	-373.04	16.3	-7.93	0	0.9523*L2+0.9*L5+0.9523*L6+0.95*L7
1	4	Characteristic values	185.34	1.05	-377.38	-333.9	20.32	15.37	0	0.8571*L2+0.8571*L6+0.8*L7-L9
1	20	Design long-term	197.22	1.32	-373.42	-377.39	16.39	-14.17	0	L2+0.45*L5+L6+0.95*L7
2	9	Design values	150.24	0.51	-369.96	-191.03	-10.36	4.54	0	L2+L3+L6
2	18	Characteristic long-term	84.45	0.61	-368.89	-183.28	16.53	-5.74	0	0.9523*L2+0.5*L5+0.9523*L6
2	3	Design values	145.69	0.53	-366.93	-189.95	-6.98	2.81	0	L2+0.9*L3+L6+0.9*L8
2	9	Design long-term	126.	0.59	-	-	6.54	-	0	L2+0.5*L3+L6

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
			11		366.01	189.16		4.03		
1	14	Design values	214.24	1.38	-365.64	-382.92	16.23	-20.19	0	L2+L6+L7
1	14	Design long-term	214.24	1.38	-365.64	-382.92	16.23	-20.19	0	L2+L6+L7
1	20	Characteristic long-term	192.36	1.29	-365.02	-368.62	15.87	-13.57	0	0.9523*L2+0.45*L5+0.9523*L6+0.95*L7
2	3	Design long-term	123.84	0.6	-364.5	-188.62	8.23	-4.9	0	L2+0.45*L3+L6+0.45*L8
3	1	Characteristic values	79.45	0.67	-361.77	-145.89	89.67	-43.05	0	0.8571*L2+0.8571*L6+0.5*L8+L9
1	2	Design values	252.05	1.2	-359.92	-376.34	0.97	-4.38	0	L2+0.9*L3+L6+0.95*L7
2	1	Design long-term	102.74	0.74	-358.58	-185.52	38.86	-20.44	0	0.45*L1+L2+L6+0.45*L8
1	17	Design values	252.33	1.2	-358.39	-375.63	0.96	-4.4	0	L2+0.9*L3+L6+0.95*L7+0.9*L8
1	2	Design long-term	230.34	1.27	-358.05	-374.66	8.47	-12.09	0	L2+0.45*L3+L6+0.95*L7
1	17	Design long-term	230.48	1.27	-357.28	-374.31	8.46	-12.1	0	L2+0.45*L3+L6+0.95*L7+0.45*L8
1	14	Characteristic values	209.38	1.35	-357.24	-374.16	15.71	-19.59	0	0.9523*L2+0.9523*L6+L7
1	14	Characteristic long-term	209.38	1.35	-357.24	-374.16	15.71	-19.59	0	0.9523*L2+0.9523*L6+L7
1	4	Design long-term	209.24	1.41	-355.24	-371.56	23.56	-27.63	0	0.45*L1+L2+L6+0.95*L7
2	1	Design values	103.49	0.81	-355.1	-183.75	54.3	-28.27	0	0.9*L1+L2+L6+0.9*L8
1	10	Design long-term	209.38	1.41	-354.47	-371.2	23.56	-27.64	0	0.45*L1+L2+L6+0.95*L7+0.45*L8
1	4	Design values	209.85	1.48	-354.3	-370.13	31.17	-35.46	0	0.9*L1+L2+L6+0.95*L7
1	10	Design values	210.13	1.49	-352.76	-369.43	31.16	-35.47	0	0.9*L1+L2+L6+0.95*L7+0.9*L8
2	9	Characteristic values	145.38	0.48	-352.72	-182.11	-11.48	5.14	0	0.9523*L2+L3+0.9523*L6
1	2	Characteristic values	247.2	1.17	-351.52	-367.57	0.46	-3.78	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
1	17	Characteristic values	247.47	1.17	-349.99	-366.87	0.44	-3.8	0	0.9523*L2+0.9*L3+0.9523*L6+0.95*L7+0.9*L8
2	3	Characteristic values	140.83	0.5	-349.69	-181.03	-8.1	3.41	0	0.9523*L2+0.9*L3+0.9523*L6+0.9*L8
1	2	Characteristic long-term	225.48	1.24	-349.65	-365.89	7.95	-11.49	0	0.9523*L2+0.45*L3+0.9523*L6+0.95*L7
1	17	Characteristic long-term	225.62	1.24	-348.88	-365.54	7.94	-11.5	0	0.9523*L2+0.45*L3+0.9523*L6+0.95*L7+0.45*L8
2	9	Characteristic long-term	121.25	0.56	-348.77	-180.24	5.42	-3.43	0	0.9523*L2+0.5*L3+0.9523*L6
2	3	Characteristic long-term	118.98	0.57	-347.26	-179.7	7.11	-4.3	0	0.9523*L2+0.45*L3+0.9523*L6+0.45*L8
1	4	Characteristic long-term	204.38	1.38	-346.84	-362.79	23.05	-27.03	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7
1	10	Characteristic long-term	204.52	1.38	-346.07	-362.44	23.04	-27.04	0	0.45*L1+0.9523*L2+0.9523*L6+0.95*L7+0.45*L8
1	4	Characteristic values	205	1.45	-345.9	-361.37	30.66	-34.86	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7
1	10	Characteristic values	205.27	1.46	-344.36	-360.67	30.64	-34.87	0	0.9*L1+0.9523*L2+0.9523*L6+0.95*L7+0.9*L8
2	1	Characteristic long-term	97.88	0.71	-341.34	-176.6	37.75	-19.84	0	0.45*L1+0.9523*L2+0.9523*L6+0.45*L8
2	13	Design long-term	113.88	0.69	-339.7	-182.74	28.17	-18.41	0	L2+0.45*L4+L6+0.45*L8
2	1	Characteristic values	98.63	0.78	-337.86	-174.83	53.18	-27.67	0	0.9*L1+0.9523*L2+0.9523*L6+0.9*L8
2	24	Design values with seismic loads	107.48	0.44	-331.68	-171.72	-14.52	6.51	0	0.9*L2+0.9*L6+L10
2	3	Design values with seismic loads	107.63	0.44	-330.44	-171.33	-14.52	6.5	0	0.9*L2+0.9*L6+0.5*L8+L10
2	9	Design long-term	91.79	0.6	-325.86	-168.56	21.09	-11.34	0	0.9*L2+0.9*L6+0*L9
2	18	Design long-term	91.79	0.6	-325.86	-168.56	21.09	-11.34	0	0.9*L2+0.9*L6+0*L10
2	24	Design long-term	91.79	0.6	-325.86	-168.56	21.09	-11.34	0	0.9*L2+0.9*L6+0*L10
2	1	Design long-term	91.86	0.6	-325.24	-168.37	21.09	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L9
2	3	Design long-term	91.86	0.6	-325.2	-168.	21.09	-11.3	0	0.9*L2+0.9*L6+0.25*L8+0*L10

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	r_X	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
					4	37		5		
2	641	Design long-term	91.86	0.6	-325.24	-168.37	21.09	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L10
2	13	Characteristic long-term	109.02	0.66	-322.46	-173.82	27.05	-17.81	0	0.9523*L2+0.45*L4+0.9523*L6+0.45*L8
2	18	Design values with seismic loads	76.09	0.76	-320.04	-165.41	56.7	-29.19	0	0.9*L2+0.9*L6-L10
2	641	Design values with seismic loads	76.25	0.76	-318.79	-165.02	56.7	-29.2	0	0.9*L2+0.9*L6+0.5*L8-L10
2	13	Design values	125.78	0.71	-317.34	-178.19	32.91	-24.22	0	L2+0.9*L4+L6+0.9*L8
2	24	Characteristic values	103.11	0.41	-316.16	-163.69	-15.52	7.05	0	0.8571*L2+0.8571*L6+L10
2	3	Characteristic values	103.26	0.42	-314.92	-163.3	-15.52	7.04	0	0.8571*L2+0.8571*L6+0.5*L8+L10
1	2	Design values with seismic loads	197.28	1.01	-312.83	-327.9	-3.8	0.44	0	0.9*L2+0.9*L6+0.8*L7+L10
1	17	Design values with seismic loads	197.44	1.01	-311.98	-327.51	-3.81	0.43	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L10
2	9	Characteristic long-term	87.42	0.57	-310.34	-160.54	20.08	-10.8	0	0.8571*L2+0.8571*L6+0*L9
2	18	Characteristic long-term	87.42	0.57	-310.34	-160.54	20.08	-10.8	0	0.8571*L2+0.8571*L6+0*L10
2	24	Characteristic long-term	87.42	0.57	-310.34	-160.54	20.08	-10.8	0	0.8571*L2+0.8571*L6+0*L10
1	2	Design long-term	181.59	1.17	-310.15	-324.74	14.07	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L10
1	4	Design long-term	181.59	1.17	-310.15	-324.74	14.07	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L9
1	421	Design long-term	181.59	1.17	-310.15	-324.74	14.07	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0*L10
1	10	Design long-term	181.67	1.17	-309.72	-324.54	14.06	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L9
1	17	Design long-term	181.67	1.17	-309.72	-324.54	14.06	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L10
1	23	Design long-term	181.67	1.17	-309.72	-324.54	14.06	-17.41	0	0.9*L2+0.9*L6+0.8*L7+0.25*L8+0*L10
2	1	Characteristic long-term	87.49	0.57	-309.72	-160.34	20.09	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L9
2	3	Characteristic long-	87.4	0.57	-	-	20.09	-	0	0.8571*L2+0.8571*L6+0.25*L8+

Section	Criterion	Type of combination	N	Mk	My	Qz	Mz	Qy	rX	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
		term	9		309.72	160.34		10.81		0*L10
2	641	Characteristic long-term	87.49	0.57	-309.72	-160.34	20.09	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L10
1	421	Design values with seismic loads	165.9	1.33	-307.47	-321.58	31.93	-35.26	0	0.9*L2+0.9*L6+0.8*L7-L10
1	23	Design values with seismic loads	166.05	1.33	-306.62	-321.19	31.93	-35.27	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8-L10
1	2	Characteristic values	192.91	0.98	-305.27	-320.01	-4.27	0.98	0	0.8571*L2+0.8571*L6+0.8*L7+L10
2	18	Characteristic values	71.72	0.73	-304.52	-157.38	55.69	-28.65	0	0.8571*L2+0.8571*L6-L10
1	17	Characteristic values	193.06	0.98	-304.42	-319.62	-4.27	0.97	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8+L10
2	641	Characteristic values	71.88	0.73	-303.27	-156.99	55.69	-28.66	0	0.8571*L2+0.8571*L6+0.5*L8-L10
1	2	Characteristic long-term	177.22	1.14	-302.59	-316.85	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L10
1	4	Characteristic long-term	177.22	1.14	-302.59	-316.85	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L9
1	421	Characteristic long-term	177.22	1.14	-302.59	-316.85	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0*L10
1	10	Characteristic long-term	177.3	1.14	-302.16	-316.66	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L9
1	17	Characteristic long-term	177.3	1.14	-302.16	-316.66	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L10
1	23	Characteristic long-term	177.3	1.14	-302.16	-316.66	13.6	-16.87	0	0.8571*L2+0.8571*L6+0.8*L7+0.25*L8+0*L10
2	13	Characteristic values	120.92	0.68	-300.1	-169.27	31.79	-23.62	0	0.9523*L2+0.9*L4+0.9523*L6+0.9*L8
1	421	Characteristic values	161.53	1.3	-299.91	-313.7	31.47	-34.72	0	0.8571*L2+0.8571*L6+0.8*L7-L10
1	23	Characteristic values	161.68	1.3	-299.06	-313.31	31.46	-34.73	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8-L10
1	10	Design values with seismic loads	173.63	1.26	-234.51	-307.3	7.34	-49.66	0	0.9*L2+0.9*L6+0.8*L7+0.5*L8+L9
1	9	Design values with seismic loads	99.9	0.51	-233.55	-182.68	16.46	20.9	0	0.9*L2+0.9*L6-L9
2	1	Design values with seismic loads	83.82	0.69	-232.78	-151.13	47.8	-43.59	0	0.9*L2+0.9*L6+0.5*L8+L9

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	rX	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
1	10	Characteristic values	169.26	1.23	-226.95	-299.42	6.88	-49.12	0	0.8571*L2+0.8571*L6+0.8*L7+0.5*L8+L9
1	9	Characteristic values	95.53	0.48	-225.99	-174.79	16	21.44	0	0.8571*L2+0.8571*L6-L9
2	1	Characteristic values	79.45	0.67	-217.27	-143.1	46.79	-43.05	0	0.8571*L2+0.8571*L6+0.5*L8+L9
1	18	Design values	76.63	0.62	-214.72	-193.84	11.78	-0.07	0	L2+L5+L6
1	18	Characteristic values	71.77	0.59	-206.32	-185.08	11.26	0.53	0	0.9523*L2+L5+0.9523*L6
1	18	Design long-term	89.31	0.64	-195.56	-188.94	11.3	-6.34	0	L2+0.5*L5+L6
1	18	Characteristic long-term	84.45	0.61	-187.16	-180.18	10.79	-5.74	0	0.9523*L2+0.5*L5+0.9523*L6
1	9	Design values	150.24	0.51	-180.56	-187.77	-5.82	4.54	0	L2+L3+L6
1	3	Design values	145.69	0.53	-178.61	-186.7	-4.17	2.81	0	L2+0.9*L3+L6+0.9*L8
1	9	Design long-term	126.11	0.59	-178.48	-185.91	2.5	-4.03	0	L2+0.5*L3+L6
1	3	Design long-term	123.84	0.6	-177.5	-185.37	3.33	-4.9	0	L2+0.45*L3+L6+0.45*L8
1	26	Design long-term	102.67	0.75	-175.35	-182.46	19.28	-21.3	0	0.5*L1+L2+L6
1	1	Design long-term	102.74	0.74	-174.69	-182.27	18.43	-20.44	0	0.45*L1+L2+L6+0.45*L8
1	26	Design values	103.35	0.82	-174.31	-180.88	27.73	-29.99	0	L1+L2+L6
1	1	Design values	103.49	0.81	-172.98	-180.49	26.03	-28.27	0	0.9*L1+L2+L6+0.9*L8
1	9	Characteristic values	145.38	0.48	-172.16	-179.01	-6.34	5.14	0	0.9523*L2+L3+0.9523*L6
1	3	Characteristic values	140.83	0.5	-170.21	-177.93	-4.69	3.41	0	0.9523*L2+0.9*L3+0.9523*L6+0.9*L8
1	9	Characteristic long-term	121.25	0.56	-170.08	-177.14	1.99	-3.43	0	0.9523*L2+0.5*L3+0.9523*L6
1	3	Characteristic long-term	118.98	0.57	-169.1	-176.6	2.81	-4.3	0	0.9523*L2+0.45*L3+0.9523*L6+0.45*L8
1	26	Characteristic long-term	97.81	0.71	-166.9	-173.	18.76	-20.7	0	0.5*L1+0.9523*L2+0.9523*L6

Section	Criterion	Type of combination	N	M_k	M_y	Q_z	M_z	Q_y	rX	Formula
			kN	kN*m	kN*m	kN	kN*m	kN	kN/m	
					5	7				
1	1	Characteristic long-term	97.88	0.71	-166.29	-173.5	17.91	-19.84	0	0.45*L1+0.9523*L2+0.9523*L6+0.45*L8
1	26	Characteristic values	98.49	0.79	-165.91	-172.12	27.22	-29.39	0	L1+0.9523*L2+0.9523*L6
1	1	Characteristic values	98.63	0.78	-164.58	-171.73	25.51	-27.67	0	0.9*L1+0.9523*L2+0.9523*L6+0.9*L8
1	24	Design values with seismic loads	107.48	0.44	-161.44	-168.79	-8.12	6.51	0	0.9*L2+0.9*L6+L10
1	321	Design values with seismic loads	107.63	0.44	-160.58	-168.4	-8.13	6.5	0	0.9*L2+0.9*L6+0.5*L8+L10
1	9	Design long-term	91.79	0.6	-158.76	-165.63	9.75	-11.34	0	0.9*L2+0.9*L6+0*L9
1	18	Design long-term	91.79	0.6	-158.76	-165.63	9.75	-11.34	0	0.9*L2+0.9*L6+0*L10
1	24	Design long-term	91.79	0.6	-158.76	-165.63	9.75	-11.34	0	0.9*L2+0.9*L6+0*L10
1	13	Design long-term	113.88	0.69	-158.59	-179.49	9.76	-18.41	0	L2+0.45*L4+L6+0.45*L8
1	1	Design long-term	91.86	0.6	-158.33	-165.44	9.74	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L10
1	3	Design long-term	91.86	0.6	-158.33	-165.44	9.74	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L9
1	321	Design long-term	91.86	0.6	-158.33	-165.44	9.74	-11.35	0	0.9*L2+0.9*L6+0.25*L8+0*L10
1	18	Design values with seismic loads	76.09	0.76	-156.08	-162.48	27.61	-29.19	0	0.9*L2+0.9*L6-L10
1	1	Design values with seismic loads	76.25	0.76	-155.23	-162.09	27.61	-29.2	0	0.9*L2+0.9*L6+0.5*L8-L10
1	24	Characteristic values	103.11	0.41	-153.88	-160.9	-8.59	7.05	0	0.8571*L2+0.8571*L6+L10
1	321	Characteristic values	103.26	0.42	-153.02	-160.51	-8.59	7.04	0	0.8571*L2+0.8571*L6+0.5*L8+L10
1	9	Characteristic long-term	87.42	0.57	-151.2	-157.75	9.28	-10.8	0	0.8571*L2+0.8571*L6+0*L9
1	18	Characteristic long-term	87.42	0.57	-151.2	-157.75	9.28	-10.8	0	0.8571*L2+0.8571*L6+0*L10
1	24	Characteristic long-term	87.42	0.57	-151.2	-157.75	9.28	-10.8	0	0.8571*L2+0.8571*L6+0*L10
1	1	Characteristic long-	87.4	0.57	-	-	9.28	-	0	0.8571*L2+0.8571*L6+0.25*L8+

