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Optimization of the support frame for clay model cars.

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design

Autor práce: **Jayaprakash Lakshmanasamy**
Vedoucí práce: Ing. Petr Zelený, Ph.D.

Liberec 2018

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Faculty of Mechanical Engineering

Optimization of the support frame for clay model cars.

Master thesis

Study programme: N2301 – Mechanical Engineering
Study branch: 2302T010 – Machines and Equipment Design

Author: **Jayaprakash Lakshmanasamy**
Supervisor: Ing. Petr Zelený, Ph.D.

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Technical University of Liberec
Faculty of Mechanical Engineering
Academic year: **2017/2018**

DIPLOMA THESIS ASSIGNMENT

(PROJECT, ART WORK, ART PERFORMANCE)

First name and surname:	**Jayaprakash Lakshmanasamy**
Study program:	**N2301 Mechanical Engineering**
Identification number:	**S16000542**
Specialization:	**Machines and Equipment Design**
Topic name:	**Optimization of the support frame for clay model cars.**
Assigning department:	**Department of Manufacturing Systems and Automation**

Rules for elaboration:

The aim of this thesis is an analysis and subsequent optimization of the support frame for the clay car model in terms of weight, stiffness and price. Furthermore this thesis occupies the new material selection for frame and one frame for different model cars.

1. Literature review about preexisting possibilities of frames for clay models of car.
2. Initially study the existing frame design.
3. Perform FEM analysis.
4. Create a new frame design for maximum frame weight reduction.
5. Maintain stiffness and shape optimization with required parameters and dimensions.
6. Create production drawing.

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[1] BUDYNAS, R. G. and J. K. NISBETT. Shigley's Mechanical Engineering Design (in SI Units). 10th ed. Asia: McGraw-Hill, 2015, 1104 p. ISBN 978-981-4595-28-5.
[2] MAREK, J. et al. Design of CNC Machine Tools. Praha: MM publishing, 2015, 730 p. ISBN 978-80-260-8637-6.

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Head of Department

Liberec, dated: 15 November 2017

DECLARATION

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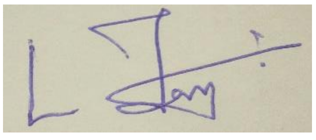
Signature: 

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ABSTRACT

This work is an analysis and subsequent optimization of the frame for the clay model car designed by Svott.sro. The material of the existing frame is structural steel. The optimization in terms of weight, stiffness and price. Initially study about the existing frame design and perform FEM analysis then develop a new frame design for maximum weight reduction, maximum stiffness and shape optimization with wanted parameters and dimensions. In clay model car, Frame forms the structural backbone. The main function of frame is to support the elements placed thereon. The frame is under static load due to the clay and wood board. The responses of the frame which has the stress distribution and displacement under various loading conditions are observed. Furthermore, this thesis occupies the new material choice for the frame and the frame design ought to appropriate for diverse model cars. The 3-D model of frame is created using CATIA V5 later the maximum deflection and stress determined using ANSYS 17.1.

Keywords: frame, optimization, FEM analysis, static load, CATIA, ANSYS.

ABSTRAKT

Tato práce se zabývá analýzou a následnou optimalizací rámu pro automobilový model z modelářské hlíny, který byl postaven firmou Svott, s.r.o. Materiál stávajícího rámu je konstrukční ocel. Optimalizace byla zaměřena na hmotnost, tuhost a cenu. Byly provedeny studie existujících konstrukcí rámů. Byla provedena FEM analýza nového návrhu rámu pro maximální snížení hmotnosti, maximální tuhost a optimalizaci tvaru dle požadovaných parametrů a rozměrů. Rám je nosnou konstrukcí pro hliněný model auta. Hlavním úkolem rámu je podpora prvků na něm umístěných. Rám je staticky zatížen díky hlíně a dřevěné desce. Byly zjišťovány deformace rámu, rozložení napětí a posunutí za různých zatěžovacích podmínek. Dále se tato práce zabývá možnou změnou materiálu rámu a konstrukcí rámu, aby odpovídala různým modelovým vozům. 3 D model rámu je vytvořen pomocí sw CATIA V5 a maximální deformace a napětí jsou vypočtené pomocí ANSYS 17.1.

Klíčová slova: rám, optimalizace, FEM analýza, statické zatížení, CATIA, ANSYS.

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1. INTRODUCTION

Now days automobile designers have all sort of design software's and virtual fact tool. So, we'd count on the automotive industry could possibly give up on clay modelling. However, they wish to make certain curves look excellent, they trust one of globe's oldest method clay modelling. The antique art of layering lots of kilos of clay over a foam core, outlay months shaping each curve via hand, continues to be seen a necessity within the automotive industry.[1]

Plasticine was made-up in 1897 by means of William Harbutt in United Kingdom, it absolutely was a mix of oils, waxes and clay minerals. In contrast to modelling clay employed by ceramicists and sculptor's plasticine could not be fired in an oven, heat caused it to soften and disintegrate. It may but be simply worked with simple wire tools and material may well be additional, removed or used once more, though plasticine will slowly loose its physical property plasticity and can't be very smoothly finished. To conquer those shortcomings a special material, 'Plasticine' changed into advanced and proprietary in Germany by an individual, Franz Kolb, in 1880.After that 'Plasticine' was developed in France by Claude Chavant in 1892 and have become patented in 1927. These substances have become referred to as 'Industrial Plasticine' however nowadays they're referred to as modelling or styling clay and are wide utilized in automotive design studios for manufacturing each scale and large models of future product.[2]

Clay has been utilized in car design since 1930s. Legendary General Motors designer Harley Earl is believed to be one of its pioneers. Each automotive by every big carmaker like Mercedes, Skoda is shaped in clay before manufacturing. They sculpt each detail, from windows to door handles, they sculpt interiors too.[3]

Clay more specifically, industrial plasticine is the favoured medium for design modelling because it's easy to build with and easy to manipulate as the work evolves. sculptors spend hours working with dozens of tool types including metal rakes, loops, texture tools, wrinkle tools, and steel blades to craft the perfect lines. The clay is usually built up from a smaller-scale foam structure supported by steel or wood. It's thick enough to allow for removal and shaping of the clay, but not so thick that the model ends up weighing thousands of pounds. A cubic foot of standard industrial plasticine weighs 90 pounds. The surfaces can be polished to a gloss and painted for a variety of finish options.[4]

In clay modelling, the frame plays a significant role and it is the backbone of car. It gives support to the skeleton and clay. Frame made up with different cross members and they all welded together. The wood board bolted with the frame, the board and foam form the skeleton of clay model. Frame should rigid enough to withstand the load. The loads from wood, foam and clay are static.

1.1 DIPLOMA THESIS

The topic for this master's Diploma thesis is "Analysis and subsequent optimization of the support frame for the 1: 1 design model". The central aim of this thesis work is to analysis the frame design with given parameters and design a new frame with all requirements in terms of weight reduction, stiffness and price.

The thesis work has five parts:

- FEM Analysis of existing frame
- Selection of new material for the frame
- Proposal for new model frame
- FEM analysis of new model frame
- Results and comparisons of both frames

The initial few chapters of the thesis work describe the theoretical part of the work, composed of the literature study and research from sources. It contains about chassis design and materials for conventional frames. There are very fewer sources especially about clay modelling frame design but it has similarities with real car chassis design for that we have a lot of sources.so initially studied the chassis design and it very helpful for new frame design. The core plot of the project is Finite element analysis.

Initially, a detailed study was done about existing frame design, dimensions and its parameters. Using the dimensions, a 3-D CAD model frame was created using CATIA V5-6 and then the 3-D model converted to step file. Finally, Finite element analysis is performed by using ANSYS17.1.

Using problem solving process, the new model was designed very carefully to meet all required parameters. For modelling and analysis, the same procedure followed like the former. Finally, the results of all frames are compared.

