CZECH TECHNICAL UNIVERSITY IN PRAGUE
Faculty of civil engineering
Department of steel structures

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BACHELOR THESIS

Design of single story curved spatial building

Jean Philippe Cam

Study program: Stavební inženýrství

Field of study: Konstrukce a dopravní stavby

Supervisor of bachelor Thesis: Ing. Jiří Mareš, PhD

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: Cam Jméno: Jean Philippe Osobní číslo: 437027

Zadávající katedra: K134

Studijní program: Stavební inženýrství

Studijní obor: 3647R013

II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce: Konstrukce prostorové obloukové jednopodlažní haly

Název bakalářské práce anglicky: Design of single storey curved spatial building

Pokyny pro vypracování:
Navrhněte prostorovou halu ze zaskružených nosníků uspořádaných do prostorové konstrukce. Konstrukce střechy bude uložena na čtyřech rohových sloupech. Proveďte studii nad různými variantami konstrukčního uspořádání. Na vybrané variantě stanovte zatížení, zpracujte prostorový výpočetní model a určete dimenze prvků a spojů. Zpracujte výkresovou dokumentaci hlavních prvků.

Seznam doporučené literatury:

[1] Bittnar, Z., Jirásek, M., Konvalinka, P.: Statika stavebních konstrukcí II, ES ČVUT, Praha 1996
[2] Jirásek, M., Konvalinka, P.: Statika stavebních konstrukcí I, ES ČVUT, Praha 1990
[3] Studnička, Holický, Ocelové konstrukce 20, Zatížení staveb podle Eurokodu, ES ČVUT, Praha 2005
[4] Eliášová, Sokol, Ocelové konstrukce 1, Příklady ES ČVUT, Praha 2014

Jméno vedoucího bakalářské práce: Ing. Jiří Mareš, PhD

Datum zadání bakalářské práce: 16.2.2019 Termín odevzdání bakalářské práce: 26.5.2019

Údaj uveďte v souladu s datem v časovém plánu příslušného ak. roku

Podpis vedoucího práce Podpis vedoucího katedry

III. PŘEVZETÍ ZADÁNÍ

Beru na vědomí, že jsem povinen vypracovat bakalářskou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je nutné uvést v bakalářské práci a při citování postupovat v souladu s metodickou příručkou ČVUT „Jak psát vysokoškolské závěrečné práce" a metodickým pokynem ČVUT „O dodržování etických principů při přípravě vysokoškolských závěrečných prací".

18.2.2019

Datum převzetí zadání Podpis studenta(ky)

AUTHOR'S DECLARATION:

I Declare that I have wrote this bachelor thesis independently, except for provided consultations. All Documents I used to write this work are duly cited and listed in the list of *cited literature in accordance with Guideline n. 1/2009*

In Prague 25.05.2019

....
Jean Philippe Cam

Special thanks:

I would like to give special thanks to the supervisor of this bachelor thesis, Ing. Jiří Mareš, PhD. For his advices and consultations during the making of this thesis.

I would also like to thank my dearly departed grandmother, for the sacrifices she has made to support me in my studies. I would not be where I am now if she would not have been there for me when I needed it the most.

Abstract:

This bachelor thesis deals with the design study, design and structural analysis of a roof structure using curved castellated beams. The structure is a 30m x 30m object in Liberec and is built on four pillars.

This thesis consists of three parts: A design study of possible designs to build this type of structure, Design and structural analysis of the structure, and project documentation.

Keywords

Castellated beam, curved beam, curved castellated beam, arched hall, large span roof, spherical roof system

List of used literature:

Norms:

[1] ČSN EN 1993-1-1-3: Navrhování ocelových konstrukcí.
Český normalizační úřad, 2006

[2] ČSN EN 1991-1-1-3: Zatížení konstrukcí– zatížení sněhem.
Český normalizační ústav, 2003

[3] ČSN EN 1991-1-1-3: Obecná zatížení – zatížení větrem.
Český normalizační ústav, 2007

Books:

[4] Ocelové konstrukce, Normy – Prof. Ing. Studnička, DrSc.

[5] Ocelové konstrukce, Příklady – Martina Eliášová, Zdeněk Sokol

[6] Betonové a zděné konstrukce 1 – Ing Hana Hanzlová CSc., Ing Jiří Šmejkal CSc.

Introduction:

The subject of this thesis is the creation of a new large span roof system for halls. This system consists of a grid of curved castellated beam, anchored into side beams, that rest on 4 pillars.

The work consists of 3 parts: A design study, design and structural analysis of a 30m x 30m structure, and project documentation.

The goal of this work is to create an adaptable and modular support system for medium and large span halls, design and structural analysis of a structure of this type to prove feasibility, and project documentation.

The structural system will be assessed for ultimate limit state in accordance with applicable European standards.

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BACHELOR THESIS

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A: Design study

Jean Philippe Cam

Design philosophy:

Before I can start my design study, it is important to stop, and think about a very important question. That question is: What is my goal, and how can I best achieve it?

Formally speaking the goal of this work is to make a 30m x 30m roof structure using curved beams. However, the idea behind this is to make an entire system that can be used for various geometries, climactic conditions, and uses.

In an ideal work, I could make a system that could work everywhere and for any size. However, that is easier said than done. The most realistic way this goal is to make a modular and adaptable system, consisting of multiple interchangeable parts, that can be used depending on the circumstances.

In short, my goals are:

- Feasibility
  - Feasibility of design
  - Feasibility of construction
- Adaptability
  - Adaptability to various geometry
  - Adaptability to various climatic conditions
  - Adaptability to various uses
- Simplicity
  - Simplicity of design
  - Simplicity of assembly
- Standardization
  - Standardization of design
  - Standardization of calculation and analysis
  - Standardization of construction
- Minimalization of costs
  - Design costs
  - Material costs
  - Labor costs
- Elegance
  - From an engineering perspective
  - From an aesthetic perspective

○

Structure geometry:

The geometry of the structure is crucial for its function. It is necessary to make a structure that is statically sound, simple of assembly and aesthetically pleasing.

Radius:

Before I start designing the larger geometry it is necessary to choose a radius for the curvature of the beams. It is my belief that choosing a single radius for every component would lead to much simpler manufacturing of the components. However, due to my goal of designing an adaptable and multipurpose system, it is necessary to either choose a radius that is reasonable to use for multiple construction sizes, or use a set of radii, with the possibility of choosing a radius depending on the geometry of the construction.

My construction being 30x30m, I have chosen a radius of 50m. This radius gives us an elevation of 2.303m at the center of the side beam, and an elevation of 4.723m at the middle of the structure.

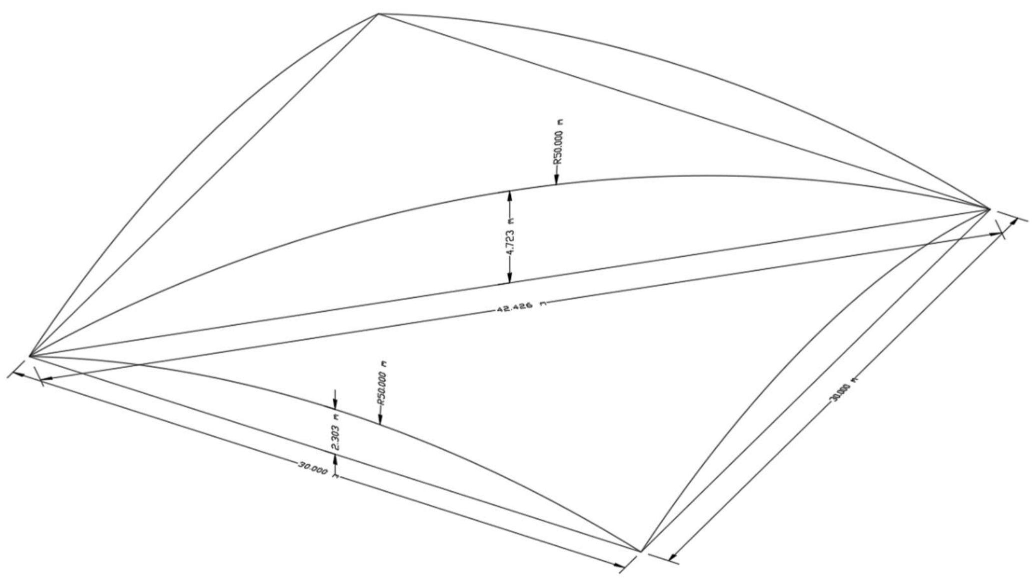


Figure 1: Axial elevation of curved beams

Overview of basic structural assemblies:

The next step of my work is designing what I call the macro-geometry, meaning the spatial configuration of the main construction assemblies. Before I can even start doing that, I must define what the main construction assemblies are.

Pillar assembly:

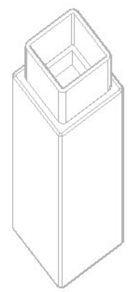


Figure 2: Example of a pillar assembly

Anchored to the ground, the function of this assembly is evident: its primary function is to transfer the load from the roof structure into the ground. Its secondary function is to assist in preventing sideway deformation of the side beam assembly. The pillar assembly can be made of a single pillar component, or in multiple components.

Side beam assembly (primary beam) :

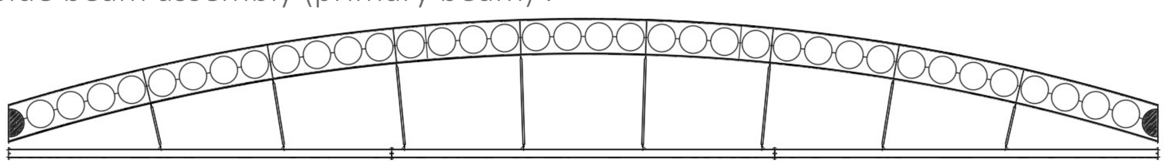


Figure 3: Example of a side beam assembly

The side beam assembly is anchored into the pillars. It transfers the load from the central beam assembly into the pillar assemblies. Due to the large number of central beam assemblies (secondary beams) anchored into it, it must sustain a high load. The assembly can be made of one beam, but it can also contain a tension rod to increase load bearing capability.

Grid beam assembly (secondary beam):

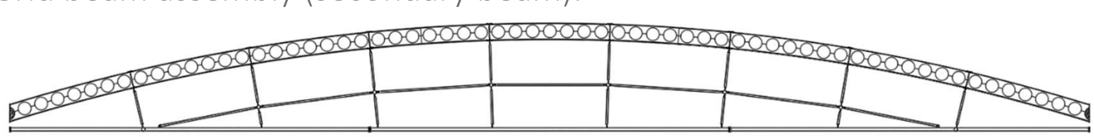


Figure 4: Example of a central beam assembly

The grid beam assembly is anchored into the side beam assembly. It transfers the load from the roof into the side beam assembly, it can be made of a single beam, but can also incorporate a tension rod, and struts to ensure stability of the tension rod in case of compression.

Spatial configuration of assemblies:

Now that I have defined the basic components, the next step is to choose a spatial configuration. I have identified 2 possible configurations.

Assembly configuration A: Parallel assembly configuration

Assembly configuration A consists of parallel primary beams that are each anchored into the secondary beam. Each assembly would be at a different height.

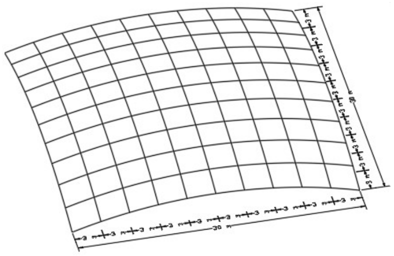


Figure 6: 3D view of parallel assembly configuration

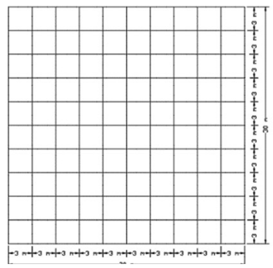


Figure 7: Top view of parallel assembly configuration

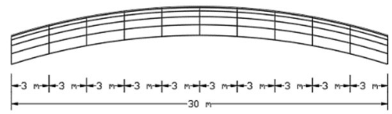


Figure 5: Side view of parallel assembly configuration

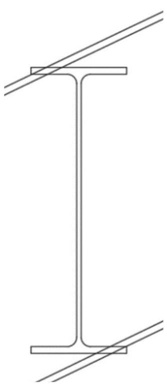


Figure 8: Parallel assembly configuration grid joint

While this configuration is geometrically simple and easy to grasp, it leads to very complicated joints at the meeting points of the secondary beams. This configuration offers 2 possibilities to connect the grid assemblies: A shear connection using screws, or a weld. Both are inadequate.

A shear connection would transfer torque at the joints, leading to a construction that is stiff in one direction, but not in the other. This would remove the point of having a construction being bidirectional and make the premise of my design redundant. A moment connection is required for the design to work.

A weld would transfer torque but would have to be welded multiple meters above ground, a quite laborious process. While this is possible and perfectly feasible, Side welding would be required. This solution, while feasible, would be slow and expensive, and will have inherited limitations due to demands placed on the process of site welding

Assembly configuration B: Radial assembly configuration

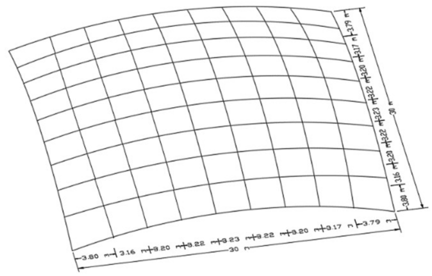


Figure 11: 3D view of radial beam configuration

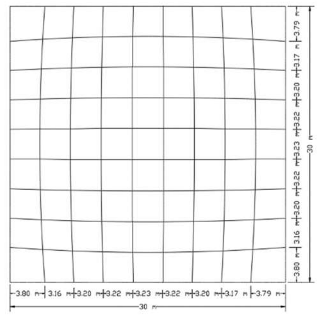


Figure 10: Top view of radial assembly configuration

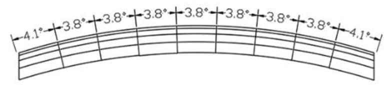


Figure 9: Side view of radial beam configuration

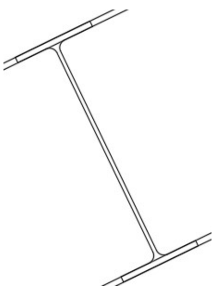


Figure 12: Radial assembly configuration grid joint

Assembly configuration B would entail having radially rotated secondary beams, with beams in both directions being rotated along a single point. This would create a bidirectionally curved surface with a radius of 50m in both directions.

This continuous surface would allow relatively simple joints on the connections between the different secondary beams, meaning it would be possible to use screwed joints, greatly reducing labor, and thus, cost.

The disadvantage of this solution is increased complexity, it would also mean that every secondary beam is of different axial length, meaning that each beam section would need to have different castellation parameters. Configuration A does not have this problem.

Chosen configuration:

Due to the reasons stated above, it is obvious that the correct choice is the radial assembly configuration. Its greater complexity is offset by the simplicity of its joints.

Assembly design:

Now that I have chosen the assembly configuration, I can use this parameter to influence the geometry and design of the assemblies themselves. Each assembly has multiple possible designs, depending on environmental loads, method of construction, cost of material vs cost of labor, design philosophy, and aesthetic preferences.

Pillar assembly:

Possibilities of geometry:

The pillar assembly is by far the simplest of all assemblies in this construction and is very straightforward. Despite this however, there are still multiple options to choose from and deliberations to be made. The First deliberation to be made regards the possibility of having the assembly be made of either a single, or multiple components.

Single component pillar assembly:

A single component pillar assembly is the most straightforward option possible. It would entail having a single pillar connected to the foundation at the bottom, and to the side beam assembly at the top.

Multiple component pillar assembly:

A multiple component pillar assembly would entail exactly what it sounds like. The assembly would be made from multiple components that would have to be jointed to each other during construction.

This assembly has multiple advantages that the more traditional single component pillar assembly does not have. These advantages are:

- It permits the use of different materials for construction
  (for instance a concrete pillar with a rectangular hollow section on top for easy joint construction)
- It permits on the ground assembly of the roof structure, and subsequent lifting of the structure in position.
  (this topic will be discussed later in this work)

Loads:

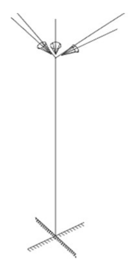


Figure 13: Diagram of forces acting on the pillar

The pillars will be under high loads, these loads can be separated into two categories:

- Axial forces:

Due to the small number of pillars relative to the size of the structure, the pillar assemblies will be under significant axial load.

- Shear and moment forces:

Due to their nature, arches are under significant compression, and the structures they are anchored to must also transfer this load. These loads will manifest themselves as shear and moment loads.

Possible materials and cross sections:

Reinforced concrete pillar:

A reinforced concrete pillar would be a very cost-effective solution. RC supports compressive loads very well, and with enough reinforcement, can also support considerable Moment and shear loads.

Using a concrete pillar has also some negative aspects. Concrete takes a long time to cure and requires complicated form work to be poured. This problem is easily remedied if it is prefabricated and shipped to the construction site as a finished component.

Another negative aspect of using a concrete pillar is the difficulty of connecting the side beam assembly with the pillar, particularly if precast concrete is used. This is remedied by using a multiple component pillar assembly, with a steel section serving as the top of the assembly.

Steel hollow section with concrete fill

Another good solution is to use a hollow steel section with concrete fill. The concrete fill will increase the load bearing capability of the pillar and ensure its stability under buckling.

Using a concrete filled steel pillar has the advantage of allowing for easy joints between the pillar assembly and the side beam assembly.

It also has the advantage of permitting a faster construction of the structure. If designed properly, it is possible to start construction of the roof structure before the concrete has finished curing, using the load bearing capability of the steel part of the pillar to support the weight of the roof structure.

The steel section is also notably lighter than a prefab concrete pillar, making assembly easier.

These positive aspects are however negated by the additional cost of steel, which is more expensive than concrete.

Steel hollow section:

It is possible to use a hollow section to support the roof structure, however, due to the threat of buckling, it is only possible to have short pillars. Despite this massive drawback, using a non-fill concrete section is advantageous for the top part of a multi part pillar assembly. Such a solution allows for easy joints with the side beam assembly.

Additionally, it is also possible to connect the steel hollow section with a concrete pillar (or concrete filled steel pillar) using a steel anchor bolt. These bolts are traditionally used for anchoring steel structures into foundations, but it is perfectly usable for this purpose, if a bit unorthodox.

Also noteworthy is the possibility of using this option for construction and fill the hollow section with concrete afterwards to increase fire safety.

Side beam assembly:

Possibilities of geometry:

The side beam assembly is the most demanding assembly from a statics and stiffness point of view. While it does not transfer as much load as the pillar assembly, it must resist bending moments in all 3 directions. It is also of high importance to limit sideways deformation of the assembly, to ensure the arch effect in the grid beam assembly.

To ensure this, the assembly must have a high load bearing capability and lateral stiffness. There are multiple possibilities that ensure this.

Simple curved beam:

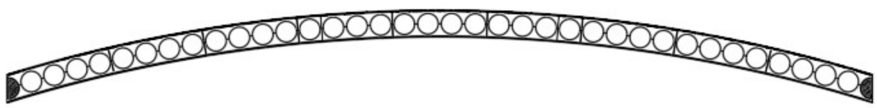


Figure 14: Simple curved beam

A simple curved beam provides the simplest possible solution from a geometry standpoint, and requires very few joints, meaning that the cost of construction is lower.

However, the lack of a tension rod will allow the pillar assembly to deform sideways, greatly lowering the sideways reaction forces. The lack of these forces would lower the arch effect, decreasing the compression forces at the cost of greatly increased moment forces. In a worst-case scenario, where no there is no sideways reaction forces, the beam would receive as much moment forces as a linear beam, completely negating of designing a curved beam.

These problems can be mitigated by having very stiff supports. Either by shortening pillars, having thick pillars, by adding some diagonal component specifically for this task (creating a truss effect), or by anchoring the pillar into an adjacent construction. This would have to be made in all pillars to be effective.

This option is most practical for small structure with short pillars and low loads.

Curved beam with tension rod:

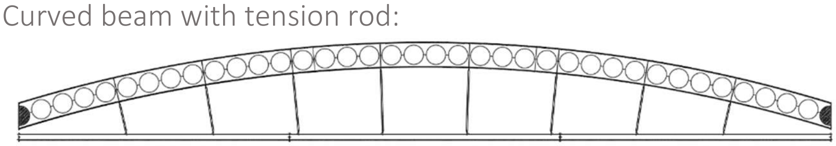


Figure 15: Curved beam with tension rod

A curved beam with a tension rod ensures that the supports of the side beam assembly do not deform sideways, allowing the arches to transfer compressive forces and make full use of the arch effect. Such an assembly would be able to make use of that effect to resist high loads.

The tension rods must be supported by support rods. Regular supporting of the tension rod will prevent exceeding bending moments, allowing for a more effective design. These support rods could also act as braces, preventing vertical buckling of the beam. They can also be used to regulate sideways buckling, depending on their configuration.

The supports can be anchored in the beam at regular intervals, but their best position is in underneath the joints with the grid beam assembly. This would allow the beam to be anchored right underneath the bracing of the joint. This will be discussed in detail in the chapter about micro-geometry.

Truss:

It is also possible to use a truss to transfer loads, but that goes outside of the boundaries of this work, so I shall not elaborate on it.

Loads:

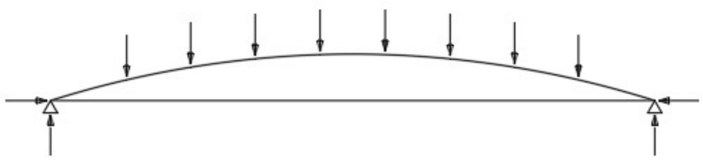


Figure 16: Diagram of forces acting on the side beam assembly

The side beam assembly (primary beam) is heavily loaded by all the grid beam assemblies that connect into it. There are multiple forces acting on the assembly, all of them depend on multiple factors. These forces are:

- Forces acting on the beam:
  - Vertical forces:
    Will translate into:
    - Compressive forces (depending on tension rod and/or supports)
    - Moment forces on Y axis (depending on tension rod and/or supports)
    - Shear forces on Z axis
    - Tension forces (can be expected in certain wind combinations)
  - Lateral forces: Will only be present if the grid beam assemblies do not feature tension rods. Will translate into:
    - Moment forces on Z axis
    - Shear forces on Y axis
    - Torsional moment (due to eccentricity of the grid beam)
- Forces acting on the tension rod (if one is present)
  - Tension forces
  - Compressive forces (can be expected in certain wind combinations)

Possible beam cross sections:

Castellated I beam:

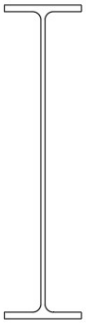


Figure 17: Castellated I beam

A castellated I beam is the simplest solution. It has high load bearing capability for moment in the Y axis and can transfer moderate amount of compressive forces, making it useful in case there is low arch effect (such as a beam assembly with no tension rod)

It however offers low torsional stability, and load bearing capability for moment in the Z axis, which means it is also vulnerable to buckling.

This solution is practical for small constructions, or construction with a low load. It is also perfectly usable for the secondary beams, which are significantly less loaded than the primary beams.

Welded double I beam:

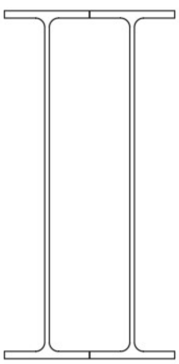


Figure 18: Double castellated I beam

A welded double I beam consists of 2 castellated I beams, side by side, that are welded together at the flanges, creating a castellated box girder with an II shape.

It offers high torsional stability thanks to its box girder nature, despite the castellation, and it is also very stiff against moment in the Z axis. This increased stiffness is also great against buckling, making it great in the case where there is high arch effect (such as a beam assembly with tension rod)

It is also noteworthy that its high lateral stability allows grid beams connected to it to have a certain amount of arch effect, even if they do not have a tension rod.

This solution is practical for mid-size and larger construction. Its larger size makes it inadequate for use in the grid beam assembly, where high lateral stability is not as important.

Built up cross section:

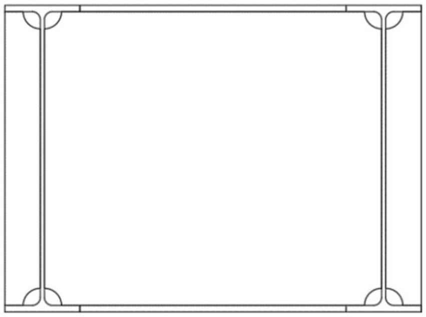


Figure 21: Built up cross section

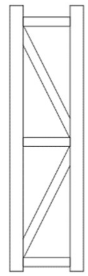


Figure 19: Truss setup

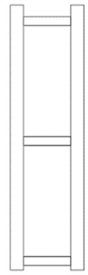


Figure 20: Box setup

A built-up cross section consists of 2 castellated I beam set at distance from each other, and connected by the bracing of the beam, which extends from one beam to the other. This offers enormous stiffness against bending moment in the Z direction, and outstanding torsional stability.

This stability would ensure very low lateral deformation of the beam, even under heavy load. This would in turn permit the beam to support the high lateral reaction forces necessary for the arch effect of the grid beams. This would allow the grid (primary) beams to be used without tension rods, and would lead to enormous simplification in detailing

Composite double beam with concrete fill

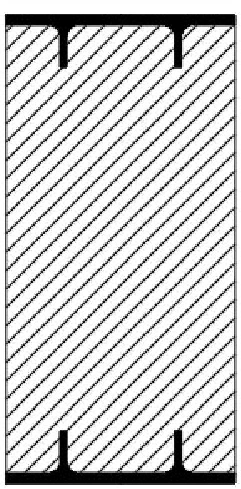


Figure 22: Composite double beam with concrete fill

One of the more unconventional ideas I had would be to use a composite beam composed of a welded double beam that would be filled with concrete to increase load bearing capability and stiffness. The additional material would high a very high moment of inertia, making the beam extremely stiff, at the cost of high weight. It would also be excellent at transferring compression forces, which are present in the side beam assembly in high amounts.