Section	Criterion	Type of combination	N kN	Mk kN*m	My kN*m	Qz kN	Mz kN*m	Qy kN	rx kN/m	Formula
		term	9		150.77	157.55		10.81		0*L10
1	3	Characteristic long-term	87.49	0.57	-150.77	-157.55	9.28	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L9
1	321	Characteristic long-term	87.49	0.57	-150.77	-157.55	9.28	-10.81	0	0.8571*L2+0.8571*L6+0.25*L8+0*L10
1	13	Characteristic long-term	109.02	0.66	-150.19	-170.72	9.24	-17.81	0	0.9523*L2+0.45*L4+0.9523*L6+0.45*L8
1	18	Characteristic values	71.72	0.73	-148.52	-154.59	27.15	-28.65	0	0.8571*L2+0.8571*L6-L10
1	1	Characteristic values	71.88	0.73	-147.67	-154.2	27.14	-28.66	0	0.8571*L2+0.8571*L6+0.5*L8-L10
1	13	Design values	125.78	0.71	-140.78	-174.94	8.69	-24.22	0	L2+0.9*L4+L6+0.9*L8
1	13	Characteristic values	120.92	0.68	-132.38	-166.17	8.17	-23.62	0	0.9523*L2+0.9*L4+0.9523*L6+0.9*L8
1	3	Design values with seismic loads	83.82	0.69	-83.11	-148.2	3.02	-43.59	0	0.9*L2+0.9*L6+0.5*L8+L9
1	3	Characteristic values	79.45	0.67	-75.55	-140.31	2.56	-43.05	0	0.8571*L2+0.8571*L6+0.5*L8+L9

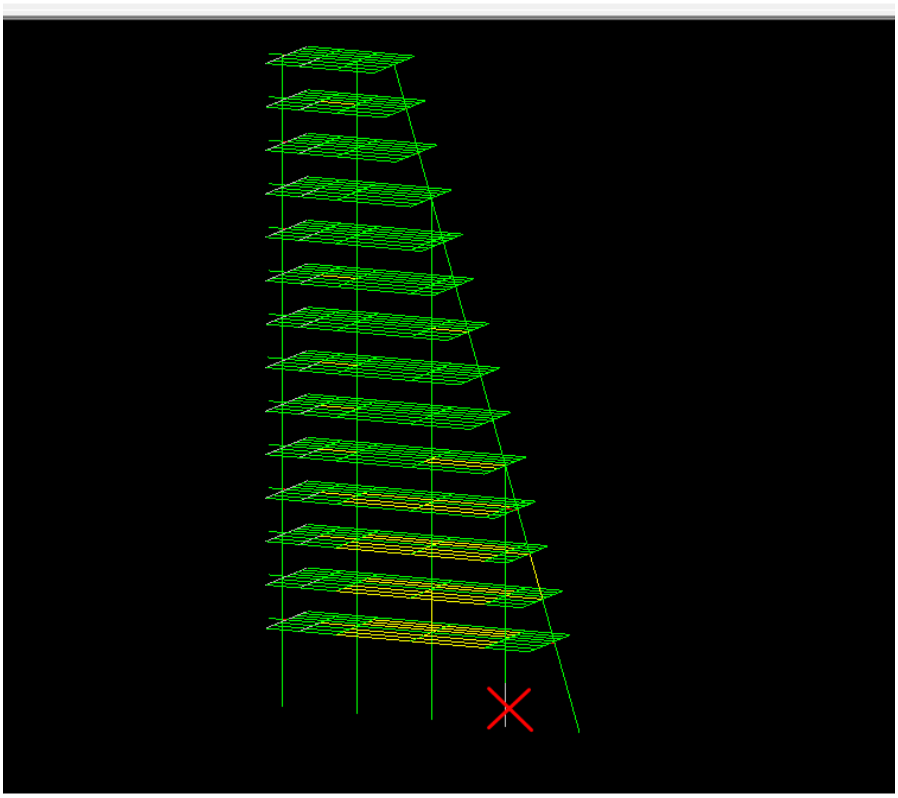


Fig. 4.1.7. Bearing capacity of elements during progressive collapse.

Analysis complies with DBN B.2.6-198:2014
Structural group Column. Element No. 36

Distance between lateral-torsional restraints exceeds that of the member.
Steel: C325
Length of the element 5.4 m
Limit slenderness for compression members: 180 - 60□
Limit slenderness for tension members: 300

Service factor 1

Spacing of stiffeners 0.5 m

Table 4.1.6.

Number of constraints of a compression chord in a span	**Type of load in the span**	**M diagram**	**Loaded chord**
Without constraints	Uniformly distributed		Compression

Importance factor (emergency state) 1

Effective length factor in the X_1OZ_1 Plane 1
Effective length factor in the X_1OY_1 Plane 1
Length between restraints out of the bending plane 6 m

Section

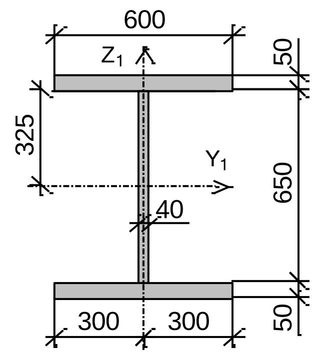


Table 4.1.7.

Results of analysis	Check	Utilization Factor	Combination
Sec. 9.2.1	Strength under bending moment My	0.02	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 9.2.1	Strength under bending moment Mz	0.44	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 9.2.1	Strength under lateral force Vy	0.04	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 9.2.1	Strength under lateral force Vz	0.01	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 10.1.1	Strength under combined action of axial force and bending moments, no plasticity	0.95	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Secs. 8.1.3, 8.2.2, 8.2.5	Stability under compression in XOY (XoU) plane	0.54	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Secs. 8.1.3, 8.2.2, 8.2.5	Stability under compression in XOZ (XoV) plane	0.49	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 10.2.2, 10.2.10	Stability in the moment My plane under eccentric compression	0.49	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 10.2.9, 10.2.10	Stability in compression and bending in two planes	0.71	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 8.3.2, 9.5.1-9.5.8, 10.4.2, 10.4.5	Ultimate web slenderness based on local stability constraint	0.38	0.95*L2+0.95*L6+0.87*L7+0.67*L8
Sec. 8.3.7, 9.5.14, 10.4.6, 10.4.7	Ultimate flange overhang (flange plate) slenderness based on local stability constraint	0.42	0.95*L2+0.95*L6+0.87*L7+0.67*L8

Utilization Factor 0.95 - Strength under combined action of axial force and bending moments, no plasticity

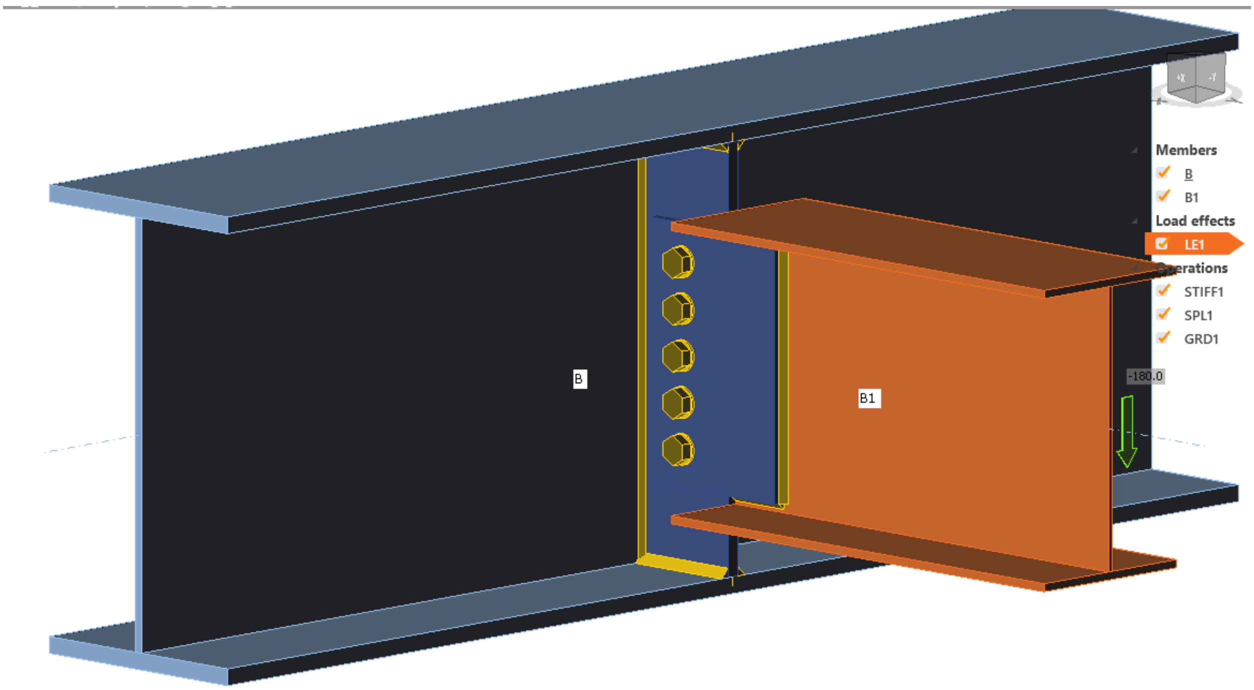


Fig. 4.1.8. Connection of main and secondary beams.

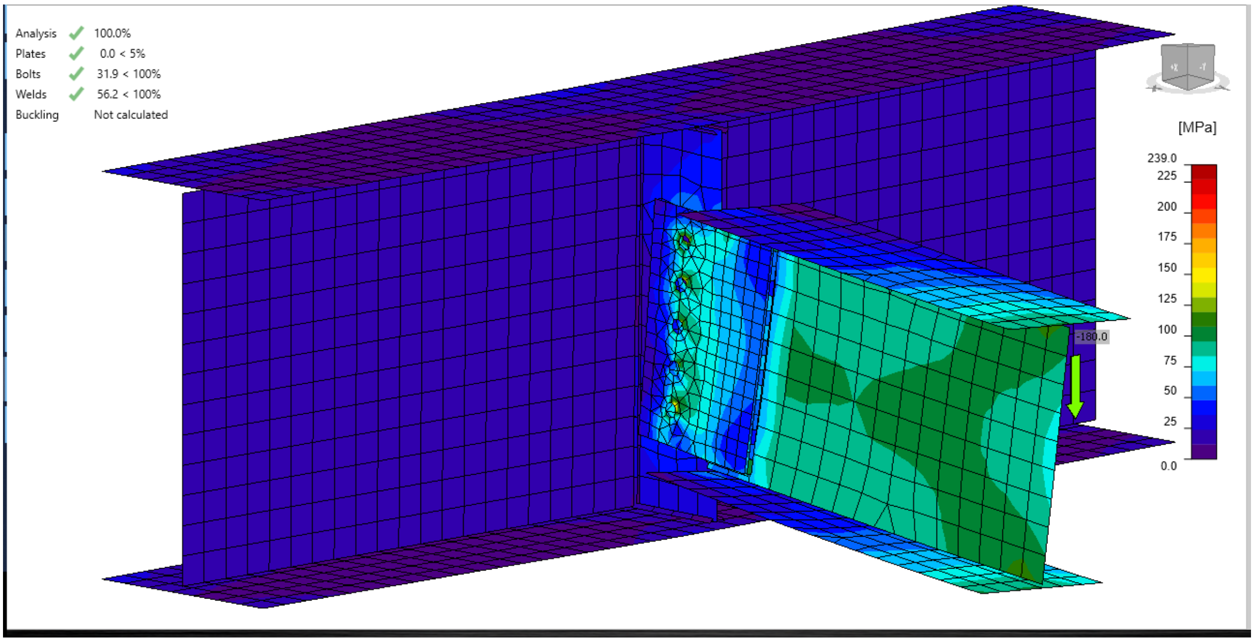


Fig. 4.1.9. Equivalent stress.

Project data

Project name	
Project number	
Author	
Description	
Date	06.12.2020
Design code	SP

Material

Steel	C345, C245
Concrete	B25

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Table 4.1.8.

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
B	3 - Iw700x370	0.0	0.0	0.0	0	0	0	Node
B1	4 - Iw450x275	-90.0	0.0	0.0	200	-6	0	Bolts

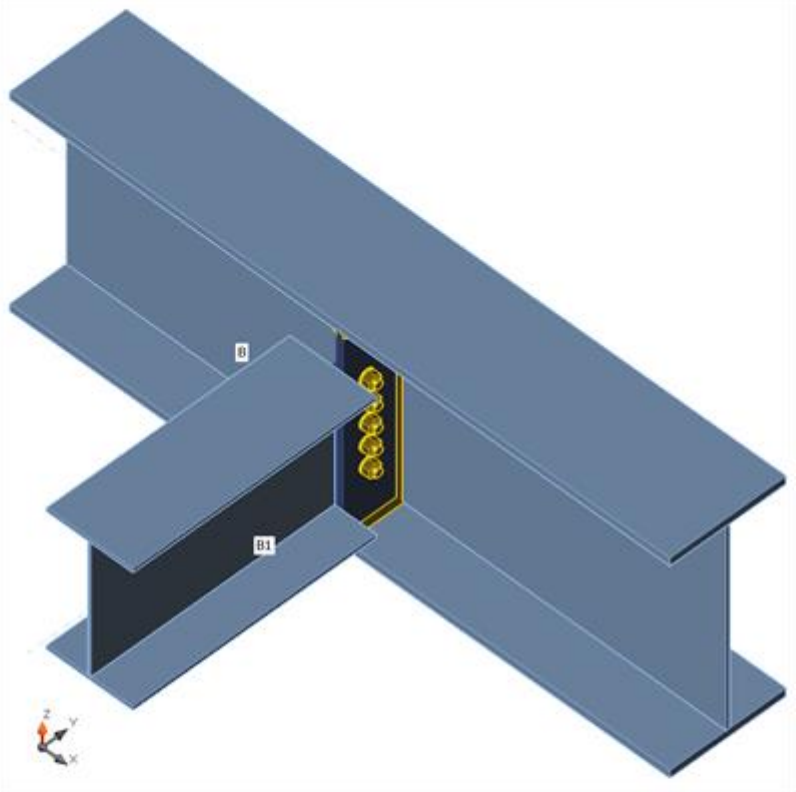


Fig. 4.1.10. 3-D view of connection.

Cross-sections

Table 4.1.9.

Name	Material
3 - Iw700x370	C245
4 - Iw450x275	C245

Bolts

Table 4.1.10.

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M24 10.9 A	M24 10.9 A	24	1040.0	452

Load effects (equilibrium not required)

Table 4.1.11.

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B1	0.0	0.0	-180.0	0.0	0.0	0.0

Check

Summary

Table 4.1.12.

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.0 < 5%	OK
Bolts	31.9 < 100%	OK
Welds	56.2 < 100%	OK
Buckling	Not calculated	

Plates

Table 4.1.13.

Name	Material	R_y [MPa]	Thickness [mm]	Loads	σ [MPa]	ε_{Pl} [%]	Check status
B-tfl 1	C245	229.3	25.0	LE1	29.1	0.0	OK
B-bfl 1	C245	229.3	25.0	LE1	28.7	0.0	OK
B-w 1	C245	229.3	12.0	LE1	21.9	0.0	OK
B1-tfl 1	C245 - 1	239.0	12.0	LE1	98.3	0.0	OK
B1-bfl 1	C245 - 1	239.0	12.0	LE1	98.6	0.0	OK
B1-w 1	C245 - 1	239.0	8.0	LE1	108.6	0.0	OK
STIFF1a	C245 - 1	239.0	20.0	LE1	14.6	0.0	OK
STIFF1b	C245 - 1	239.0	20.0	LE1	117.8	0.0	OK
SPL1	C245 - 1	239.0	20.0	LE1	147.8	0.0	OK

Design data

Table 4.1.14.

Material	Ry [MPa]	ε_{lim} [%]
C245	229.3	5.0
C245 - 1	239.0	5.0

Symbol explanation

ε_{Pl} Strain
σ Average stress in concrete
R_y Yield strength
ε_{lim} Limit of plastic strain

Fig. 4.1.11. Overall check.