The most important part of the analysis is taking boundary conditions, loading conditions. If there is any mistake in boundary, loading conditions it may give wrong results during analysis. In my case, there is no dynamic load only static load due to clay and foam. The major load is clay. In boundary conditions, there are four fixed positions and for loading conditions, there are two possibilities .One is design the clay, foam and placed upon frame the other one is calculating the force and apply it directly on contacted area in frame.

1.2 METHODOLOGY.

The main objective of this thesis is investigating the support frame in order to reduce the weight, price and increase the stiffness. ***Fig 1*** explains the processes involved in thesis.

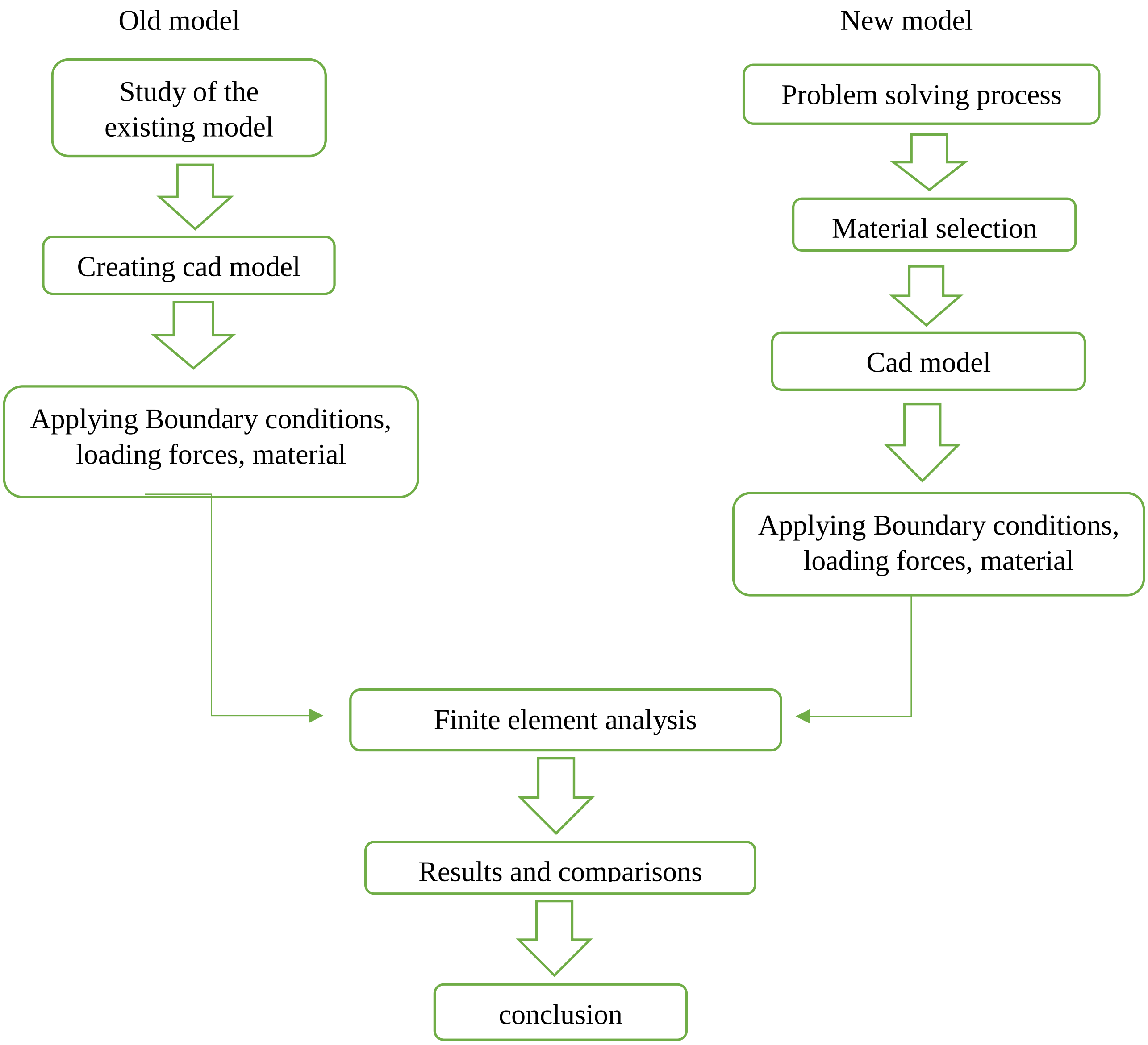


Fig 1 Methodology

2. CLAY MODELLING

Clay modelling is a meticulous manner that involves modeler and designers operating closely with each other, repeatedly redoing the details of car exteriors and also interiors. In an automotive, the design is extremely indispensable to differentiate the product from the other competitors. vehicle design starts with designer’s drawings.

Once the designers have narrowed down some thoughts, sculptors create 1:3-scale clay models of their drawings. A complete clay model is a next step a skeleton is created from foam, plywood, after which cover it with two to three inches of warm clay, that is heated in unique ovens for 24 hours before it's used. Once the clay cools, it's geared up for sculpting. vehicle firms use milling machines to carve out the rough form of the vehicle, a method that takes about 2 days. Then sculptors do the element work, shaping the refined arches across the wheels or the headlight patterns. Sculptors conjointly work with designers. Additionally, they work closely with virtual sculptors, who can experiment the clay version and send that information to engineers. Engineers would possibly send again adjustments to make sure the design meets crash-test requirements. The very last design of a vehicle might be changed 12 or more times. One essential check comes once the clay model is roofed with a film that looks like paint and is taken out of doors to envision how the natural light plays on its curves. It takes 3-4 years from the primary drawing to a car running off the road.[5]

In old days designers used hand drawn designs ***Fig 2***. But nowadays companies used computerised 3-D model.

Fig 2 General motor design studio (1954). [6]

Using the drawings 1:3 scale clay model car was developed and tested in wind tunnel to check its aerodynamic design ***Fig 3***.[7]

Fig 3 American motors scale model studio (1961) 1:3 clay model. [8]

After successful design of 1:3 clay model, full size clay model created. In ancient times full- size model was created using hand but nowadays milling machines used to speed up the removal of clay's top layers but however final shaping and the details are done by hand ***Fig 4.***

Fig 4. Making of Full size clay models in general motor, left: at1954, right: at 2017. [6]

However, after a clay model is created, it needs to be digitized into a CAD model so that certain areas can be made mathematically more precise. The CAD model is also used to generate as many copies of the clay model as are needed during the review process.

The full-size clay models are digitized into computer aided design for further evaluation. For Digitization both contact and non-contact methods are used. For example, contact method CMM (coordinate measuring machine), Non-contact method Atos scan.

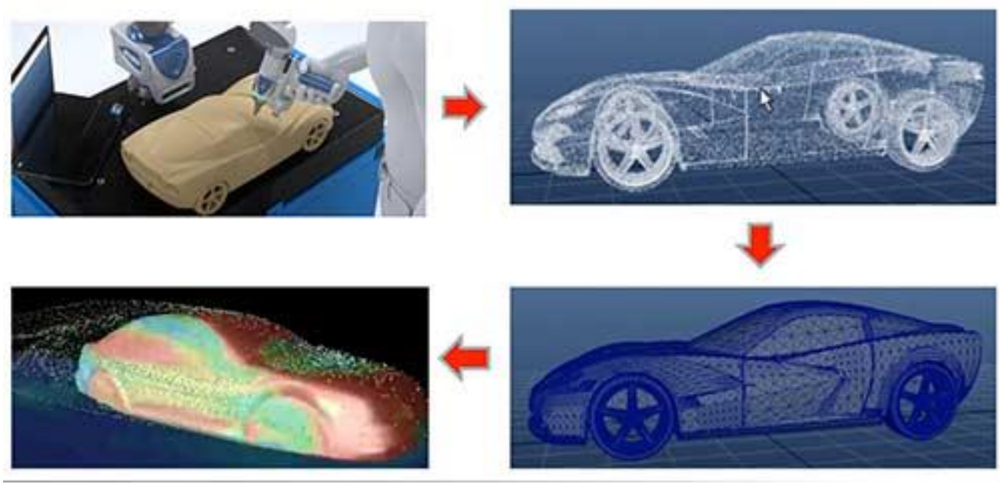


Fig 5 Process of digitizing clay model. [9]

Fig 5 shows the digitization of clay model using a portable laser line probe. Once the model was digitized it send to further departments for testing include CFD (computational fluid dynamics), FEA (finite element analysis), aerodynamic wind tunnel simulation, crash simulation[9]. After checking the results, they make necessary correction in design and they check again they will routine the process until it gives satisfaction. Automotive clay sculpting help translate a designer's vision into a tangible reality. During milling and other operations some amount of clay was wasted. The wasted clay was gathered and recycled. The recycle machine compresses and churns the clay chips with multiple blades, sucking all the air out in the process. The clay is then passed through a nozzle that's heated just enough to churn it out with the proper consistency so that it can be reused.