For assembly the double beam can be welded with joint plates at the ends (serving as side shuttering), reinforcement inserted inside, placed on its side on a wooden plank (which would serve as bottom shuttering), and pour the concrete from the top. The opening (from castellation) mean that concrete can be easily poured in.

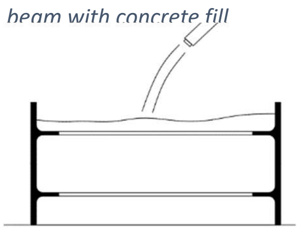


Figure 23: Concrete pouring of composite beam

This option would be very heavy but offer a very stiff component for relatively little work (the work on shuttering would be minimal, as described above). This could be useful for single beam grid beam assemblies.

Possible tension rod cross sections:

Tubular tension rod with a single support rod:

Figure 24: Tubular tension rod with single support rod

A tubular tension rod with a single support rod is the simplest tension rod possible. It is supported by support rods in order to not have too much moment due to its own weight. These tension rods may be discarded if the distance is short enough.

This setup is viable for tension forces, however, if there are combination in which compression forces are present, this setup is not viable. That is due to the lack of lateral stability. The tension rods only offering vertical stability. This means there will be lateral buckling under compression.

Tubular tension rod with V support rods:

Figure 25: Tubular tension rod with V support rods

A possible solution to this is to set up the tension rods In V configuration, this allows the tension rods to offer lateral stability.

This is only possible however, if the beam has a certain width. Making it only possible if the beam consists of a double I beam or a built-up cross section.

Even then, due to the difference in height between the tension rod and the beam being variable changing, the tension rod receives more bracing against lateral buckling at its sides, than at its top.

For this reason, the tubular tension rod with V support rods is more suited for medium size constructions with a small amount of compressive force in the tension rod.

Built up cross section:

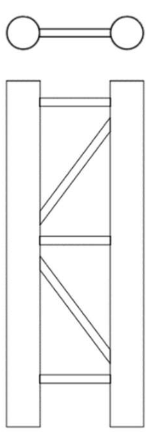


Figure 26: Built up cross section

A built-up cross section, either using a box or truss setup, is a very good solution to the problem of lateral buckling.

It has high moment of inertia in the Z direction, giving a high resistance against lateral buckling.

Furthermore, thanks to the fact that it does not require braces against lateral buckling, it only requires bracing against vertical buckling, which is provided by the support rods.

This solution Is attractive for large constructions, in cases where there are high compressive forces in the tension rod, or where large height difference makes V supports impractical.

Grid beam assembly:

Possibilities of geometry:

Simple curved beam:

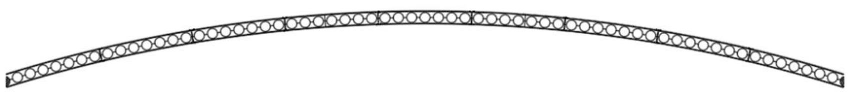


Figure 27: Simple curved beam

Using a curved beam is, once again, the simplest, and cheapest way to build. However, once again, the lack of a tension rod means that the beam will have to rely on the stiffness of the side beam assembly to retain the arch effect.

This means that the stiffer the side beam assembly is, the more pronounced the arch effect in the grid beam assembly gets. Therefore, this option is most effective when using a double beam side beam assembly, or a built-up cross section side beam assembly.

It is also of note that the longer the side beam assembly is, the less stiff it is. For this reason, this option is best used for small to medium sized roof structures.

Curved beam with tension rod:

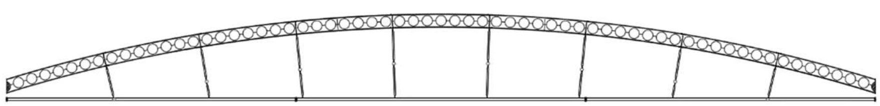


Figure 28: Curved beam with tension rod

A curved beam with tension rods ensures the supports of the beam do not deform sideways, ensuring the arch effect in the beam. This allows to use the full arch effect, even if the side beam it is anchored in is malleable, such as a single beam side beam assembly.

One quirk of this option is that the tension rods are going to be intersecting the tension rods of the perpendicular grid beam assemblies, unless they are present in only one direction. However, since the grid beam assemblies are anchored at different heights, the tension rods will also be at different heights. Only tension rods anchored at the same radial angle will be intersecting.

The tension rods need to be supported, to prevent exceeding bending moment due to self-weight. For this reason, it is necessary to use support rods. The best positioning of these rods is at the intersection between the planes on which the grid beam assemblies are placed. This position has the particularity that both tension rods and the beam joint are aligned.

This option has no bracing against lateral buckling, meaning it is not usable if there is a load combination in which there are compressive forces in the tension rods.

Curved beam with tension rod and braces:

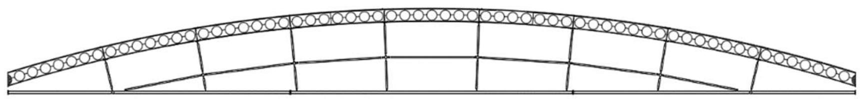


Figure 29: Curved beam with tension rods and braces.
On this image the braces of the perpendicular assemblies are visible.

In case there is a load combination that would result in compression in the tension rods, it is necessary to add braces to the tension rod grid. The most effective way to brace the tension rods is to anchor the bracing into the perpendicular tension rods. The brace will then travel into all the parallel tension rods, which are naturally at different height, creating a circular shape.

This option is the only way to use tension rods if there is a force combination that would result in them being compressed.

Loads:

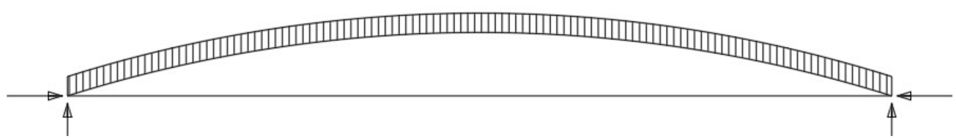


Figure 30: Diagram of forces acting on the grid beam assembly

The grid beam assembly receives relatively little load, but that load is spread over a wide area, meaning that the internal forces will still be high. These forces are:

- Forces acting on the beam:
  - Vertical forces:
    Will translate into:
    - Compressive forces (depending on tension rod and/or supports)
    - Moment forces on Y axis (depending on tension rod and/or supports)
    - Shear forces on Z axis
    - Tension forces (can be expected in certain wind combinations)
- Forces acting on the tension rod (if one is present)
  - Tension forces
  - Compressive forces (can be expected in certain wind combinations)

Possible beam cross sections:

Castellated I beam:

A castellated I beam is the simplest, but also one of the most effective options there is. It is light, can carry a high moment load and a respectable amount of compressive force. It does not need to achieve any more than this. I believe it is the only option.

Possible tension rod cross sections:

Rod cross section:

A rod is great for transferring tension forces, it can withstand a lot of tension, and is very small compared to a tube. It would not perform when subject to moment and buckling, it is perfectly usable unless there is a force combination that would expose it to compressive forces.

Tube cross section:

A tube has the advantage of being great against compressive forces, it can withstand a lot of buckling, and is therefore very practical if the tension rods are to be exposed to compressive forces.

Construction of structure:

One of the factors that will most influence the choice of assembly components and joints is going to be the method of construction, there are two main construction methods for this type of structure. These construction methods are:

In-position construction

Method of assembly:

In position construction involves assembling each component in its final place using a small crane and making all the joint work there. While this method does not require a large and expensive crane, and relatively few laborers need to be present at each step of the construction process, this solution has severe drawbacks.

Since every bit of work done on the construction would be done multiple meters in the air, this would require some sort of way to lift the laborers, such as a scissor lift. Health and safety requirements will have to be strictly followed, and modern safety methods, such as safety nets will have to be used.

Despite these drawbacks, this method has its merits, it is the conventional method for assembling steel structures.

On-the-ground construction

Method of assembly:

On the ground construction involves constructing the entire roof structure on the ground, supported by the top part of the pillar assembly (which needs to be a 2-part pillar assembly). The top part of the pillar assembly, on which the entire roof structure rests, are placed on pads to spread the load and not damage the ground.

This allows the entire construction to be built on the ground. A crane is still required to lift the component to their position, but it allows laborers to easily access the structure. Ladders and scaffolding will be necessary to access the upper parts of the structure, but the safety risk will be much lower.

After completion, the entire structure would be lifted using two cranes. Ideally these cranes would be mobile cranes, which would be called to the worksite, lift the structure, and leave at the end of the day.

Due to the need to lift the entire roof structure, any structure assembled using on-the-ground construction needs to be optimized to save weight. For this reason, it is often more profitable to design a lighter, more complex structure, than a heavy simple one. This does go against the design philosophy of simplicity, but it does save costs.

Connection of roof structure with pillars

Joint using a Steel anchor bolt

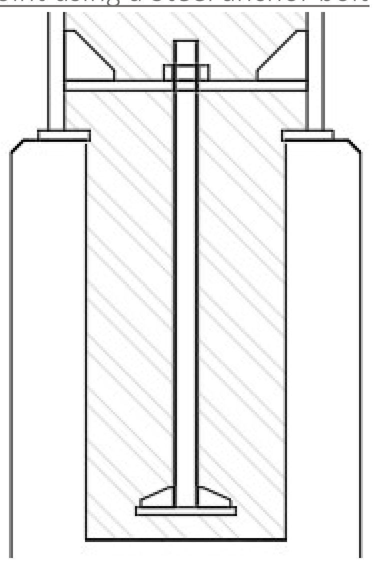


Figure 31: Joint using a steel anchor bolt

In the case a multi part pillar assembly is chosen, with a concrete or composite component at the base, and a steel component at the top, it is possible to use a foundation anchor bolt to connect the two components.

One requirement of this design is to have a hole on the top of the pillar, this hole is where the anchor bolt will be placed and will be poured over with concrete. This design results in an articulated joint.

The greatest advantage of this design is that it offers high tolerances for imperfect placement, making it a great solution for on the ground construction.

Before being lifted by crane, the anchor should ideally be stored inside the steel hollow section. This would allow the structure to rest on the steel hollow section.

Joint using a baseplate

A baseplate is the simplest way to connect the two components and has the advantage of permitting the transfer of moment loads. However, baseplates have low tolerances. This means that on the ground assembly of the roof structure will be next to impossible due to the difficulty of meeting those tolerances during the lifting of the roof into position.

Required Lifting technology:

This construction requires mobile cranes with medium to high load capacity. The roof structure designed in part B weighs approximately 65 tons. Due to the size of the structure, attaching the crane cable at the middle of the structure would result in a lever arm of 20 meters or more. Such a lever arm would require a crane with a lifting ability of more than 1300 Ton-meters.

A more practical solution is to use two smaller mobile cranes, and to lift the structure by its sides. The structure would be built at a rotated angle, and then simply rotated into position. The lateral movement required for this operation would be small.

As a result of the low amount of lateral movement required, little arm movement will be required. This low amount of movement does not require great extension of the arm of the crane. This allows the cranes to carry much more load. A smaller crane is therefore necessary.

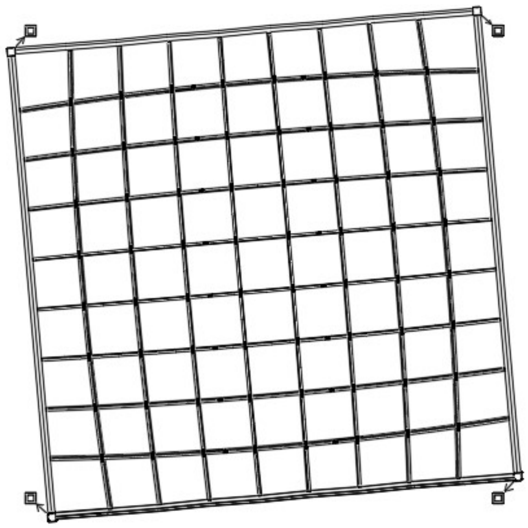


Figure 32: Rotation of the structure in position

CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of civil engineering

Department of steel structures

BACHELOR THESIS

Design of single story curved spatial building

B: Design and structural analysis of a 30m x 30m hall in Liberec

Jean Philippe Cam

Design of the structure:

Input data:

Location of structure:

Location: Liberec, Czech Republic
Wind area: II
Snow area: V

Dimensions:

Height of pillars: 10 m
Axial distance between pillars: 30m x 30m
Radius of beams: 50m

Chosen assemblies:

Pillar assembly:

The pillar assembly is going to be a two-part pillar assembly. This will permit on the ground construction of the structure, saving significant cost.

The bottom component consists of a prefabricated concrete section. Its dimensions are 700 mm x 700 mm of C25/30 concrete, reinforced by 24xø25mm B500B steel reinforcement bars.

The top component consists of a steel square hollow section. it is made using a SHS 550x32 profile, using S355 steel.

The joint between the two will make use of a steel anchor bolt joint, this option has been chosen because its high tolerance for inaccuracy allows the structure to be easily lifted in position.

Side beam assembly (primary beam) :

The side beam assembly is going to be a curved beam with tension rod. This option has been chosen to prevent sideway deformation of the beams' support, allowing it to make full effect of the arch effect.

The beam will be made using a double castellated beam. It is made with two IPE 600 beams, castellated to 900mm with a ø700 mm opening. Both beams will have identical castellation parameters. It will be made using S235 steel.

The tension rod will be made using a tubular cross section with V shaped support rods. It is made with a CHS 193.7x4 profile, using S355 steel. It will be supported by 2 tension rods. These are made with CHS 48.3x3.2 profiles.

Grid beam assembly

The grid beam assembly is going to be a curved beam with tension rod and bracing. This option has been chosen to permit using a smaller beam, and thus minimize the mass of the structure to allow it to be lifted by the cranes during final assembly.

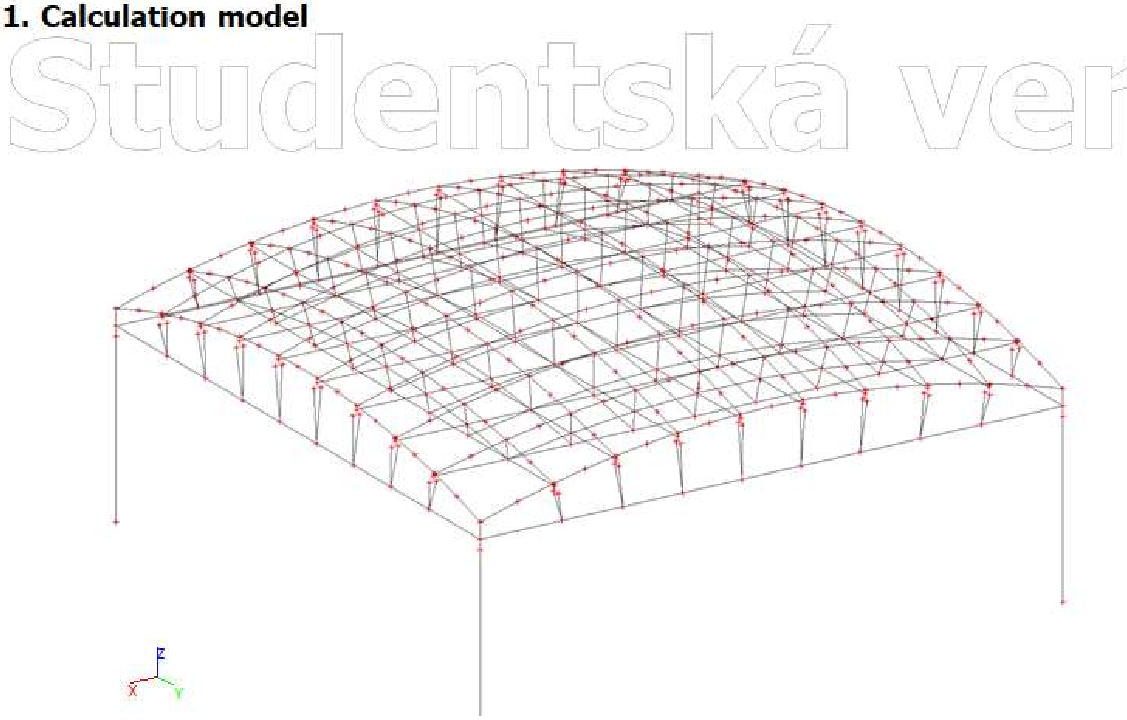
The beam will be made using an IPE 350 beam, castellated to 450 mm with a ø350mm opening. It will be made using S355 steel.

The tension rod will be made using a CHS 88.9x3 profile. It will be braced using CHS 48.3x3.2 profiles.

Calculation model:

Calculation of internal forces will be made using the program SCIA Engineer 18. I have modeled the entire structure in 3D using this program.

1. Calculation model



2. Calculation model with 3D representation of components

Calculation of loads:

Load due to dead weight:

Loads due to the weight of the structure will be calculated automatically by SCIA Engineer.

Snow loading:

Snow loading has been calculated manually. The output shown has been generated using a symbolic language displaying all equations. Equations were coded by myself using the freely available software Smath studio.

SNOW LOADING:

Structure geometry:

$H := 2,3\ \mathrm{m}$

$B := 30\ \mathrm{m}$

Default snow loading:

Snow category area: V

$s_k := 2,5\ \mathrm{kN\ m^{-2}}$

Exposition coefficient:

Area: Normal

$C_e := 1,0$

Heat coefficient:

Default value: 1,0

$C_t := 1,0$

un-winded snow loading:

$\mu_{3,NE} := 0,8$

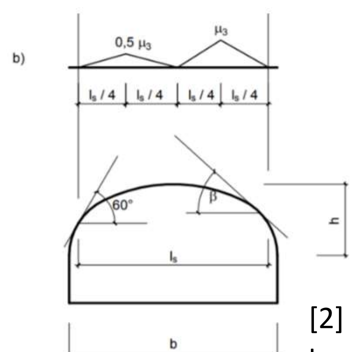
$s_{NE} := \mu_{3,NE} \cdot C_e \cdot C_t \cdot s_k = 2\ \mathrm{kN\ m^{-2}}$

winded snow loading type B:

$$\mu_{3,NA} := \min\left(\left[\begin{matrix} 0,2 + 10 \cdot \frac{H}{B} \\ 2 \end{matrix}\right]\right) = 0,967$$

$s_{NA,B,L} := 0,5 \cdot \left(\mu_{3,NA} \cdot C_e \cdot C_t \cdot s_k\right) = 1,2083\ \mathrm{kN\ m^{-2}}$

$s_{NA,B,P} := \mu_{3,NA} \cdot C_e \cdot C_t \cdot s_k = 2,4167\ \mathrm{kN\ m^{-2}}$



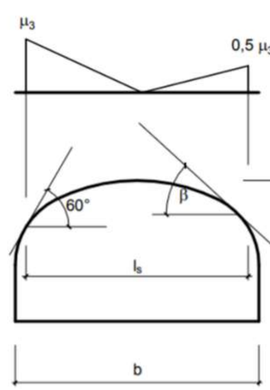
[2] ČSN EN 1991-1-1-3: Zatížení konstrukcí– zatížení sněhem. Český normalizační ústav, 2003

winded snow loading type C:

$$\mu_{3,NA} := \min\left(\left[\begin{matrix} 0,2 + 10 \cdot \frac{H}{B} \\ 2 \end{matrix}\right]\right) = 0,9667$$

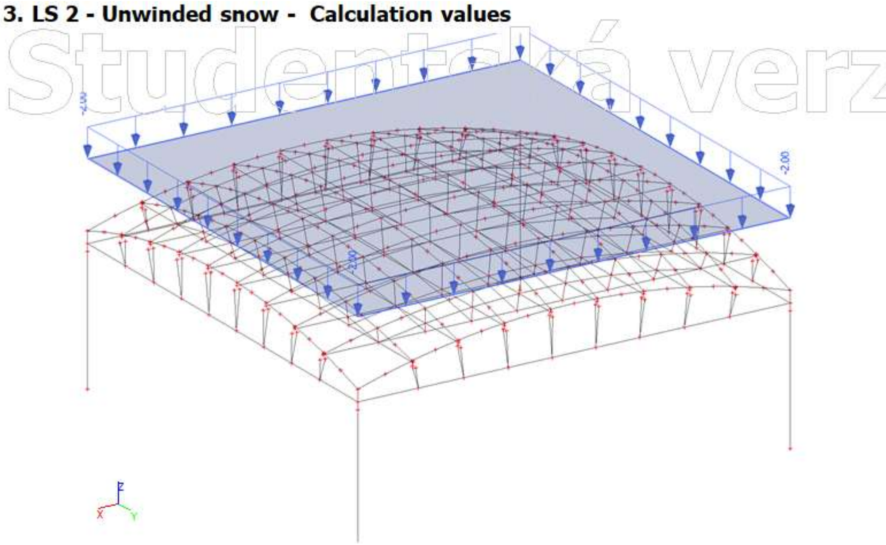
$s_{NA,B,L} := \mu_{3,NA} \cdot C_e \cdot C_t \cdot s_k = 2,4167\ \mathrm{kN\ m^{-2}}$

$s_{NA,B,P} := 0,5 \cdot \left(\mu_{3,NA} \cdot C_e \cdot C_t \cdot s_k\right) = 1,2083\ \mathrm{kN\ m^{-2}}$

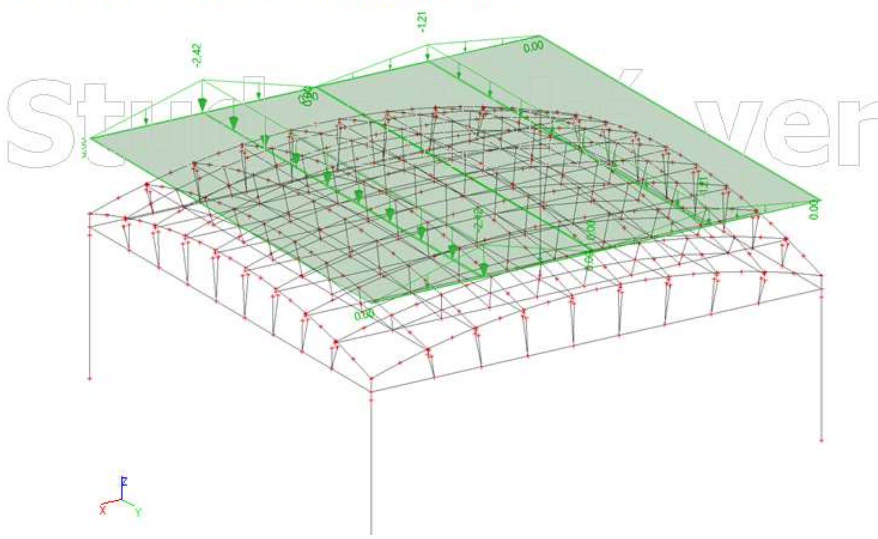


[2] ČSN EN 1991-1-1-3: Zatížení konstrukcí– zatížení sněhem. Český normalizační ústav, 2003

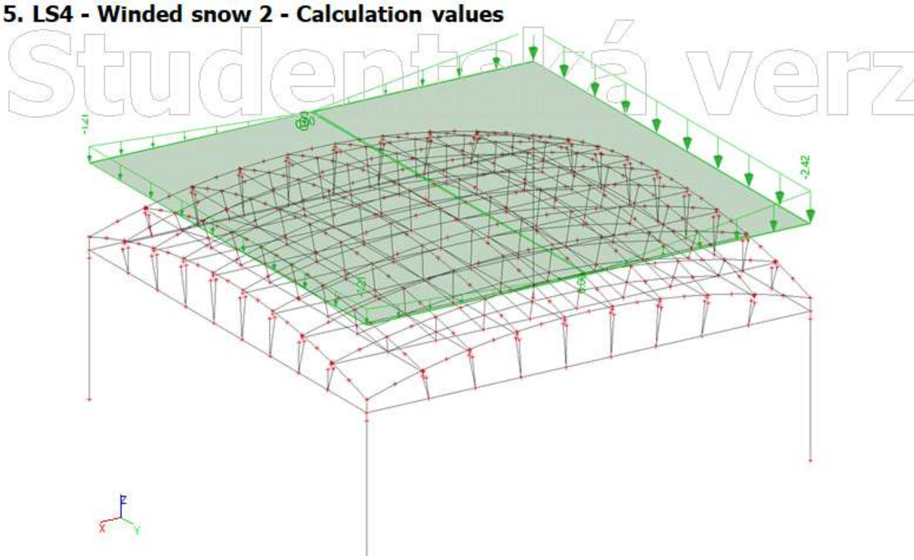
3. LS 2 - Unwinded snow - Calculation values



4. LS 3 - winded snow 1 - Calculation values



5. LS4 - Winded snow 2 - Calculation values



Wind loading:

WIND LOADING:

Default wind speed:

Wind area II:

$V_{b,0} := 25\ \mathrm{m\ s^{-1}}$

$c_{dir} := 1{,}00$

$c_{season} := 1{,}00$

$v_b := c_{dir} \cdot c_{season} \cdot V_{b,0} = 25\ \mathrm{m\ s^{-1}}$

Average wind speed:

Terrain category:

III - area with vegetation and/or buildings

$z_0 := 0{,}3\ \mathrm{m}$

$z_{min} := 5\ \mathrm{m}$

$z_{0,II} := 0{,}05\ \mathrm{m}$

$z_{min,II} := 2\ \mathrm{m}$

Building height

$z_{TOP} := 15\ \mathrm{m}$

$$k_r := 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0,07} = 0{,}215$$

$$c_r(z) := k_r \cdot \ln\left(\frac{\max\left(\left[z \ \ z_{min}\right]\right)}{z_0}\right)$$

$c_0(z) := 1{,}00$

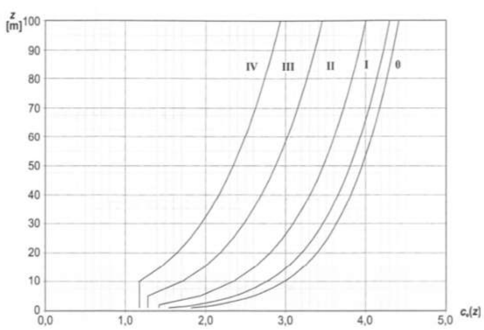
$v_m(z) := c_r(z) \cdot c_0(z) \cdot v_b$

$v_m := v_m(z_{TOP}) = 21{,}065\ \mathrm{m\ s^{-1}}$

Characteristic wind loading:

$\rho_v := 1{,}25\ \mathrm{kg\ m^{-3}}$

$$q_b := \frac{1}{2} \cdot \rho_v \cdot v_m^{\ 2} = 0{,}277\ \mathrm{kN\ m^{-2}}$$



Obrázek 1-29: Graf pro přibližné určení součinitele expozice $c_e(z)$

$c_e(z) := 2{,}00$

$q_p(z) := c_e(z) \cdot q_b = 0{,}555\ \mathrm{kN\ m^{-2}}$

Wind loading has been calculated manually. The output shown has been generated using a symbolic language displaying all equations. Equations were coded by myself using the freely available software Smath studio.