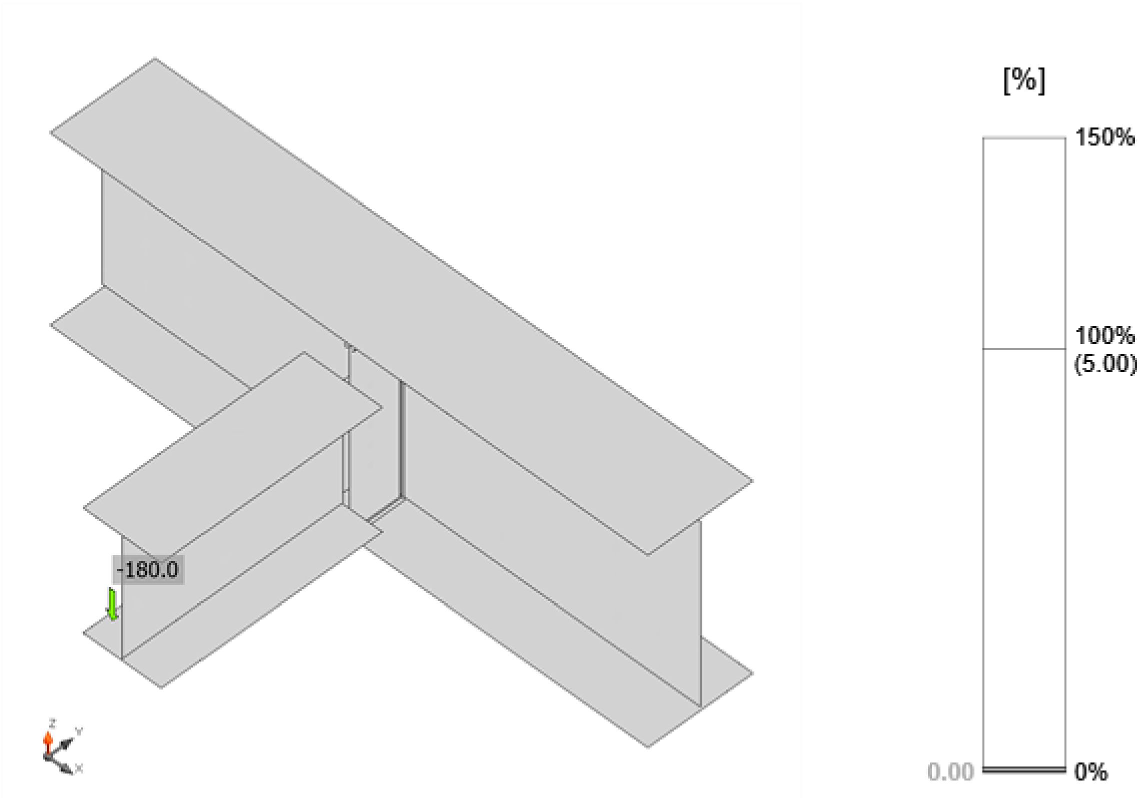


Fig. 4.1.12. Strain check.

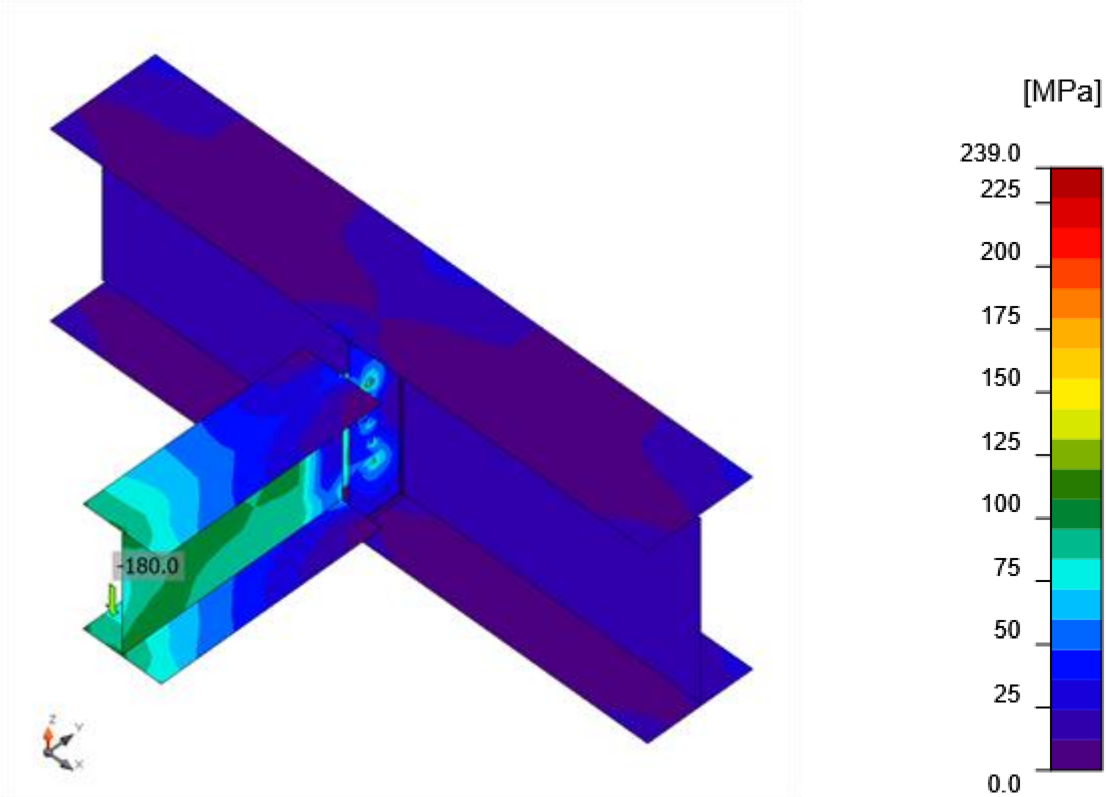
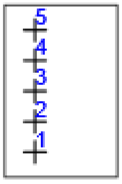


Fig. 4.1.13. Equivalent stress.

Bolts

Table 4.1.15.

Shape	Item	Grade	Loads	N_t [kN]	N_s [kN]	N_{bp} [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M24 10.9 A - 1	LE1	12.2	59.3	277.2	4.8	31.5	31.9	OK	OK
	B2	M24 10.9 A - 1	LE1	0.1	42.5	277.2	0.0	22.6	22.6	OK	OK
	B3	M24 10.9 A - 1	LE1	1.1	36.0	277.2	0.4	19.1	19.1	OK	OK
	B4	M24 10.9 A - 1	LE1	3.2	42.0	277.2	1.3	22.3	22.4	OK	OK
	B5	M24 10.9 A - 1	LE1	8.8	58.9	277.2	3.4	31.3	31.5	OK	OK

Design data

Table 4.1.16.

Grade	N_{bt} [kN]	N_{bs} [kN]
M24 10.9 A - 1	257.0	188.0

Symbol explanation

N_t Tension force
N_s Resultant of shear forces Vy, Vz in bolt
N_{bp} Bearing resistance - SP16-Cl.14.2.9
Ut_t Utilization in tension
Ut_s Utilization in shear
Ut_{ts} Interaction of tension and shear - SP16-Cl.14.2.13
N_{bt} Tension resistance - SP16-Cl.14.2.9
N_{bs} Shear resistance - SP16-Cl.14.2.9

Welds

Table 4.1.17.

Item	Electrode	k_f [mm]	l [mm]	l_{we} [mm]	Loads	N [kN]	U_{twm} [%]	U_{tbm} [%]	Detailing	Status
B-bfl 1	Э50	◢14.1◣	179	42	LE1	3.4	3.8	3.4	OK	OK
	Э50	◢14.1◣	179	42	LE1	3.7	4.1	3.7	OK	OK
B-w 1	Э50	◢8.5◣	649	49	LE1	5.2	7.3	7.5	OK	OK
	Э50	◢8.5◣	649	49	LE1	4.8	6.6	6.8	OK	OK
B-tfl 1	Э50	◢14.1◣	179	42	LE1	3.5	3.8	3.5	OK	OK
	Э50	◢14.1◣	179	42	LE1	3.5	3.8	3.5	OK	OK
B-bfl 1	Э50	◢14.1◣	179	42	LE1	7.3	8.1	7.3	OK	OK
	Э50	◢14.1◣	179	42	LE1	5.1	5.7	5.2	OK	OK
B-w 1	Э50	◢8.5◣	649	49	LE1	10.5	14.6	15.1	OK	OK
	Э50	◢8.5◣	649	49	LE1	10.5	14.6	15.2	OK	OK
B-tfl 1	Э50	◢14.1◣	179	42	LE1	7.3	8.1	7.3	OK	OK
	Э50	◢14.1◣	179	42	LE1	5.2	5.7	5.2	OK	OK
B1-w 1	Э50	◢10.0	100	22	LE1	15.1	39.2	40.6	Not OK!	OK
B1-w 1	Э50	◢10.0	395	24	LE1	17.8	43.0	44.5	Not OK!	OK
B1-w 1	Э50	◢10.0	100	22	LE1	21.0	54.2	56.2	Not OK!	OK

Symbol explanation

k_f Leg size of the weld
l Actual weld length
l_{we} Design weld element length
N Force acting on a weld element
U_{twm} Utilization in weld metal
U_{tbm} Utilization in base metal

Code settings

Table 4.1.18.

Item	Value	Unit	Reference
Stop at limit strain	No		
Detailing	Yes		SP16 - Cl.14.1.7, Table 38,40
Frictional coefficient for preloaded bolts μ	0.35	-	SP16 - Table 42
Preloaded bolts load type	Static		SP16 - Table 42
Welding type	Automatic and machine (d=1.4-2mm)		SP16 - Table 39
Anchor length for stiffness calculation [d]	8	-	EN 1993-1-8 - Table 6.11
Service factor γc	1.00	-	SP16 - Table 1
Limit plastic strain	0.05	-	EN 1993-1-5 - Cl.C.8
Local deformation check	No		
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Allow large deformations of hollow sections
Braced system	No		

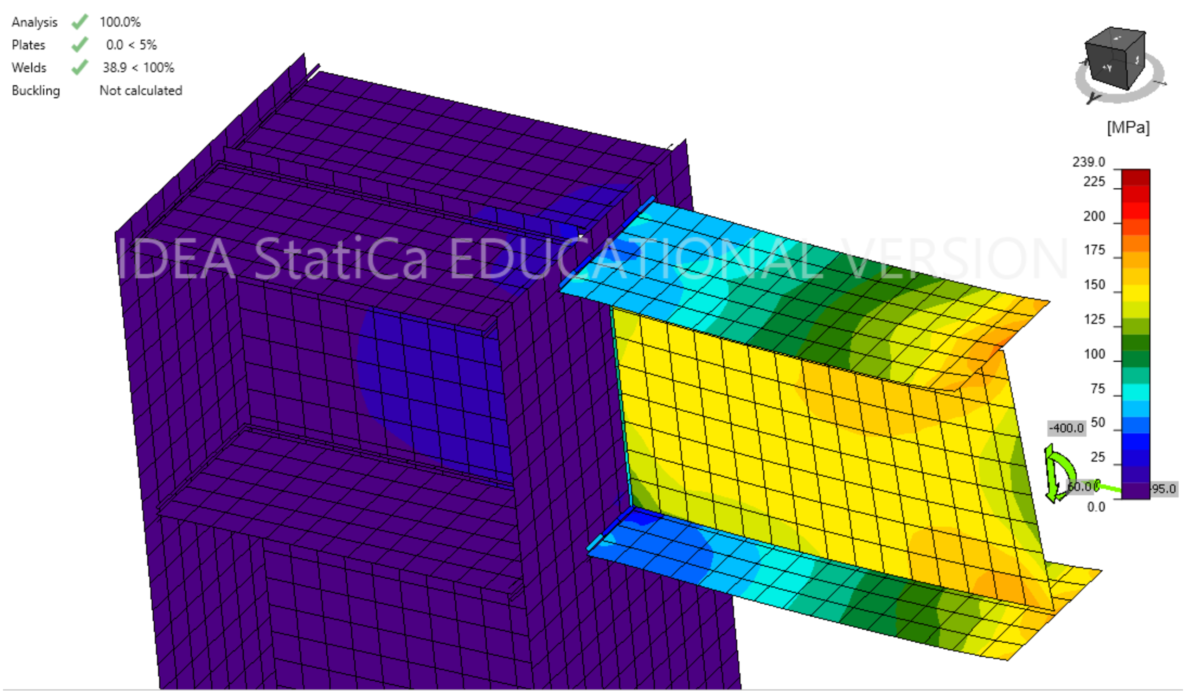


Fig. 4.1.14. Equivalent stress

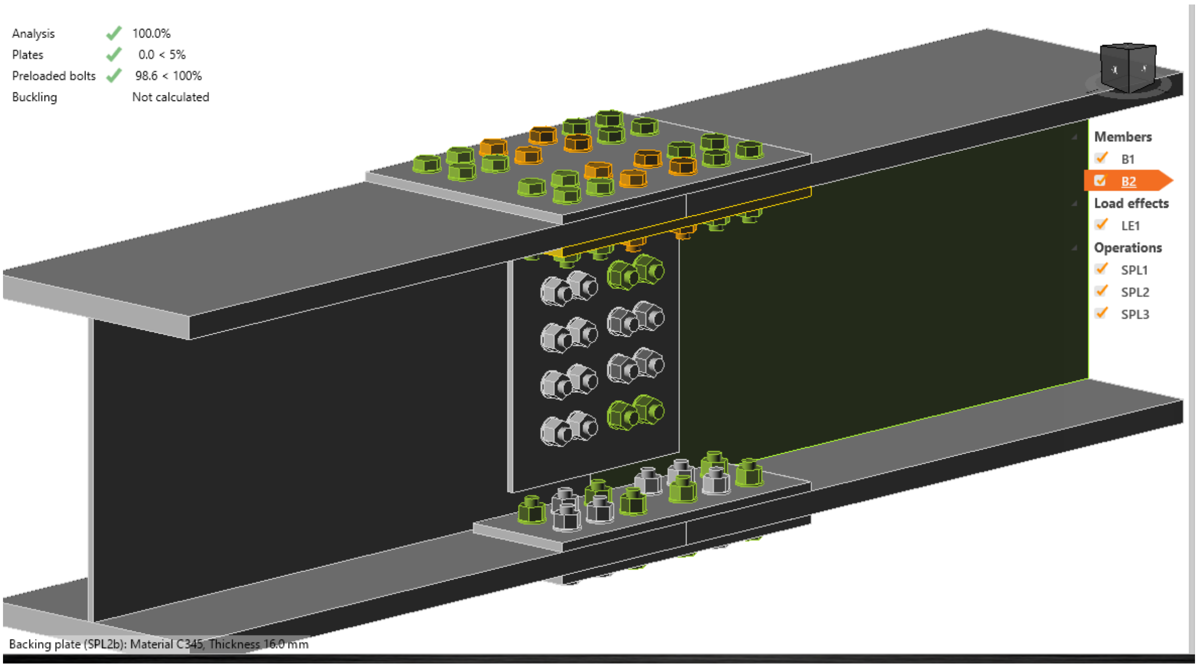


Fig. 4.1.15. 3-D view of connection.

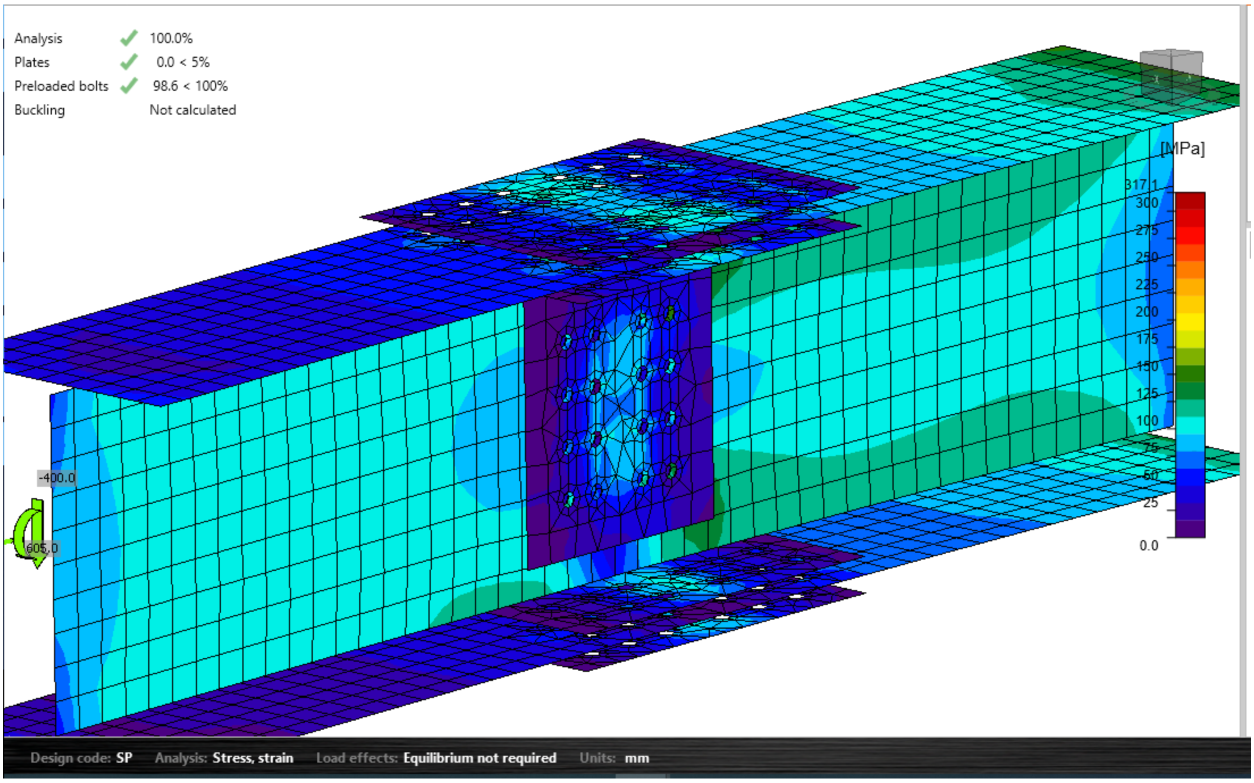


Fig. 4.1.16. Equivalent stress.