3. BASIC FRAME TYPES.

For clay modelling support frame there is no specific types. It is conventional frame but the design similar to car frames. For Design a new support frame the study about car frame types is very important. Automobile frame provides strength and flexibility and it is the backbone of automobile. Automotive frame is basically manufactured from steel. It provides strength needed for supporting vehicular components and payload placed upon it. [10]

3.1 LADDER FRAME.

The ladder frame is one of the simplest and oldest of all designs ***Fig 6.*** It consists of two symmetrical beams, rails or channels running the length of the vehicle. The frame resembles a ladder with two rails and several cross beams. The ladder frame constructed with side frames and several transverse cross members connecting them. The chassis ladder frames do not have the rigidity in torsion because of the two-dimensional design frameworks. This has little importance on road that helps better contact with the ground when needed to go off road. However, this chassis is heavier at the same time than a single body. The chassis does not provide any protection against any side impacts. The greatest advantage of the ladder frame is its adaptability to various vehicle body shapes.

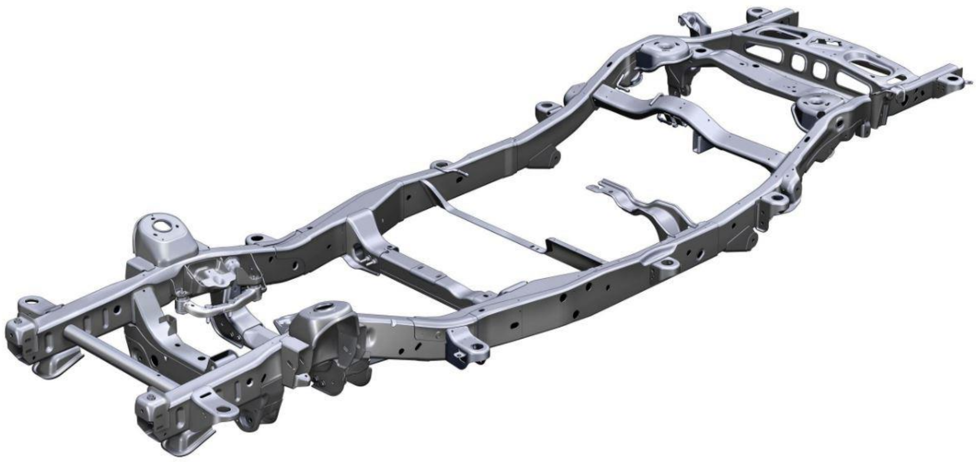


Fig 6 Ladder frame [10]

3.2 BACKBONE TUBE.

The back-bone tube design is very commonly found is sports car ***Fig 7.*** A backbone chassis is a type of automobile construction chassis that is similar to the body-on-frame design. Instead of two-dimensional ladder type structure, it consists of a strong tubular backbone (usually rectangular in cross section) that connects the front and rear suspension attachment areas. This design was first developed in 1923 by Hans Ledwinka who was the chief designer at Tatra heavy trucks. He further enhanced this design which had great off-road abilities. Some cars also make use of the backbone frame are Lotus and Skoda. The back-bone is used to strengthen in some cars such as Volkswagen Beetle. Thus, the concept of hybrid back-bone ladder frame developed. The half-axles have better contact with the ground when operated off-road. This has little importance on roads. The vulnerable parts of the drive shaft are covered by a thick tube. The whole system is extremely reliable. However, if a problem occurs, repairs are more complicated. The backbone chassis is heavier for a given torsional stiffness than a uni-body. The chassis gives no protection against side impacts.

Fig 7 Backbone frame [10]

3.3 MONOCOQUE STRUCTURE.

It is also known as Uni-body frame. Monocoque is a structural approach whereby loads are supported through an objects external skin, similar to an egg shell ***Fig 8***. The technique also called structural skin. The word monocoque is a French term for “single shell”. Monocoque chassis is a one-piece structure that prescribes the overall shape of a vehicle. This type of automotive chassis is manufactured by welding floor pan and other pieces together. Since monocoque chassis is a cost effective and suitable for robotized production, most of the vehicles today make use of steel plated monocoque chassis.

Fig 8 Monocoque frame [10]

4. FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) is a computational technique used to obtain approximate solutions of boundary value problems in engineering. It is very useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained [11]. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables and satisfy specific conditions on the boundary of the domain [12].

An unsophisticated description of the FE method is that involves discretization of a structure, describing the behaviour of each element in a simple way, then reconnecting elements at nodes as if nodes were pins or drop of glue that hold elements together **Fig *9***. This process results in a set of simultaneous algebraic equations of the nodes. There may be several hundred or several thousand such equations, which means that computer implementation is mandatory. [13]

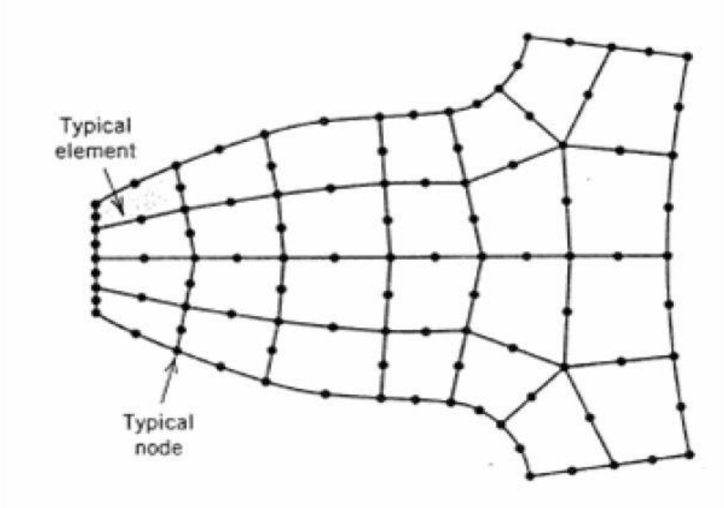


Fig 9 A coarse mesh, 2-D model of gear tooth [13]

BASIC PRINCIPLES OF COMPUTER MODEL CREATION

- Assessment of the physical behaviour: linear or nonlinear problem.
- Model dimension selection 1D, 2D, 3D.
- Element type selection.
- Use of symmetry.
- Suppressing the influence of singularities arising from model simplification.

Selection of dimension and element type often depends upon the type of the requested result.

GENERAL PROCEDURE FOR FINITE ELEMENT ANALYSIS

This includes three stages they explained below. [11]

PRE-PROCESSING

- Geometric model creation.
- Define element type.
- Finite element mesh generation.
- Define material properties.
- Geometrical properties assignment.
- Define physical constraints.
- Apply the loadings.

PROCESSING

- Computes the unknown values of the primary variables.
- Computed values are then used back by substitution to compute additional, derived variables, such as reaction forces, element stresses, heat flow, etc.

POST PROCESSING

- Display the output in a graphical or numerical form.

INTERPOLATION FUNCTIONS FOR GENERAL ELEMENT FORMULATION

In finite element analysis, solution accuracy is judged in terms of convergence as the element “mesh” is refined. there are two types of mesh refinement.