[3] ČSN EN 1991-1-1-3: Obecná zatížení – zatížení větrem. Český normalizační ústav, 2007

Due to the complexity of calculating the wind loading on a spherical roof, I have chosen instead to model the roof as multiple planes and used the automatic wind load calculation provided by SCIA Engineer. In total, SCIA engineer has created 16 wind load states. I will not show all of them here, because it would take too many pages.

Name	Load direction	+Cpi	-Cpi	Region	Zones	+Cpe	-Cpe
WD1	0	0.2000	-0.3000	1	Fup	-2.2980	-2.2980
				2	Flow	-1.7700	-1.7700
				3	G	-1.8660	-1.8660
				4	H	-0.7320	-0.7320
				5	I	-0.6320	-0.6320
	90	0.2000	-0.3000	1	F1	-2.4320	-2.4320
				2	F2	-2.4320	-2.4320
				3	G	-1.3000	-1.3000
				4	H	-0.8660	-0.8660
	180	0.2000	-0.3000	1	Fup	-2.2980	-2.2980
				2	Flow	-1.7700	-1.7700
				3	G	-1.8660	-1.8660
				4	H	-0.7320	-0.7320
				5	I	-0.6320	-0.6320
	270	0.2000	-0.3000	1	F1	0.1320	-1.1720
				2	F2	0.1320	-1.1720
				3	G	0.1320	-0.9360
				4	H	0.1320	-0.4020
WD2	0	0.2000	-0.3000	1	F1	-2.3100	-2.3100
				2	F2	-2.3100	-2.3100
				3	G	-1.3000	-1.3000
				4	H	-0.8050	-0.8050
	90	0.2000	-0.3000	1	F1	-2.3100	-2.3100
				2	F2	-2.3100	-2.3100
				3	G	-1.3000	-1.3000
				4	H	-0.8050	-0.8050
	180	0.2000	-0.3000	1	F1	0.0100	-1.6600
				2	F2	0.0100	-1.6600
				3	G	0.0100	-1.1800
				4	H	0.0100	-0.5850
	270	0.2000	-0.3000	1	F1	0.0100	-1.6600
				2	F2	0.0100	-1.6600
				3	G	0.0100	-1.1800
				4	H	0.0100	-0.5850

Figure 33: Excerpt from calculation of wind by SCIA engineer. The entire protocol is too long for the purposes of this work

6. LS5 - Wind 1 - calculation values

Combinations:

12. Combinations

Name	Description	Type	Load cases	Coeff. [-]
MSU Sada B (auto)		EN-ULS (STR/GEO) Set B	ZS1 - Vlastní tíha	1.00
			ZS2 - Sníh,1 - Nenavátý sníh	1.00
			3DVítr1 - 0, + CPE, + CPI	1.00
			3DVítr2 - 0, + CPE, - CPI	1.00
			3DVítr3 - 0, - CPE, + CPI	1.00
			3DVítr4 - 0, - CPE, - CPI	1.00
			3DVítr5 - 90, + CPE, + CPI	1.00
			3DVítr6 - 90, + CPE, - CPI	1.00
			3DVítr7 - 90, - CPE, + CPI	1.00
			3DVítr8 - 90, - CPE, - CPI	1.00
			3DVítr9 - 180, + CPE, + CPI	1.00
			3DVítr10 - 180, + CPE, - CPI	1.00
			3DVítr11 - 180, - CPE, + CPI	1.00
			3DVítr12 - 180, - CPE, - CPI	1.00
			3DVítr13 - 270, + CPE, + CPI	1.00
			3DVítr14 - 270, + CPE, - CPI	1.00
			3DVítr15 - 270, - CPE, + CPI	1.00
			3DVítr16 - 270, - CPE, - CPI	1.00
			ZS3 - Sníh,2 - Navátý sníh	1.00
			ZS4 - Sníh,3 - Navátý sníh	1.00

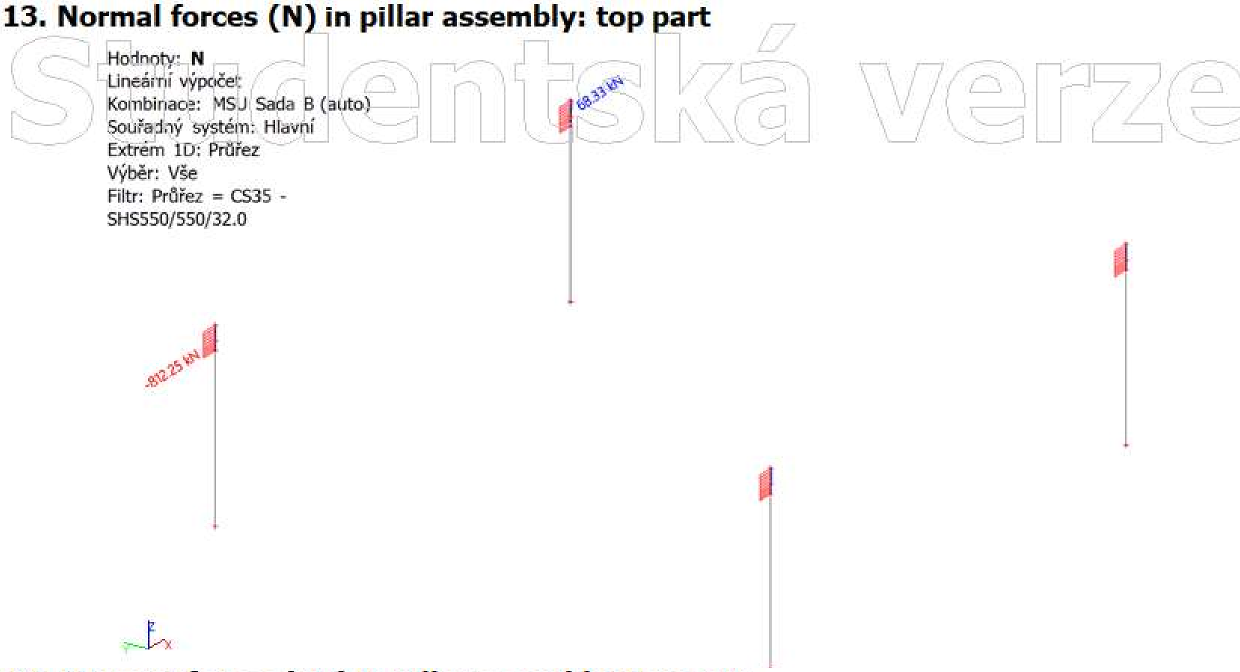
Figure 34: Ultimate limit state calculation.
Note: SCIA Engineer automatically accounts for ULS coefficients, user input is not required.
The coefficients visible on this table are additional coefficients, not ULS coefficients

Ultimate limit state internal forces:

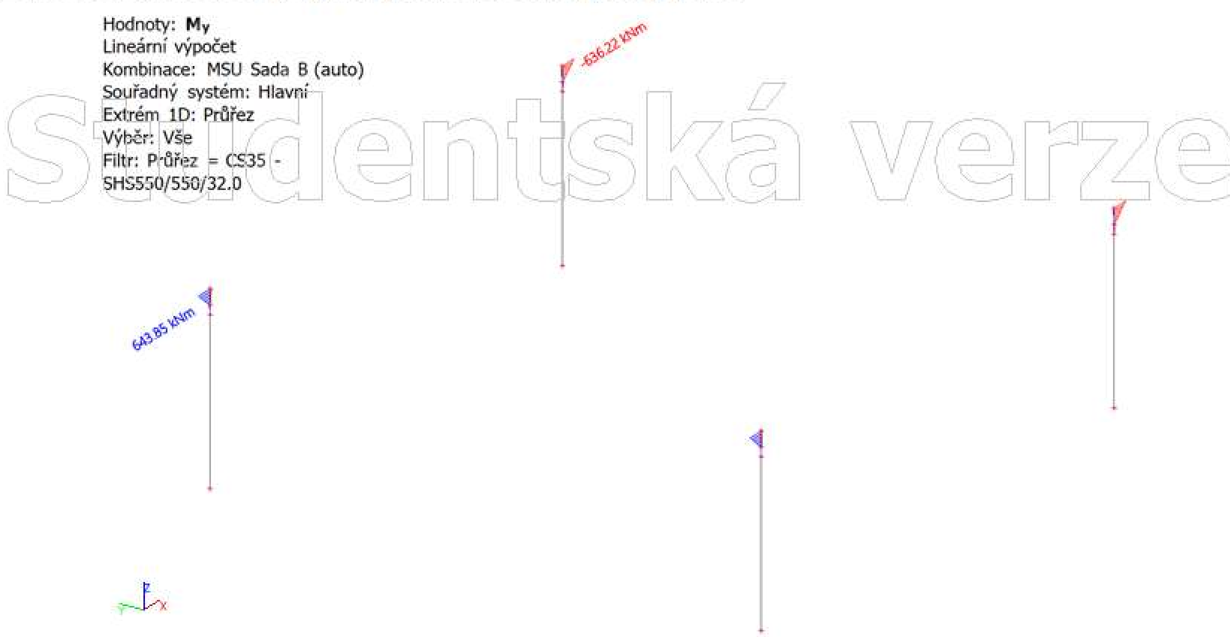
Pillar assembly:

Top part:

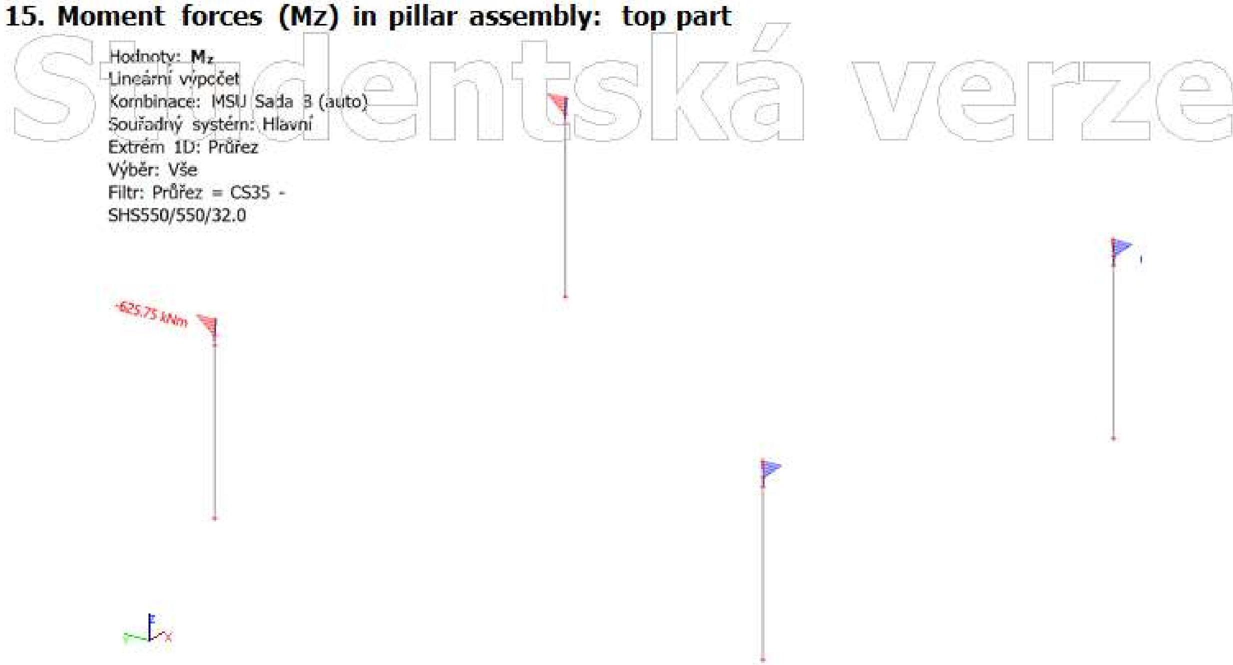
13. Normal forces (N) in pillar assembly: top part



14. Moment forces (My) in pillar assembly: top part



15. Moment forces (Mz) in pillar assembly: top part

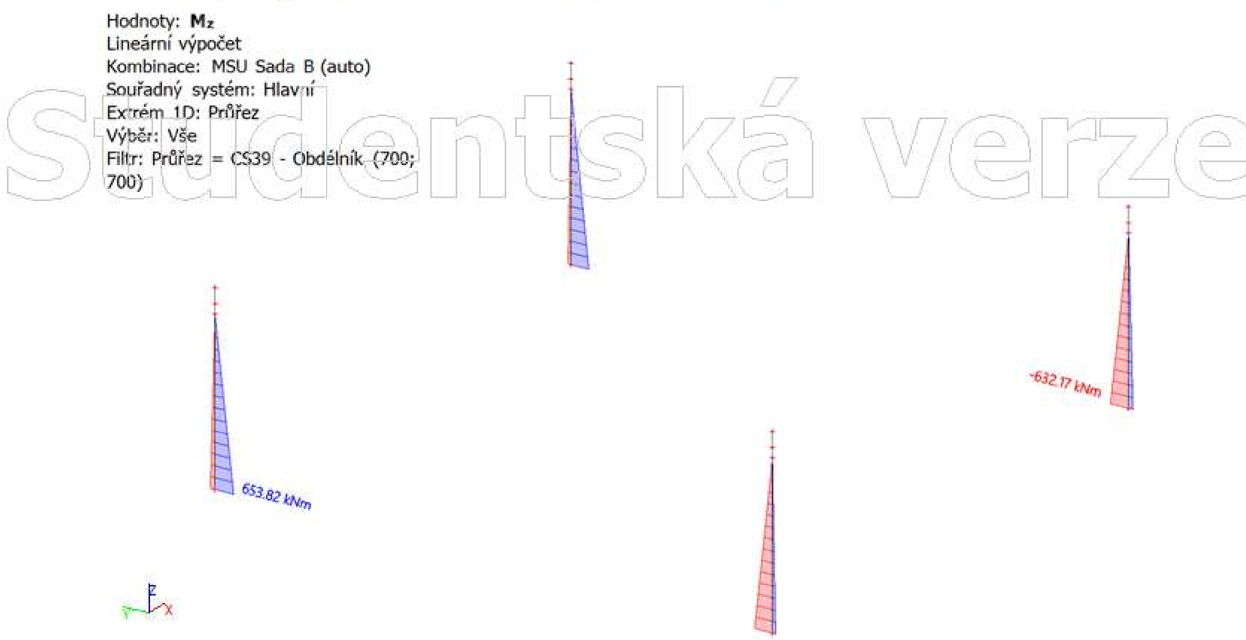


Bottom part:

16. Normal forces (N) in pillar assembly: bottom part

17. Moment forces (My) in pillar assembly: bottom part

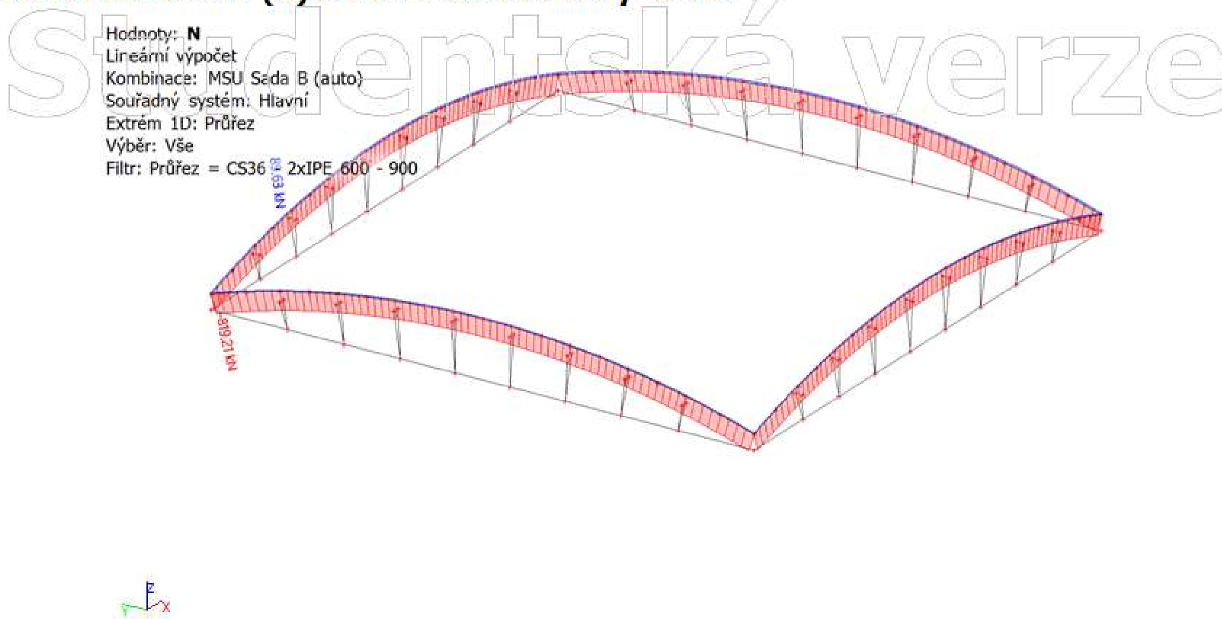
18. Moment forces (Mz) in pillar assembly: bottom part



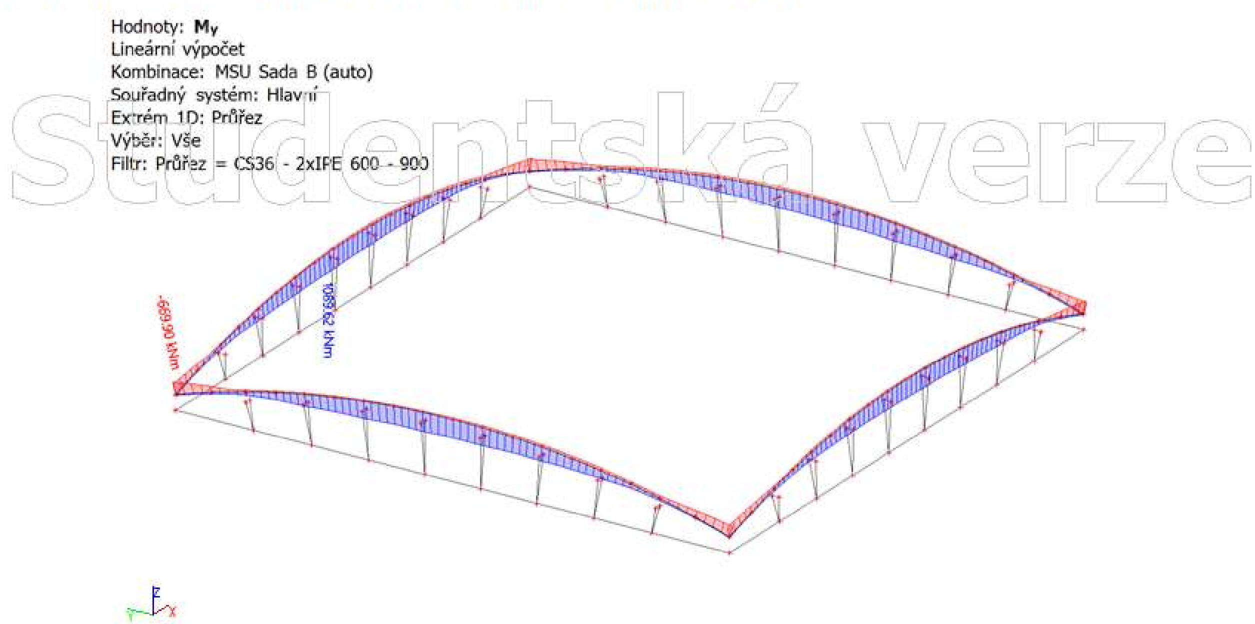
Side beam assembly (primary beams):

Beam:

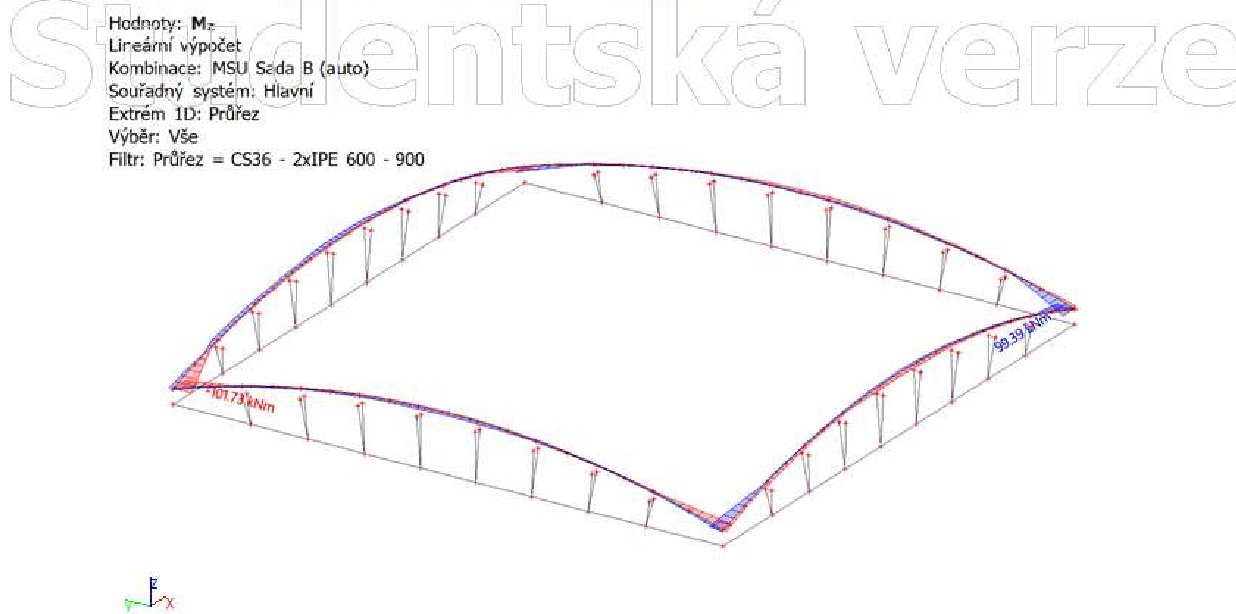
19. Normal forces (N) in side beam assembly: beam



20. Moment forces (My) in side beam assembly: beam

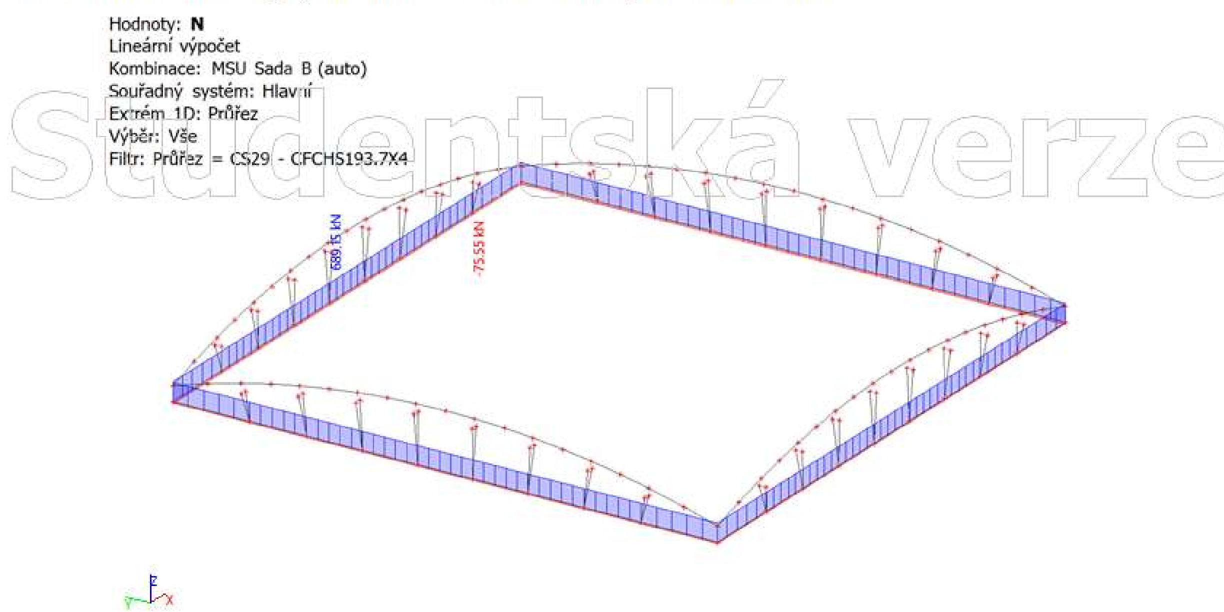


21. Moment forces (Mz) in side beam assembly: beam



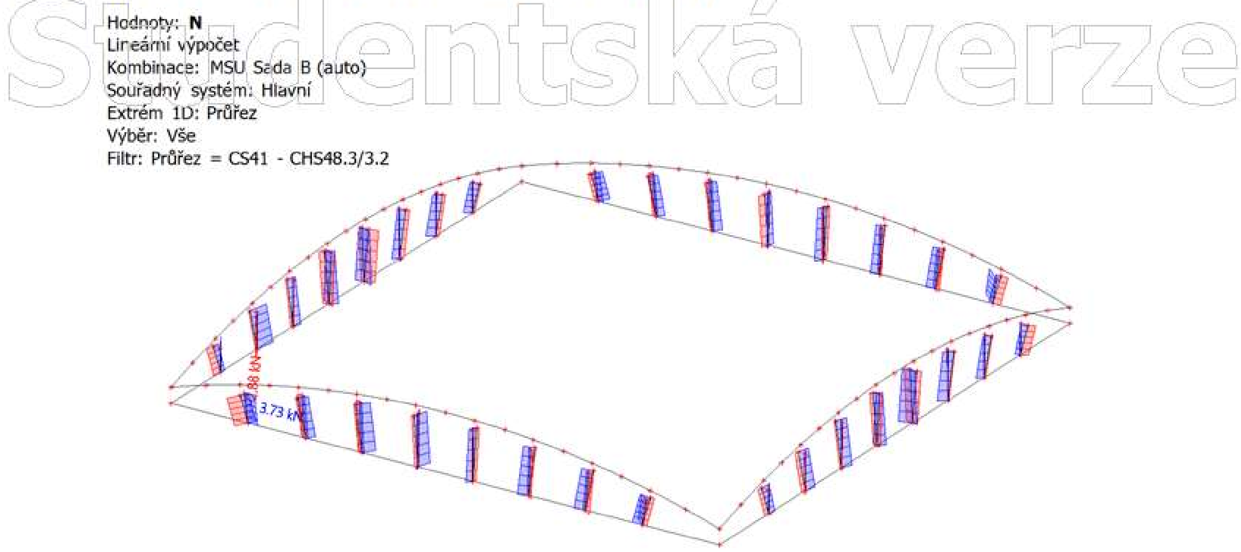
Tension rod:

22. Normal forces (N) in side beam assembly: Tension rod



Support rod:

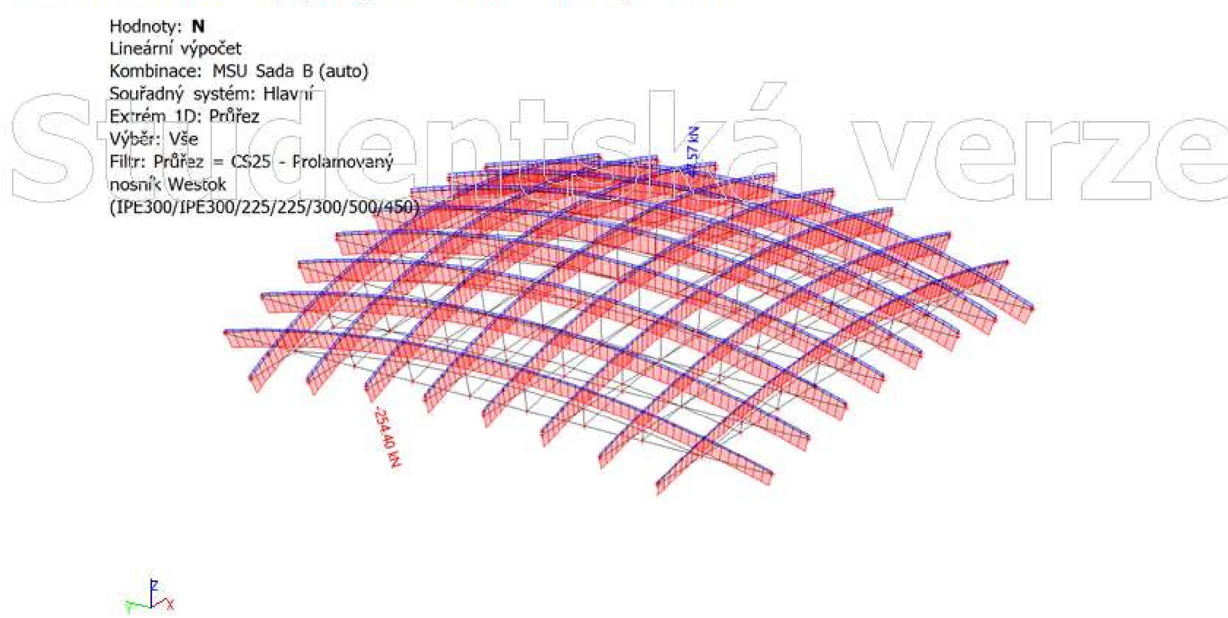
23. Normal forces (N) in side beam assembly: support rods



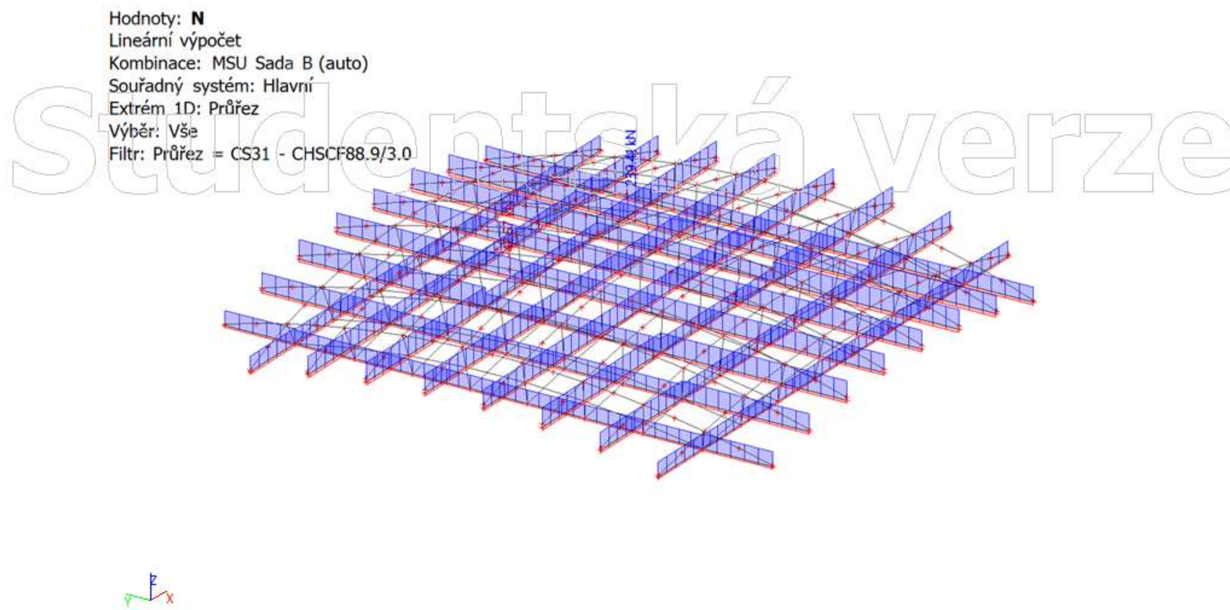
Grid beam assembly (secondary beams):

Beams:

24. Normal forces (N) in grid beam assembly: beam

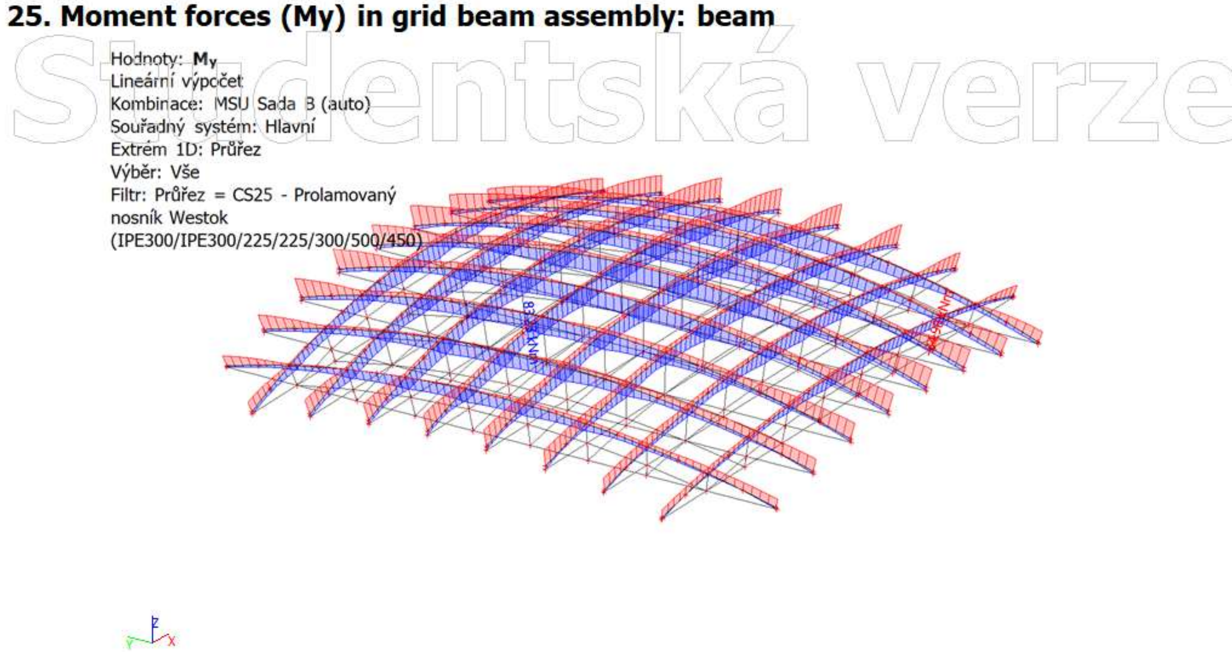


26. Normal forces (N) in grid beam assembly: tension rod



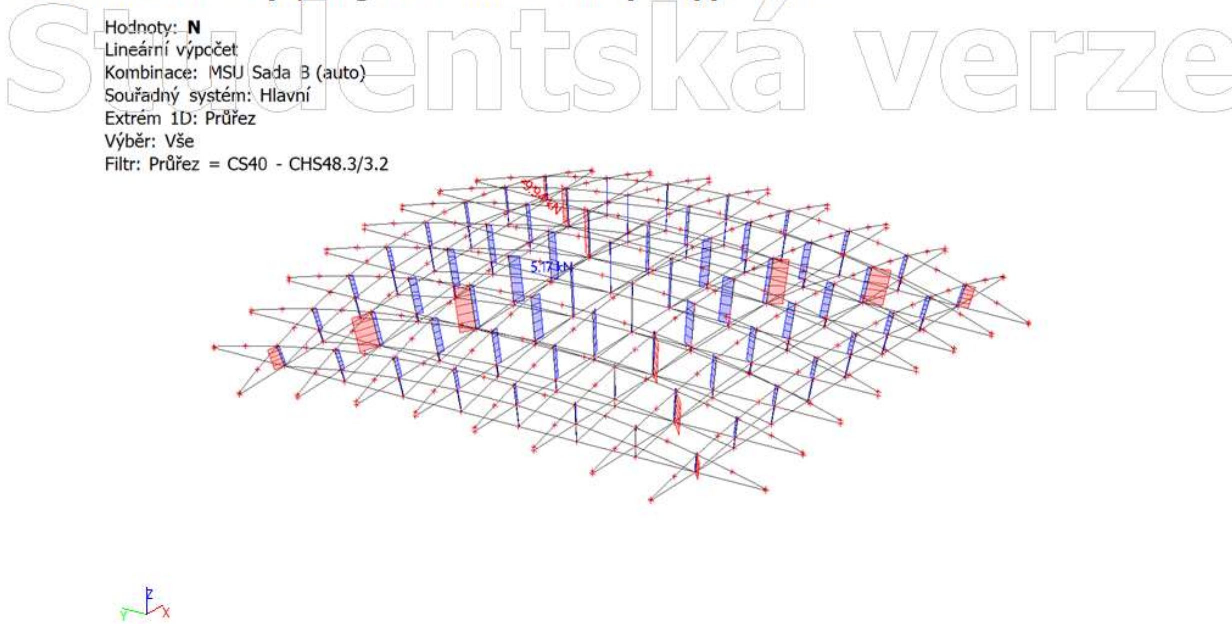
Tension rods:

25. Moment forces (My) in grid beam assembly: beam



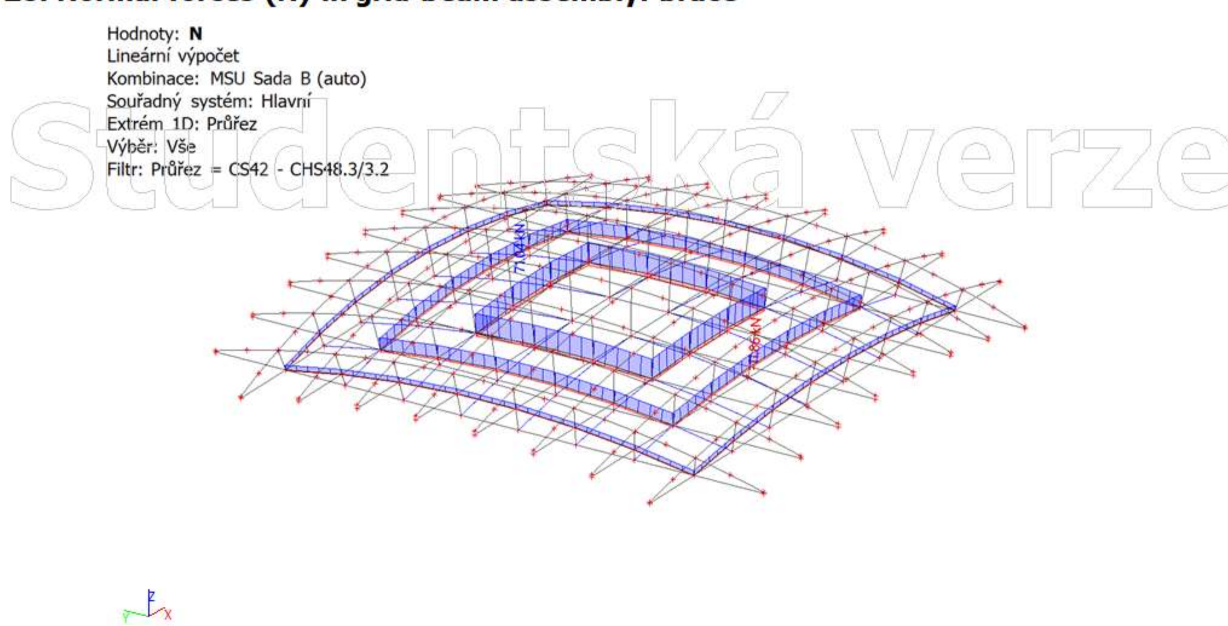
Support rods:

27. Normal forces (N) in grid beam assembly: support rod



Brace:

28. Normal forces (N) in grid beam assembly: brace



Load bearing capacity assessment:

Assessment method:

Steel structures:

Steel structures will be assessed in bending and axial load using the program Microsoft excel. The method of assessment consists of multiple steps:

- Calculation of internal forces at ULS using SCIA Engineer 18
- Extraction of internal forces at every calculated section, and for every force combination into Microsoft excel
- Calculation of load bearing capacity of the cross section for tension/buckling, and moment in both Y and Z axes
- Expression, in percentage point, of usage of structure for each load type, and at every calculated section and force combination.
- Addition of these percentage into one number for each calculated section and combination
- The highest of these numbers represent the usage of the cross section across the entire construction compared to its load bearing capability. The highest satisfactory number is 99-100%

In this work will be included small parts of the calculation file, the calculation file contains over 200.000 values. For this reason, I have decided to only include small excerpts. These excerpts will contain the highest usage values.

Concrete structures

Concrete structures will be assessed via an interaction diagram. An interaction diagram will be calculated for every concrete element present in the structure. After that, the forces acting on the element will be inserted into the diagram. The element is judged satisfactory if all forces are contained within the diagram.

Once again, every force present at every calculated section for every load combination will be assessed.

Pillar assembly:

Bottom part:

Calculation of interaction diagram:

Wind loading has been calculated manually. The output shown has been generated using a symbolic language displaying all equations. Equations were coded by myself using the freely available software Smath studio.

CONCRETE INTERACTION DIAGRAM:

INPUT DATA:

MATERIAL CHARACTERISTICS:

CONCRETE C25/20:

$$f_{ck} := 25\ \text{MPa}$$

$$\gamma_c := 1{,}35$$

$$f_{cd} := \frac{f_{ck}}{\gamma_c} = 18{,}519\ \text{MPa}$$

$$c := 35\ \text{mm}$$

$$\lambda := 0{,}8$$

Reinforcement B500B

$$f_{yk} := 500\ \text{MPa}$$

$$\gamma_s := 1{,}15$$

$$f_{yd} := \frac{f_{yk}}{\gamma_s} = 434{,}783\ \text{MPa}$$

$$\xi_{bal,1} := \frac{700\ \text{MPa}}{700\ \text{MPa} + f_{yd}} = 0{,}617$$

GEOMETRY:

$$H := 700\ \text{mm}$$

$$B := H = 700\ \text{mm}$$

$$A_c := H \cdot B = 0{,}49\ \text{m}^2$$

$$n_{s,1} := 7$$

$$\phi_s := 25\ \text{mm}$$

$$d_{min} := c + \frac{\phi_s}{2} = 47{,}5\ \text{mm}$$

$$d := 50\ \text{mm}$$

$$A_{s,1} := \pi \cdot \frac{\phi_s^{\,2}}{4} = 490{,}8739\ \text{mm}^2$$

$$e_0 := \frac{H - 2 \cdot d}{n_{s,1} - 1} = 100\ \text{mm}$$

$$z := \begin{bmatrix} 3 \\ 2 \\ 1 \\ 0 \\ -1 \\ -2 \\ -3 \end{bmatrix} \cdot e_0 = \begin{bmatrix} 300 \\ 200 \\ 100 \\ 0 \\ -100 \\ -200 \\ -300 \end{bmatrix} \text{mm} \qquad n_i := \begin{bmatrix} n_{s,1} \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ n_{s,1} \end{bmatrix} = \begin{bmatrix} 7 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 7 \end{bmatrix}$$

$$n_s := \sum n_i = 24$$

CALCULATION OF INTERACTION DIAGRAM:

POINT 0: FULL COMPRESSION

$$N_{Rd0} := -\left(A_c \cdot f_{cd} + n_s \cdot A_{s,1} \cdot f_{yd}\right) = -14196{,}236\ \text{kN}$$

$$M_{Rd,0} := A_{s,1} \cdot f_{yd} \cdot \sum_{i=1}^{7} z_i \cdot n_i = 0\ \text{kN m}$$

Figure 36: Page 1 of calculation

POINT 1: NEUTRAL AXIS = AXIS OF LOWER REINFORCEMENT

$$z_{0,1} := z - z_7 = \begin{bmatrix} 600 \\ 500 \\ 400 \\ 300 \\ 200 \\ 100 \\ 0 \end{bmatrix} \text{mm}$$

$$F_{s,1} := \begin{bmatrix} A_{s,1} \cdot f_{yd} \cdot n_{i_1} \cdot \frac{z_{0,1_1}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_2} \cdot \frac{z_{0,1_2}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_3} \cdot \frac{z_{0,1_3}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_4} \cdot \frac{z_{0,1_4}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_5} \cdot \frac{z_{0,1_5}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_6} \cdot \frac{z_{0,1_6}}{z_{0,1_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_7} \cdot \frac{z_{0,1_7}}{z_{0,1_1}} \end{bmatrix} = \begin{bmatrix} 1493{,}964 \\ 355{,}706 \\ 284{,}565 \\ 213{,}423 \\ 142{,}282 \\ 71{,}141 \\ 0 \end{bmatrix} \text{kN}$$

$$B_{c,2} := (H - d) \cdot \lambda = 520\ \text{mm}$$

$$A_{c,2} := H \cdot B_{c,2} = 0{,}364\ \text{m}^2$$

$$N_{Rd,1} := -\left(A_{c,2} \cdot f_{cd} + \left(\sum F_{s,1}\right)\right) = -9301{,}822\ \text{kN}$$

$$M_{Rd,1} := A_{c,2} \cdot f_{cd} \cdot \frac{B - B_{c,2}}{2} + \sum_{i=1}^{7} F_{s,1_i} \cdot z_i = 1125{,}997\ \text{kN m}$$

POINT 2: FULL COMPRESSION AND TENSION IN REINFORCEMENTS

$$x_{bal,1} := \xi_{bal,1} \cdot (H - d) = 400{,}958\ \text{mm}$$

$$z_{0,2} := z = \begin{bmatrix} 300 \\ 200 \\ 100 \\ 0 \\ -100 \\ -200 \\ -300 \end{bmatrix} \text{mm}$$

Figure 35: Page 2 of calculation

$$F_{s,2} := \begin{bmatrix} A_{s,1} \cdot f_{yd} \cdot n_{i_1} \cdot \dfrac{z_{0,2_1}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_2} \cdot \dfrac{z_{0,2_2}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_3} \cdot \dfrac{z_{0,2_3}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_4} \cdot \dfrac{z_{0,2_4}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_5} \cdot \dfrac{z_{0,2_5}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_6} \cdot \dfrac{z_{0,2_6}}{z_{0,2_1}} \\ A_{s,1} \cdot f_{yd} \cdot n_{i_7} \cdot \dfrac{z_{0,2_7}}{z_{0,2_1}} \end{bmatrix} = \begin{bmatrix} 1493,9639 \\ 284,5646 \\ 142,2823 \\ 0 \\ -142,2823 \\ -284,5646 \\ -1493,9639 \end{bmatrix} \text{kN}$$

$$N_{Rd,2} := -\left(B \cdot x_{bal,1} \cdot f_{cd} + \left(\sum F_{s,2}\right)\right) = -5197,602 \text{ kN}$$

$$M_{Rd,2} := B \cdot x_{bal,1} \cdot f_{cd} \cdot \frac{\left(B - \lambda \cdot x_{bal,1}\right)}{2} + \sum_{i=1}^{7} F_{s,2_i} \cdot z_i = 2024,214 \text{ kN m}$$

POINT 3: FULL MOMENT:

$$x_{TN} := 520,8068145 \text{ mm}$$

$$z_{0,3} := x_{TN} - \begin{bmatrix} d + e_0 \cdot 6 \\ d + e_0 \cdot 5 \\ d + e_0 \cdot 4 \\ d + e_0 \cdot 3 \\ d + e_0 \cdot 2 \\ d + e_0 \\ d \end{bmatrix} = \begin{bmatrix} -129,193 \\ -29,193 \\ 70,807 \\ 170,807 \\ 270,807 \\ 370,807 \\ 470,807 \end{bmatrix} \text{mm}$$

$$F_{s,3} := \begin{bmatrix} f_{yd} \cdot A_{s,1} \cdot n_{i_1} \cdot \dfrac{z_{0,3_1}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_2} \cdot \dfrac{z_{0,3_2}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_3} \cdot \dfrac{z_{0,3_3}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_4} \cdot \dfrac{z_{0,3_4}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_5} \cdot \dfrac{z_{0,3_5}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_6} \cdot \dfrac{z_{0,3_6}}{z_{0,3_7}} \\ f_{yd} \cdot A_{s,1} \cdot n_{i_7} \cdot \dfrac{z_{0,3_7}}{z_{0,3_7}} \end{bmatrix} = \begin{bmatrix} -409,956 \\ -26,467 \\ 64,195 \\ 154,858 \\ 245,521 \\ 336,184 \\ 1493,964 \end{bmatrix} \text{kN}$$

$$F_{s,3,\Sigma} := \sum F_{s,3} = 1858,3 \text{ kN}$$

$$F_{c,3} := -\left(f_{cd} \cdot B \cdot \lambda \cdot \left(H - x_{TN}\right)\right) = -1858,3 \text{ kN}$$

Figure 38: Page 3 of calculation

$$N_{Rd,3} := F_{s,3,\Sigma} + F_{c,3} = 1,4103 \cdot 10^{-6} \text{ kN}$$

$$M_{Rd,3} := -\left(F_{c,3} \cdot \frac{\left(B - \lambda \cdot x_{TN}\right)}{2}\right) - \sum_{i=1}^{7} F_{s,3_i} \cdot z_i = 925,118 \text{ kN m}$$

POINT 4: FULL TENSION:

$$N_{Rd,4} := n_s \cdot A_{s,1} \cdot f_{yd} = 5122,162 \text{ kN}$$

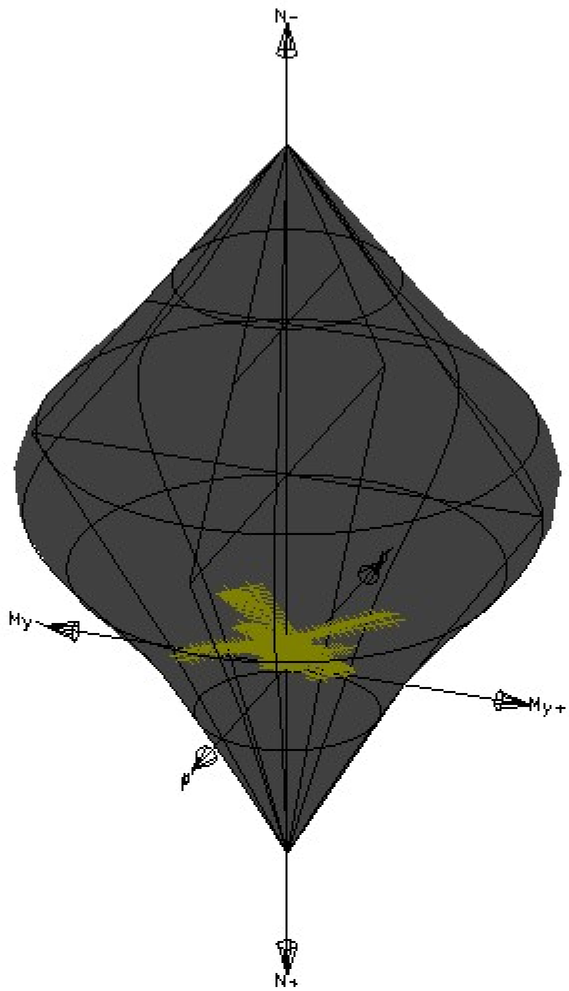
$$M_{Rd,4} := 0$$

3D interaction diagram: method:

To take into account a combination of My and Mz, the diagram will be drazn in the XZ and YZ planes, and Values outside of the XZ and YZ axes will be interpolated by rotating the diagram.