Project data

Project name
Project number
Author
Description
Date 07.12.2020
Design code SP

Material

Steel C345
Concrete B25, B60

Project item CON1

Design

Name CON1
Description
Analysis Stress, strain/ simplified loading

Beams and columns

Table 4.1.19.

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
COL	2 - Iw750x600	0.0	-90.0	0.0	0	0	0	Node

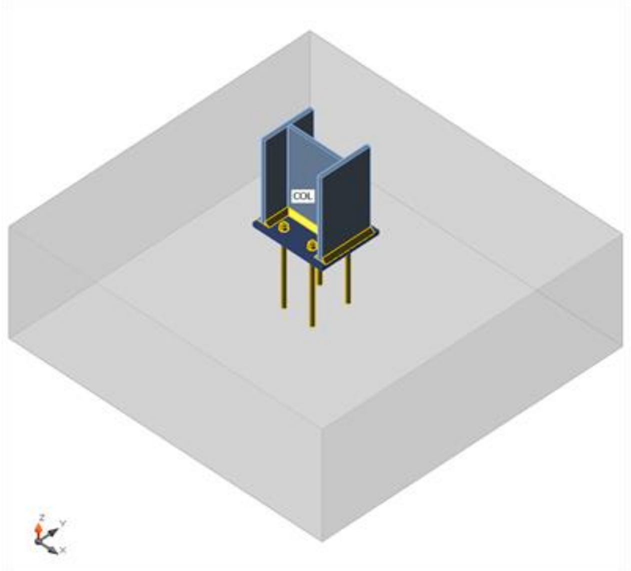


Fig. 4.1.17. 3-D view

Cross-sections

Table 4.1.20.

Name	Material
2 - Iw750x600	C345

Anchors

Table 4.1.21.

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M48 8.8 B	M48 8.8 B	48	830.0	1809

Load effects (equilibrium not required)

Table 4.1.22.

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	COL	-19000.0	0.0	0.0	0.0	0.0	0.0

Foundation block

Table 4.1.23.

Item	Value	Unit
CB 1		
Dimensions	3700 x 3850	mm
Depth	1500	mm
Anchor	M48 8.8 B	
Anchoring length	1000	mm
Shear force transfer	Friction	

Check

Summary

Table 4.1.24.

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.3 < 5%	OK
Anchors	Not calculated	
Welds	97.1 < 100%	OK
Concrete block	59.9 < 100%	OK
Buckling	Not calculated	

Plates

Table 4.1.25.

Name	R_y [MPa]	Thickness [mm]	Loads	σ [MPa]	ε_{Pl} [%]	Check status
COL-tfl 1	297.6	50.0	LE1	298.2	0.3	OK
COL-bfl 1	297.6	50.0	LE1	298.2	0.3	OK
COL-w 1	297.6	40.0	LE1	297.6	0.0	OK
BP1	297.6	50.0	LE1	297.8	0.1	OK

Design data

Table 4.1.26.

Material	Ry [MPa]	ε_{lim} [%]
C345	297.6	5.0

Symbol explanation

ε_{Pl}	Strain
σ	Average stress in concrete
R_y	Yield strength
ε_{lim}	Limit of plastic strain

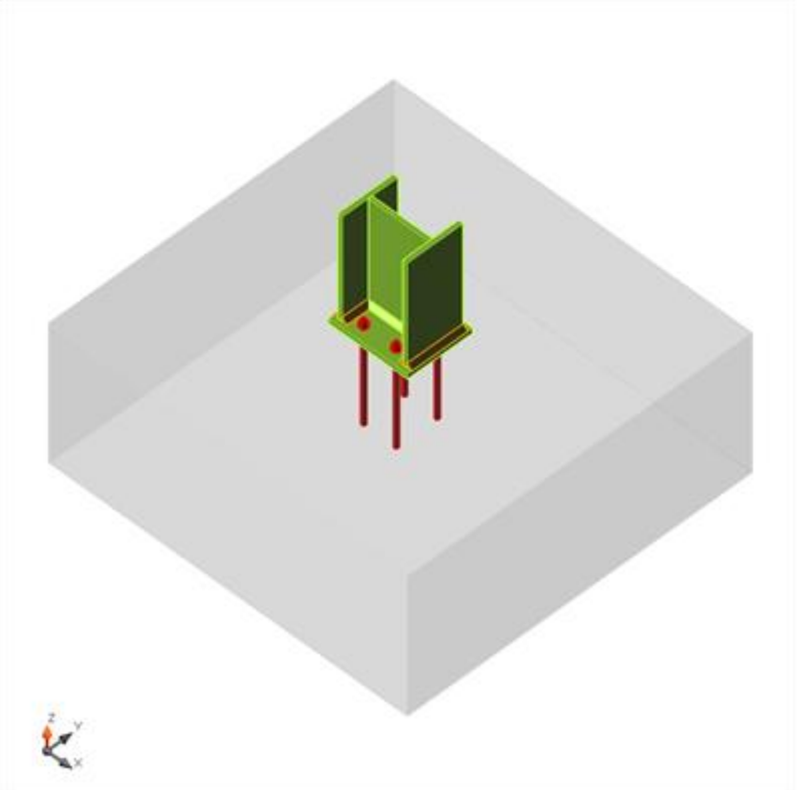


Fig. 4.1.18. Over all check.

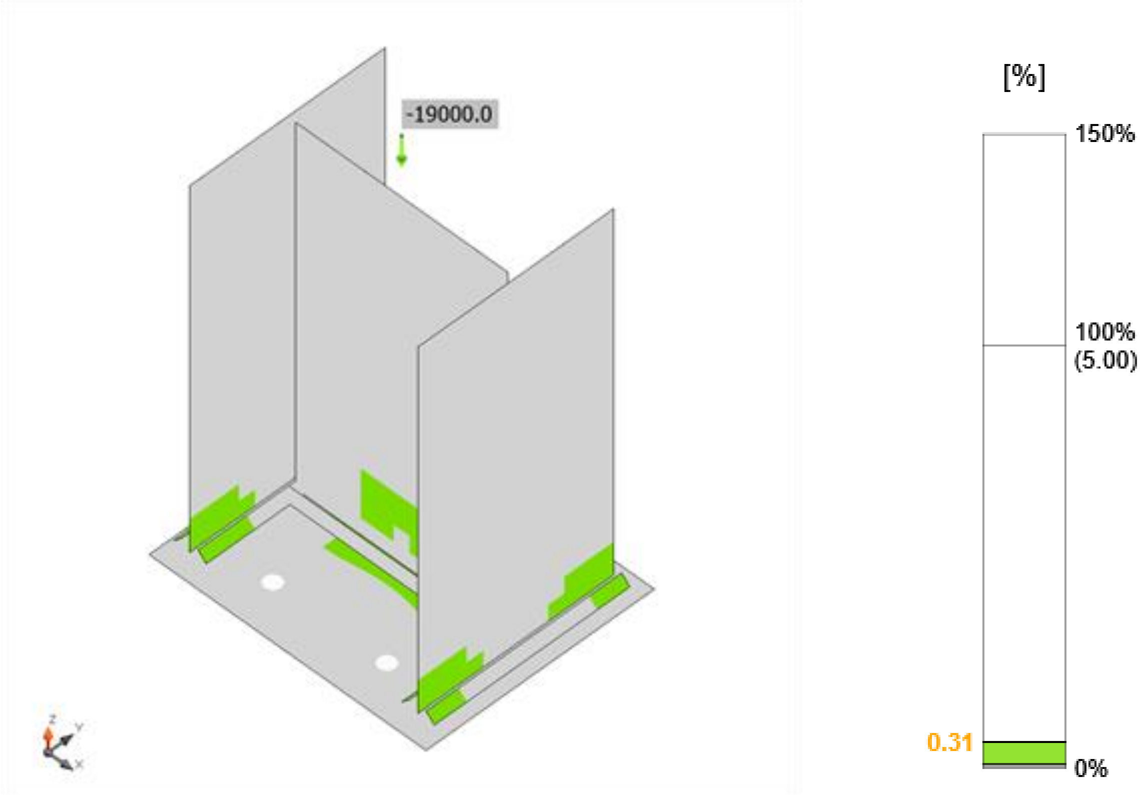


Fig. 4.1.19. Strain check.

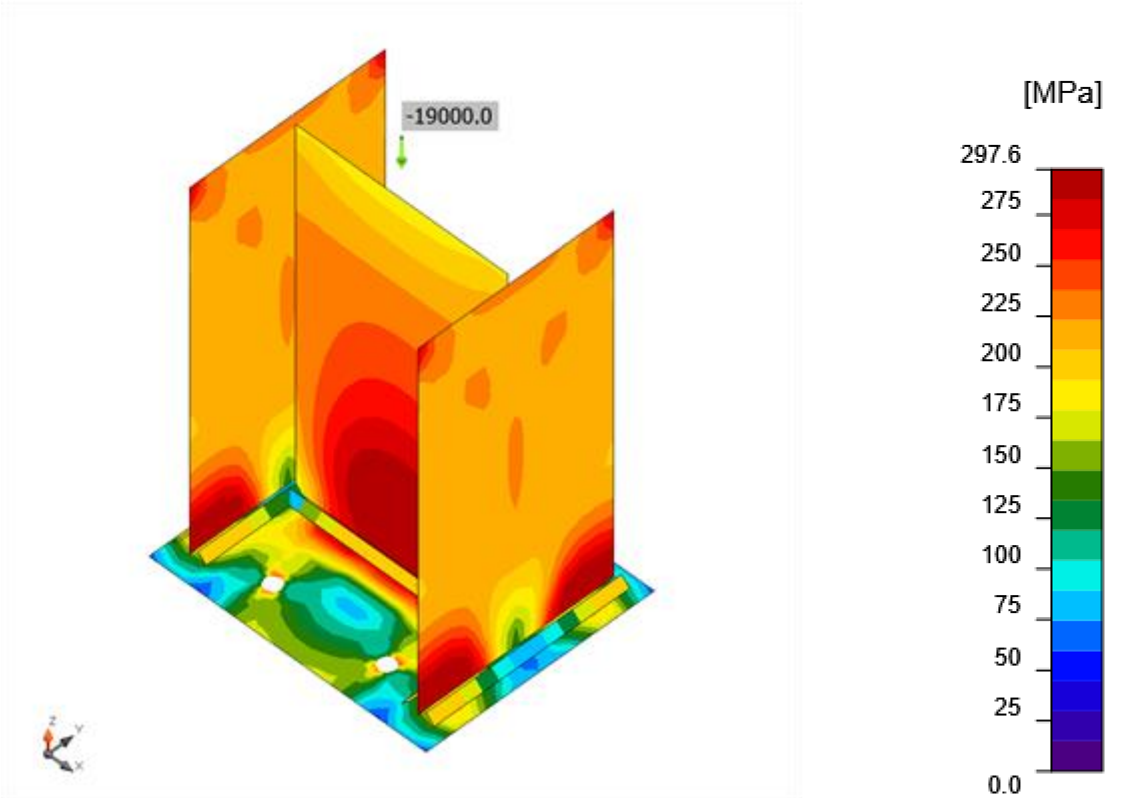
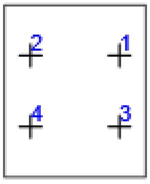


Fig. 4.1.20. Equivalent stress.

Anchors

Table 4.1.27.

Shape	Item	Loads	N_t [kN]	N_s [kN]
	A1	LE1	0.0	0.0
	A2	LE1	0.0	0.0
	A3	LE1	0.0	0.0
	A4	LE1	0.0	0.0

Symbol explanation

N_t Tension force

N_s Resultant of shear forces Vy, Vz in bolt

Welds

Table 4.1.28.

Item	Electrode	k_f [mm]	l [mm]	l_{we} [mm]	Loads	N [kN]	U_{twm} [%]	U_{tbm} [%]	Detailing	Status
BP1	Э50	◢35.0◣	599	49	LE1	359.8	97.1	70.8	OK	OK
	Э50	◢35.0◣	599	49	LE1	360.0	97.1	70.8	OK	OK
BP1	Э50	◢35.0◣	599	49	LE1	360.0	97.1	70.8	OK	OK
	Э50	◢50.0◣	599	49	LE1	359.8	97.1	70.8	OK	OK
BP1	Э50	◢28.0◣	649	49	LE1	313.6	94.0	68.5	OK	OK
	Э50	◢28.0◣	649	49	LE1	313.3	93.9	68.5	OK	OK

Symbol explanation

k_f Leg size of the weld

l Actual weld length

l_{we} Design weld element length

N Force acting on a weld element

U_{twm} Utilization in weld metal

U_{tbm} Utilization in base metal

Concrete block

Table 4.1.29.

Item	Loads	N [kN]	$R_{b,loc}$ [MPa]	$A_{b,loc}$ [mm2]	Ut [%]	Status
CB 1	LE1	19036.4	80.3	527598	59.9	OK

Symbol explanation

N	Local compressive force from an external load
$R_{b,loc}$	Design compressive resistance of concrete in case of the local impact of compressive force
$A_{b,loc}$	Application area of the compressive force (bearing area surface) determined by finite element method as area in contact between base plate and concrete block
Ut	Utilization

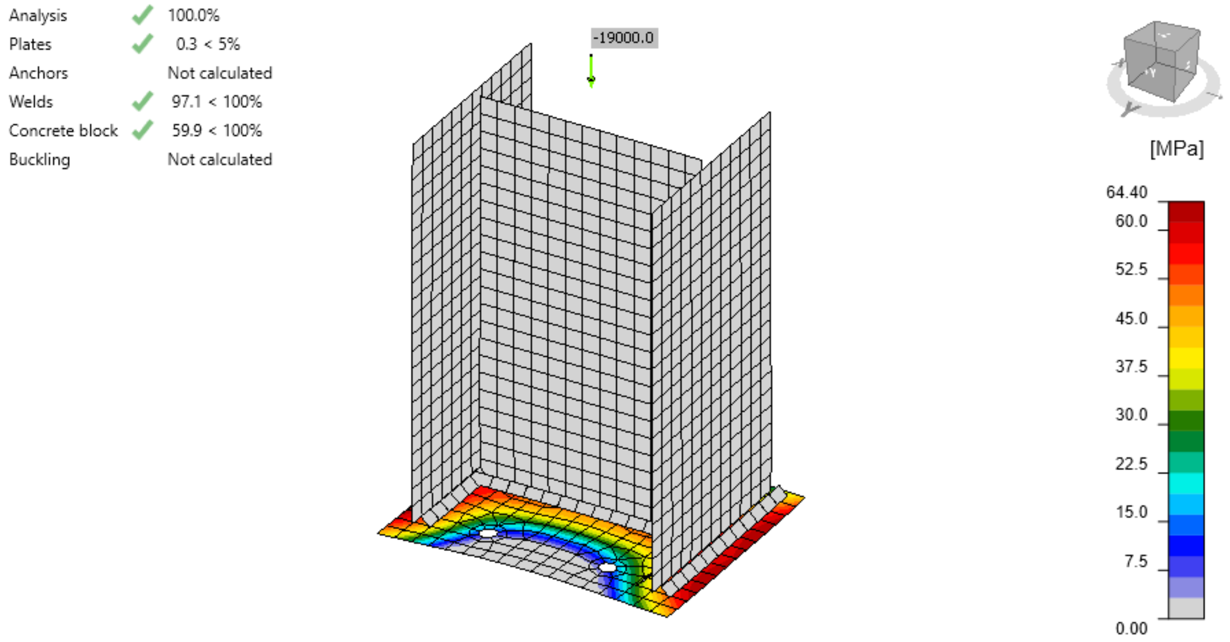


Fig. 4.1.21. Stress in concrete.

Code settings

Table 4.1.30.