- In the first, known as h-refinement, mesh refinement refers to the process of increasing the number of elements used to model a given domain. consequently, reducing individual element size.
- The second method, p-refinement, element size unchanged but the order of the polynomials used as interpolation function is increased

The objective of mesh refinement in either method is to obtain sequential solutions that exhibit asymptotic convergence to values representing the exact solution.

5. LITERATURE REVIEW

Many researchers carried out stress analysis in car and truck chassis. From that lot of information taken out like optimization using different cross sections, changing materials of frame and how to apply loads, boundary conditions. They are mentioned below.

K.Venkatarao, J.Sekhar [14] represents optimization and analysis of chassis using composite materials. For this analysis they considered two composite materials namely E-Glass fibre and S-Glass fibre. The existing material was structural steel. By employing a polymeric composite chassis, we can reduce 70-80% weight. For analysis three models were prepared with different materials. From the results S-Glass fibre has superior strength with less deformation.

S.Sanjay, K.Abhijeet, G.Pradeep [15] it presents finite element analysis of fire truck with material optimization using carbon fibre. The frame ought to be very rigid and robust enough to resist shocks vibrations and stresses acting on vehicle and the material used for construction is steel. In this study steel is replaced by ultra-light weight carbon fibre because of its high strength to low weight ratio. They making analysis with both steel and carbon fibre. From the results the frame weight is reduced by 68% with same stiffness.

A.Kumar, P.Maareddygari [16] the project is to design a chassis for E-vehicle. For this they study the existing chassis types and selected carbon fibre material for light weight. They also mentioned advanced materials used for chassis production in automotive industry. Quality Function Deployment(QFD) used for selection of material and selection of chassis types. Finite element analysis used for analysing design.

V.Raju, B.Prasad, M.Balaramakrishna [17] this paper describes modelling and structural analysis of conventional type heavy vehicle frame. The frame constructed using C-type cross section with steel material. For weight reduction and stiffness improvement they using three different composite materials namely carbon fibre, E-glass fibre, S-glass fibre. They designed four frames and analyse finally comparing all the results. Because of polymeric composites the frame weight was reduced up to 80%. Based on results carbon fibre has high strength to weight ratio.

H.Mangole [18] presents cross-section and material optimization of an automotive ladder chassis using FEA. chassis constructed using C and I sections material was steel alloy. For optimization they using rectangular hollow sections and three different materials steel alloy

ASTM A710, ASTM A302, Al alloy 6063. From the results rectangular sections with ASTM A302 giving better results for high loads with low deformation and reduced stiffness. For normal loading C cross section with ASTM A302 material, for low loading and reduced weight C cross section with Al alloy 6063 used.

Kamlesh Y.Patil, Eknath, R.Decore [19] this paper describes, structural analysis and optimization of ladder chassis under maximum load. For optimization they using three different cross sections namely C, I AND Rectangular hollow section. So, they prepared three different vehicle chassis. For the three models they performing FEA and they compare all the results. From the results rectangular hollow section having the least deflection.

Hemant B.Patil, Sharad D.Kachave, Eknath R.Deore [20] performs stress analysis of ladder type truck chassis. To reduce the expanses of the chassis of the trucks, the chassis thickness reduced. In order to achieve reduction in the magnitude of stress at critical point of the chassis, side member thickness, cross member thickness and position of cross member from rear end were varied.

Erik Olofsson [21] describes about truck frame design and frame model calculations currently being used. It gives recommendation on how to approach using finite element analysis when designing chassis frame. In this paper Truck is subjected to three load cases lateral loading, frame torsion, and vertical load.

Karthick Kelkar, Siddharant Gawai, Tushar Suryawanshi, Shaikh Ubaid, Rajratna Kharat [22] explains static analysis of go kart chassis. It represents simplify the overall design, selection of different materials for frame and reduce the weight without losing performance and durability. The design subjected to different types of loads from front, side and rear.

European Journal of scientific research [23] represents static analysis of off-highway vehicle chassis. In this analysis maximum stress distribution areas of the frame investigated. Method of analysis is finite element analysis. From this methodology of static analysis and problem-solving process for designing a product has been found.

Teo Han fui, Roslan Abd. Rahman [24] this paper has been used in many journals. This paper presents the study of vibration characteristics of the truck chassis that include the natural frequencies and shape modes. The responses of the truck chassis the stress distribution and displacement under various loading conditions are observed. The mode shape results determine the suitable mounting locations of components like engine and suspension system. Some modifications also suggested to reduce vibrations and improve strength of the truck chassis.

M.Nor, H.Rashid, W.Mahyuddin [25] describes simulation and stress analysis of low loader chassis consisting I- beams design application of 35 ton trailer. They concern about structural design of the I-beams for info and data gathering, which will be used for further design improvement. Firstly, finite element model was designed and stress displacement contours are constructed and the maximum deflection and stress determined by performing stress analysis. Computed results are later compared with analytical calculation and safety factor for the low loader chassis also calculated.

O. Kuradi, M.Tamin [26] explains the most important steps in development of new truck chassis, prediction of fatigue life span and durability loading of the chassis frame. The both are necessary in order to verify the safety of chassis during its operation. Stress analysis finite element method used to locate the critical point which has highest stress. This critical point is one of the factors that may cause fatigue failure. The magnitude of the stress can be used to predict the life span of chassis.

S.Kotari, V.Gopinath [27] this paper deals with analysis of chassis frame for improving its payload by adding stiffener and C channel at maximum stress region of chassis frame. The FEM analysis has been carried out with various alternatives. The results illuminate the new creative ways for optimum frame design which makes more sustainable concerns. The frame analysed with both dynamic and static load condition.

R.Rahman, M.Tamin, O.Kurdi [28] it presents stress analysis of heavy duty truck chassis. the material of chassis is ASTM low alloy steel A 710 C. They perform stress analysis of heavy duty truck as a preliminary data for its fatigue life prediction. From this I knew about basic concepts of FEM and general procedure of finite element analysis. They mentioned also about truck classification in Malaysia.

Monika S.Agarwal [29] it describes finite element analysis of ladder truck frame. The study is to produce results to rectify problems associated with structures of a commercial vehicle such as strength, stiffness and fatigue properties along with stress, bending moment and vibration. This achieved by static and dynamic analysis, combining theoretical and advanced analytical methods.

M.Bajwa, Y.Raturi, A.Joshi [30] presents static load analysis of tata ace chassis and its verification using solid mechanics. It consists of two different cross section C type and rectangular hollow section. This paper is very similar to this thesis because in this paper they static load and uniformly distributed load using. Firstly, they doing stress analysis and they compared with solid mechanics.

A.bajaj, S.Alam, A.Uniyal [31] this paper describes study of static structural characteristics of the truck chassis at different load condition and the responses of the truck chassis which includes the stress distribution and displacement under various loading conditions, also observed the model analysis of truck chassis which include the natural frequencies and model shapes. First, they found out the results using theoretically and after that they analytically using Ansys, finally they compare both results.

A.Gaikwad, P.Ghawade [32] this report deals with structural analysis of ladder frame using finite element method. Ladder chassis was designed with C- cross section and material used was St 52, they performed stress, strain, deformation analysis. The acting loads are considered as static for both numerical and analytical. Finally, they compare the results its merely different. Using stress magnitude, they calculate life span the chassis.

S,Chandan, N.Vinayaka, G.Sandeep [33] explains design, analysis and optimization of race car chassis for its structural performance. Instead of using regular Taguchi method of optimization, poisons and orthogonal continuity model is used for optimization.

M.D.Birajdar, J.Y.Mule [34] this research describes analysis of ladder chassis. They reduced cross section of chassis for reducing weight and analysed the effect of reduction in cross section area with constrains of bending stress, shear stress and deflection. Four different cases are considered in each case height is reduced for some specific span of chassis where the intensity of load is less. Reduction in area for some specific span will distribute uniform across its whole area. Because of reduction in cross section leads to increase in stress they maintain the stress within the yield limit.