Figure 37: Page 4 of calculation

Insertion of forces inside the interaction diagram:



The forces have been inserted into the 3D diagram using the program AutoCAD. They are visible as yellow points.

It is visible that all calculated forces are located inside of the interaction diagram.

Therefore, the pillar is structurally satisfactory.

Top part:

B330	0.5	MSU Sada B (auto)/14	CS35 - SHS550/550/32.0	53.99	-0.77	-6.68	-6.77	0	0	ZS1 + 1.50*3DVítr11
B330	0.5	MSU Sada B (auto)/5	CS35 - SHS550/550/32.0	-667.68	-71.33	-63.24	7.88	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B330	0.5	MSU Sada B (auto)/15	CS35 - SHS550/550/32.0	-79.58	12.67	-3.56	-16.93	0	0	ZS1 + 1.50*3DVítr5
B330	0.5	MSU Sada B (auto)/6	CS35 - SHS550/550/32.0	-668.8	-64.01	-71.26	-9.22	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B330	0.5	MSU Sada B (auto)/18	CS35 - SHS550/550/32.0	-79.36	-3.34	11.52	17.24	0	0	ZS1 + 1.50*3DVítr1
B330	0.5	MSU Sada B (auto)/16	CS35 - SHS550/550/32.0	-356.32	-13.18	-29.2	-17.24	0	0	ZS1 + 0.75*ZS2 + 1.50*3DVítr5
B330	0.5	MSU Sada B (auto)/17	CS35 - SHS550/550/32.0	-236.52	-19.57	1.49	19.45	0	0	1.15*ZS1 + 1.50*3DVítr1 + 0.75*ZS4 - Sníh,3
B330	0.5	MSU Sada B (auto)/9	CS35 - SHS550/550/32.0	-740.1	-54.39	-63.36	-10.5	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B331	0	MSU Sada B (auto)/14	CS35 - SHS550/550/32.0	30.4	-55.23	35.69	3.12	-28.6	49.03	ZS1 + 1.50*3DVítr11
B331	0	MSU Sada B (auto)/19	CS35 - SHS550/550/32.0	-159.21	200.55	-43.54	-33.33	34.72	-176.43	ZS1 + 1.50*3DVítr5 + 0.75*ZS4 - Sníh,3
B331	0	MSU Sada B (auto)/20	CS35 - SHS550/550/32.0	-487.41	370.39	-476.76	27.71	404.9	-306.22	1.15*ZS1 + 0.75*ZS2 + 1.50*3DVítr14
B331	0	MSU Sada B (auto)/2	CS35 - SHS550/550/32.0	45.61	-26	86.96	-18.01	-75.32	19.26	ZS1 + 1.50*3DVítr7
B331	0	MSU Sada B (auto)/7	CS35 - SHS550/550/32.0	-802.65	738.26	-709.22	-12.69	595.91	-625.75	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B331	0	MSU Sada B (auto)/5	CS35 - SHS550/550/32.0	-804.39	684.32	-760.07	17.02	643.85	-574.59	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B331	0.160-	MSU Sada B (auto)/14	CS35 - SHS550/550/32.0	29.62	-55.23	35.69	3.12	-22.89	40.19	ZS1 + 1.50*3DVítr11
B331	0.160-	MSU Sada B (auto)/19	CS35 - SHS550/550/32.0	-160	200.55	-43.54	-33.33	27.75	-144.34	ZS1 + 1.50*3DVítr5 + 0.75*ZS4 - Sníh,3
B331	0.160-	MSU Sada B (auto)/20	CS35 - SHS550/550/32.0	-488.31	370.39	-476.76	27.71	328.61	-246.96	1.15*ZS1 + 0.75*ZS2 + 1.50*3DVítr14
B331	0.160-	MSU Sada B (auto)/2	CS35 - SHS550/550/32.0	44.82	-26	86.96	-18.01	-61.41	15.1	ZS1 + 1.50*3DVítr7
B331	0.160-	MSU Sada B (auto)/7	CS35 - SHS550/550/32.0	-803.55	738.26	-709.22	-12.69	482.43	-507.63	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B331	0.160-	MSU Sada B (auto)/5	CS35 - SHS550/550/32.0	-805.29	684.32	-760.07	17.02	522.24	-465.1	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B330	0.5	MSU Sada B (auto)/14	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/5	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/15	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/6	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/18	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/16	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/17	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B330	0.5	MSU Sada B (auto)/9	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/14	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/19	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/20	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/2	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/7	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0	MSU Sada B (auto)/5	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/14	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/19	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/20	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/2	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/7	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01
B331	0.160-	MSU Sada B (auto)/5	3.55E+05	6.37E-02	2.79E-03	2.79E-03	1.01E-02	1.01E-02	1.24E-02	1.24E-02	2.09E-01	2.09E-01

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ_1	$\bar{\lambda}_y$	$\bar{\lambda}_z$	α	Φx	Φy	χy	χz
B330	0.5	MSU Sada B (auto)/14	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/5	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/15	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/6	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/18	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/16	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/17	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B330	0.5	MSU Sada B (auto)/9	1	1	2	2	76.40915	0.1252386	0.1252386	0.49	0.489526	0.489526	1.03868	1.03868
B331	0	MSU Sada B (auto)/14	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0	MSU Sada B (auto)/19	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0	MSU Sada B (auto)/20	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0	MSU Sada B (auto)/2	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0	MSU Sada B (auto)/7	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0	MSU Sada B (auto)/5	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/14	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/19	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/20	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/2	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/7	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805
B331	0.160-	MSU Sada B (auto)/5	1.6	1.6	2	2	76.40915	0.2003818	0.2003818	0.49	0.52017	0.52017	0.999805	0.999805

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B330	0.5	MSU Sada B (auto)/14	53.99	22613.50	0.24%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	0.24%	37.62%
B330	0.5	MSU Sada B (auto)/5	667.68	23488.19	2.84%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	2.84%	
B330	0.5	MSU Sada B (auto)/15	79.58	23488.19	0.34%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	0.34%	
B330	0.5	MSU Sada B (auto)/6	668.8	23488.19	2.85%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	2.85%	
B330	0.5	MSU Sada B (auto)/18	79.36	23488.19	0.34%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	0.34%	
B330	0.5	MSU Sada B (auto)/16	356.32	23488.19	1.52%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	1.52%	
B330	0.5	MSU Sada B (auto)/17	236.52	23488.19	1.01%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	1.01%	
B330	0.5	MSU Sada B (auto)/9	740.1	23488.19	3.15%	0.00	3585.50	0.00%	0.00	3585.50	0.00%	3.15%	
B331	0	MSU Sada B (auto)/14	30.4	22613.50	0.13%	28.60	3585.50	0.80%	49.03	3585.50	1.37%	2.30%	
B331	0	MSU Sada B (auto)/19	159.21	22609.09	0.70%	34.72	3585.50	0.97%	176.43	3585.50	4.92%	6.59%	
B331	0	MSU Sada B (auto)/20	487.41	22609.09	2.16%	404.90	3585.50	11.29%	306.22	3585.50	8.54%	21.99%	
B331	0	MSU Sada B (auto)/2	45.61	22613.50	0.20%	75.32	3585.50	2.10%	19.26	3585.50	0.54%	2.84%	
B331	0	MSU Sada B (auto)/7	802.65	22609.09	3.55%	595.91	3585.50	16.62%	625.75	3585.50	17.45%	37.62%	
B331	0	MSU Sada B (auto)/5	804.39	22609.09	3.56%	643.85	3585.50	17.96%	574.59	3585.50	16.03%	37.54%	
B331	0.160-	MSU Sada B (auto)/14	29.62	22613.50	0.13%	22.89	3585.50	0.64%	40.19	3585.50	1.12%	1.89%	
B331	0.160-	MSU Sada B (auto)/19	160	22609.09	0.71%	27.75	3585.50	0.77%	144.34	3585.50	4.03%	5.51%	
B331	0.160-	MSU Sada B (auto)/20	488.31	22609.09	2.16%	328.61	3585.50	9.16%	246.96	3585.50	6.89%	18.21%	
B331	0.160-	MSU Sada B (auto)/2	44.82	22613.50	0.20%	61.41	3585.50	1.71%	15.10	3585.50	0.42%	2.33%	
B331	0.160-	MSU Sada B (auto)/7	803.55	22609.09	3.55%	482.43	3585.50	13.46%	507.63	3585.50	14.16%	31.17%	
B331	0.160-	MSU Sada B (auto)/5	805.29	22609.09	3.56%	522.24	3585.50	14.57%	465.10	3585.50	12.97%	31.10%	

Side beam assembly (primary beam):

Beam:

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B1004	3.446+	MSU Sada B (auto)/7	CS36 - 2xIPE 600 - 900	-770.91	-27.4	-180.01	-1.35	-532.71	-78.54	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B1004	3.446+	MSU Sada B (auto)/8	CS36 - 2xIPE 600 - 900	-18.66	2.23	10.16	0.01	-33.44	4.45	ZS1 + 1.50*3DVítr9
B1004	3.446+	MSU Sada B (auto)/12	CS36 - 2xIPE 600 - 900	88.49	-1.14	4.94	-0.14	77.38	-3.95	ZS1 + 1.50*3DVítr7
B1004	3.446+	MSU Sada B (auto)/6	CS36 - 2xIPE 600 - 900	-743.73	-28.87	-165.28	-1.58	-526.77	-87.86	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B1004	3.446+	MSU Sada B (auto)/67	CS36 - 2xIPE 600 - 900	-66.61	5.43	-13.71	0.36	-46.88	19.81	ZS1 + 1.50*3DVítr13
B1004	3.446+	MSU Sada B (auto)/3	CS36 - 2xIPE 600 - 900	-817.26	-22.42	-171.83	-1.14	-588.93	-65.33	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B1004	3.927	MSU Sada B (auto)/7	CS36 - 2xIPE 600 - 900	-772.94	-27.4	-173.57	-2.11	-617.72	-91.71	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B1004	3.927	MSU Sada B (auto)/8	CS36 - 2xIPE 600 - 900	-18.82	2.23	9.49	0.06	-28.72	5.52	ZS1 + 1.50*3DVítr9
B1004	3.927	MSU Sada B (auto)/12	CS36 - 2xIPE 600 - 900	88.28	-1.14	3.24	-0.18	79.35	-4.5	ZS1 + 1.50*3DVítr7
B1004	3.927	MSU Sada B (auto)/6	CS36 - 2xIPE 600 - 900	-745.62	-28.87	-159.11	-2.42	-604.76	-101.73	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B1004	3.927	MSU Sada B (auto)/67	CS36 - 2xIPE 600 - 900	-67	5.43	-13.92	0.55	-53.52	22.42	ZS1 + 1.50*3DVítr13
B1004	3.927	MSU Sada B (auto)/3	CS36 - 2xIPE 600 - 900	-819.21	-22.42	-164.95	-1.76	-669.9	-76.1	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B1005	0	MSU Sada B (auto)/12	CS36 - 2xIPE 600 - 900	49.21	1.74	-16.62	0.01	27.85	-1.09	ZS1 + 1.50*3DVítr7
B1005	0	MSU Sada B (auto)/5	CS36 - 2xIPE 600 - 900	-3.14	1.62	-17.64	-0.13	-22.31	2.59	ZS1 + 1.50*3DVítr5
B1005	0	MSU Sada B (auto)/3	CS36 - 2xIPE 600 - 900	-749.15	-19.38	126.65	-1.39	-597.16	66.08	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B1005	0	MSU Sada B (auto)/7	CS36 - 2xIPE 600 - 900	-712.14	-19.91	104.68	-1.78	-580.69	77.19	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B1005	0	MSU Sada B (auto)/58	CS36 - 2xIPE 600 - 900	-173.35	0.98	32.41	0.4	-135.43	-10.01	ZS1 + 1.50*3DVítr9 + 0.75*ZS4 - Sníh,3
B1005	0	MSU Sada B (auto)/11	CS36 - 2xIPE 600 - 900	82.83	-1.25	-12.45	-0.23	62.99	8.93	ZS1 + 1.50*3DVítr3
B1005	0	MSU Sada B (auto)/8	CS36 - 2xIPE 600 - 900	-67.88	1.7	19.88	0.39	-51.06	-11.61	ZS1 + 1.50*3DVítr9
B1005	0	MSU Sada B (auto)/1	CS36 - 2xIPE 600 - 900	-786.43	-17.04	121.91	-1.23	-635.53	58.76	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B1004	3.446+	MSU Sada B (auto)/7	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.446+	MSU Sada B (auto)/8	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.446+	MSU Sada B (auto)/12	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.446+	MSU Sada B (auto)/6	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.446+	MSU Sada B (auto)/67	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.446+	MSU Sada B (auto)/3	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/7	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/8	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/12	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/6	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/67	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1004	3.927	MSU Sada B (auto)/3	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/12	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/5	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/3	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/7	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/58	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/11	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/8	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01
B1005	0	MSU Sada B (auto)/1	2.35E+05	2.16E-02	5.01E-03	3.29E-04	1.00E-02	1.50E-03	1.04E-02	2.38E-03	4.81E-01	1.23E-01

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ_1	$\bar{\lambda}_y$	$\bar{\lambda}_z$	α	Φ_x	Φ_y	χ_y	χ_z
B1004	3.446+	MSU Sada B (auto)/7	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.446+	MSU Sada B (auto)/8	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.446+	MSU Sada B (auto)/12	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.446+	MSU Sada B (auto)/6	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.446+	MSU Sada B (auto)/67	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.446+	MSU Sada B (auto)/3	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/7	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/8	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/12	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/6	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/67	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1004	3.927	MSU Sada B (auto)/3	3.927	3.927	1	1	76.40915	0.106849	0.417840	0.49	0.482886	0.640666	1.048434	0.887845
B1005	0	MSU Sada B (auto)/12	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/5	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/3	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/7	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/58	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/11	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/8	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788
B1005	0	MSU Sada B (auto)/1	3.928	3.928	1	1	76.40915	0.106876	0.417947	0.49	0.482896	0.640737	1.04842	0.887788

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B1004	3.446+	MSU Sada B (auto)/7	770.91	4508.79	17.10%	532.71	2353.29	22.64%	78.54	351.56	22.34%	62.08%	71.17%
B1004	3.446+	MSU Sada B (auto)/8	18.66	4508.79	0.41%	33.44	2353.29	1.42%	4.45	351.56	1.27%	3.10%	
B1004	3.446+	MSU Sada B (auto)/12	88.49	5078.35	1.74%	77.38	2353.29	3.29%	3.95	351.56	1.12%	6.15%	
B1004	3.446+	MSU Sada B (auto)/6	743.73	4508.79	16.50%	526.77	2353.29	22.38%	87.86	351.56	24.99%	63.87%	
B1004	3.446+	MSU Sada B (auto)/67	66.61	4508.79	1.48%	46.88	2353.29	1.99%	19.81	351.56	5.63%	9.10%	
B1004	3.446+	MSU Sada B (auto)/3	817.26	4508.79	18.13%	588.93	2353.29	25.03%	65.33	351.56	18.58%	61.73%	
B1004	3.927	MSU Sada B (auto)/7	772.94	4508.79	17.14%	617.72	2353.29	26.25%	91.71	351.56	26.09%	69.48%	
B1004	3.927	MSU Sada B (auto)/8	18.82	4508.79	0.42%	28.72	2353.29	1.22%	5.52	351.56	1.57%	3.21%	
B1004	3.927	MSU Sada B (auto)/12	88.28	5078.35	1.74%	79.35	2353.29	3.37%	4.50	351.56	1.28%	6.39%	
B1004	3.927	MSU Sada B (auto)/6	745.62	4508.79	16.54%	604.76	2353.29	25.70%	101.73	351.56	28.94%	71.17%	
B1004	3.927	MSU Sada B (auto)/67	67	4508.79	1.49%	53.52	2353.29	2.27%	22.42	351.56	6.38%	10.14%	
B1004	3.927	MSU Sada B (auto)/3	819.21	4508.79	18.17%	669.90	2353.29	28.47%	76.10	351.56	21.65%	68.28%	
B1005	0	MSU Sada B (auto)/12	49.21	5078.35	0.97%	27.85	2353.29	1.18%	1.09	351.56	0.31%	2.46%	
B1005	0	MSU Sada B (auto)/5	3.14	4508.50	0.07%	22.31	2353.29	0.95%	2.59	351.56	0.74%	1.75%	
B1005	0	MSU Sada B (auto)/3	749.15	4508.50	16.62%	597.16	2353.29	25.38%	66.08	351.56	18.80%	60.79%	
B1005	0	MSU Sada B (auto)/7	712.14	4508.50	15.80%	580.69	2353.29	24.68%	77.19	351.56	21.96%	62.43%	
B1005	0	MSU Sada B (auto)/58	173.35	4508.50	3.84%	135.43	2353.29	5.75%	10.01	351.56	2.85%	12.45%	
B1005	0	MSU Sada B (auto)/11	82.83	5078.35	1.63%	62.99	2353.29	2.68%	8.93	351.56	2.54%	6.85%	
B1005	0	MSU Sada B (auto)/8	67.88	4508.50	1.51%	51.06	2353.29	2.17%	11.61	351.56	3.30%	6.98%	
B1005	0	MSU Sada B (auto)/1	786.43	4508.50	17.44%	635.53	2353.29	27.01%	58.76	351.56	16.71%	61.16%	

Tension rod

The side beam assembly tension rod is problematic from a buckling perspective. The support rods provide bracing against vertical buckling, but, due to the variable height difference between the beam and the tension rod, it is not correct to model the rod as being braced against sideways buckling. However, the bracing at the sides of the beam add a certain amount of stiffness to the joint, rendering possible the modeling of the beam as being supporter on both ends by stiff joints. This in effect, divides the effective buckling distance by 2. A more thorough stability analysis will be required for more conclusive results.

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B787	0.607+	MSU Sada B (auto)/67	CS29 - CFCHS193.7X4	312.14	-0.17	0.28	-0.04	1.14	0.15	1.15*ZS1 + 0.90*3DVítr10 + 1.50*ZS3 - Sníh,2
B787	0.607+	MSU Sada B (auto)/3	CS29 - CFCHS193.7X4	89.6	0.24	0.03	0.13	0.39	0.04	ZS1 + 1.50*3DVítr1 + 0.75*ZS4 - Sníh,3
B787	0.607+	MSU Sada B (auto)/53	CS29 - CFCHS193.7X4	231.89	0.23	0.02	0.16	0.94	0.12	ZS1 + 0.90*3DVítr1 + 1.50*ZS4 - Sníh,3
B787	0.607+	MSU Sada B (auto)/68	CS29 - CFCHS193.7X4	238.97	-0.12	0.3	-0.03	0.87	0.14	1.35*ZS1 + 0.90*3DVítr10 + 0.75*ZS3 - Sníh,2
B787	0.607+	MSU Sada B (auto)/59	CS29 - CFCHS193.7X4	212.18	-0.15	0.3	-0.05	0.73	0.27	1.15*ZS1 + 1.50*3DVítr10 + 0.75*ZS3 - Sníh,2
B787	0.607+	MSU Sada B (auto)/32	CS29 - CFCHS193.7X4	689.15	0.04	0.15	0.07	2.99	-1.01	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B787	0.607+	MSU Sada B (auto)/22	CS29 - CFCHS193.7X4	652.68	0.13	0.09	0.1	2.88	-1.21	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B787	0.607+	MSU Sada B (auto)/48	CS29 - CFCHS193.7X4	107.07	0.03	0.19	0.04	0.31	0.43	ZS1 + 1.50*3DVítr9 + 0.75*ZS4 - Sníh,3
B787	0.607+	MSU Sada B (auto)/56	CS29 - CFCHS193.7X4	-75.18	0.11	0.15	0.03	-0.36	0.05	ZS1 + 1.50*3DVítr7
B787	1.213-	MSU Sada B (auto)/67	CS29 - CFCHS193.7X4	312.14	-0.17	0.16	-0.04	1.28	0.05	1.15*ZS1 + 0.90*3DVítr10 + 1.50*ZS3 - Sníh,2
B787	1.213-	MSU Sada B (auto)/3	CS29 - CFCHS193.7X4	89.6	0.24	-0.09	0.13	0.37	0.19	ZS1 + 1.50*3DVítr1 + 0.75*ZS4 - Sníh,3
B787	1.213-	MSU Sada B (auto)/53	CS29 - CFCHS193.7X4	231.89	0.23	-0.09	0.16	0.92	0.26	ZS1 + 0.90*3DVítr1 + 1.50*ZS4 - Sníh,3
B787	1.213-	MSU Sada B (auto)/59	CS29 - CFCHS193.7X4	212.18	-0.15	0.17	-0.05	0.87	0.18	1.15*ZS1 + 1.50*3DVítr10 + 0.75*ZS3 - Sníh,2
B787	1.213-	MSU Sada B (auto)/32	CS29 - CFCHS193.7X4	689.15	0.04	0.02	0.07	3.04	-0.99	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B787	1.213-	MSU Sada B (auto)/1	CS29 - CFCHS193.7X4	627.31	0.08	0	0.08	2.77	-1.16	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B787	1.213-	MSU Sada B (auto)/48	CS29 - CFCHS193.7X4	107.07	0.03	0.08	0.04	0.4	0.45	ZS1 + 1.50*3DVítr9 + 0.75*ZS4 - Sníh,3
B787	1.213-	MSU Sada B (auto)/56	CS29 - CFCHS193.7X4	-75.18	0.11	0.03	0.03	-0.3	0.11	ZS1 + 1.50*3DVítr7
B787	1.213+	MSU Sada B (auto)/67	CS29 - CFCHS193.7X4	312.14	-0.17	0.16	-0.04	1.28	0.05	1.15*ZS1 + 0.90*3DVítr10 + 1.50*ZS3 - Sníh,2
B787	1.213+	MSU Sada B (auto)/3	CS29 - CFCHS193.7X4	89.6	0.24	-0.09	0.13	0.37	0.19	ZS1 + 1.50*3DVítr1 + 0.75*ZS4 - Sníh,3
B787	1.213+	MSU Sada B (auto)/53	CS29 - CFCHS193.7X4	231.89	0.23	-0.09	0.16	0.92	0.26	ZS1 + 0.90*3DVítr1 + 1.50*ZS4 - Sníh,3
B787	1.213+	MSU Sada B (auto)/59	CS29 - CFCHS193.7X4	212.18	-0.15	0.17	-0.05	0.87	0.18	1.15*ZS1 + 1.50*3DVítr10 + 0.75*ZS3 - Sníh,2
B787	1.213+	MSU Sada B (auto)/32	CS29 - CFCHS193.7X4	689.15	0.04	0.02	0.07	3.04	-0.99	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B787	1.213+	MSU Sada B (auto)/1	CS29 - CFCHS193.7X4	627.31	0.08	0	0.08	2.77	-1.16	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B787	1.213+	MSU Sada B (auto)/48	CS29 - CFCHS193.7X4	107.07	0.03	0.08	0.04	0.4	0.45	ZS1 + 1.50*3DVítr9 + 0.75*ZS4 - Sníh,3
B787	1.213+	MSU Sada B (auto)/56	CS29 - CFCHS193.7X4	-75.18	0.11	0.03	0.03	-0.3	0.11	ZS1 + 1.50*3DVítr7

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B787	0.607+	MSU Sada B (auto)/67	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/3	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/53	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/68	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/59	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/32	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/22	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/48	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	0.607+	MSU Sada B (auto)/56	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/67	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/3	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/53	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/59	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/32	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/1	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/48	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213-	MSU Sada B (auto)/56	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/67	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/3	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/53	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/59	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/32	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/1	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/48	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02
B787	1.213+	MSU Sada B (auto)/56	3.55E+05	2.38E-03	1.07E-05	1.07E-05	1.11E-04	1.11E-04	1.44E-04	1.44E-04	6.70E-02	6.70E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ_1	$\bar{\lambda}_y$	$\bar{\lambda}_z$	α	Φ_x	Φ_y	χ_y	χ_z
B787	0.607+	MSU Sada B (auto)/67	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/3	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/53	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/68	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/59	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/32	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/22	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/48	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	0.607+	MSU Sada B (auto)/56	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/67	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/3	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/53	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/59	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/32	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/1	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/48	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213-	MSU Sada B (auto)/56	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/67	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/3	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/53	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/59	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/32	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/1	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/48	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303
B787	1.213+	MSU Sada B (auto)/56	3.033	30	1	0.5	76.40915	0.5924508	2.9300236	0.49	0.771649	5.461375	0.78985	0.099303