Item	Value	Unit	Reference
Stop at limit strain	No		
Detailing	Yes		SP16 - Cl.14.1.7, Table 38,40
Frictional coefficient for preloaded bolts μ	0.35	-	SP16 - Table 42
Preloaded bolts load type	Static		SP16 - Table 42
Welding type	Automatic and machine (d=1.4-2mm)		SP16 - Table 39
Anchor length for stiffness calculation [d]	8	-	EN 1993-1-8 - Table 6.11
Service factor γc	1.00	-	SP16 - Table 1
Limit plastic strain	0.05	-	EN 1993-1-5 - Cl.C.8
Local deformation check	No		
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Allow large deformations of hollow sections
Braced system	No		

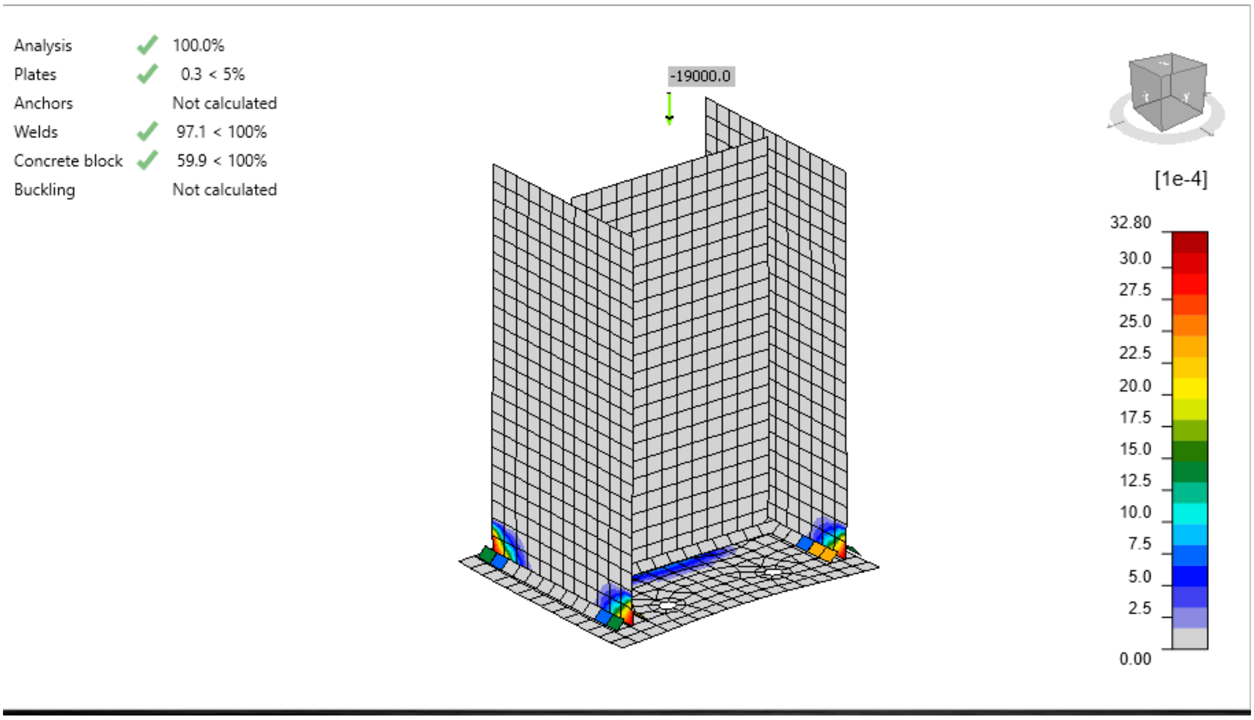


Fig. 4.1.22. Plastic strain.

Project data

Project name
Project number
Author
Description
Date 07.12.2020
Design code SP

Material

Steel C345

Project item CON1

Design

Name CON1
Description
Analysis Stress, strain/ simplified loading

Beams and columns

Table 4.1.31.

Name	**Cross-section**	**β – Direction [°]**	**γ - Pitch [°]**	**α - Rotation [°]**	**Offset ex [mm]**	**Offset ey [mm]**	**Offset ez [mm]**	**Forces in**
C	3 - Iw750x600	0.0	-90.0	0.0	0	0	0	Node
B	4 - Iw600x450	0.0	0.0	0.0	0	0	0	Node

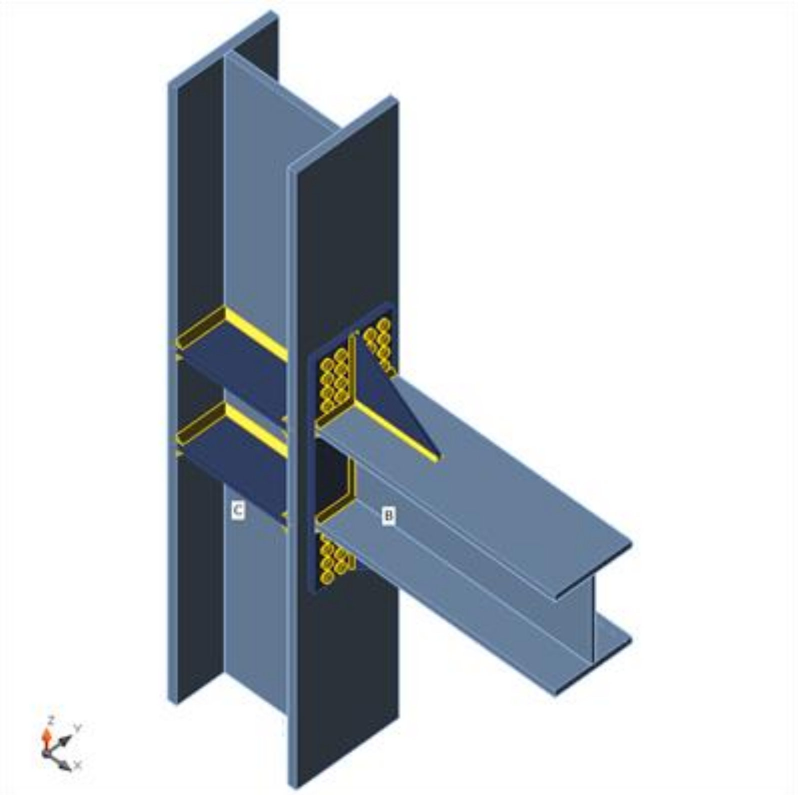


Fig. 4.1.23. 3-D view of connection.

Cross-sections

Table 4.1.32.

Name	Material
3 - Iw750x600	C345
4 - Iw600x450	C345

Bolts

Table 4.1.33.

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M30 10.9 A	M30 10.9 A	30	1040.0	706

Load effects (equilibrium not required)

Table 4.1.34.

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	0.0	0.0	-700.0	0.0	1900.0	0.0

Check

Summary

Table 4.1.35.

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.1 < 5%	OK
Bolts	80.7 < 100%	OK
Welds	97.7 < 100%	OK
Buckling	Not calculated	

Plates

Table 4.1.36.

Name	Material	R_y [MPa]	Thickness [mm]	Loads	σ [MPa]	ε_{Pl} [%]	Check status
C-tfl 1	C345	297.6	50.0	LE1	42.0	0.0	OK
C-bfl 1	C345	297.6	50.0	LE1	210.7	0.0	OK
C-w 1	C345	297.6	40.0	LE1	89.7	0.0	OK
B-tfl 1	C345	297.6	40.0	LE1	203.2	0.0	OK
B-bfl 1	C345	297.6	40.0	LE1	163.3	0.0	OK
B-w 1	C345	297.6	25.0	LE1	138.9	0.0	OK
EP1	C345	297.6	36.0	LE1	283.3	0.0	OK
STIFF1a	C345	297.6	50.0	LE1	54.6	0.0	OK
STIFF1b	C345	297.6	50.0	LE1	54.6	0.0	OK
STIFF1c	C345	297.6	50.0	LE1	98.7	0.0	OK
STIFF1d	C345	297.6	50.0	LE1	98.4	0.0	OK
WID1a	C345 - 1	317.1	20.0	LE1	275.0	0.0	OK
WID1b	C345 - 1	317.1	20.0	LE1	291.8	0.1	OK

Design data

Table 4.1.37.

Material	Ry [MPa]	ε_{lim} [%]
C345	297.6	5.0
C345 - 1	317.1	5.0

Symbol explanation

ε_{Pl} Strain
σ Average stress in concrete
R_y Yield strength
ε_{lim} Limit of plastic strain

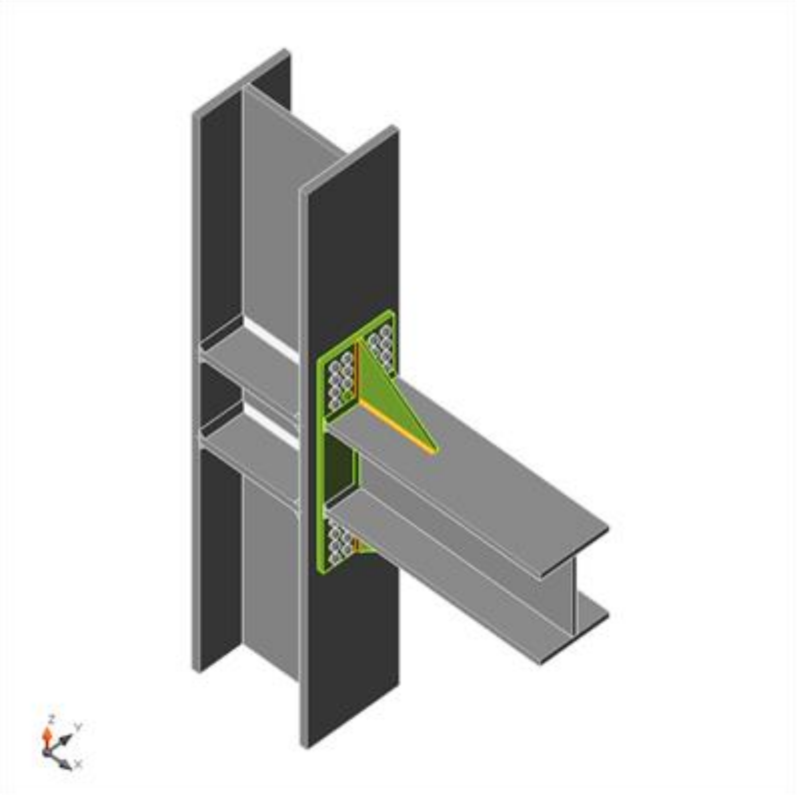


Fig. 4.1.24. Overall check

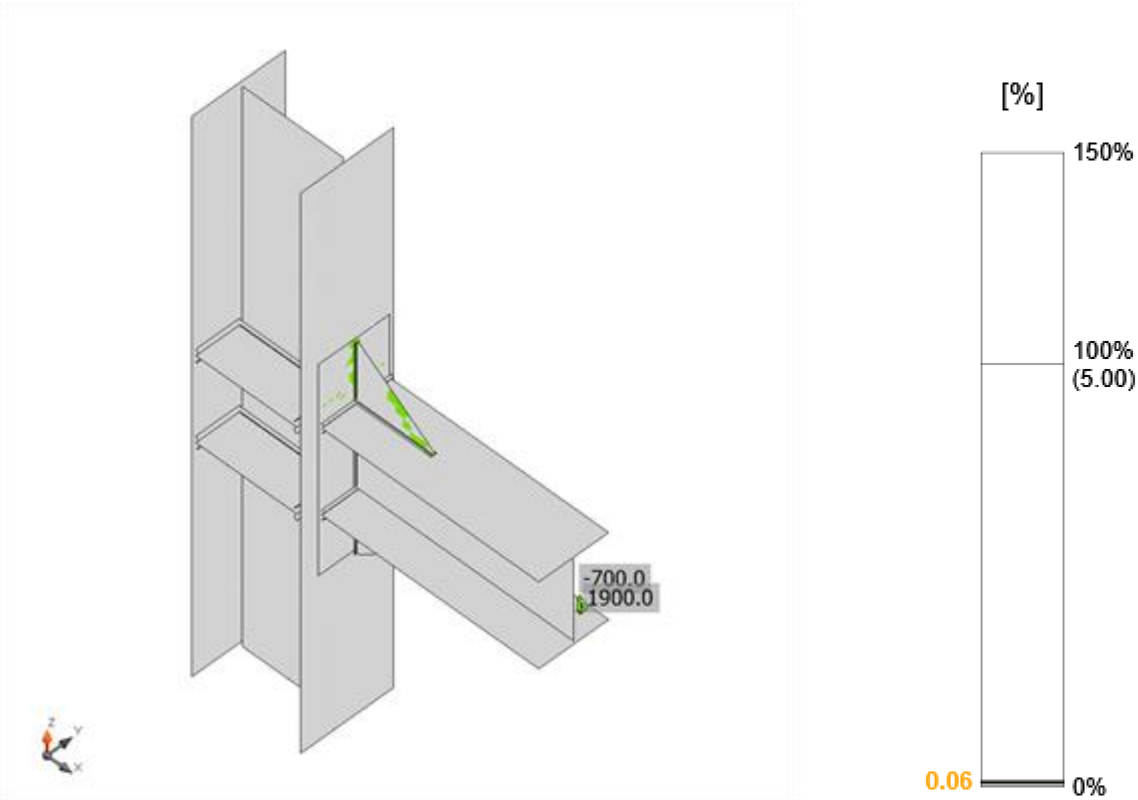


Fig. 4.1.25. Strain check

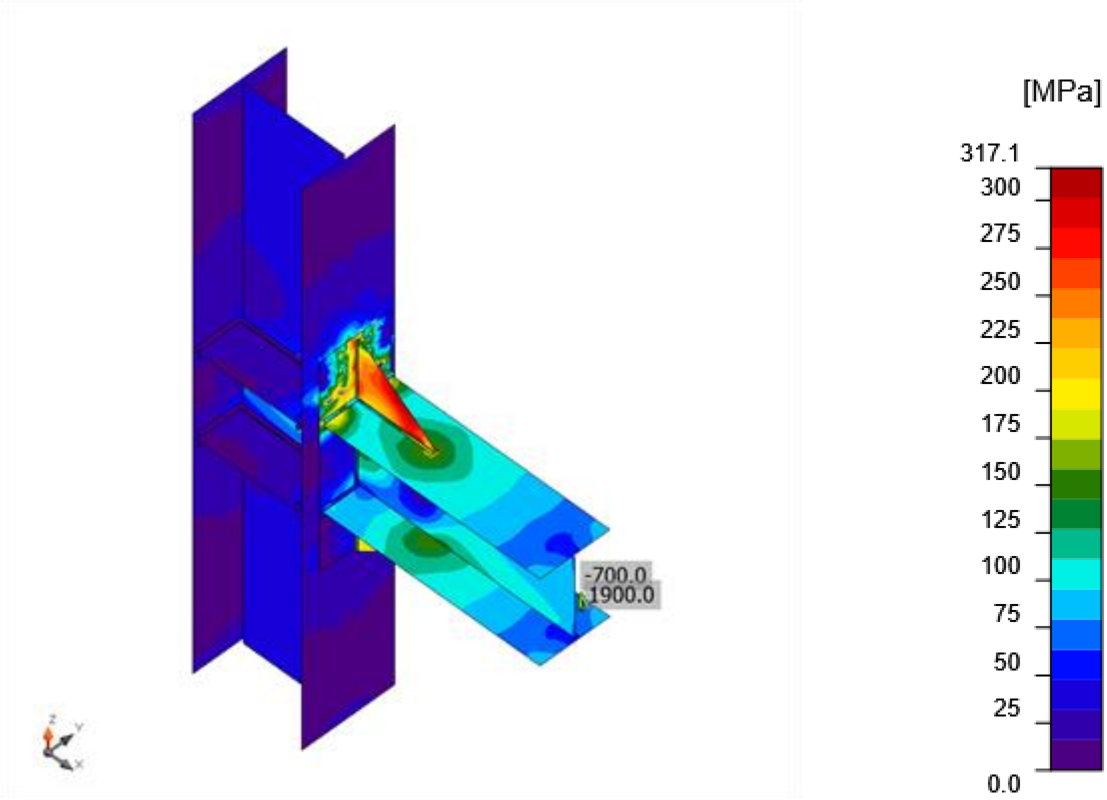
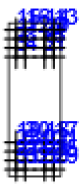


Fig. 4.1.26. Equivalent stress.

Bolts

Table 4.1.38.