A.Patel, A.Srivastava [35] in this paper explains optimization of the truck chassis by changing material. Firstly, FEA analysis carried out in existing chassis later they changed the material with three different alloys and perform the same analysis. The three-material used are grey cast iron, AISI 4130 alloy steel and ASTM A710 steel. From the analysis AISI 4130 giving better results and compared others it is lighter than that. For improving stiffness, they optimise the frame. For optimization two different techniques are used they are boxing optimization, reinforcement optimization.

S.Begum, S.Murty [36] deals with modelling and structural analysis of vehicle chassis frame using polymeric composite material. Mahindra bolero vehicle chassis is taken and modelling with three composite material carbon fibre, E-glass, S-glass fibre. For shape optimization three different cross sections used namely C, I and rectangular hollow sections. From results comparisons the rectangular hollow sections have less deformation, where as I cross section has high deformation and C-cross section has highest deformation. Carbon fibre has least deformation with superior strength among all the three.

J.Nagaraju, U.Hari babu [37] describes design and structural analysis of chassis and composite material optimization in varying reinforcement angles of layers. Carbon fibre and E-glass fibre used instead of steel. Three models were developed using steel, carbon, fibre glass among the that carbon fibre gives more strength to low weight ratio. The weight of the chassis was reduced 4times less than steel.

From literature review I knew about design optimization and material optimization of chassis and how to do finite element analysis. For optimization of design we can change cross section, change the length, height between two cross members, remove the members having less stress magnitude. For material optimization we can choose the materials like carbon fibre, glass fibre, using the composite materials we can reduce weight up to 60-70%.

6.ANALYSIS OF EXISTING FRAME

6.1. GEOMETRIC MODELLING

In order to proceed with this study, the dimensions of the frame were gathered from existing frame. A three-dimensional solid model of the clay model car frame modelled in the CATIA V5-6. In order to build the model accurately, first the parts of model were build and they are assembled to make complete geometric model.

6.2. CREATING PARTS AND ASSEMBLY

Each part of the frame (side and cross members) was built as a separate part in CATIA V5-6. This frame mainly consists of three different size rectangular sections, they are 80×80×3,80×60×3 and 60×60×3.once part modelling was completed they are imported and combined together in assembly as shown in **Fig *10***.

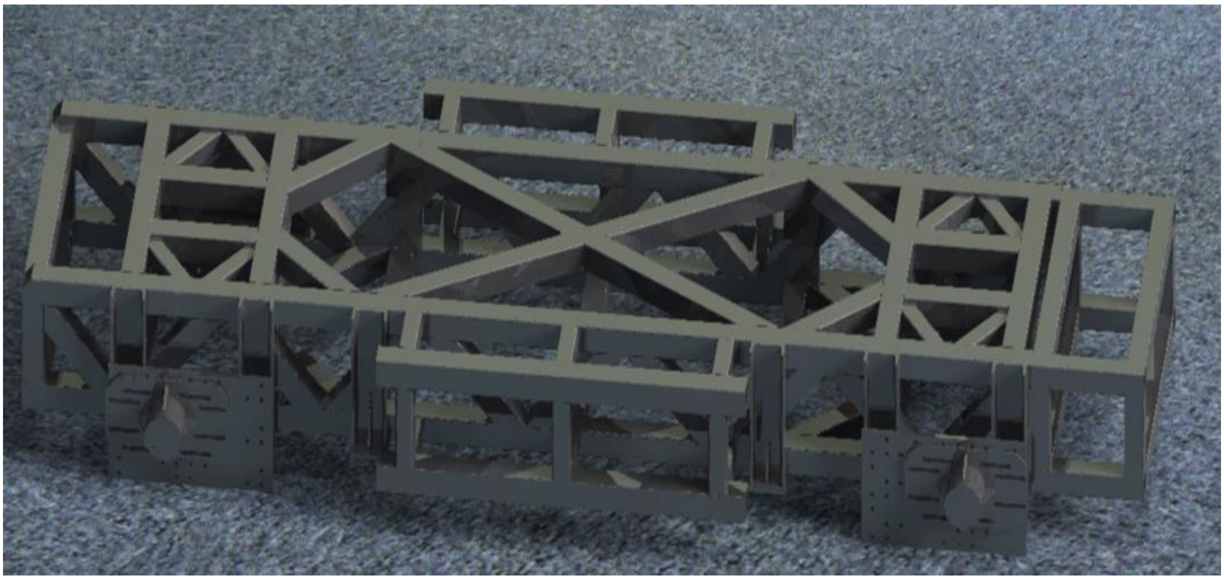


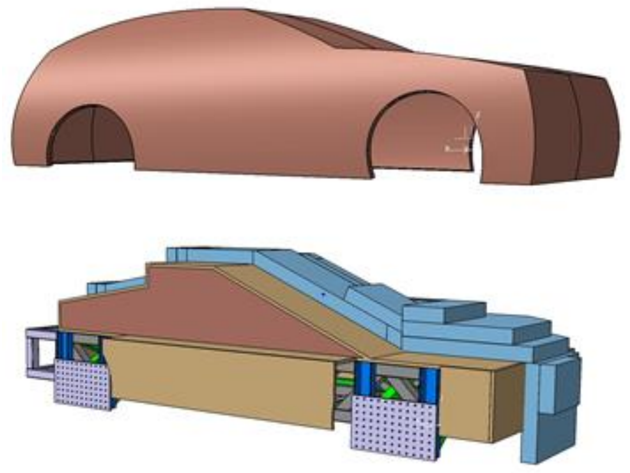
Fig 10 Existing model

6.3 STRUCTURAL ANALYSIS

Static analysis calculates the effects of loading in structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. However, it includes inertia load of gravity. The frame loads are clay, foam, chipboard desk. The major load from clay, foam and chipboard desk also plays a significant role.

6.4 APPLICATION OF LOADS

The load application is major part in the analysis. As I said earlier the major load is from clay 1800kg. The thickness of clay uniform throughout the length so the load is uniform except that slanting faces. In slanting faces only, small load increasing compared to the whole structure. The load from clay is not directly applied on frame it is applied through chipboard desk. Because of chipboard stiffness the load is distributed evenly. So, this load is considered as uniformly distributed load throughout length. ***Fig 11*** shows loads acting in model.



Clay 1400-1800kg

Foam 50-80 kg

Chipboard desk 120-180 kg

Fig 11 Acting loads

Total load = clay + foam + chipboard desk

= 1800 + 80 + 180 = 2060 kg

6.5 ANALYSIS USING STRUCTURAL STEEL

It is steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and mechanical properties. Structural steel shape, size, composition, strength, etc is regulated in most industrialized countries.

Composition 0.565%C, 1.8% Si, 0.7% Mn, 0.045%P and 0.045 % S.

Physical properties of material.

Modulus elasticity = 210 Gpa.

Density = 7850 kg/m^3.

Tensile strength = 460 Mpa.

Yield strength = 250 Mpa.

Poisson’s ratio = 0.3

6.6 MESHING OF CHASSIS FRAME

It is not always necessary to set mesh controls because the mesh controls are appropriate for many models. If no controls are specified, the program will use the default settings (DESIZE) to produce a free mesh. Alternatively, you can use the smart size feature to produce better quality free mesh. In order to achieve better results, finer mesh is given **Fig *12***.