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B787	0.607+	MSU Sada B (auto)/67	312.14	846.32	36.88%	1.14	39.32	2.90%	0.15	39.32	0.38%	40.16%	91.68%
B787	0.607+	MSU Sada B (auto)/3	89.6	846.32	10.59%	0.39	39.32	0.99%	0.04	39.32	0.10%	11.68%	
B787	0.607+	MSU Sada B (auto)/53	231.89	846.32	27.40%	0.94	39.32	2.39%	0.12	39.32	0.31%	30.10%	
B787	0.607+	MSU Sada B (auto)/68	238.97	846.32	28.24%	0.87	39.32	2.21%	0.14	39.32	0.36%	30.80%	
B787	0.607+	MSU Sada B (auto)/59	212.18	846.32	25.07%	0.73	39.32	1.86%	0.27	39.32	0.69%	27.61%	
B787	0.607+	MSU Sada B (auto)/32	689.15	846.32	81.43%	2.99	39.32	7.60%	1.01	39.32	2.57%	91.60%	
B787	0.607+	MSU Sada B (auto)/22	652.68	846.32	77.12%	2.88	39.32	7.32%	1.21	39.32	3.08%	87.52%	
B787	0.607+	MSU Sada B (auto)/48	107.07	846.32	12.65%	0.31	39.32	0.79%	0.43	39.32	1.09%	14.53%	
B787	0.607+	MSU Sada B (auto)/56	75.18	84.04	89.46%	0.36	39.32	0.92%	0.05	39.32	0.13%	90.50%	
B787	1.213-	MSU Sada B (auto)/67	312.14	846.32	36.88%	1.28	39.32	3.26%	0.05	39.32	0.13%	40.26%	
B787	1.213-	MSU Sada B (auto)/3	89.6	846.32	10.59%	0.37	39.32	0.94%	0.19	39.32	0.48%	12.01%	
B787	1.213-	MSU Sada B (auto)/53	231.89	846.32	27.40%	0.92	39.32	2.34%	0.26	39.32	0.66%	30.40%	
B787	1.213-	MSU Sada B (auto)/59	212.18	846.32	25.07%	0.87	39.32	2.21%	0.18	39.32	0.46%	27.74%	
B787	1.213-	MSU Sada B (auto)/32	689.15	846.32	81.43%	3.04	39.32	7.73%	0.99	39.32	2.52%	91.68%	
B787	1.213-	MSU Sada B (auto)/1	627.31	846.32	74.12%	2.77	39.32	7.04%	1.16	39.32	2.95%	84.12%	
B787	1.213-	MSU Sada B (auto)/48	107.07	846.32	12.65%	0.40	39.32	1.02%	0.45	39.32	1.14%	14.81%	
B787	1.213-	MSU Sada B (auto)/56	75.18	84.04	89.46%	0.30	39.32	0.76%	0.11	39.32	0.28%	90.50%	
B787	1.213+	MSU Sada B (auto)/67	312.14	846.32	36.88%	1.28	39.32	3.26%	0.05	39.32	0.13%	40.26%	
B787	1.213+	MSU Sada B (auto)/3	89.6	846.32	10.59%	0.37	39.32	0.94%	0.19	39.32	0.48%	12.01%	
B787	1.213+	MSU Sada B (auto)/53	231.89	846.32	27.40%	0.92	39.32	2.34%	0.26	39.32	0.66%	30.40%	
B787	1.213+	MSU Sada B (auto)/59	212.18	846.32	25.07%	0.87	39.32	2.21%	0.18	39.32	0.46%	27.74%	
B787	1.213+	MSU Sada B (auto)/32	689.15	846.32	81.43%	3.04	39.32	7.73%	0.99	39.32	2.52%	91.68%	
B787	1.213+	MSU Sada B (auto)/1	627.31	846.32	74.12%	2.77	39.32	7.04%	1.16	39.32	2.95%	84.12%	
B787	1.213+	MSU Sada B (auto)/48	107.07	846.32	12.65%	0.40	39.32	1.02%	0.45	39.32	1.14%	14.81%	
B787	1.213+	MSU Sada B (auto)/56	75.18	84.04	89.46%	0.30	39.32	0.76%	0.11	39.32	0.28%	90.50%	

Support rod:

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B1262	2.108+	MSU Sada B (auto)/34	CS41 - CHS48.3/3.2	1.17	0	0	0	0	0	1.15*ZS1 + 1.50*3DVítr5
B1262	2.108+	MSU Sada B (auto)/6	CS41 - CHS48.3/3.2	0.17	0	0	0	0	0	1.35*ZS1
B1262	2.108+	MSU Sada B (auto)/42	CS41 - CHS48.3/3.2	0.95	0	0	0	0	0	ZS1 + 1.50*3DVítr6
B1262	2.108+	MSU Sada B (auto)/49	CS41 - CHS48.3/3.2	-0.98	0	0	0.01	0	0	1.15*ZS1 + 0.75*ZS2 + 1.50*3DVítr11
B1262	2.108+	MSU Sada B (auto)/50	CS41 - CHS48.3/3.2	-2.11	0	0	0.01	0	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr13
B1262	2.635	MSU Sada B (auto)/34	CS41 - CHS48.3/3.2	1.15	0	0	0	0	0	1.15*ZS1 + 1.50*3DVítr5
B1262	2.635	MSU Sada B (auto)/6	CS41 - CHS48.3/3.2	0.14	0	0	0	0	0	1.35*ZS1
B1262	2.635	MSU Sada B (auto)/42	CS41 - CHS48.3/3.2	0.93	0	0	0	0	0	ZS1 + 1.50*3DVítr6
B1262	2.635	MSU Sada B (auto)/49	CS41 - CHS48.3/3.2	-1	0	0	0.01	0	0	1.15*ZS1 + 0.75*ZS2 + 1.50*3DVítr11
B1262	2.635	MSU Sada B (auto)/50	CS41 - CHS48.3/3.2	-2.13	0	0	0.01	0	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr13
B1263	0	MSU Sada B (auto)/37	CS41 - CHS48.3/3.2	1.14	0	0.01	0	0	0	1.15*ZS1 + 0.90*3DVítr2 + 1.50*ZS3 - Sníh,2
B1263	0	MSU Sada B (auto)/6	CS41 - CHS48.3/3.2	0.59	0	0.01	0	0	0	1.35*ZS1
B1263	0	MSU Sada B (auto)/41	CS41 - CHS48.3/3.2	-0.41	0	0.01	-0.01	0	0	ZS1 + 0.90*3DVítr2 + 1.50*ZS4 - Sníh,3
B1263	0	MSU Sada B (auto)/40	CS41 - CHS48.3/3.2	-0.89	0	0.01	0.01	0	0	1.15*ZS1 + 1.50*3DVítr9 + 0.75*ZS3 - Sníh,2
B1263	0	MSU Sada B (auto)/38	CS41 - CHS48.3/3.2	-1.77	0	0.01	0	0	0	ZS1 + 1.50*3DVítr11 + 0.75*ZS4 - Sníh,3

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B1262	2.108+	MSU Sada B (auto)/34	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.108+	MSU Sada B (auto)/6	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.108+	MSU Sada B (auto)/42	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.108+	MSU Sada B (auto)/49	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.108+	MSU Sada B (auto)/50	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.635	MSU Sada B (auto)/34	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.635	MSU Sada B (auto)/6	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.635	MSU Sada B (auto)/42	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.635	MSU Sada B (auto)/49	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1262	2.635	MSU Sada B (auto)/50	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1263	0	MSU Sada B (auto)/37	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1263	0	MSU Sada B (auto)/6	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1263	0	MSU Sada B (auto)/41	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1263	0	MSU Sada B (auto)/40	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1263	0	MSU Sada B (auto)/38	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ1	λy	λz	α	Φx	Φy	χy	χz
B1262	2.108+	MSU Sada B (auto)/34	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.108+	MSU Sada B (auto)/6	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.108+	MSU Sada B (auto)/42	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.108+	MSU Sada B (auto)/49	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.108+	MSU Sada B (auto)/50	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.635	MSU Sada B (auto)/34	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.635	MSU Sada B (auto)/6	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.635	MSU Sada B (auto)/42	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.635	MSU Sada B (auto)/49	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1262	2.635	MSU Sada B (auto)/50	2.635	2.635	1	1	76.40915	2.1553375	2.1553375	0.49	3.301798	3.301798	0.172322	0.172322
B1263	0	MSU Sada B (auto)/37	2.438	2.438	1	1	76.40915	1.9941985	1.9941985	0.49	2.927992	2.927992	0.197165	0.197165
B1263	0	MSU Sada B (auto)/6	2.438	2.438	1	1	76.40915	1.9941985	1.9941985	0.49	2.927992	2.927992	0.197165	0.197165
B1263	0	MSU Sada B (auto)/41	2.438	2.438	1	1	76.40915	1.9941985	1.9941985	0.49	2.927992	2.927992	0.197165	0.197165
B1263	0	MSU Sada B (auto)/40	2.438	2.438	1	1	76.40915	1.9941985	1.9941985	0.49	2.927992	2.927992	0.197165	0.197165
B1263	0	MSU Sada B (auto)/38	2.438	2.438	1	1	76.40915	1.9941985	1.9941985	0.49	2.927992	2.927992	0.197165	0.197165

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B1262	2.108+	MSU Sada B (auto)/34	1.17	160.82	0.73%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.73%	7.69%
B1262	2.108+	MSU Sada B (auto)/6	0.17	160.82	0.11%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.11%	
B1262	2.108+	MSU Sada B (auto)/42	0.95	160.82	0.59%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.59%	
B1262	2.108+	MSU Sada B (auto)/49	0.98	27.71	3.54%	0.00	1.70	0.00%	0.00	1.70	0.00%	3.54%	
B1262	2.108+	MSU Sada B (auto)/50	2.11	27.71	7.61%	0.00	1.70	0.00%	0.00	1.70	0.00%	7.61%	
B1262	2.635	MSU Sada B (auto)/34	1.15	160.82	0.72%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.72%	
B1262	2.635	MSU Sada B (auto)/6	0.14	160.82	0.09%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.09%	
B1262	2.635	MSU Sada B (auto)/42	0.93	160.82	0.58%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.58%	
B1262	2.635	MSU Sada B (auto)/49	1	27.71	3.61%	0.00	1.70	0.00%	0.00	1.70	0.00%	3.61%	
B1262	2.635	MSU Sada B (auto)/50	2.13	27.71	7.69%	0.00	1.70	0.00%	0.00	1.70	0.00%	7.69%	
B1263	0	MSU Sada B (auto)/37	1.14	160.82	0.71%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.71%	
B1263	0	MSU Sada B (auto)/6	0.59	160.82	0.37%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.37%	
B1263	0	MSU Sada B (auto)/41	0.41	31.71	1.29%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.29%	
B1263	0	MSU Sada B (auto)/40	0.89	31.71	2.81%	0.00	1.70	0.00%	0.00	1.70	0.00%	2.81%	
B1263	0	MSU Sada B (auto)/38	1.77	31.71	5.58%	0.00	1.70	0.00%	0.00	1.70	0.00%	5.58%	

Grid beam assembly (secondary beam):

Beam:

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B45	3.392	MSU Sada B (auto)/2	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B45	3.392	MSU Sada B (auto)/37	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B45	3.392	MSU Sada B (auto)/25	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B45	3.392	MSU Sada B (auto)/119	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B45	3.392	MSU Sada B (auto)/24	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B45	3.392	MSU Sada B (auto)/4	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/17	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/40	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/24	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/25	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/7	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0	MSU Sada B (auto)/4	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/17	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/40	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/24	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/25	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/7	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02
B46	0.439-	MSU Sada B (auto)/4	3.55E+05	3.79E-03	1.77E-04	6.02E-06	7.87E-04	8.03E-05	8.18E-04	1.21E-04	2.16E-01	4.00E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ1	λy	λz	α	Φx	Φy	χy	χz
B45	3.392	MSU Sada B (auto)/2	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B45	3.392	MSU Sada B (auto)/37	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B45	3.392	MSU Sada B (auto)/25	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B45	3.392	MSU Sada B (auto)/119	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B45	3.392	MSU Sada B (auto)/24	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B45	3.392	MSU Sada B (auto)/4	3.392	3.392	0.5	1	76.40915	0.102761	1.109815	0.49	0.481456	1.338749	1.050621	0.479052
B46	0	MSU Sada B (auto)/17	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0	MSU Sada B (auto)/40	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0	MSU Sada B (auto)/24	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0	MSU Sada B (auto)/25	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0	MSU Sada B (auto)/7	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0	MSU Sada B (auto)/4	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/17	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/40	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/24	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/25	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/7	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169
B46	0.439-	MSU Sada B (auto)/4	3.444	3.444	0.5	1	76.40915	0.104336	1.126828	0.49	0.482005	1.361944	1.049778	0.470169

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B45	3.392	MSU Sada B (auto)/2	92.26	644.52	14.31%	31.25	279.44	11.18%	0.94	28.50	3.30%	28.80%	85.34%
B45	3.392	MSU Sada B (auto)/37	21.04	644.52	3.26%	7.95	279.44	2.84%	0.37	28.50	1.30%	7.41%	
B45	3.392	MSU Sada B (auto)/25	37.11	1345.41	2.76%	12.82	279.44	4.59%	1.29	28.50	4.53%	11.87%	
B45	3.392	MSU Sada B (auto)/119	119.71	644.52	18.57%	41.04	279.44	14.69%	4.06	28.50	14.24%	47.50%	
B45	3.392	MSU Sada B (auto)/24	7.16	1345.41	0.53%	2.21	279.44	0.79%	3.36	28.50	11.79%	13.11%	
B45	3.392	MSU Sada B (auto)/4	245.87	644.52	38.15%	84.98	279.44	30.41%	0.56	28.50	1.96%	70.52%	
B46	0	MSU Sada B (auto)/17	23.19	1345.41	1.72%	6.79	279.44	2.43%	1.87	28.50	6.56%	10.71%	
B46	0	MSU Sada B (auto)/40	102	632.57	16.12%	32.97	279.44	11.80%	2.15	28.50	7.54%	35.47%	
B46	0	MSU Sada B (auto)/24	13.62	632.57	2.15%	4.43	279.44	1.59%	2.43	28.50	8.53%	12.26%	
B46	0	MSU Sada B (auto)/25	43.49	1345.41	3.23%	14.08	279.44	5.04%	1.44	28.50	5.05%	13.32%	
B46	0	MSU Sada B (auto)/7	218.82	632.57	34.59%	71.21	279.44	25.48%	7.20	28.50	25.26%	85.34%	
B46	0	MSU Sada B (auto)/4	250.79	632.57	39.65%	81.58	279.44	29.19%	3.88	28.50	13.61%	82.45%	
B46	0.439-	MSU Sada B (auto)/17	23.19	1345.41	1.72%	3.65	279.44	1.31%	1.43	28.50	5.02%	8.05%	
B46	0.439-	MSU Sada B (auto)/40	101.82	632.57	16.10%	27.83	279.44	9.96%	1.63	28.50	5.72%	31.77%	
B46	0.439-	MSU Sada B (auto)/24	13.54	632.57	2.14%	3.89	279.44	1.39%	1.91	28.50	6.70%	10.23%	
B46	0.439-	MSU Sada B (auto)/25	43.51	1345.41	3.23%	12.11	279.44	4.33%	1.09	28.50	3.82%	11.39%	
B46	0.439-	MSU Sada B (auto)/7	218.73	632.57	34.58%	70.85	279.44	25.35%	5.52	28.50	19.37%	79.30%	
B46	0.439-	MSU Sada B (auto)/4	250.67	632.57	39.63%	79.61	279.44	28.49%	2.95	28.50	10.35%	78.47%	

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B45	3.392	MSU Sada B (auto)/2	CS25 - Prolamovaný nosník \	-92.26	-0.51	-21.19	-0.01	-31.25	-0.94	1.15*ZS1 + 0.90*3DVítr2 + 1.50*ZS4 - Sníh,3
B45	3.392	MSU Sada B (auto)/37	CS25 - Prolamovaný nosník \	-21.04	0.18	2.76	0.01	-7.95	0.37	ZS1 + 1.50*3DVítr10
B45	3.392	MSU Sada B (auto)/25	CS25 - Prolamovaný nosník \	37.11	-0.68	0.33	-0.01	12.82	-1.29	ZS1 + 1.50*3DVítr7
B45	3.392	MSU Sada B (auto)/119	CS25 - Prolamovaný nosník \	-119.71	-2.14	-5.61	-0.06	-41.04	-4.06	1.15*ZS1 + 0.75*ZS2 + 1.50*3DVítr6
B45	3.392	MSU Sada B (auto)/24	CS25 - Prolamovaný nosník \	7.16	1.74	0.35	0.05	2.21	3.36	ZS1 + 1.50*3DVítr13
B45	3.392	MSU Sada B (auto)/4	CS25 - Prolamovaný nosník \	-245.87	0.27	-9.99	0.01	-84.98	0.56	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B46	0	MSU Sada B (auto)/17	CS25 - Prolamovaný nosník \	23.19	1.01	-6.91	0.02	6.79	-1.87	ZS1 + 1.50*3DVítr1
B46	0	MSU Sada B (auto)/40	CS25 - Prolamovaný nosník \	-102	1.21	11.34	0.03	-32.97	-2.15	1.15*ZS1 + 0.90*3DVítr10 + 1.50*ZS3 - Sníh,2
B46	0	MSU Sada B (auto)/24	CS25 - Prolamovaný nosník \	-13.62	-1.18	1.28	-0.04	-4.43	2.43	ZS1 + 1.50*3DVítr13
B46	0	MSU Sada B (auto)/25	CS25 - Prolamovaný nosník \	43.49	0.8	-4.18	0.02	14.08	-1.44	ZS1 + 1.50*3DVítr7
B46	0	MSU Sada B (auto)/7	CS25 - Prolamovaný nosník \	-218.82	3.82	-0.02	0.11	-71.21	-7.2	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B46	0	MSU Sada B (auto)/4	CS25 - Prolamovaný nosník \	-250.79	2.13	3.48	0.06	-81.58	-3.88	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B46	0.439-	MSU Sada B (auto)/17	CS25 - Prolamovaný nosník \	23.19	0.99	-7.32	0.01	3.65	-1.43	ZS1 + 1.50*3DVítr1
B46	0.439-	MSU Sada B (auto)/40	CS25 - Prolamovaný nosník \	-101.82	1.18	12	0.02	-27.83	-1.63	1.15*ZS1 + 0.90*3DVítr10 + 1.50*ZS3 - Sníh,2
B46	0.439-	MSU Sada B (auto)/24	CS25 - Prolamovaný nosník \	-13.54	-1.21	1.19	-0.02	-3.89	1.91	ZS1 + 1.50*3DVítr13
B46	0.439-	MSU Sada B (auto)/25	CS25 - Prolamovaný nosník \	43.51	0.78	-4.77	0.01	12.11	-1.09	ZS1 + 1.50*3DVítr7
B46	0.439-	MSU Sada B (auto)/7	CS25 - Prolamovaný nosník \	-218.73	3.79	1.67	0.06	-70.85	-5.52	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B46	0.439-	MSU Sada B (auto)/4	CS25 - Prolamovaný nosník \	-250.67	2.09	5.45	0.04	-79.61	-2.95	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14

Tension rod:

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B859	3.532	MSU Sada B (auto)/1	CS31 - CHSCF88.9/3.0	226.37	0	-0.03	-0.01	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B859	3.532	MSU Sada B (auto)/13	CS31 - CHSCF88.9/3.0	217.53	-0.01	-0.03	0.02	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B859	3.532	MSU Sada B (auto)/30	CS31 - CHSCF88.9/3.0	-6.37	0	-0.09	-0.03	0	0	ZS1 + 1.50*3DVítr13
B859	3.532	MSU Sada B (auto)/80	CS31 - CHSCF88.9/3.0	44.37	0	-0.12	-0.01	0	0	1.35*ZS1 + 0.90*3DVítr9 + 0.75*ZS3 - Sníh,2
B859	3.532	MSU Sada B (auto)/63	CS31 - CHSCF88.9/3.0	217.3	-0.01	-0.01	0.01	0	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B859	3.532	MSU Sada B (auto)/81	CS31 - CHSCF88.9/3.0	26.47	0	-0.09	-0.03	0	0	1.15*ZS1 + 1.50*3DVítr13 + 0.75*ZS4 - Sníh,3
B859	3.532	MSU Sada B (auto)/82	CS31 - CHSCF88.9/3.0	78.39	-0.01	-0.05	0.03	0	0	ZS1 + 0.75*ZS2 + 1.50*3DVítr5
B859	3.532	MSU Sada B (auto)/39	CS31 - CHSCF88.9/3.0	-32.98	0	-0.09	0.01	0	0	ZS1 + 1.50*3DVítr7
B860	0	MSU Sada B (auto)/1	CS31 - CHSCF88.9/3.0	239.18	-0.01	0.23	0.02	-0.37	0.02	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B860	0	MSU Sada B (auto)/13	CS31 - CHSCF88.9/3.0	211.29	-0.01	0.23	0.05	-0.38	0.03	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B860	0	MSU Sada B (auto)/24	CS31 - CHSCF88.9/3.0	-2.42	0	0.12	-0.01	-0.04	0	ZS1 + 1.50*3DVítr9
B860	0	MSU Sada B (auto)/37	CS31 - CHSCF88.9/3.0	14.86	0	0.16	-0.02	-0.1	-0.01	1.15*ZS1 + 1.50*3DVítr13
B860	0	MSU Sada B (auto)/36	CS31 - CHSCF88.9/3.0	207.78	-0.01	0.21	0.05	-0.36	0.03	ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B860	0	MSU Sada B (auto)/20	CS31 - CHSCF88.9/3.0	221.25	-0.01	0.24	0.04	-0.41	0.02	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B860	0	MSU Sada B (auto)/68	CS31 - CHSCF88.9/3.0	-19.11	0	0.15	0.01	-0.15	-0.01	ZS1 + 1.50*3DVítr1
B860	0	MSU Sada B (auto)/39	CS31 - CHSCF88.9/3.0	-39.18	0	0.14	0.01	-0.09	0	ZS1 + 1.50*3DVítr7
B860	0.716-	MSU Sada B (auto)/1	CS31 - CHSCF88.9/3.0	239.18	-0.01	0.18	0.02	-0.22	0.02	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr14
B860	0.716-	MSU Sada B (auto)/13	CS31 - CHSCF88.9/3.0	211.29	-0.01	0.18	0.05	-0.23	0.02	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B860	0.716-	MSU Sada B (auto)/24	CS31 - CHSCF88.9/3.0	-2.42	0	0.08	-0.01	0.03	0	ZS1 + 1.50*3DVítr9
B860	0.716-	MSU Sada B (auto)/37	CS31 - CHSCF88.9/3.0	14.86	0	0.11	-0.02	-0.01	-0.01	1.15*ZS1 + 1.50*3DVítr13
B860	0.716-	MSU Sada B (auto)/36	CS31 - CHSCF88.9/3.0	207.78	-0.01	0.17	0.05	-0.23	0.02	ZS1 + 1.50*ZS2 + 0.90*3DVítr6
B860	0.716-	MSU Sada B (auto)/20	CS31 - CHSCF88.9/3.0	221.25	-0.01	0.19	0.04	-0.25	0.02	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B860	0.716-	MSU Sada B (auto)/68	CS31 - CHSCF88.9/3.0	-19.11	0	0.11	0.01	-0.06	-0.01	ZS1 + 1.50*3DVítr1
B860	0.716-	MSU Sada B (auto)/39	CS31 - CHSCF88.9/3.0	-39.18	0	0.09	0.01	-0.01	0	ZS1 + 1.50*3DVítr7

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B859	3.532	MSU Sada B (auto)/1	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/13	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/30	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/80	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/63	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/81	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/82	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B859	3.532	MSU Sada B (auto)/39	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/1	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/13	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/24	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/37	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/36	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/20	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/68	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0	MSU Sada B (auto)/39	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/1	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/13	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/24	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/37	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/36	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/20	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/68	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02
B860	0.716-	MSU Sada B (auto)/39	3.55E+05	8.10E-04	7.48E-07	7.48E-07	1.68E-05	1.68E-05	2.18E-05	2.18E-05	3.00E-02	3.00E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ1	λy	λz	α	Φx	Φy	χy	χz
B859	3.532	MSU Sada B (auto)/1	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/13	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/30	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/80	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/63	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/81	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/82	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B859	3.532	MSU Sada B (auto)/39	3.532	3.532	1	1	76.40915	1.540828	1.540828	0.49	2.015578	2.015578	0.301662	0.301662
B860	0	MSU Sada B (auto)/1	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/13	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/24	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/37	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/36	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/20	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/68	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0	MSU Sada B (auto)/39	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/1	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/13	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/24	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/37	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/36	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/20	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/68	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533
B860	0.716-	MSU Sada B (auto)/39	3.58	3.58	1	1	76.40915	1.561768	1.561768	0.49	2.053192	2.053192	0.29533	0.29533