Shape	Item	Grade	Loads	N_t [kN]	N_s [kN]	N_{bp} [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M30 10.9 A - 1	LE1	193.6	27.3	775.5	47.4	9.3	48.3	OK	OK
	B2	M30 10.9 A - 1	LE1	326.0	26.2	775.5	79.8	8.9	80.3	OK	OK
	B3	M30 10.9 A - 1	LE1	193.9	27.2	775.5	47.5	9.2	48.4	OK	OK
	B4	M30 10.9 A - 1	LE1	327.4	26.3	775.5	80.2	9.0	80.7	OK	OK
	B5	M30 10.9 A - 1	LE1	0.0	19.6	775.5	0.0	6.7	6.7	OK	OK
	B6	M30 10.9 A - 1	LE1	158.8	23.0	775.5	38.9	7.8	39.7	OK	OK
	B7	M30 10.9 A - 1	LE1	0.0	19.6	775.5	0.0	6.7	6.7	OK	OK
	B8	M30 10.9 A - 1	LE1	159.0	23.0	775.5	38.9	7.8	39.7	OK	OK
	B9	M30 10.9 A - 1	LE1	0.0	21.4	775.5	0.0	7.3	7.3	OK	OK
	B10	M30 10.9 A - 1	LE1	157.1	25.8	775.5	38.5	8.8	39.5	OK	OK
	B11	M30 10.9 A - 1	LE1	0.0	21.4	775.5	0.0	7.3	7.3	OK	OK
	B12	M30 10.9 A - 1	LE1	157.5	25.9	775.5	38.6	8.8	39.6	OK	OK
	B13	M30 10.9 A -	LE1	16.4	24.3	775.5	4.0	8.3	9.2	OK	OK

		1									
	B14	M30 10.9 A - 1	LE1	214.8	28.1	775.5	52.6	9.6	53.5	OK	OK
	B15	M30 10.9 A - 1	LE1	16.2	24.3	775.5	4.0	8.3	9.2	OK	OK
	B16	M30 10.9 A - 1	LE1	214.2	28.0	775.5	52.4	9.5	53.3	OK	OK
	B17	M30 10.9 A - 1	LE1	0.0	13.7	775.5	0.0	4.6	4.6	OK	OK
	B18	M30 10.9 A - 1	LE1	0.0	14.1	775.5	0.0	4.8	4.8	OK	OK
	B19	M30 10.9 A - 1	LE1	0.0	13.6	775.5	0.0	4.6	4.6	OK	OK
	B20	M30 10.9 A - 1	LE1	0.0	14.1	775.5	0.0	4.8	4.8	OK	OK
	B21	M30 10.9 A - 1	LE1	4.5	16.7	775.5	1.1	5.7	5.8	OK	OK
	B22	M30 10.9 A - 1	LE1	0.0	18.8	775.5	0.0	6.4	6.4	OK	OK
	B23	M30 10.9 A - 1	LE1	4.6	16.7	775.5	1.1	5.7	5.8	OK	OK
	B24	M30 10.9 A - 1	LE1	0.0	18.8	775.5	0.0	6.4	6.4	OK	OK
	B25	M30 10.9 A - 1	LE1	4.6	20.2	775.5	1.1	6.9	7.0	OK	OK
	B26	M30 10.9 A - 1	LE1	0.0	23.7	775.5	0.0	8.1	8.1	OK	OK
	B27	M30 10.9 A - 1	LE1	4.5	20.2	775.5	1.1	6.9	7.0	OK	OK
	B28	M30 10.9 A - 1	LE1	0.0	23.7	775.5	0.0	8.1	8.1	OK	OK
	B29	M30 10.9 A - 1	LE1	2.9	24.0	775.5	0.7	8.2	8.2	OK	OK
	B30	M30 10.9 A - 1	LE1	0.0	29.2	775.5	0.0	9.9	9.9	OK	OK
	B31	M30 10.9 A - 1	LE1	2.9	24.0	775.5	0.7	8.2	8.2	OK	OK
	B32	M30 10.9 A - 1	LE1	0.0	29.1	775.5	0.0	9.9	9.9	OK	OK

Design data

Table 4.1.39.

Grade	N_{bt} [kN]	N_{bs} [kN]
M30 10.9 A - 1	408.4	293.7

Symbol explanation

N_t	Tension force
N_s	Resultant of shear forces Vy, Vz in bolt
N_{bp}	Bearing resistance - SP16-Cl.14.2.9
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear - SP16-Cl.14.2.13
N_{bt}	Tension resistance - SP16-Cl.14.2.9
N_{bs}	Shear resistance - SP16-Cl.14.2.9

Welds

Table 4.1.40.

Item	Electrode	k_f [mm]	l [mm]	l_{we} [mm]	Loads	N [kN]	U_{twm} [%]	U_{tbm} [%]	Detailing	Status
EP1	Э50	◢25.5◣	449	49	LE1	135.1	72.1	52.5	OK	OK
	Э50	◢25.5◣	449	49	LE1	73.2	39.1	28.5	OK	OK
EP1	Э50	◢25.5◣	450	49	LE1	57.3	30.5	22.3	OK	OK
	Э50	◢25.5◣	450	49	LE1	75.2	40.1	29.2	OK	OK
EP1	Э50	◢17.7◣	520	51	LE1	91.4	67.2	49.0	OK	OK
	Э50	◢17.7◣	520	51	LE1	91.6	67.4	49.2	OK	OK
C-bfl 1	Э50	◢35.4◣	279	45	LE1	28.4	11.9	8.7	OK	OK
	Э50	◢35.4◣	279	45	LE1	46.5	19.4	14.1	OK	OK
C-w 1	Э50	◢28.3◣	649	49	LE1	12.2	5.8	4.2	OK	OK
	Э50	◢28.3◣	649	49	LE1	17.3	8.2	6.0	OK	OK
C-tfl 1	Э50	◢35.4◣	280	45	LE1	18.8	7.8	5.7	OK	OK
	Э50	◢35.4◣	279	45	LE1	9.5	4.0	2.9	OK	OK
C-bfl 1	Э50	◢35.4◣	279	45	LE1	45.1	18.8	13.7	OK	OK
	Э50	◢35.4◣	279	45	LE1	28.4	11.9	8.7	OK	OK
C-w 1	Э50	◢28.3◣	649	49	LE1	17.3	8.2	6.0	OK	OK
	Э50	◢28.3◣	649	49	LE1	12.2	5.8	4.3	OK	OK
C-tfl 1	Э50	◢35.4◣	279	45	LE1	9.5	4.0	2.9	OK	OK
	Э50	◢35.4◣	280	45	LE1	18.9	7.9	5.7	OK	OK
C-bfl 1	Э50	◢35.4◣	279	45	LE1	69.2	28.9	21.1	OK	OK
	Э50	◢35.4◣	279	45	LE1	29.4	12.3	9.0	OK	OK
C-w 1	Э50	◢28.3◣	649	49	LE1	16.2	7.7	5.6	OK	OK
	Э50	◢28.3◣	649	49	LE1	17.5	8.3	6.1	OK	OK
C-tfl 1	Э50	◢35.4◣	279	45	LE1	8.3	3.5	2.5	OK	OK
	Э50	◢35.4◣	280	45	LE1	19.1	8.0	5.8	OK	OK
C-bfl 1	Э50	◢35.4◣	279	45	LE1	27.3	11.4	8.3	OK	OK
	Э50	◢35.4◣	279	45	LE1	69.0	28.8	21.0	OK	OK
C-w 1	Э50	◢28.3◣	649	49	LE1	17.5	8.3	6.1	OK	OK
	Э50	◢28.3◣	649	49	LE1	16.3	7.8	5.7	OK	OK
C-tfl 1	Э50	◢35.4◣	280	45	LE1	19.0	7.9	5.8	OK	OK
	Э50	◢35.4◣	279	45	LE1	8.4	3.5	2.6	OK	OK
EP1	Э50	◢14.1◣	380	46	LE1	95.7	97.0	70.7	OK	OK

	Э50	◢14.1◣	380	46	LE1	95.7	97.0	70.7	OK	OK
B-bfl 1	Э50	◢14.1◣	500	49	LE1	101.5	97.1	70.8	OK	OK
	Э50	◢14.1◣	500	49	LE1	101.5	97.1	70.8	OK	OK
EP1	Э50	◢14.1◣	379	46	LE1	96.2	97.7	71.2	OK	OK
	Э50	◢14.1◣	379	46	LE1	96.2	97.6	71.2	OK	OK
B-tfl 1	Э50	◢14.1◣	500	49	LE1	101.5	97.1	70.8	OK	OK
	Э50	◢14.1◣	500	49	LE1	101.5	97.1	70.8	OK	OK

Symbol explanation

k_f Leg size of the weld
l Actual weld length
l_{we} Design weld element length
N Force acting on a weld element
U_{twm} Utilization in weld metal
U_{tbm} Utilization in base metal

Buckling

Buckling analysis was not calculated.

Code settings

Table 4.1.41.

Item	Value	Unit	Reference
Stop at limit strain	No		
Detailing	Yes		SP16 - Cl.14.1.7, Table 38,40
Frictional coefficient for preloaded bolts μ	0.35	-	SP16 - Table 42
Preloaded bolts load type	Static		SP16 - Table 42
Welding type	Automatic and machine (d=1.4-2mm)		SP16 - Table 39
Anchor length for stiffness calculation [d]	8	-	EN 1993-1-8 - Table 6.11
Service factor γc	1.00	-	SP16 - Table 1
Limit plastic strain	0.05	-	EN 1993-1-5 - Cl.C.8
Local deformation check	No		
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Allow large deformations of hollow sections
Braced system	No		

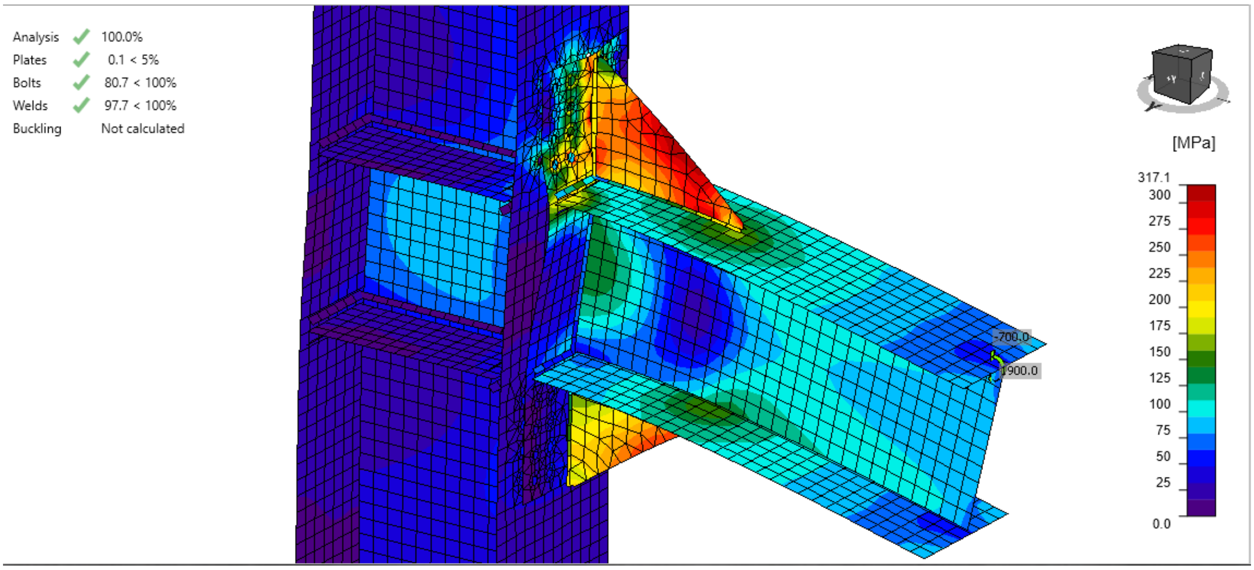


Fig. 4.1.27. Equivalent stress in connection of main beam and column.

Chapter 5

BASES AND FOUNDATIONS

5.1. Initial data

Loads acting on foundation:

N=10000kN

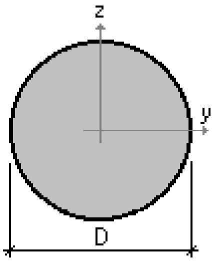
T=500kN

5.2. Calculation

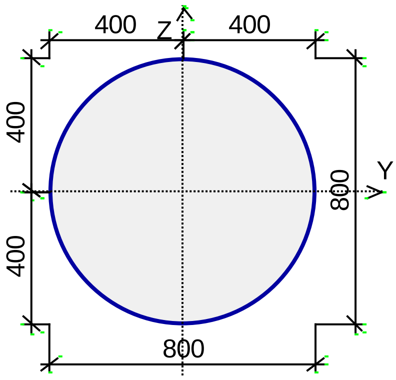
Load-bearing Capacity of the Pile
Analysis complies with DBN B.2.1-10-2009

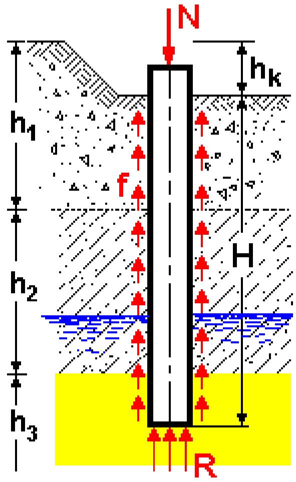
Type of pile - Drilled shaftsDrilled shafts
Service factor for the pile in soil $\gamma_c = 1$
Service factor for soil under the pile tip $\gamma_{cR} = 1$

Section



D = 800 mm





Depth of penetration of the pile tip, H = 15 m
Excavation depth h_k = 1 m

Soils

Table 5.2.1.

	Name	Thickness of layer	Soil type	Sand type	Index of liquidity I_L	Specific weight	Angle of internal friction	Porosity index	Service factor for soil on the side surface γ_{cf}
		m				kN/m^3	degree		
1		1	clayey		0.1	17	16		1
2		2	clayey		0.1	10	18		1
3		10	sand	gravelly		10	35	0.3	1
4		15	sand	gravelly		10.2	40	0.2	1
5		10	sand	gravelly		10	35	0.3	1

Results of analysis

Table 5.2.2.

Load-bearing capacity of a pile subjected to vertical load F_d	5095.396	kN
Load-bearing capacity of a pile subjected to uplift load F_{du}	1826.515	kN

Analysis of pile
Analysis complies with DBN B.2.1-10-2009

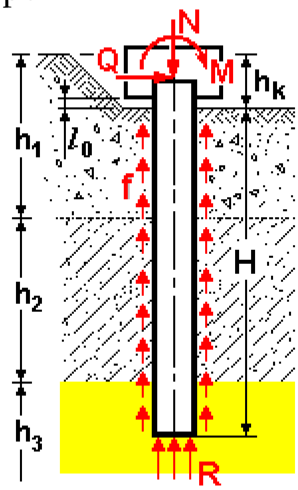
Type of pile - Drilled shafts
Arrangement of piles in a foundation with pile cap - single-row
Ground-contacting pile cap
Heavy-weight concrete, Class B60

Design loads applied to the pile at the ground level

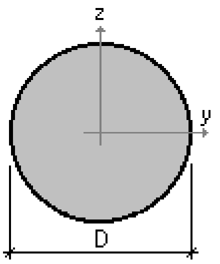
Table 5.2.3.

	N	M	Q	Load safety factor
	kN	kN*m	kN	
1	3000	0	0	1

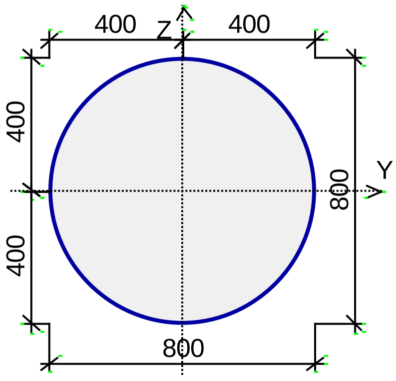
Fraction of the temporary component in the total moment in the foundation cross-section at the level of the pile tip0



Section



D = 800 mm



Depth of penetration of the pile tip, H = 15 m
Distance from the pile cap base to the ground level l_0 = 0 m
Excavation depth $h_?$ = 1 m
Connection between pile and pile cap – hinged

Soils

Table 5.2.4.

	Name	Thickness of layer	Soil type	Sand type	Index of liquidity I_L	Specific weight	Unit cohesion	Angle of internal friction	Porosity index
		m				kN/m^3	kPa	degree	
1		1	clayey		0.1	17	5	16	
2		2	clayey		0.1	10	5	18	
3		10	sand	gravelly		10	0.1	35	0.3
4		15	sand	gravelly		10.2	0.1	40	0.2
5		10	sand	gravelly		10	0.1	35	0.3

Results of analysis

Table 5.2.5.

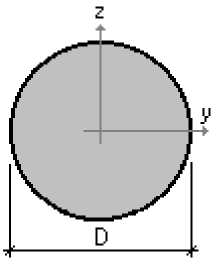
Utilization factor of restrictions on stability of subsoil surrounding a pile	0	
Minimal design bending moment Mz in the pile cross-section (depth 0 m)	0	kN*m
Maximal design bending moment Mz in the pile cross-section (depth 0 m)	0	kN*m
Minimal design shear force Qz in the pile cross-section (depth 0 m)	0	kN
Maximal design shear force Qz in the pile cross-section (depth 0 m)	0	kN
Design longitudinal force in the pile cross-section	3000	kN
Design value of the pile horizontal displacement at the pile cap base level	0	m
Design value of the pile rotation angle at the pile cap base level	0	degree

Settlement of the Pile
Analysis complies with DBN B.2.1-10-2009
Driven piles of all kinds

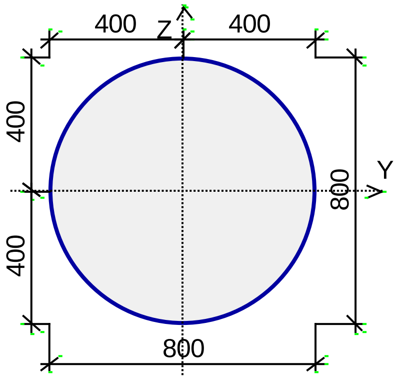
Service factor for the pile in soil $\gamma_c = 1$

Service factor for soil under the pile tip $\gamma_{cR} = 1$

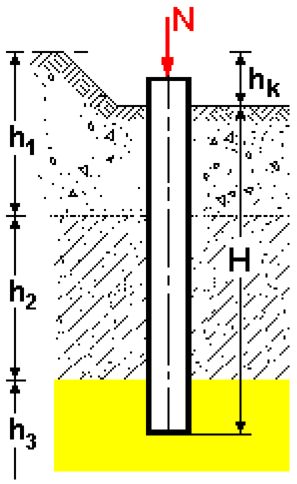
Section



D = 800 mm



Heavy-weight concrete, Class B60



Vertical load transferred to the pile 3000 kN
Depth of penetration of the pile tip, H = 15 m
Excavation depth h_k = 1 m

Soils

Table 5.2.6.