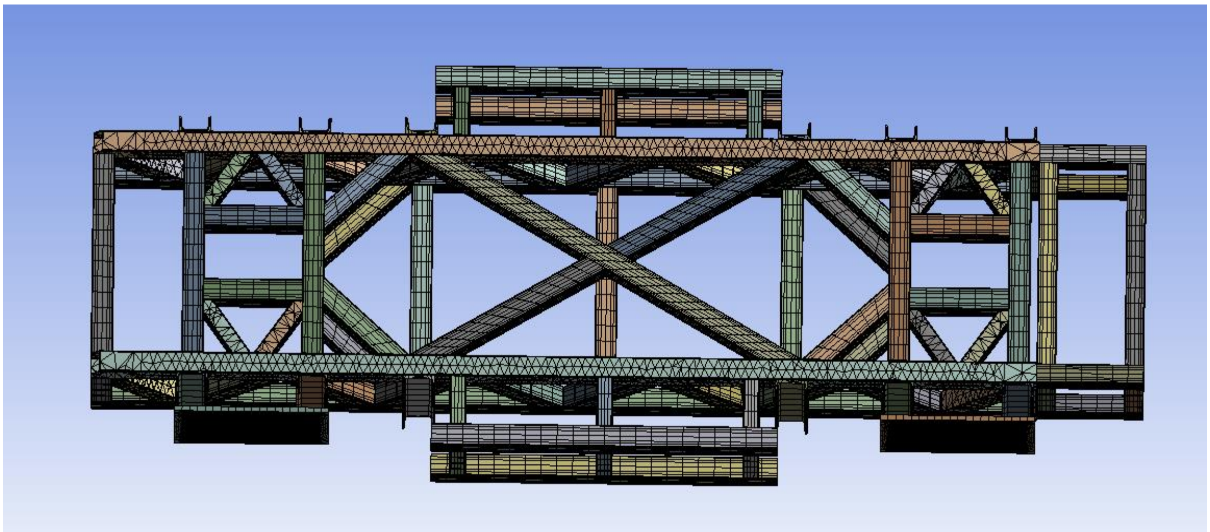


Fig 12 Model meshing

6.7 LOADING AND BOUNDARY CONDITIONS

In this analysis, static forces are applied as loads on chassis model. Maximum loaded weight of frame is 2060 kg. It is assumed that the load is uniformly distributed over the frame model. Standard earth gravity is also considered for this analysis, the frame weight is 750kg. It is shown in **Fig *13***. Fixed supports are given side plates where tyres are fixed. The type of connection bonded is employed in this analysis is for side bars and cross bars.

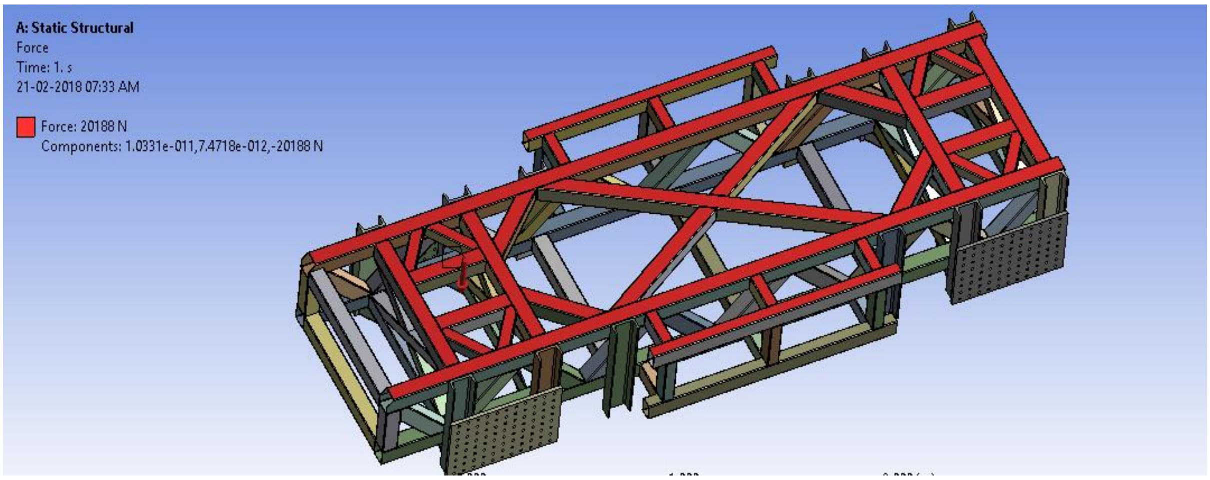


Fig 13 Load application

6.8 EQUIVALENT STRESS

When an elastic body is subjected to loads in its three dimensions, the stresses will get developed along the principle axis of the body stresses. These stresses should not exceed the yield stress of the material. Von Mises postulated that, even though none of the principal stresses exceeds the yield stress of the material, it is possible for yielding of the same from the combination of stresses. So, all these stresses in three dimensions are together called as equivalent stress. Von Mises stress is consideration is very important for design engineers. Using this information an engineer can say his design will fail, if the maximum value of Von Mises stress induced in material is more than the strength of material. It works for most cases, especially when material is ductile in nature. ***Fig 14*** shows stress developed in model.

Maximum equivalent stress = 33.646 Mpa

Minimum equivalent stress = 4.351×10^{-5} Mpa

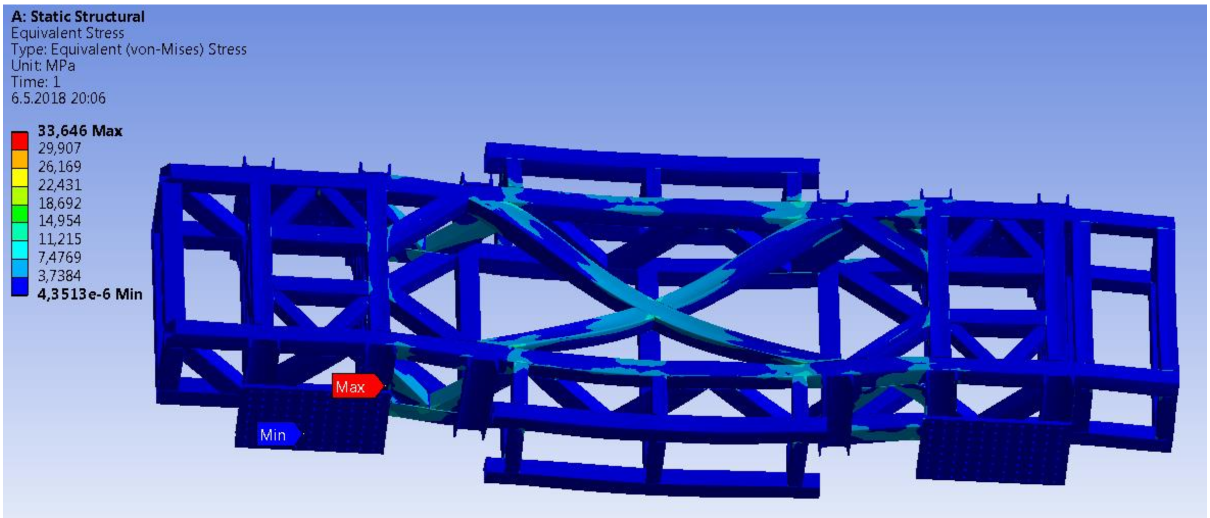


Fig 14 Equivalent stress in existing model

6.9 EQUIVALENT STRAIN

Strain is a measure of the amount of stretch or compression along a material (Normal strains), or the amount of distortion associated with the sliding of layers within a material (Shear strains). Strain measurement is a key element of materials testing. The physical properties of materials are usually represented by a stress-strain curve and knowledge of the stress-strain curve allows engineers to compare different materials and predict the behaviour of a part or structure made from a particular material (e.g. stiffness and failure strength) during processing operations like pressing and forging and during service. Internal strain within a metal is either elastic or plastic. In the case of elastic strain this is observed as a distortion of the crystal lattice, in the case of plastic strain this is observed by the presence of dislocations, the displacement of part of the crystal lattice. ***Fig 15*** shows equivalent strain in existing model.

Maximum Equivalent strain = 17.324×10^{-5} mm/mm.

Minimum equivalent strain = 2.528×10^{-10} mm/mm.