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B859	3.532	MSU Sada B (auto)/1	226.37	287.55	78.72%	0.00	5.96	0.00%	0.00	5.96	0.00%	78.72%	89.72%
B859	3.532	MSU Sada B (auto)/13	217.53	287.55	75.65%	0.00	5.96	0.00%	0.00	5.96	0.00%	75.65%	
B859	3.532	MSU Sada B (auto)/30	6.37	86.74	7.34%	0.00	5.96	0.00%	0.00	5.96	0.00%	7.34%	
B859	3.532	MSU Sada B (auto)/80	44.37	287.55	15.43%	0.00	5.96	0.00%	0.00	5.96	0.00%	15.43%	
B859	3.532	MSU Sada B (auto)/63	217.3	287.55	75.57%	0.00	5.96	0.00%	0.00	5.96	0.00%	75.57%	
B859	3.532	MSU Sada B (auto)/81	26.47	287.55	9.21%	0.00	5.96	0.00%	0.00	5.96	0.00%	9.21%	
B859	3.532	MSU Sada B (auto)/82	78.39	287.55	27.26%	0.00	5.96	0.00%	0.00	5.96	0.00%	27.26%	
B859	3.532	MSU Sada B (auto)/39	32.98	86.74	38.02%	0.00	5.96	0.00%	0.00	5.96	0.00%	38.02%	
B860	0	MSU Sada B (auto)/1	239.18	287.55	83.18%	0.37	5.96	6.20%	0.02	5.96	0.34%	89.72%	
B860	0	MSU Sada B (auto)/13	211.29	287.55	73.48%	0.38	5.96	6.37%	0.03	5.96	0.50%	80.35%	
B860	0	MSU Sada B (auto)/24	2.42	84.92	2.85%	0.04	5.96	0.67%	0.00	5.96	0.00%	3.52%	
B860	0	MSU Sada B (auto)/37	14.86	287.55	5.17%	0.10	5.96	1.68%	0.01	5.96	0.17%	7.01%	
B860	0	MSU Sada B (auto)/36	207.78	287.55	72.26%	0.36	5.96	6.04%	0.03	5.96	0.50%	78.80%	
B860	0	MSU Sada B (auto)/20	221.25	287.55	76.94%	0.41	5.96	6.87%	0.02	5.96	0.34%	84.15%	
B860	0	MSU Sada B (auto)/68	19.11	84.92	22.50%	0.15	5.96	2.52%	0.01	5.96	0.17%	25.19%	
B860	0	MSU Sada B (auto)/39	39.18	84.92	46.14%	0.09	5.96	1.51%	0.00	5.96	0.00%	47.65%	
B860	0.716-	MSU Sada B (auto)/1	239.18	287.55	83.18%	0.22	5.96	3.69%	0.02	5.96	0.34%	87.20%	
B860	0.716-	MSU Sada B (auto)/13	211.29	287.55	73.48%	0.23	5.96	3.86%	0.02	5.96	0.34%	77.67%	
B860	0.716-	MSU Sada B (auto)/24	2.42	84.92	2.85%	0.03	5.96	0.50%	0.00	5.96	0.00%	3.35%	
B860	0.716-	MSU Sada B (auto)/37	14.86	287.55	5.17%	0.01	5.96	0.17%	0.01	5.96	0.17%	5.50%	
B860	0.716-	MSU Sada B (auto)/36	207.78	287.55	72.26%	0.23	5.96	3.86%	0.02	5.96	0.34%	76.45%	
B860	0.716-	MSU Sada B (auto)/20	221.25	287.55	76.94%	0.25	5.96	4.19%	0.02	5.96	0.34%	81.47%	
B860	0.716-	MSU Sada B (auto)/68	19.11	84.92	22.50%	0.06	5.96	1.01%	0.01	5.96	0.17%	23.68%	
B860	0.716-	MSU Sada B (auto)/39	39.18	84.92	46.14%	0.01	5.96	0.17%	0.00	5.96	0.00%	46.30%	

Support rod:

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B1125	1.783+	MSU Sada B (auto)/2	CS40 - CHS48.3/3.2	-0.27	0	0	0	0	0	1.35*ZS1
B1125	1.783+	MSU Sada B (auto)/49	CS40 - CHS48.3/3.2	-0.65	0	0	0	0	0	1.15*ZS1 + 1.50*3DVítr13 + 0.75*ZS4 - Sníh,3
B1125	1.783+	MSU Sada B (auto)/50	CS40 - CHS48.3/3.2	-2.33	0	0	0	0	0	ZS1 + 0.90*3DVítr6 + 1.50*ZS3 - Sníh,2
B1125	1.783+	MSU Sada B (auto)/78	CS40 - CHS48.3/3.2	1.99	0	0	0	0	0	ZS1 + 1.50*3DVítr7
B1125	1.783+	MSU Sada B (auto)/19	CS40 - CHS48.3/3.2	-7.9	0	0	0	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B1125	2.228	MSU Sada B (auto)/2	CS40 - CHS48.3/3.2	-0.29	0	-0.01	0	0	0	1.35*ZS1
B1125	2.228	MSU Sada B (auto)/78	CS40 - CHS48.3/3.2	1.97	0	-0.01	0	0	0	ZS1 + 1.50*3DVítr7
B1125	2.228	MSU Sada B (auto)/49	CS40 - CHS48.3/3.2	-0.66	0	-0.01	0	0	0	1.15*ZS1 + 1.50*3DVítr13 + 0.75*ZS4 - Sníh,3
B1125	2.228	MSU Sada B (auto)/50	CS40 - CHS48.3/3.2	-2.34	0	-0.01	0	0	0	ZS1 + 0.90*3DVítr6 + 1.50*ZS3 - Sníh,2
B1125	2.228	MSU Sada B (auto)/19	CS40 - CHS48.3/3.2	-7.91	0	-0.01	0	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B1126	0	MSU Sada B (auto)/20	CS40 - CHS48.3/3.2	5.11	0	0	0	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr2
B1126	0	MSU Sada B (auto)/2	CS40 - CHS48.3/3.2	1.56	0	0.01	0	0	0	1.35*ZS1
B1126	0	MSU Sada B (auto)/90	CS40 - CHS48.3/3.2	1.64	0	0	0	0	0	ZS1 + 1.50*3DVítr14 + 0.75*ZS4 - Sníh,3
B1126	0	MSU Sada B (auto)/134	CS40 - CHS48.3/3.2	4.63	0	0	0	0	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr5
B1126	0	MSU Sada B (auto)/75	CS40 - CHS48.3/3.2	0.1	0	0	0	0	0	ZS1 + 1.50*3DVítr11

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B1125	1.783+	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	1.783+	MSU Sada B (auto)/49	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	1.783+	MSU Sada B (auto)/50	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	1.783+	MSU Sada B (auto)/78	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	1.783+	MSU Sada B (auto)/19	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	2.228	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	2.228	MSU Sada B (auto)/78	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	2.228	MSU Sada B (auto)/49	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	2.228	MSU Sada B (auto)/50	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1125	2.228	MSU Sada B (auto)/19	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1126	0	MSU Sada B (auto)/20	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1126	0	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1126	0	MSU Sada B (auto)/90	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1126	0	MSU Sada B (auto)/134	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1126	0	MSU Sada B (auto)/75	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ1	λy	λz	α	Φx	Φy	χy	χz
B1125	1.783+	MSU Sada B (auto)/2	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	1.783+	MSU Sada B (auto)/49	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	1.783+	MSU Sada B (auto)/50	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	1.783+	MSU Sada B (auto)/78	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	1.783+	MSU Sada B (auto)/19	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	2.228	MSU Sada B (auto)/2	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	2.228	MSU Sada B (auto)/78	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	2.228	MSU Sada B (auto)/49	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	2.228	MSU Sada B (auto)/50	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1125	2.228	MSU Sada B (auto)/19	2.228	2.228	1	1	76.40915	1.8224258	1.8224258	0.49	2.558112	2.558112	0.229711	0.229711
B1126	0	MSU Sada B (auto)/20	2.246	2.246	1	1	76.40915	1.8371492	1.8371492	0.49	2.58866	2.58866	0.226634	0.226634
B1126	0	MSU Sada B (auto)/2	2.246	2.246	1	1	76.40915	1.8371492	1.8371492	0.49	2.58866	2.58866	0.226634	0.226634
B1126	0	MSU Sada B (auto)/90	2.246	2.246	1	1	76.40915	1.8371492	1.8371492	0.49	2.58866	2.58866	0.226634	0.226634
B1126	0	MSU Sada B (auto)/134	2.246	2.246	1	1	76.40915	1.8371492	1.8371492	0.49	2.58866	2.58866	0.226634	0.226634
B1126	0	MSU Sada B (auto)/75	2.246	2.246	1	1	76.40915	1.8371492	1.8371492	0.49	2.58866	2.58866	0.226634	0.226634

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B1125	1.783+	MSU Sada B (auto)/2	0.27	36.94	0.73%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.73%	21.41%
B1125	1.783+	MSU Sada B (auto)/49	0.65	36.94	1.76%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.76%	
B1125	1.783+	MSU Sada B (auto)/50	2.33	36.94	6.31%	0.00	1.70	0.00%	0.00	1.70	0.00%	6.31%	
B1125	1.783+	MSU Sada B (auto)/78	1.99	160.82	1.24%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.24%	
B1125	1.783+	MSU Sada B (auto)/19	7.9	36.94	21.39%	0.00	1.70	0.00%	0.00	1.70	0.00%	21.39%	
B1125	2.228	MSU Sada B (auto)/2	0.29	36.94	0.79%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.79%	
B1125	2.228	MSU Sada B (auto)/78	1.97	160.82	1.23%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.23%	
B1125	2.228	MSU Sada B (auto)/49	0.66	36.94	1.79%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.79%	
B1125	2.228	MSU Sada B (auto)/50	2.34	36.94	6.33%	0.00	1.70	0.00%	0.00	1.70	0.00%	6.33%	
B1125	2.228	MSU Sada B (auto)/19	7.91	36.94	21.41%	0.00	1.70	0.00%	0.00	1.70	0.00%	21.41%	
B1126	0	MSU Sada B (auto)/20	5.11	160.82	3.18%	0.00	1.70	0.00%	0.00	1.70	0.00%	3.18%	
B1126	0	MSU Sada B (auto)/2	1.56	160.82	0.97%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.97%	
B1126	0	MSU Sada B (auto)/90	1.64	160.82	1.02%	0.00	1.70	0.00%	0.00	1.70	0.00%	1.02%	
B1126	0	MSU Sada B (auto)/134	4.63	160.82	2.88%	0.00	1.70	0.00%	0.00	1.70	0.00%	2.88%	
B1126	0	MSU Sada B (auto)/75	0.1	160.82	0.06%	0.00	1.70	0.00%	0.00	1.70	0.00%	0.06%	

Braces

Jméno	dx [m]	Combination code	Cross section	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]	Combination
B1170	0.643+	MSU Sada B (auto)/33	CS42 - CHS48.3/3.2	70.92	0	0.04	0	0.03	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B1170	0.643+	MSU Sada B (auto)/58	CS42 - CHS48.3/3.2	27.88	0	0.04	0	0.03	0	1.15*ZS1 + 0.90*3DVítr6 + 1.50*ZS3 - Sníh,2
B1170	0.643+	MSU Sada B (auto)/16	CS42 - CHS48.3/3.2	55.35	0	0.03	0.01	0.03	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr1
B1170	0.643+	MSU Sada B (auto)/2	CS42 - CHS48.3/3.2	9.63	0	0.05	0	0.04	0	1.35*ZS1
B1170	0.643+	MSU Sada B (auto)/68	CS42 - CHS48.3/3.2	-11.86	0	0.03	0	0.03	0	ZS1 + 1.50*3DVítr3
B1170	1.287-	MSU Sada B (auto)/33	CS42 - CHS48.3/3.2	70.92	0	0.01	0	0.05	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B1170	1.287-	MSU Sada B (auto)/58	CS42 - CHS48.3/3.2	27.88	0	0.01	0	0.05	0	1.15*ZS1 + 0.90*3DVítr6 + 1.50*ZS3 - Sníh,2
B1170	1.287-	MSU Sada B (auto)/16	CS42 - CHS48.3/3.2	55.35	0	0.01	0.01	0.04	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr1
B1170	1.287-	MSU Sada B (auto)/2	CS42 - CHS48.3/3.2	9.63	0	0.02	0	0.06	0	1.35*ZS1
B1170	1.287-	MSU Sada B (auto)/68	CS42 - CHS48.3/3.2	-11.86	0	0.01	0	0.04	0	ZS1 + 1.50*3DVítr3
B1170	1.287+	MSU Sada B (auto)/33	CS42 - CHS48.3/3.2	70.92	0	0.01	0	0.05	0	1.15*ZS1 + 1.50*ZS2 + 0.90*3DVítr10
B1170	1.287+	MSU Sada B (auto)/58	CS42 - CHS48.3/3.2	27.88	0	0.01	0	0.05	0	1.15*ZS1 + 0.90*3DVítr6 + 1.50*ZS3 - Sníh,2
B1170	1.287+	MSU Sada B (auto)/16	CS42 - CHS48.3/3.2	55.35	0	0.01	0.01	0.04	0	ZS1 + 1.50*ZS2 + 0.90*3DVítr1
B1170	1.287+	MSU Sada B (auto)/2	CS42 - CHS48.3/3.2	9.63	0	0.02	0	0.06	0	1.35*ZS1
B1170	1.287+	MSU Sada B (auto)/68	CS42 - CHS48.3/3.2	-11.86	0	0.01	0	0.04	0	ZS1 + 1.50*3DVítr3

Jméno	dx [m]	Combination code	fy	A	Iy	Iz	Wely	Welz	Wply	Wplz	iy	iz
B1170	0.643+	MSU Sada B (auto)/33	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	0.643+	MSU Sada B (auto)/58	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	0.643+	MSU Sada B (auto)/16	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	0.643+	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	0.643+	MSU Sada B (auto)/68	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287-	MSU Sada B (auto)/33	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287-	MSU Sada B (auto)/58	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287-	MSU Sada B (auto)/16	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287-	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287-	MSU Sada B (auto)/68	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287+	MSU Sada B (auto)/33	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287+	MSU Sada B (auto)/58	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287+	MSU Sada B (auto)/16	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287+	MSU Sada B (auto)/2	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02
B1170	1.287+	MSU Sada B (auto)/68	3.55E+05	4.53E-04	1.16E-07	1.16E-07	4.80E-06	4.80E-06	6.42E-06	6.42E-06	1.60E-02	1.60E-02

Jméno	dx [m]	Combination code	Ly	Lz	ky	kz	λ1	λy	λz	α	Φx	Φy	χy	χz
B1170	0.643+	MSU Sada B (auto)/33	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	0.643+	MSU Sada B (auto)/58	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	0.643+	MSU Sada B (auto)/16	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	0.643+	MSU Sada B (auto)/2	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	0.643+	MSU Sada B (auto)/68	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287-	MSU Sada B (auto)/33	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287-	MSU Sada B (auto)/58	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287-	MSU Sada B (auto)/16	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287-	MSU Sada B (auto)/2	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287-	MSU Sada B (auto)/68	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287+	MSU Sada B (auto)/33	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287+	MSU Sada B (auto)/58	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287+	MSU Sada B (auto)/16	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287+	MSU Sada B (auto)/2	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783
B1170	1.287+	MSU Sada B (auto)/68	3.217	3.217	1	1	76.40915	2.6313931	2.6313931	0.49	4.557806	4.557806	0.120783	0.120783

Jméno	dx [m]	Combination code	NEd	NRd	usage N	My,Ed	My,Rd	usage My	Mz,Ed	Mz,Rd	Usage Mz	Usage σ	max usage
B1170	0.643+	MSU Sada B (auto)/33	70.92	160.82	44.10%	0.03	1.70	1.76%	0.00	1.70	0.00%	45.86%	63.41%
B1170	0.643+	MSU Sada B (auto)/58	27.88	160.82	17.34%	0.03	1.70	1.76%	0.00	1.70	0.00%	19.10%	
B1170	0.643+	MSU Sada B (auto)/16	55.35	160.82	34.42%	0.03	1.70	1.76%	0.00	1.70	0.00%	36.18%	
B1170	0.643+	MSU Sada B (auto)/2	9.63	160.82	5.99%	0.04	1.70	2.35%	0.00	1.70	0.00%	8.34%	
B1170	0.643+	MSU Sada B (auto)/68	11.86	19.42	61.06%	0.03	1.70	1.76%	0.00	1.70	0.00%	62.82%	
B1170	1.287-	MSU Sada B (auto)/33	70.92	160.82	44.10%	0.05	1.70	2.93%	0.00	1.70	0.00%	47.03%	
B1170	1.287-	MSU Sada B (auto)/58	27.88	160.82	17.34%	0.05	1.70	2.93%	0.00	1.70	0.00%	20.27%	
B1170	1.287-	MSU Sada B (auto)/16	55.35	160.82	34.42%	0.04	1.70	2.35%	0.00	1.70	0.00%	36.77%	
B1170	1.287-	MSU Sada B (auto)/2	9.63	160.82	5.99%	0.06	1.70	3.52%	0.00	1.70	0.00%	9.51%	
B1170	1.287-	MSU Sada B (auto)/68	11.86	19.42	61.06%	0.04	1.70	2.35%	0.00	1.70	0.00%	63.41%	
B1170	1.287+	MSU Sada B (auto)/33	70.92	160.82	44.10%	0.05	1.70	2.93%	0.00	1.70	0.00%	47.03%	
B1170	1.287+	MSU Sada B (auto)/58	27.88	160.82	17.34%	0.05	1.70	2.93%	0.00	1.70	0.00%	20.27%	
B1170	1.287+	MSU Sada B (auto)/16	55.35	160.82	34.42%	0.04	1.70	2.35%	0.00	1.70	0.00%	36.77%	
B1170	1.287+	MSU Sada B (auto)/2	9.63	160.82	5.99%	0.06	1.70	3.52%	0.00	1.70	0.00%	9.51%	
B1170	1.287+	MSU Sada B (auto)/68	11.86	19.42	61.06%	0.04	1.70	2.35%	0.00	1.70	0.00%	63.41%	

Conclusion of structural analysis:

All elements are satisfactory. Most loaded element is the side beam assembly tension rod, which is loaded at 91.68%.

Structural analysis of joints.

Structural analysis of joints will be done manually, again with the help of Smath studio. All equations have been created by myself.

MATERIAL CHARACTERISTICS

S355 Steel

$f_y := 355\ MPa$

$f_u := 510\ MPa$

Class 8.8 screws

$f_{yb} := 640\ MPa$

$f_{ub} := 800\ MPa$

$\gamma_{M2} := 1,25$

$k_2 := 0,9$

$f_{up} := 355\ MPa$

CALCULATION OF STEEL JOINTS:

COMPONENT 1: GRID PULL ROD

$N_{Ed,1} := 245,91\ kN$

$V_{Ed,1} := 0,23\ kN$ ignored

$M_{Ed,1} := 0,32\ kN\,m$ ignored

TENSION STRESS ON SCREW:

$n_{š,1} := 8$

$\phi_{š,1} := 10\ mm$

$$A_{š,1} := \pi \cdot \frac{\phi_{š,1}^2}{4} = 78,54\ mm^2$$

$$F_{t,Rd,š,1} := \frac{k_2 \cdot f_{ub} \cdot A_{š,1}}{\gamma_{M2}} = 45,239\ kN$$

$$F_{t,Rd,1} := n_{š,1} \cdot F_{t,Rd,š,1} = 361,911\ kN$$

"JOINT SATISFACTORY"

COMPONENT 2: SIDE PULL ROD:

$N_{Ed,2} := 759,2\ kN$

$V_{Ed,1} := 1,41\ kN$ ignored

$M_{Ed,1} := 2,95\ kN\,m$ ignored

TENSION STRESS ON SCREW:

$n_{š,2} := 8$

$\phi_{š,2} := 16\ mm$

$$A_{š,2} := \pi \cdot \frac{\phi_{š,2}^2}{4} = 201,0619\ mm^2$$

$$F_{t,Rd,š,2} := \frac{k_2 \cdot f_{ub} \cdot A_{š,2}}{\gamma_{M2}} = 115,812\ kN$$

$$F_{t,Rd,2} := n_{š,2} \cdot F_{t,Rd,š,2} = 926,4934\ kN$$

"JOINT SATISFACTORY"

COMPONENT3: GRID AND SIDE PULL ROD SUPPORTS

$N_{Ed,3} := 11,5\ kN$

$V_{Ed,3} := 0\ kN$ ignored

$M_{Ed,3} := 0\ kN\,m$ ignored

SHEAR STRESS ON SCREW:

$n_{š,3} := 1$

$\phi_{š,3} := 8\ mm$

$A_{š,3} := \pi \cdot \frac{\phi_{š,3}^2}{4} = 50,2655\ mm^2$

$F_{Rd,3} := \frac{0,6 \cdot f_{ub} \cdot A_{š,3} \cdot n_{š,3}}{\gamma_{M2}} = 19,3019\ kN$

"JOINT SATISFACTORY"

COMPONENT 4: GRID BRACES

$N_{Ed,4} := 73,78\ kN$

$V_{Ed,3} := 0\ kN$ ignored

$M_{Ed,3} := 0\ kN\ m$ ignored

SHEAR STRESS ON SCREW:

$n_{š,4} := 1$

$\phi_{š,4} := 16\ mm$

$A_{š,4} := \pi \cdot \frac{\phi_{š,4}^2}{4} = 201,0619\ mm^2$

$A_4 := 50\ mm \cdot 10\ mm = 500\ mm^2$

$F_{Rd,4} := \frac{0,6 \cdot f_{ub} \cdot A_{š,4} \cdot n_{š,4}}{\gamma_{M2}} = 77,2078\ kN$

$F_{b,Rd,4} := 0,6 \cdot A_4 \cdot \frac{f_{up}}{\gamma_{M2}} = 85200\ N$

"JOINT SATISFACTORY"

COMPONENT 5: GRID BEAM:

$N_{Ed,5} := -260,72\ kN$

$N_{t,Ed,5} := 47,57\ kN$

$V_{Ed,z,5} := 29,02\ kN$

$V_{Ed,y,5} := 4,26\ kN$ ignored

$M_{Ed,y,5} := -85,58\ kN\ m$

$M_{Ed,z,5} := -8,24\ kN$ ignored

$M_{Ed,x,5} := 0,13\ kN$ ignored

A: MOMENT JOINT:

$N_{Ed,5} = -260,72\ kN$

$M_{Ed,y,5} = -85,58\ kN\ m$

SHEAR STRESS ON SCREW: COMPRESSION-MOMENT COMBINATION:

$\Delta H_5 := 450\ mm$

$F_{N,Ed,5,A} := \left| \frac{N_{Ed,5}}{2} \right| = 130,36\ kN$

$F_{M,Ed,5,A} := \left| \frac{M_{Ed,y,5}}{\Delta H_5} \right| = 190,178\ kN$

$F_{Ed,5,A} := F_{N,Ed,5,A} + F_{M,Ed,5,A} = 320,538\ kN$

$n_{š,5,A} := 8$

$\phi_{š,5,A} := 12\ mm$

$A_{š,5,A} := \pi \cdot \frac{\phi_{š,5,A}^{\ 2}}{4} = 113,0973\ mm^2$

$F_{Rd,5,A} := \frac{0,6 \cdot f_{ub} \cdot A_{š,5,A} \cdot n_{š,5,A}}{\gamma_{M2}} = 347,435\ kN$

"JOIN SATISFACTORY"

B: SHEAR JOINT:

$V_{Ed,z,5} = 29,02\ kN$

SHEAR STRESS ON SCREW: SHEAR

$n_{š,5,B} := 6$

$\phi_{š,5,B} := 8\ mm$

$A_{š,5,B} := \pi \cdot \frac{\phi_{š,5,B}^{\ 2}}{4} = 50,2655\ mm^2$

$F_{Rd,5,B} := \frac{0,6 \cdot f_{ub} \cdot A_{š,5,B} \cdot n_{š,5,B}}{\gamma_{M2}} = 115,8117\ kN$

"JOIN SATISFACTORY"

C: PLATE JOINT:

$N_{t,Ed,5} = 47,57\ kN$

$V_{Ed,z,5} = 29,02\ kN$

SHEAR AND TENSION STRESS ON SCREW: TENSION-MOMENT COMBINATION

$n_{š,5,C} := 8$

$\phi_{š,5,C} := 8\ mm$

$A_{š,5,C} := \pi \cdot \frac{\phi_{š,5,C}^{\ 2}}{4} = 50,2655\ mm^2$

$F_{V,Rd,5,C} := \frac{0,6 \cdot f_{ub} \cdot A_{š,5,C} \cdot n_{š,5,C}}{\gamma_{M2}} = 154,4156\ kN$

$F_{t,Rd,5,C} := \frac{k_2 \cdot f_{ub} \cdot A_{š,5,C} \cdot n_{š,5,C}}{\gamma_{M2}} = 231,6233\ kN$

$\frac{V_{Ed,z,5}}{F_{V,Rd,5,C}} + \frac{N_{t,Ed,5}}{1,4 \cdot F_{t,Rd,5,C}} = 0,335$

"JOIN SATISFACTORY"

COMPONENT 6: SIDE BEAM:

$N_{Ed,6} := -900,13\ kN$

$N_{t,Ed,6} := 89,63\ kN$

$V_{Ed,z,6} := -236,77\ kN$

$V_{Ed,y,6} := 24,35\ kN$ ignored

$M_{Ed,y,6} := 1141,49\ kN\ m$

$M_{Ed,z,6} := -100,29\ kN\ m$

$M_{Ed,x,6} := (-1,98)\ kN\ m$ ignored

A: MOMENT JOINT

$N_{Ed,6} = -900,13\ kN$

$M_{Ed,y,6} = 1141,49\ kN\ m$

SHEAR STRESS ON SCREW: COMPRESSION-MOMENT_y-MOMENT_z COMBINATION

$\Delta H_6 := 900\ mm$

$\Delta B_6 := 410\ mm$

$$F_{N,Ed,6,A} := \left| \frac{N_{Ed,6}}{2} \right| = 450,065\ kN$$

$$F_{My,Ed,6,A} := \left| \frac{M_{Ed,y,6}}{\Delta H_6} \right| = 1268,3222\ kN$$

$$F_{Mz,Ed,6,A} := \left| \frac{M_{Ed,z,6}}{\Delta B_6} \right| = 244,6098\ kN$$

$$F_{Ed,6,A} := F_{N,Ed,6,A} + F_{My,Ed,6,A} + F_{Mz,Ed,6,A} = 1962,997\ kN$$

$n_{š,6,A} := 18$

$\phi_{š,6,A} := 20\ mm$

$$A_{š,6,A} := \pi \cdot \frac{\phi_{š,6,A}^{\ 2}}{4} = 314,1593\ mm^2$$

$$F_{Rd,6,A} := \frac{0,6 \cdot f_{ub} \cdot A_{š,6,A} \cdot n_{š,6,A}}{\gamma_{M2}} = 2171,4688\ kN$$

"JOIN SATISFACTORY"

B: SHEAR JOINT:

$V_{Ed,z,6} = -236,77\ kN$

$$\frac{V_{Ed,z,6}}{2} = -118,385\ kN$$

SHEAR STRESS ON SCREW: SHEAR

$n_{š,6,B} := 6$

$\phi_{š,6,B} := 12\ mm$

$$A_{š,6,B} := \pi \cdot \frac{\phi_{š,6,B}^{\ 2}}{4} = 113,0973\ mm^2$$

$$F_{Rd,6,B} := \frac{0,6 \cdot f_{ub} \cdot A_{š,6,B} \cdot n_{š,6,B}}{\gamma_{M2}} = 260,5763\ kN$$