Layer	Name	Thickness of layer	Soil type	Sand type	Index of liquidity	Specific weight	Angle of internal friction	Service factor for soil on the side surface	Porosity index	Modulus of deformation	Poisson's ratio	Color
		m				kN/m^3	degree	□cf		kPa		
1		1	clayey	gravelly	0.1	17	16	1		8500	0.35	
2		2	clayey	gravelly	0.1	10	18	1		16000	0.3	
3		10	sand	gravelly		10	35	1	0.3	16000	0.3	
4		15	sand	gravelly		10.2	40	1	0.2	16000	0.3	
5		10	sand	gravelly		10	35	1	0.3	16000	0.3	

Results of analysis

Table 5.2.7.

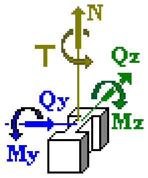
Settlement of the Pile	4.529	mm

Strength of RC Sections

Calculation complies with SNiP 2.03.01-84* (with Ukrainian modifications)

Importance factor $\gamma_n = 1$

Member length 15 m
Effective length factor in the XoY plane 0.7
Effective length factor in the XoZ plane 0.7
Random eccentricity along Z according to SNiP 2.03.01-84* (with Ukrainian modifications)
Random eccentricity along Y according to SNiP 2.03.01-84* (with Ukrainian modifications)
Structure is statically determinate
Limit slenderness - 200



Section

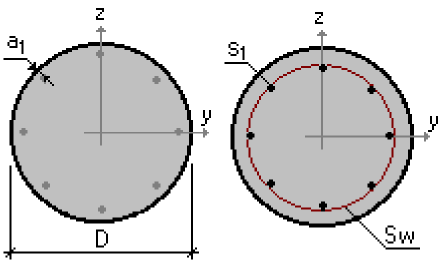
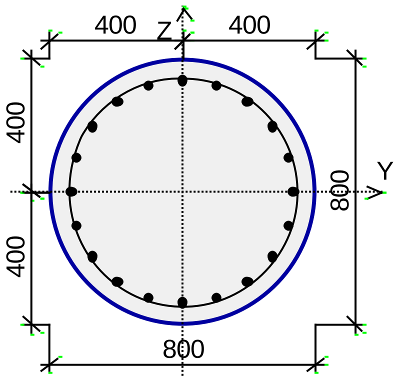
 D = 800 mm a_1 = 50 mm	 S_1 - 20□32 Transverse reinforcement 40□20, spacing of transverce reinforcement 200 mm

Table 5.2.8.

Reinforcement	Class	Service factor
Longitudinal	A-III	1
Transverse	A-I	1

Concrete

Concrete type: Heavy-weight
Concrete grade: B60
Conditions of hardening: Natural
Hardening factor 1

Table 5.2.9.

Service factor for concrete		
□$_{b2}$	allowance for the sustained loads	0.85
	resulting factor without □$_{b2}$	0.9

Results of analysis by load case combinations

Table 5.2.10.

		N	M_y	Q_z	M_z	Q_y	T	Short-term	Seismicity	Special
		kN	kN*m	kN	kN*m	kN	kN*m			
1	Design	-3000	0	0	0	0	0			
	Design long-term	-3000	0	0	0	0	0			

Table 5.2.11.

Checked according to SNiP	**Check**	**Utilization Factor**
Sec. 3.26, 3.28	Strength for the ultimate longitudinal force of the section	0.161
Sec. 3.15-3.20, 3.27-3.28	Ultimate moment strength of the section	0.355
Sec. 3.24, 3.6	Longitudinal force with the deflection taken into account for slenderness L0/i>14	0.086
Sec.5.3	Limit slenderness in XoY plane	0.263
Sec.5.3	Limit slenderness in XoZ plane	0.263

Utilization Factor 0.355 - Ultimate moment strength of the section

Chapter 6

OCCUPATIONAL SAFETY

6.1. Analysis of harmful and dangerous production factors

Welding production includes a large group of technological processes of connection, separation (cutting), surfacing, soldering, spraying, sintering, local processing of materials. These processes are performed using on-site treatment of thermal, thermomechanical or electrical energy. Sanitary and hygienic working conditions during welding are determined mainly by the peculiarity of technological processes performed using different energy sources.

The most common technological processes are:

Thermal class of welding processes. Electric arc welding and electron beam welding.

Thermomechanical class of welding processes. Joining metals by high-temperature heating and plastic deformation of metal This type of welding was the first to be created by man. It was blacksmithing or mining welding. Electric contact welding. its variety is spot welding.

Mechanical class of welding processes. Welding processes belonging to this class are performed without preheating the joining parts. The most common type of this class is cold welding.

6.1.1. Dangerous and harmful production factors during welding according ГОСТ 12.0.003-74:

physical harmful factors:

increased or decreased temperature of surfaces of equipment, materials;

increased noise in the workplace;

increased level of ultrasound;

increased voltage in the electrical circuit, the short circuit of which can occur through the human body;

increased level of static electricity;

increased electric field strength;

increased brightness of light;

increased pulsation of light flux;

sharp edges, burrs and roughness on the surfaces of workpieces, tools and equipment;

the increased dustiness and gassiness of air of a working zone;

chemical harmful factors:

toxic;

annoying;

carcinogenic;

by penetration into the human body through:

respiratory organs;

skin and mucous membranes.

The concentration of harmful substances in the air of the working area is regulated in ГОСТ 12.1.005-88 SSBT "General sanitary and hygienic requirements for air of the working area ”. According to this standard on the degree of action on the body harmful substances are divided into four classes of danger:

1. Extremely dangerous with an MPC less than 0.1 mg / m3 in the air (lethal concentration in air less than 500 mg / m3);

2. Highly dangerous - MPC - 0.1-1.0 mg / m3 (lethal concentration in air 500-5000 mg / m3);

3. Moderately dangerous - MPC - 1.1-10 mg / m3 (lethal concentration in air 5000-50000 mg / m3);

4. Slightly dangerous - MPC> 10 mg / m3 (lethal concentration in the air more than 50,000 mg / m3).

6.2. Measures to reduce the impact of harmful and dangerous production factors

Harmful substances in the form of gases are neutralized, mainly absorption by liquid reagents (absorption) and solids (adsorption). Some gaseous substances are neutralized by combustion (oxidation).

Purification of air from dust (aerosols) is carried out by means of special equipment of different designs depending on the particle sizes dust: coarse cleaning (10 ... 50 μm), medium (more than 1 μm) and fine (less than 1 μm).

Cyclones and dust chambers are used for this purpose, principle whose actions are based on the use of gravity and inertia;
fibrous and bag filters made of natural materials (cotton, linen, wool) and synthetic (polyamide, polypropylene and other fibers);
rotary dust collectors (in the form of radial fans); electrostatic precipitators that capture aerosols by charging their particles in an electric field and

further deposition.

To prevent the risk of electric shock, it is necessary that the power sources have automatic devices that turn them off when the arc breaks for no more than 0.5 s.

In order to reduce the risk of electric shock, the welder should follow the following measures:

reliable insulation of all wires connected to the power supply and welding arc;

a reliable electrode holder device with good insulation, which guarantees that there will be no accidental contact of the current-carrying parts of the electrode holder with the welded product or the welder's hands;

work in serviceable dry overalls and gloves. When working in tight compartments and confined spaces, the use of rubber galoshes and mats, light sources with a voltage of not more than 6-12 V;

To prevent the risk of splashes of molten metal and slag, use overalls (pants, jacket and gloves) made of tarpaulin or special fabric. Jackets should not be worn in trousers when working, and shoes should have a smooth top so that splashes of molten metal do not get inside the clothes, as in this case severe burns are possible.

There is a risk of fires from molten metal and slag in cases where welding is performed on metal covering wood or combustible materials, in wooden scaffolding, near flammable materials, etc.

6.2.1. Calculation of the ventilation network

Calculation of the selected depending on the location of jobs. The configuration of the ventilation network is to determine the pressure loss in the result of air movement, consisting of losses due to air friction (due to roughness of an air duct) and in local support (turns, changes of the areas, sections, filters, heaters, etc.). Total pressure loss is determined by summation pressure losses at individual settlement areas.

To do this, the network is divided into sections (a characteristic feature plots - constant air flow Li along the entire length of the plot). Everyone the plot is assigned a number in the order indicated in the diagram. Next to the room indicate the characteristics of the site air flow Li (m3 /h) and length air duct in the area of l (mm). Indicate the cross-sectional size of the duct di (or Ai5Bi). The scheme determines the longest and most costly branch-chain of sequentially connected sections. Expect total losses in ventilation scheme equal to the sum of pressure losses in the most loaded branches of the scheme and common areas. Based on the allowable air velocities (in conventional ventilation systems speed take 6… 12 m / s in aspiration units to prevent clogging 10… 25 m / s), determine the cross-sectional dimensions of the ducts. Complete pressure loss Hп, Pa:

$$H_{п} = \sum_{i=1} H^{i}_{п} = \sum_{i=1} R^{i}_{тр} l^{i} + \sum_{i=1} Z^{i}_{L} ,$$

Hi п- pressure loss in the i-th section, Pa;

Ri mp- specific friction pressure loss on i-th section, Pa / m;

l i- length i-th section, m;

Z i L- local pressure loss support on the i-th section, Pa:

$$Z_L = (\sum_{i=1}^{n} \xi')H_д = (\sum_{i=1}^{n} \xi)\frac{V^2\gamma}{2g},$$

(Σ ξ) - the sum of the coefficients of local resistance on the i-th section;

Нд – dynamic pressure on the i-th section, Pa;

V - linear velocity of air in the i-th section, m / s;

γ – density of moving air, kg / m3.

The corresponding values of the values included in expressions, find on special tables or nomograms from the special reference literature. To select a fan, first determine its performance Lв (m3 /h) and pressure Нв (Pa). The power of the fan is taken into account suction of air in air ducts Lв = (1,1…1,15) L, L – estimated the amount of air that must be removed by the ventilation network. The pressure is that should be created by the fan, should be equal to pressure losses in ventilation network taking into account 10% of the stock – Нв = 1,1 Нп. On the basis of these data make a choice of the fan on its aerodynamic a characteristic that graphically expresses the relationship between pressure, performance and k.k.d. at certain speeds (P-L characteristic). When choosing fan take into account that its performance is proportional to speed impeller rotation, full pressure - the square of the rotational speed, and power consumption - cube speed. To ensure the required operating mode of the fan installation power electric motor N (kW) for the fan is calculated by the formula:

$$N = k \cdot L \cdot P / (1000\eta_в \cdot \eta_п),$$

k - stock ratio (1.05… 1.15); L- fan capacity, m3/ year;

P - total fan pressure, PA;

$\eta_в$ – fan efficiency;

$\eta_п$ - transfer efficiency from fan to the engine.

6.3. Instruction on labor protection for electric welder manual welding

6.3.1. General labor protection requirements

6.3.1.1. Persons who have reached the age of 18 years, who have passed a mandatory medical examination, induction instruction, initial instruction at the workplace, trained in safe working methods and having an electrical safety group of at least II, are allowed to perform electric welding.

6.3.1.2. The electric welder of manual welding, who is hired, must pass the introductory instruction on labor protection, industrial sanitation, fire safety, methods and ways of providing medical care to victims, be acquainted with the working conditions, rights and benefits for work in harmful and dangerous working conditions. , about the rules of conduct in case of accidents.

6.3.1.3. Before starting work directly at the workplace, the electric welder of manual welding must undergo initial instruction on safe methods of work. Relevant entries shall be made in the Logbook of introductory briefings on labor protection and the Logbook of briefings on labor protection briefings on the conduct of introductory briefings and on-the-job briefings. The signatures of both the instructor and the instructor are required.

6.3.1.4. The electric welder hired, after the initial briefing, must undergo an internship for 2–15 shifts (depending on experience, experience and nature of work) under the guidance of an experienced, qualified manual electric welder, who is appointed by order of the organization.

6.3.1.5. Re-instruction on the rules and techniques of safe operation of the electric welder must be:

- periodically, at least once a quarter;
- with unsatisfactory knowledge of labor protection not later than one month;
- in connection with an injury or violation of labor protection requirements that did not result in injury.

6.3.1.6. The electric welder of manual welding has to work in the overalls and special footwear provided by Typical branch norms: a suit tarpaulin or a suit for the welder, mittens tarpaulin, leather boots. For outdoor work in winter: jackets and cotton pants with insulation, felt boots.

6.3.1.7. Workplaces must be provided with inventory barriers, protective and safety devices, must have sufficient lighting. The illumination of the workplace should be at least 50 lux.

6.3.1.8. The electric welder must keep the workplace in order and clean throughout the working day, not to clutter the passages to it with materials and structures.

6.3.1.9. It is forbidden to carry out external electric welding works on scaffolding during a thunderstorm, ice, fog, at a wind force of 15 m / sec and more.

6.3.1.10. Place the electric welding installation so that free access to it, convenience and safety during work are provided. When using several welding installations at the same time, they must be installed no closer than 350 mm from each other, and the width of the passages between them must be at least 800 mm.

6.3.1.11. Only connect the electric welding unit to the mains by means of a starting device. It is forbidden to supply the welding arc directly from the power and lighting networks. The length of the wires between the supply network and the mobile installation must not exceed 10 m. The cable (wiring) should be placed at a distance of at least 1 m from the oxygen and acetylene pipes.

6.3.1.12. The distance from the place of electric welding to the place of installation of the gas generator, gas cylinders and flammable materials must be not less than 10 m.

6.3.1.13. It is forbidden to store flammable materials and explosives in welding rooms.

6.3.1.14. Indoors and inside tanks, the electric welder must work in the presence of supply and exhaust ventilation. Simultaneous operation of the electric welder and the gas welder (gas cutter) inside the closed capacity or the tank is forbidden.

6.3.1.15. Workplaces when working with several electric welders in one room should be fenced with opaque boards (screens) made of refractory material, at least 1.8 m high.

6.3.1.16. Electric welding work at the height of scaffolding and other lifting equipment is allowed only after checking their strength and stability, as well as after taking measures to prevent ignition of decks, falling molten metal and electrode burns on workers or people passing nearby.
It is forbidden to use random supports.

6.3.1.17. The electric welder, if necessary, should go down in a trench (ditches) on additional ladders, pass through ditches and trenches on transition bridges.

6.3.1.18. The electrode holder must be factory-made, lightweight, provide reliable clamping and quick change of electrodes without touching the live parts and be serviceable.

The handle must be made of insulating dielectric material. It is forbidden to use electrode holders with a supply wire in the holder at a current of 600 A and more, as well as hand tools that have:
- pits, since the working ends;
- burrs and sharp ribs in the places of hand clamping;
- cracks and chips on the back of the head.

6.3.1.19. Do not wipe the parts before welding with petrol or kerosene.

6.3.1.20. Make sure your hands, shoes and clothes are always dry.

6.3.2. Safety requirements before starting work

6.3.2.1. Before starting work, the electric welder must:

- to put on overalls, special footwear, to fasten cuffs of sleeves. The jacket should not be tucked into the pants, and the pants should be released over the shoes;
- get personal protective equipment that must be used for its intended purpose:

electric welder shield - for protection against splashes of molten metal, from the action of electric arc rays;

seat belt - when working at height, inside the tank;

hose gas mask - for work inside closed tanks in the presence of aerosol, gas, dust;

helmet with two- and three-layer helmets - to protect the head from falling objects;

asbestos and tarpaulin oversleeves - for protection against splashes of molten metal during ceiling welding;

goggles with light filter brand "B", "G";

- inspect and tidy the workplace and passages near it, the floor in the workplace must be dry;
- check the insulation of welding wires, make sure that the grounding of the electric welding installation and the reliability of the connection of all contacts;
- make sure that there are no flammable and combustible materials near the welding site.

6.3.2.2. It is forbidden to perform welding work on pressure vessels.

6.3.2.3. Prior to welding, the parts (structures) must be securely fastened.

6.3.2.4. It is forbidden to leave the live electrode holder unattended, as well as to work in case of malfunction of the welding unit, welding wires, electrode holder or helmet-mask (shield).

6.3.3. Safety requirements during work

6.3.3.1. Work in closed tanks must be performed by at least two workers, one of whom must be outside the welding tank to monitor the safe conduct of work by the welder. This worker's qualification group must be at least III for this type of work.

The electric welder working in the middle of the tank must have a safety belt with a rope attached to it, the other end of which is at least 2 m long and must be in the hand of another worker outside the tank.

Portable lighting in the middle of the tank should be no more than 12 V.

When welding in the middle of boilers, tanks, the electric welder, in addition to overalls, is obliged to use dielectric gloves, galoshes, carpets, helmet to protect the head.

6.3.3.2. When carrying out electric welding work at height, the electric welder must use a bag for electrodes and a box for cinders.