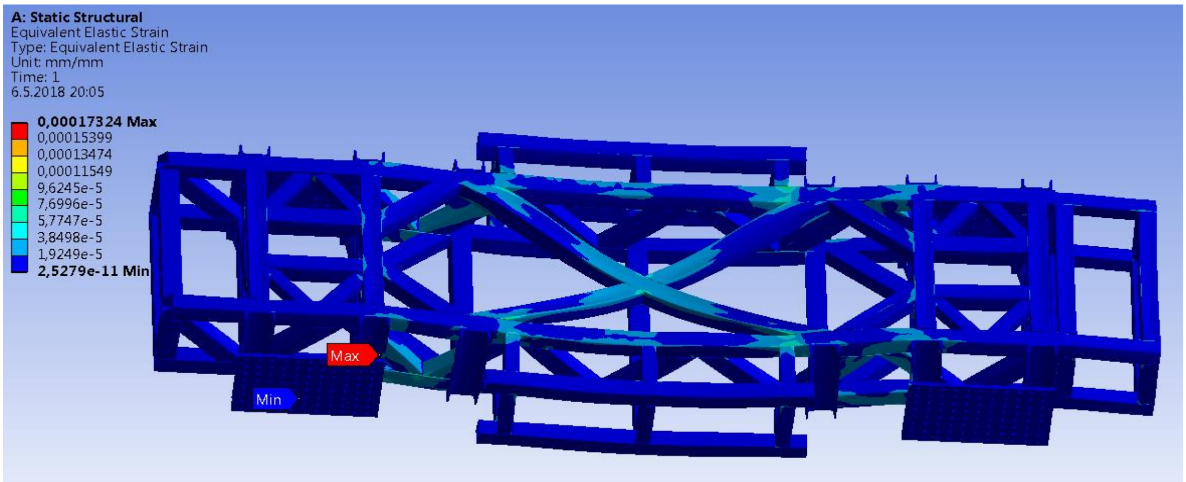


Fig 15 Equivalent strain in existing model

6.10 DEFORMATION.

When an object is subjected to loading its shape may be changed temporarily or permanently due to applied force. This change in shape is called Deformation. If the object deforms permanently is called plastic deformation or failure. If it deforms temporarily it is called elastic deformation. While analysing a frame the frame should deform elastically with in the maximum loading limit so that the design is safe. ***Fig 16*** Shows Deformation in model in the middle deformation was higher because no support from downside.

Maximum Deformation = 0.14956 mm.

Minimum Deformation = 0 m.

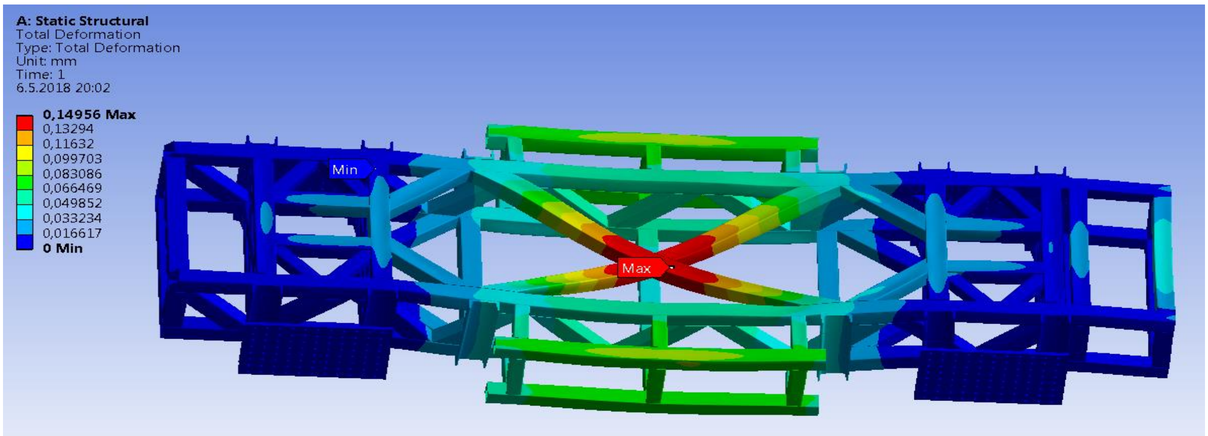


Fig 16 Deformation in existing model

6.11 MASS OF THE FRAME

The mass is the fundamental property of the object, a numerical measure of its inertia, a fundamental measure of the amount of matter in the object. Mathematical equation for mass is ***(1),***

Mass = Volume × Density, **(1)**

We know density of steel = 7850 kg/m^3,

Volume of frame = 0.089 m^3,

Total mass of frame = 7850 × 0.089 = 698.65 kg.

From the equation we found mass of frame is 698.65 kg

6.12 COST OF THE FRAME

For price of frame we consider only square sections and rectangular sections we didn't consider the C-section and the plates for fixing tyres. Because the same C-section and plates are going to use for new models. So, for price calculation we consider square section 80×80×3, and rectangular sections 80×60×3, 60×60×3,70×70×3.

Cross section size (mm)	80×80×3	80×60×3	70×70×3	60×60×3
Total length required (m)	42	17	7	1.1
Price per metre (€)	8.6	7	7	6.4
Total price (€)	361.2	119	49	7

Table 1 Price of existing frame

Total price of hollow sections = Total price of section1 + Total price of section2 + Total price of section3 + Total price of section4 **(2)**

Total price of hollow sections = 361.2 + 119 + 49 + 7 = € 536.2.

Prices are taken from F.H.BRUNDLE [38].

7.PROBLEM SOLVING PROCESS FOR NEW DESIGN

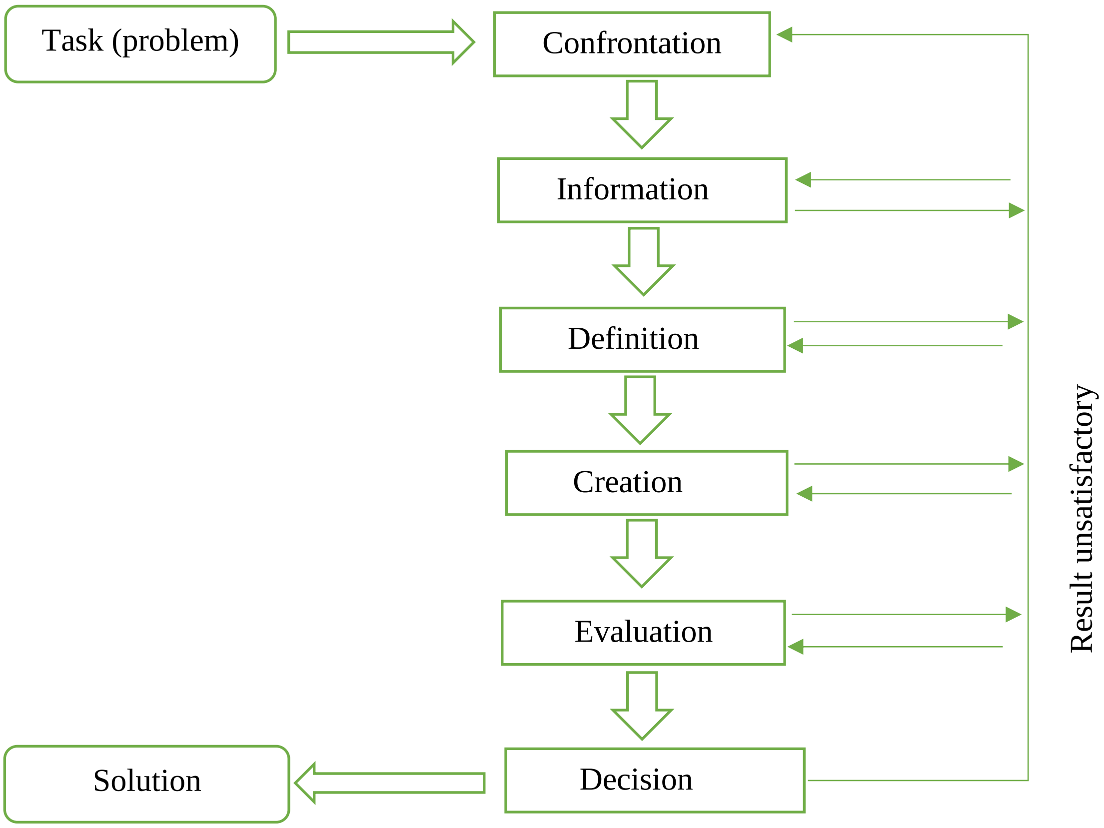


Fig 17 Problem solving process [40]

7.1 CONFRONTATION

Every task involves an initial confrontation of the elucidating what is known and unknown. The intensity of this confrontation depends on the knowledge, ability and experience of the designer, and on the particular field in which they are engaged.[39] [40]

In this thesis what we known was the loads are static.