"JOIN SATISFACTORY"

C: PLATE JOINT:

$N_{t,Ed,6} = 89,63\ kN$

$V_{Ed,z,6} = -236,77\ kN$

$M_{Ed,y,6,C} := -735\ kN\ m$

SHEAR AND TENSION STRESS ON SCREW: SEAR-COMPRESSION-MOMENT COMBINATION

PLASTIC ANALYSIS

Geometry:

$$r_{z,T,6,C} := \frac{940\ mm}{2} = 470\ mm \qquad p_{1,6,C} := 50\ mm$$

$$n_{š,i,6,C} := \begin{bmatrix} 4 \\ 4 \\ 4 \\ 4 \\ 4 \\ 4 \\ 4 \\ 4 \end{bmatrix} \qquad r_{z,i,6,C} := \begin{bmatrix} r_{z,T,6,C} + 250\ mm + 3 \cdot p_{1,6,C} \\ r_{z,T,6,C} + 250\ mm + 2 \cdot p_{1,6,C} \\ r_{z,T,6,C} + 250\ mm + p_{1,6,C} \\ r_{z,T,6,C} + 250\ mm \\ r_{z,T,6,C} - 250\ mm \\ r_{z,T,6,C} - 250\ mm - p_{1,6,C} \\ r_{z,T,6,C} - 250\ mm - 2 \cdot p_{1,6,C} \\ r_{z,T,6,C} - 250\ mm - 3 \cdot p_{1,6,C} \end{bmatrix} = \begin{bmatrix} 870 \\ 820 \\ 770 \\ 720 \\ 220 \\ 170 \\ 120 \\ 70 \end{bmatrix} mm$$

$$n_{š,6,C} := \sum n_{š,i,6,C} = 32$$

$$\phi_{š,6,C} := 12\ mm$$

$$A_{š,6,C} := \pi \cdot \frac{\phi_{š,6,C}^{\ 2}}{4} = 113,0973\ mm^2$$

Moment-tension load bearing capability:

$$F_{t,1,Rd,6,C} := \frac{k_2 \cdot f_{ub} \cdot A_{š,6,C}}{\gamma_{M2}} = 65,1441\ kN$$

$$F_{t,Ed,6,C} := \begin{bmatrix} -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_1}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_2}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_3}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_4}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_5}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_6}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_7}}} \\ -\dfrac{M_{Ed,y,6,C}}{\sum_{i=1}^{8} n_{š,i,6,C_i} \cdot \dfrac{\left(r_{z,i,6,C_i}\right)^2}{r_{z,i,6,C_8}}} \end{bmatrix} + \frac{N_{t,Ed,6}}{n_{š,6,C}} = \begin{bmatrix} 63,419 \\ 59,935 \\ 56,452 \\ 52,968 \\ 18,13 \\ 14,646 \\ 11,162 \\ 7,678 \end{bmatrix} kN$$

Shear load bearing capability:

$$F_{V,1,Rd,6,C} := \frac{0,6 \cdot f_{ub} \cdot A_{\check{s},6,C}}{\gamma_{M2}} = 43,4294 \text{ kN}$$

$$t_{6,C} := 10 \text{ mm}$$

$$d_{0,6,C} := \phi_{\check{s},6,C} + 2 \text{ mm}$$

$$\alpha_{6,C} := \min\left(\begin{bmatrix} \frac{p_{1,6,C}}{3 \cdot d_{0,6,C}} - 0,25 \\ \frac{f_{ub}}{f_{yb}} \\ 1 \end{bmatrix}\right) = 0,94$$

$$F_{b,Rd,6,C} := \frac{2,5 \cdot \alpha_{6,C} \cdot \phi_{\check{s},6,C} \cdot t_{6,C} \cdot f_u}{\gamma_{M2}} = 115,114 \text{ kN}$$

$$V_{1,Rd,6,C} := \min\left(\begin{bmatrix} F_{V,1,Rd,6,C} \\ F_{b,Rd,6,C} \end{bmatrix}\right) = 43,429 \text{ kN}$$

$$F_{v,Ed,6,C} := \frac{V_{Ed,z,6}}{n_{\check{s},6,C}} = -7,399 \text{ kN}$$

$$\frac{F_{v,Ed,6,C}}{V_{1,Rd,6,C}} + \frac{\max\left(F_{t,Ed,6,C}\right)}{1,4 \cdot F_{t,1,Rd,6,C}} = 0,525$$

"JOINT SATISFACTORY"

All joints are satisfactory. The construction is structurally sound.

Conclusion:

This type of construction, despite being relatively unconventional, offers a large amount of variability and modularity. This permits a variety of designs, which can fit a variety of needs. The variant I have designed for Liberec is quite heavily loaded and complex, and that was the result of a deliberate attempt to see the limits of this type of structure.

I was able to build a 30 m x 30 m Hall in Liberec, a city with high snow loading, without too many difficulties. I believe that this system could be used to bridge spans of 50 meters in a location with lesser climactic loads without too much difficulty. Some of the heavier configurations I proposed could probably do even more. But this system could also be used for smaller structure, in its simpler configurations, it offers a light structural system for mid-length spans. I believe this idea has potential, and that its modularity and adaptability could allow it to be used for many different purposes, and many different sizes.

CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of civil engineering

Department of steel structures

BACHELOR THESIS

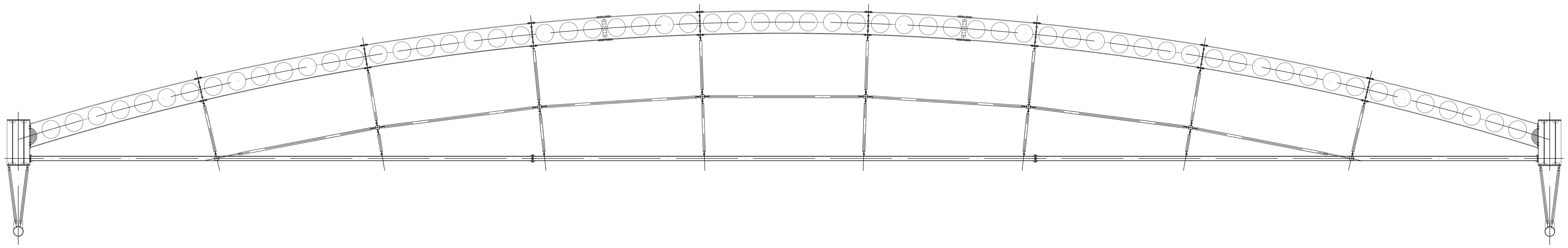
Design of single story curved spatial building

C: Project documentation

Jean Philippe Cam

VYTVORENO VE STUDENTSKE VERZI PRODUKTU AUTODESK

VYTVORENO VE STUDENTSKE VERZI PRODUKTU AUTODESK

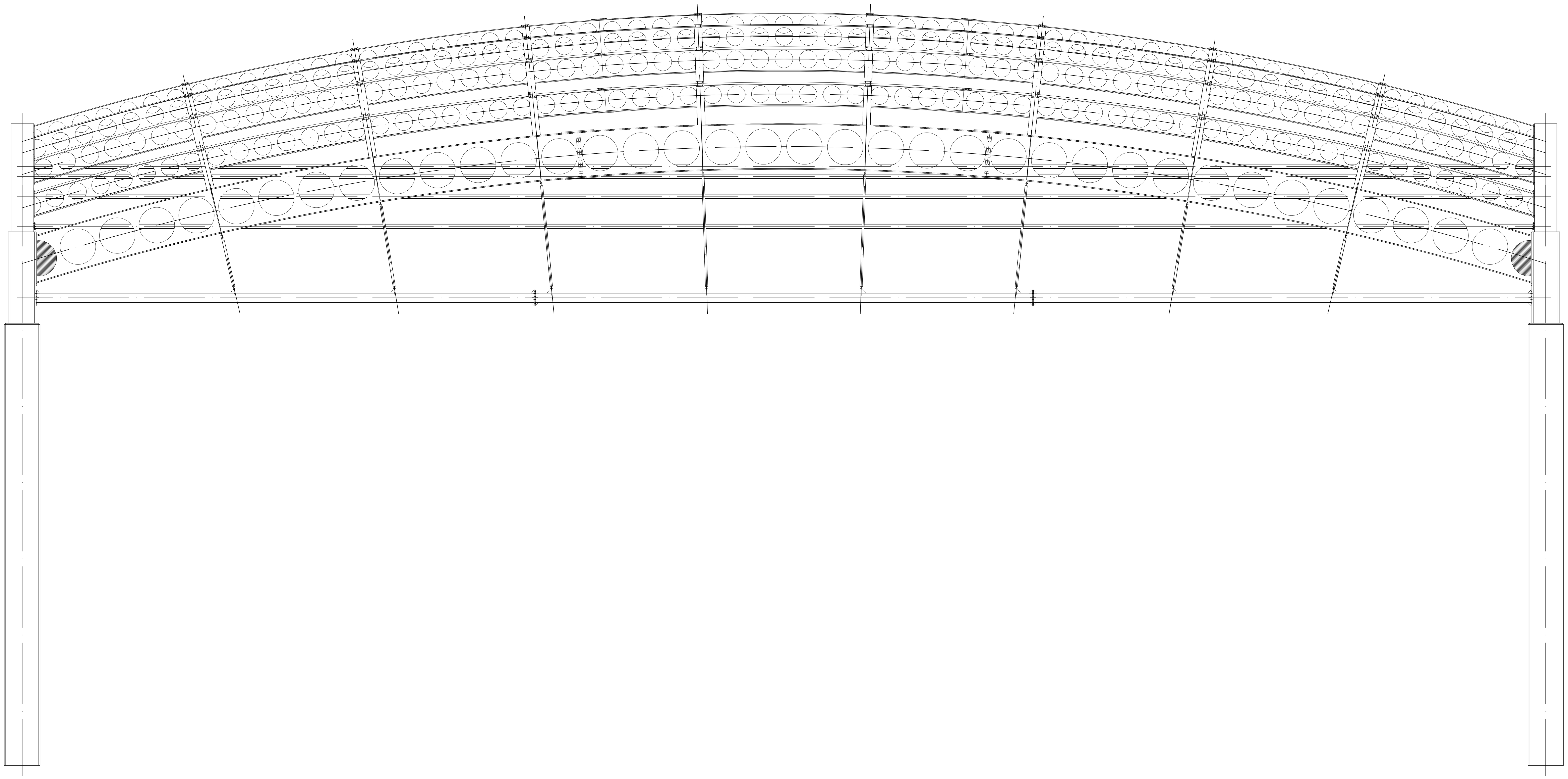


MATERIALS:
STEEL:
GRID BEAM ASSEMBLLY : S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY TENSION ROD AND SUPPORT ROD: S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY BEAM: S235 STRUCTURAL STEEL

Study subject:	Department:	student:
SI - K	K 134	Jean Philippe Cam
year: 4.		
Bachelor thesis		
Side section of grid beam assembly		

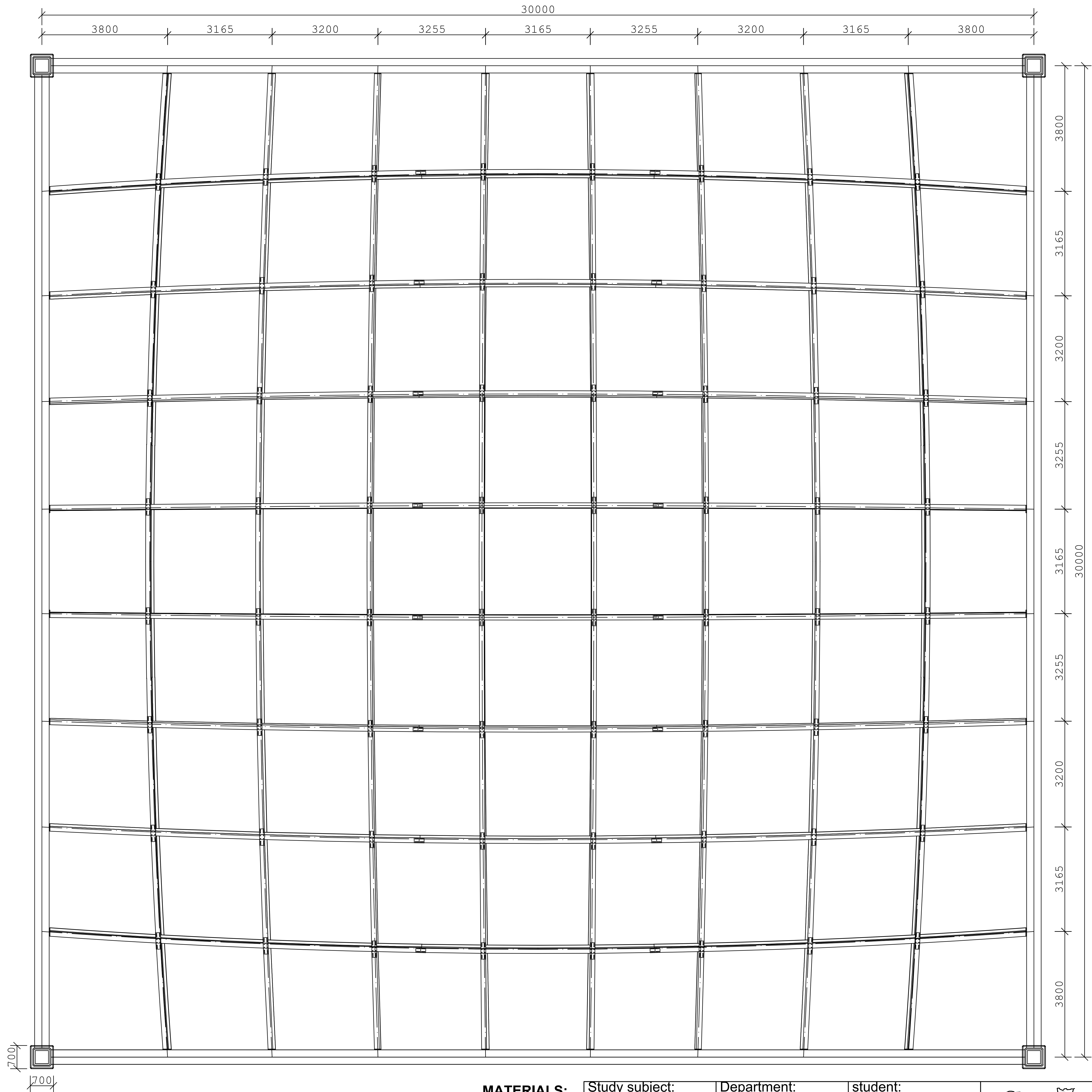
format:	A1
měřítko:	1:50
datum:	26.5.2019
číslo:	1

VYTVORENO VE STUDENTSKE VERZI PRODUKTU AUTODESK



MATERIALS:
STEEL:
GRID BEAM ASSEMBLLY: S355 STRUCTURAL STEEL
PILLAR ASSEMBLY: S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY TENSION ROD AND SUPPORT ROD: S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY BEAM: S235 STRUCTURAL STEEL
CONCRETE
C 25/30 CONCRETE
REINFORCEMENT
B500B REINFORCEMENT STEEL

Study subject:	Department:	student:	
SI - K	K 134	Jean Philippe Cam	
year:			
4.			
Bachelor thesis			
Side view of side beam assembly and pillar assembly		format:	A1
		měřítko:	1:50
		datum:	26.5.2019
		číslo:	1



VYTVOŘENO VE STUDENTSKÉ VERZI PRODUKTU AUTODESK

VYTVOŘENO VE STUDENTSKÉ VERZI PRODUKTU AUTODESK

MATERIALS:

STEEL:

GRID BEAM ASSEMBLLY: S355 STRUCTURAL STEEL

PILLAR ASSEMBLY: S355 STRUCTURAL STEEL

SIDE BEAM ASSEMBLY TENSION ROD AND SUPPORT ROD: S355 STRUCTURAL STEEL

SIDE BEAM ASSEMBLY BEAM: S235 STRUCTURAL STEEL

CONCRETE

C 25/30 CONCRETE

REINFORCEMENT

B500B REINFORCEMENT STEEL

Study subject:	Department:	student:
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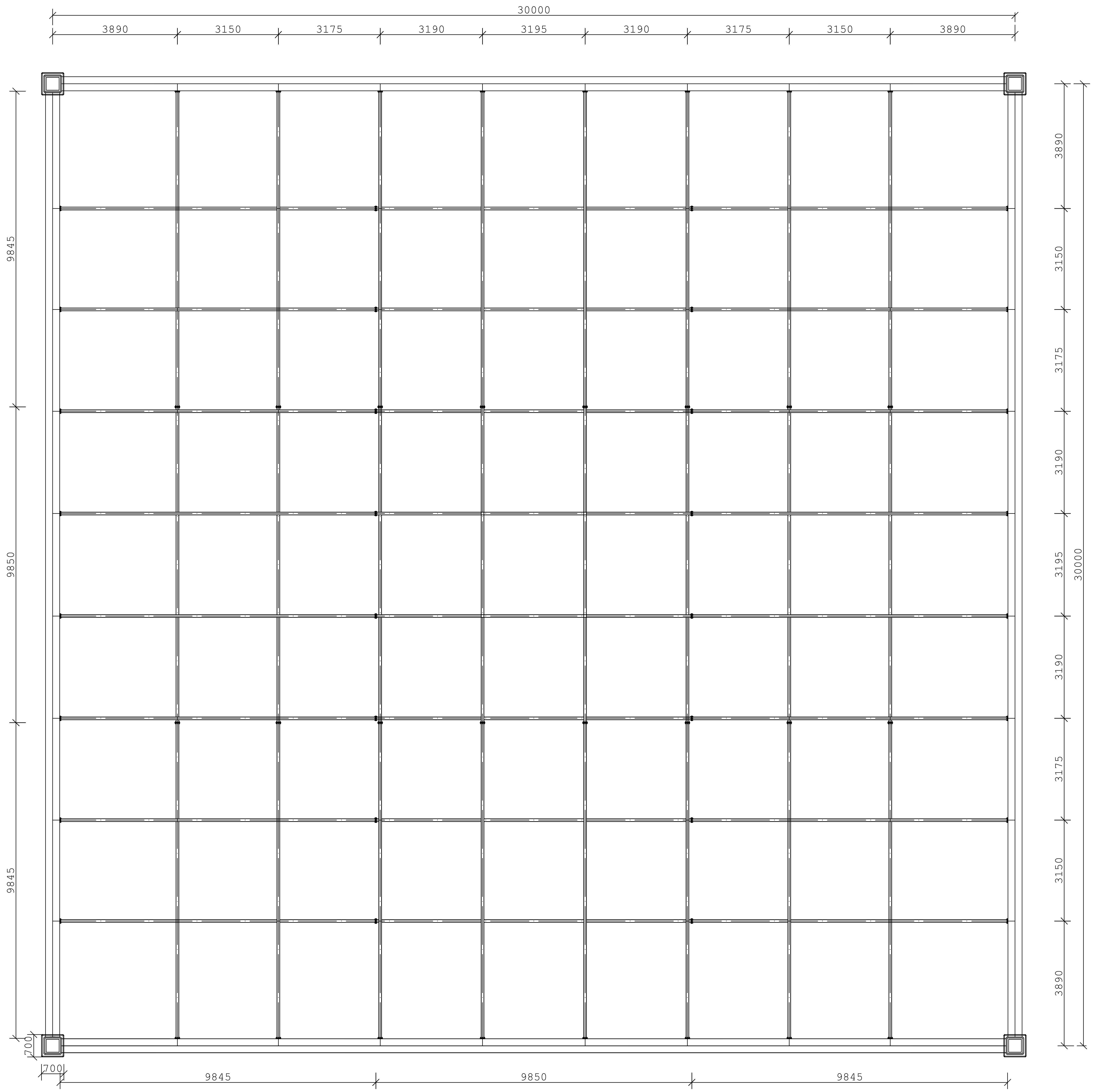
Bachelor thesis

TOP VIEW OF BEAMS

format:	A2
měřítko:	1:100
datum:	26.5.2019
číslo:	1

VYTVOŘENO VE STUDENTSKÉ VERZI PRODUKTU AUTODESK



MATERIALS:

STEEL:

GRID BEAM ASSEMBLLY: S355 STRUCTURAL STEEL
PILLAR ASSEMBLY: S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY TENSION ROD AND SUPPORT ROD: S355 STRUCTURAL STEEL
SIDE BEAM ASSEMBLY BEAM: S235 STRUCTURAL STEEL

CONCRETE

C 25/30 CONCRETE

REINFORCEMENT

B500B REINFORCEMENT STEEL

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year:		
4.		

Bachelor thesis

TOP VIEW OF GRID TENSION RODS

format:	A2
měřítko:	1:100
datum:	26.5.2019
číslo:	1

VYTVOŘENO VE STUDENTSKÉ VERZI PRODUKTU AUTODESK
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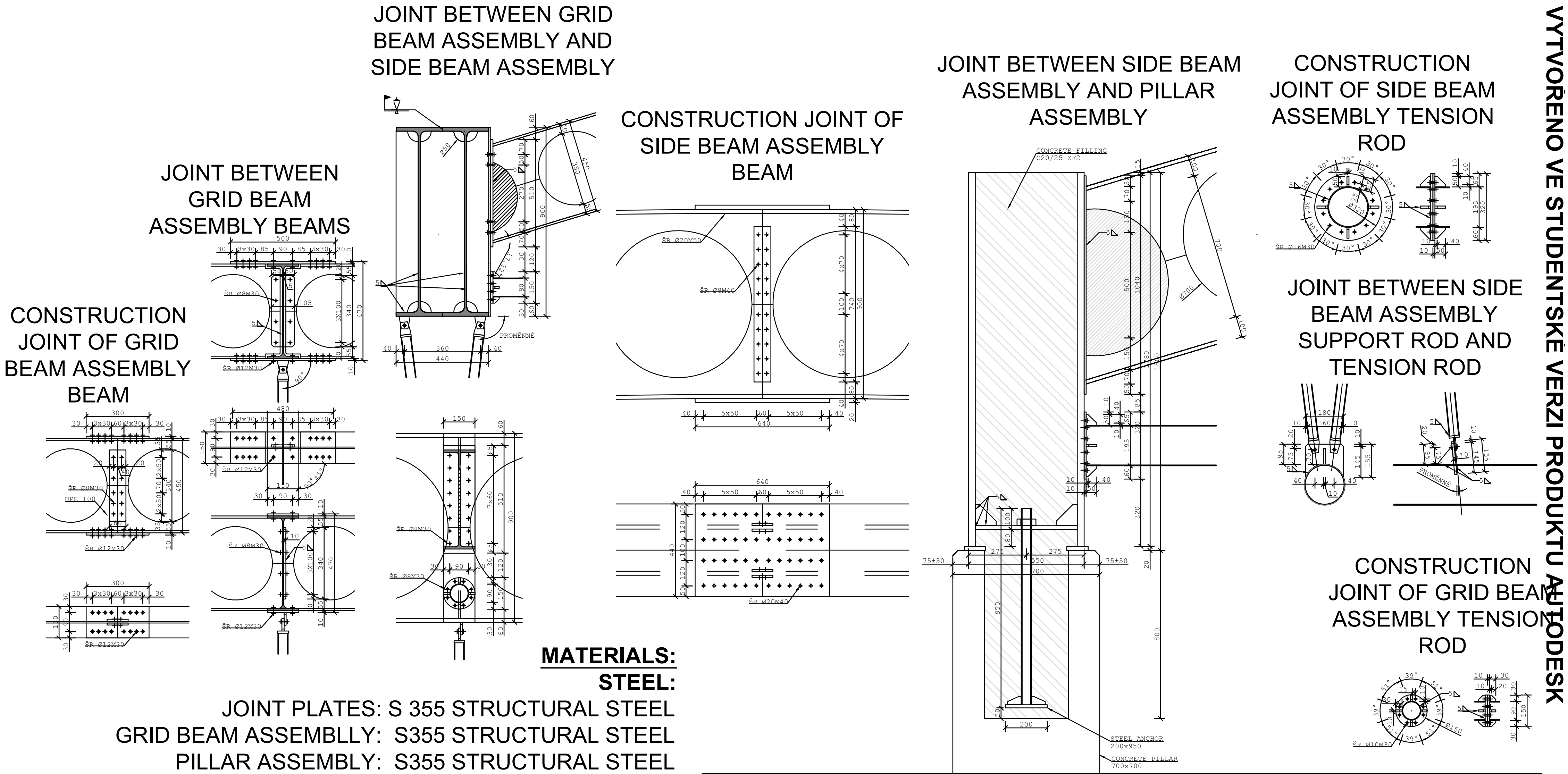

MATERIALS:

STEEL:

JOINT PLATES: S 355 STRUCTURAL STEEL

GRID BEAM ASSEMBLLY: S355 STRUCTURAL STEEL

PILLAR ASSEMBLY: S355 STRUCTURAL STEEL

SIDE BEAM ASSEMBLY TENSION ROD AND: S355 STRUCTURAL STEEL

SUPPORT ROD: S355 STRUCTURAL STEEL

SIDE BEAM ASSEMBLY BEAM: S235 STRUCTURAL STEEL

CONCRETE

PILLAR ASSEMBLY: C 25/30 CONCRETE

CONCRETE FILL: C16/20 CONCRETE

REINFORCEMENT

B500B REINFORCEMENT STEEL

BOLTS

CLASS 8.8 SCREWS

Study subject:	Department:	student:
SI - K	K 134	Jean Philippe Cam
year:		
4.		

Bachelor thesis

JOINT SECTIONS

format:	A3
měřítko:	1:25
datum:	26.5.2019
číslo:	1

VYTVOŘENO VE STUDENTSKÉ VERZI PRODUKTU AUTODESK
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