It is forbidden to scatter cinders.

6.3.3.3. The welding unit must be connected to the mains via an individual circuit breaker with a wire of the appropriate cross-section in accordance with the operating instructions of the welding units. The distance between the welding unit and the wall must be at least 0.5 m.

Only electricians must connect to the mains and disconnect from it, as well as repair them. Electric welders are not allowed to perform these operations.

6.3.3.4. Work in particularly dangerous areas can be performed only after obtaining an order of admission, if the unit has an electric lock, which provides automatic shutdown of the welding circuit when replacing the electrode, at idle.

6.3.3.5. When ceiling welding it is necessary to use asbestos or tarpaulin oversleeves, when welding non-ferrous metals and alloys containing zinc, copper, lead - respirators with a chemical filter and work only when working local suction.

6.3.3.6. It is forbidden:

- cut and weld metal in a hanging position;
- to carry out welding works from additional ladders.

6.3.3.7. When performing welding work, it is necessary to cover the face with a shield with light filters to protect the eyes and face from the effects of electric arc rays, as well as splashes of molten metal.

6.3.3.8. When carrying out electric welding work directly on the car, the electric welder must first ground the frame or body of the car. If welding is carried out directly near the fuel tank, cover it with a sheet of iron or asbestos from sparks.

6.3.3.9. Before carrying out welding works on the gas-balloon car (gas-diesel) gas it is necessary to let out, and to blow cylinders with inert gas and to inform about it the master.

6.3.3.10. Welding when repairing the fuel tank should be done after treating them with 15-20% caustic soda solution or blowing dry steam, followed by checking the content of hazardous substances in the tank using a gas analyzer. Welding should be carried out with the lids open.

6.3.3.11. The electric welder is forbidden:

- look at yourself and allow others to look at the electric welding arc without goggles, shields;
- work with a shield, glasses that have cracks and crevices;
- work on electrical equipment with bare wires and open live parts;
- sequential connection of several electric welding installations to the grounding conductor.

6.3.3.12. The welding machine must be earthed before it is connected to the mains. Metal parts of welding installations that are not live during operation must be earthed. Above the terminals of welding transformers should be visors and inscriptions: "High side", "Low side".

6.3.3.13. It is forbidden to block accesses and passages to fire-fighting equipment, fire extinguishers and hydrants.

6.3.3.14. Welding installations must be disconnected from the mains while they are moving.

6.3.3.15. It is forbidden to use electric welding wires with damaged braid or insulation. The cores of the welding wires should be connected by crimping, welding, soldering or special clamps (with the obligatory power outage).

6.3.3.16. It is forbidden to use as a return wire the grounding circuit, pipes of sanitary networks (water supply, gas pipeline, etc.), metal constructions of buildings and technological equipment.

6.3.3.17. The no-load voltage of welding current sources must not exceed the maximum values specified in the passport of welding equipment.

6.3.3.18. The electric welder must immediately notify the master of all cases of wire breakage, grounding device malfunctions and other damage to electrical equipment.

6.3.4. Safety requirements after work

6.3.4.1. At the end of the electric welder must:
- disconnect the electric welding installation from power sources;
- turn off ventilation.

6.3.4.2. Arrange the workplace, equipment, tools and devices. Remove the wires and tools in the space provided or hand them over to the pantry.

6.3.4.3. Remove overalls and footwear, clean it of dust and other dirt and put it in a storage place and change clothes. Then wash your face and hands with warm soapy water or take a shower.

6.3.4.4. Notify the master of the completion of work and any problems during the work.

6.3.5. Safety requirements in emergency situations

6.3.5.1. In the event of an emergency, the manual electric welder must turn off the power in the case of:

- fires in the work area;

- injuries that happened to one of the workers;

- electric shock.

6.3.5.2. The electric welder, noticing the fire, must immediately begin to extinguish the fire with available means and notify the administration.

6.3.5.3. To extinguish a fire in an electric welding machine, the electric welder must use a carbon dioxide fire extinguisher, dry sand or coarse cloth.

6.3.5.4. If it is not possible to put out the fire on your own, the electric welder must immediately call the nearest fire brigade by phone or any means of communication.

Chapter 7

ENVIRONMENT PROTECTION

7.1. Analysis of the impact on the environment during the construction of a high-rise office building

At the stage of construction of an office building the following influences are possible:

- air pollution;
- pollution of surface and groundwater;
- violation and contamination of the soil cover;
- removal or damage of flora;
- waste generation;
- impact on the objects of the nature reserve fund and the objects of the historical and cultural heritage;
- impact on the health of construction personnel;
- occurrence of emergency situations;
- violation of traffic organization;
- social influences.

During the construction and installation works with the use of machines and mechanisms, the measures provided for in the Project of Execution of Works are carried out to ensure man-caused and fire safety, air protection, safe working conditions, safe levels of sound and vibration loads and impact on the microclimate from construction machines, vehicles, production equipment, mechanization, devices, equipment, hand machines and tools.

Construction and installation works in territories with limited economic activity (territories and objects of nature reserve fund, protection zones, coastal and forest protection strips, etc.) are carried out in accordance with the documents determining the status of these territories, laws and codes of Ukraine on environmental protection. environment, in compliance with the requirements contained in the comprehensive conclusion of the state investment examination of the project documentation.

On the territory of the objects under construction, the demolition of woody and shrubby vegetation and the backfilling of the soil by the root necks and trunks of growing trees and shrubs is not allowed in accordance with the established procedure.

The demolition of greenery envisaged by the approved documentation is compensated by creation of equal (or larger) and equivalent new plantings in the places determined by the relevant state bodies during the approval of the documentation (in particular, the mentioned compensation is performed during landscaping of the object under construction and its sanitary zone). .

Works related to deforestation and shrubs, changes in the existing water area of water bodies, development of areas of natural meadows and steppes, provide for their gradualness, which allows local fauna to migrate in a timely manner outside the construction site.

It is not allowed to divert surface wastewater from the construction site directly to the terrain, ie without the implementation of engineering measures to prevent the occurrence of foci of man-made soil erosion.

During construction and planning works, the soil cover (fertile soil layer) is removed, transferred and stored for further use during landscaping, land reclamation, etc. (in accordance with current environmental legislation).

Temporary highways and other access roads are arranged taking into account the requirements for the prevention of damage to agricultural lands and woody and shrubby vegetation.

During construction and installation works in residential areas in accordance with the Law of Ukraine "On Protection of Atmospheric Air" measures are taken to prevent dust formation and air pollution. It is forbidden to discharge waste from buildings without the use of closed streams and storage bins.

Construction waste and secondary raw materials in accordance with the Law of Ukraine "On Waste" are exported to their places of storage or waste management facilities, agreed with the local state administration. Waste transportation is carried out in accordance with the rules established by local state administrations or local governments.

In the process of drilling when reaching aquifers Take measures to prevent unorganized discharge of groundwater, their flow to deeper aquifers, as well as the penetration of surface runoff into groundwater aquifers.

When performing works on artificial consolidation of weak soils, measures are taken to prevent pollution of groundwater of lower horizons.

7.1.1. Impact on atmospheric air

Calculations of the amount of pollutant emissions during construction works should be carried out and maximum concentrations of pollutants at the housing boundary should be determined. Maximum concentrations for all pollutants at the border of the nearest residential building during the construction of tram tracks should not exceed the maximum one-time maximum permissible concentrations for settlements.

7.1.2. Noise exposure

During the construction works, noise protection measures aimed at reducing the noise level at the source and technological measures are envisaged.

7.1.3. Impact on water bodies

The project activity will be carried out outside the boundaries of water protection zones and coastal protection strips. Surface water bodies do not fall into the zone of influence of the projected activity. The main negative impact on the aquatic environment during the preparatory and construction works of the planned activities is the additional consumption of water resources to meet the production, drinking and hygienic needs of the construction team. The construction site will provide temporary sewerage - mobile toilets with drainage of domestic wastewater into a metal container. As the metal container accumulates, wastewater is discharged to the nearest treatment plant.

7.1.4. Impact on soil cover and groundwater

Indirect impact on soils at the stage of construction works is the contamination of the territory with dust, emissions from vehicles, fuels and lubricants, garbage.

Soil and groundwater can be contaminated by accidental spills, leaks from any construction equipment, temporary storage of oil and / or fuel, storage of long-term material, such as on construction sites, and other activities related to the use of equipment, including concrete mixing plants. . There is a potential risk of contamination of both soil and groundwater, as well as the risk of soil disturbance, compaction and damage.

7.1.5. Waste

Prior to the start of construction, the general contractor must enter into the necessary agreements with organizations licensed for the further disposal and disposal of hazardous waste. Some materials, such as asbestos, may require on-site treatment, may pose a health hazard to workers if the need for precautions has not been taken and if workers have not been properly informed and trained. If asbestos is found on a construction site, it must be clearly marked as hazardous material. Asbestos should be properly packaged and sealed to minimize exposure. Prior to removal (if necessary), any asbestos will be treated with a wetting agent to minimize asbestos dust. Asbestos should be handled and disposed of by qualified and experienced professionals who will wear all PPE (personal protective equipment) as needed. Any reuse of asbestos-containing waste is prohibited.

7.1.6. Impact on the health of construction personnel

Construction sites are potentially dangerous, and there is a risk that workers or visitors may be injured on construction and dismantling sites if safety and health regulations are not followed. Excessive noise, dust, risk of injury, exposure to sunlight and road safety issues can also become critical issues during construction. The project provides for occupational safety measures defined by current regulations aimed at preventing occupational injuries, reducing the incidence of production and general improvement of working conditions. The construction site is fenced with a 2.0 m high fence. The boundaries of dangerous areas of construction equipment are fenced with protective fences 1.20 m high.

The territory of the construction site, work areas, workplaces, driveways and passages to them are illuminated at night, at the entrance to the construction site the traffic scheme is established, the speed of traffic near the work sites should not exceed 10 km / h on direct sections and 5 km / h on turns. Passages, passages and workplaces must be cleaned, not blocked, and sprinkled with sand in winter. Loading and unloading areas must be planned and have a slope of not more than 5. Prior to the admission to work of employees enrolled in the staff of the organization, as well as when they perform work, managers must provide training and instruction on occupational safety. All people who are in places where there is or may be an industrial hazard (not related to the nature of the work they perform), the responsible contractor must issue a permit in the appropriate form. All people on the site are required to wear safety helmets. All construction workers must be provided with drinking water of the required quality. Workplaces and passages to them at a height of 1.3 m and more and at a distance of less than 2 m from the limit of the difference in height must be fenced with a temporary fence. If it is impossible to install these fences, work at height must be performed using seat belts. The contractor should prepare an Occupational Health and Safety Plan as a guide for safety management.

7.1.7. Road safety

Intensified movement of heavy machinery and trucks to construction and demolition sites can increase the risk of road accidents. The Contractor shall prepare a comprehensive traffic management plan to determine the optimal routes and times for delivery of construction materials, transportation of construction and construction waste to temporary storage or disposal sites; for parking of construction vehicles, etc.

7.1.8. Social impact

Traffic violations cause temporary inconvenience during construction work, impact on the health of construction personnel, the possibility of accidents.

7.2. Measures to reduce (or eliminate) negative impact on the environment during the construction of a high-rise office building

7.2.1. Measures to protect the air and reduce emissions pollutants.

Monitoring compliance with emission standards for pollutants atmosphere is carried out by the enterprise (production control). External control carried out by the relevant state regulatory authorities. Emission control pollutants into the atmosphere involves:

- control of emissions, including: content (mass concentration) and the amount of emissions (mass flow) of pollutants;
- comparison of the amount of emissions and the content of pollutants with the standards maximum allowable emissions and technological standards.

Measures to control emissions of pollutants into the atmosphere air must ensure compliance with the requirements of the Law of Ukraine "On protection of atmospheric air ", branch normative documents. Use of serial technological equipment with internal engines combustion, which has the appropriate certificates on the conditions of emissions of harmful gases.

Introduction of modern equipment and advanced planning solutions that leads to a decrease in energy consumption and air pollution. The need to develop to regulate emissions of pollutants in the period NMU (adverse weather conditions) is agreed with the management of hydrometeorology and environmental control.

7.2.2. Measures aimed at reducing the noise level at the source include:

- use of construction equipment with additional mufflers and special soundproof hoods;
- sealing of the diesel compartment, installation of screens on the openings;
- if possible, use of equipment with electric drives;
- use of modern low-noise technological and energy equipment;
- the use of soundproof walls and partitions in rooms where placed equipment that are sources of noise and vibration;

- ventilation systems and equipment that are sources of noise and vibration, are established on vibration-insulating shock-absorbers, in noise-protected sections.

7.2.3. Landscaping

Measures to ensure proper waste management. Waste collection, storage, transportation and disposal operations should be carried out in compliance with environmental safety standards and legislation Of Ukraine.

All types of waste that will be generated in the process of making a grain dryer complex, subject to removal, accumulation and placement in a special designated areas for further disposal or disposal. In order to avoid possible waste entering the environment provides for complete collection, proper storage and prevention waste destruction and spoilage. Responsibilities of the person to be appointed responsible in the field of waste management at the enterprise will include monitoring of laces waste storage and primary current accounting of quantity, type and composition waste generated, collected, stored and sent for disposal.

7.2.4. Protection of geological and aquatic environments, soils.

Sewage is supposed to be diverted by a network of self-flowing sewerage to septic tank with subsequent discharge to the filter well. Rainwater drainage is not designed. Drainage of rain and melt water is provided vertical planning.

7.2.5. Measures to reduce negative impact on the environment from wastes, during the construction of a high-rise office building.

Prior to construction, the general contractor must enter into the necessary agreements with organizations licensed for further disposal and utilization of hazardous waste (Law of Ukraine "On Waste" №187 / 98-VR, Law of Ukraine "On withdrawal from circulation, processing, disposal, destruction or further use of low-quality and dangerous products "№ 1393-14).

Scrap metal is transferred for processing to specialized enterprises that carry out operations with scrap metal, own or assigned to enterprises on the right of economic management of weight, scrap processing and lifting equipment, provide fire, explosive, environmental and radiation safety (Law of Ukraine "On Metal »№ 619-14).

Transportation of waste generated during the construction works will be carried out by a specialized enterprise according to the agreed transport schemes. Prior to the start of construction, the general contracting construction organization must enter into the necessary contract for the removal of waste to its location, disposal, processing and disposal. Transportation of generated waste will be carried out on specially equipped transport (Law of Ukraine "On Transportation of Dangerous Goods" № 1644-14).

Liquid household waste should be taken out under the contract which will be concluded by the contracting construction organization - to drain stations by means of the sewage machine. Municipal solid waste should be taken to landfills (advanced landfills), composting fields, processing and incineration plants with a specialized vehicle. Industrial, non-utilized waste is transported by transport to special landfills or facilities for industrial waste.

The equipment to be dismantled is exported and stored on the territory of certain distances and organizations of the balance holder. The possibility of further use of the equipment is solved comprehensively with representatives of these industries.

Some materials, such as asbestos, may require on-site treatment, may pose a health hazard to workers if the need for precautions has not been taken and if workers have not been properly informed and trained.

If asbestos is found on a construction site, it must be clearly marked as hazardous material. Asbestos should be properly packaged and sealed to minimize exposure. Prior to removal (if necessary), any asbestos will be treated with a wetting agent to minimize asbestos dust.

7.3. Conclusion

During the preparatory and construction works for the construction of the facility, measures must be taken to protect the environment during construction, provided for in the Project of works execution materials as part of the project documentation.

Construction and installation works on the construction of the facility are carried out in compliance with the requirements of current legislation on the protection and preservation of the natural environment, ensuring the sanitary and epidemiological well-being of the population and the safety of adjacent man-made objects. Permissible levels of noise, vibration, infrasound and low-frequency noise in residential and civil buildings and in the area adjacent to the construction site must comply with applicable regulations.

In Ukraine, access to environmental information was ensured by the ratification in 1999 by the Verkhovna Rada of Ukraine of the «Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters. The Ministry of Environment has developed a number of regulations to implement the provisions of this convention.»

Any person and / or organization may request the necessary information from public authorities by sending an official letter to the responsible public authority. According to the Law of Ukraine "On Access to Public Information" of 13.01.2011 for №2939-VI, the state body is responsible for providing the necessary information within 5 days. If the information is related to human life and health, food quality, disaster or emergency, the public authority must provide the necessary information to the public within 48 hours. If the required information is comprehensive and additional data is required, the public authority may extend the period of preparation of this information to 20 days and notify the person or organization of this extension in writing.

CONCLUSION

During design of this project, according to the design task –steel was used as a main building material, building with very complicated form was designed from different steel transversal frames.

Important fact of project is that there is no braces inside the building, all braces are located on perimeter and was chosen rigid connection of main beam with the column, which provides stability of the frame.

The structure was designed to withstand progressive collapse, as an sample one column of the first floor was deleted, and the structure didn’t lose its stability. After that it was investigated the influence of numerical stiffness of nodes on bearing capacity of steel members of a high-rise building in case of emergency situation.

In conclusion it can be said that that during calculation of building of high Class of Consequences (CC3) it should be done the check of influence of numerical stiffness of nodes on bearing capacity of structural members, as it can increase bending moments in elements.

Drawwings

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