What we should know before designing new frame was deformation, stress magnitude and strain were developed in existing frame and how to find it. So, for that first we proceeding with geometric modelling and analysis of existing frame.

7.2 INFORMATION

In all cases, however, more detailed information about the task itself, about the constraints, about possible solution principles and about known solution for similar problems is extremely useful since it clarifies the precise nature of the requirements. This information can also reduce confrontation and increase confidence that solutions can be found.

Here they give information like geometrical properties of frame, frame material, load acting on frame and boundary conditions.

7.3 DEFINITION

The definition phase where the essential problems are defined on a more abstract plane, in order to set the objectives and main constraints. Such solution-neutral definitions open the way to an unconstrained search for solutions.

The problem definition was we have to reduce weight while maintain stiffness, shape optimization, material optimization. For shape optimization and weight reduction we can choose different types of cross section. For material selection we can choose currently available material in market.

7.4 CREATION

The creation where solutions are developed by various means and then varied and combined using methodical guidelines.

Different models have to be created using different cross sections and different materials with wanted geometrical parameters.

7.5 EVALUATION AND DECISION

If the number of variants is large, there must also be an evaluation which is then used to select best variant through decision. Because each step of the design process must be evaluated, evaluation serves as a check on progress towards the overall objective.

If we created N number of models from that we have to select the appropriate model using analysis and comparison. Comparison in terms of weight, stiffness, price we have make it again and again and finally select an appropriate model.

For this evaluation we using finite element analysis. Here we are going to create three models and making analysis in terms of stress, strain, deformation. We also making weight and cost analysis of model.

For decision we are compare the all the parameters like stress, strain, deformation, price, weight. From this comparison we can choose best model design instead of old model.

8.MATERIAL SELECTION [41] [42]

8.1. STEEL

When it comes to chassis construction, steel is the first choice. From past few decades, the performance characteristics of steel such as strength and stiffness have improved. There have been many developments in iron and steel manufacturing therefore increasingly light weight steel is not only used to manufacture engines and wheels of vehicle bodies but also chassis. Iron and steel form a critical element for the structure of majority of vehicles as they are of lower cost. The primary reason for using steel in the body structure is its inherent capability to absorb impact energy in crush situations.

8.2. ALUMINIUM

Aluminium has the potential to reduce the weight of the vehicle body as it has a low density and high specific energy absorption performance. It also exhibits good corrosion resistance and a good specific strength. The aluminium usage in automotive industry has increased over the past decades. For chassis applications, the aluminium castings are used for about 40% of wheels and brackets. The recent developments have shown that up to 50% weight saving for the body weight by substituting steel by aluminium. Pure Al bodies have been developed and implemented for mainly luxury cars such as Audi A8 and BMW 28, because of their comparatively high material and production cost.

8.3. MAGNESIUM

It is another light weight metal that is becoming increasingly common in automotive engineering. It is 33% lighter than Al. And 75% lighter than steel cast iron components. Although the tensile strength of magnesium is same as Al, it has a lower ultimate tensile strength, fatigue strength when compared to Al. And the thermal expansion co-efficient is higher for Magnesium. It has better machinability, manufacturability, longer die life and faster solidification.

8.4 ADVANCED MATERIALS

8.4.1 FIBRE REINFORCED COMPOSITES.

It is popular due to its benefits that have a potential for weight saving offered by low density. As the weight reduction, could lead to lower fuel consumption, resulting in wider economic and environmental impacts. They have excellent resistance to corrosion and other chemical environments which could help manufacturer to pro-long the life time of individual components of vehicles. It is mainly used in automobile industry for the manufacture of body components, engine, chassis, etc. Fibre reinforced composites materials consist of fibres of high strength and modulus embedded in or bonded to a matrix with distinct interfaces between them.

8.4.1.1 CARBON FIBRE COMPOSITES.

In recent times, racing car companies rely on the composites, it would be in the form of plastic composites such as Kevlar and most importantly carbon fibre epoxy composites. It is because the composite structures have high strength or low weight ratio, which particularly benefits the racing car structures. The basic chassis of the formula one racing car is a monocoque construction which has 3 layers. It is used to construct the outer skin by building several layers of Carbon fibre reinforced epoxy in a mould. Furthermore, the flexibility of this process authorizes new design ideas which are not possible by using metal construction.

8.4.1.2 GLASS FIBRE COMPOSITES

The most common reinforcement for the polymer matrix composites is a glass fibre. Most of the fibre are based on silica ($SiO2$), with addition of oxides of Ca, B, Fe, and Al. The glass fibres divided into three classes E-glass, S- glass and C-glass. The E- glass is designated for electrical use and the S-glass for high strength. The C-glass is for high corrosion resistance. The glass fibre strength and modulus can degrade with increasing temperature. Although the glass material creeps under a sustained load, it can be designed to perform satisfactorily. The fibre itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel. It is currently being used in sports cars such as formula one. And is lighter than steel and Al, it is easy to shape and is rust proof. Furthermore, importantly it is inexpensive when produced in smaller quantity. Currently, Lotus, TVR, GM’s Camaro, etc., have used glass fibre in the non-stressed upper body that helps to get tolerance between the connecting points resulting in improved aerodynamic efficiency and more attractive enclosures.

8.5 PROS AND CONS OF MATERIALS

- Material: Steel

S.NO	PROS	CONS
1	They have been used from many decades for the construction of engines, wheels, and chassis as they are stronger, stiffer and have improved performance.	Steel is susceptible to corrosion.
2	It is easily available and it is the least expensive material used for manufacture of automobile chassis and motorcycle frames.	Buckling and high deformation due to small sizes of members.
3	Steel has the property of ductility therefore it is easy to form shape and weld when relatively large forces are applied to it.	

Table 2 Steel properties

- Material: Aluminium

S.NO	PROS	CONS
1	Aluminium is light in weight as it has low density.	It has poor weldability.
2	Al has excellent thermal conductivity useful in scenarios in rapid transmission and exit of heat especially engines and fins	Its fatigue resistance and young's modulus low. Also, it has poor strength unless alloyed.

Table 3 Aluminium properties

- Material: Magnesium

S.NO	PROS	CONS
1	Lower assembly cost and higher production speed.	Magnesium is highly flammable in its pure form.
2	It improves reliability and has superior dimensional stability.	It is expensive when compared with Al and steel.
3	Magnesium leaves lesser scarp	When Mg is exposed to white light it Emits UV rays, which is harmful to the human eyes.

Table 4 Magnesium properties

- Material: Carbon fibre

S.NO	PROS	CONS
1	Carbon fibre composites are 3.8 times stronger than steel, 4.5 times stronger than aluminium alloys, 7.4 times stronger than titanium.	Carbon fibre is expansive.
2	It has excellent strength to weight ratio when compared to other materials.	The recyclability of carbon fibres is difficult.
3	It has good production flexibility as it can easily be formed into complex shapes.	

Table 5 Carbon fibre properties

- Material: Glass fibre

S.NO	PROS	CONS
1	They have high temperature resistance.	They are brittle.
2	They are inexpensive.	They have week abrasive resistance.
3	They are non-flammable.	

Table 6 Glass fibre properties

Taking account of all pros and cons glass fibre and carbon fibre has high strength to weight ratio. Aluminium also less weight but it is expansive than steel. Using carbon fibres and glass fibres we can reduce 70-80% weight[14]. But carbon fibres are very expansive so we can't use. Coming to glass fibres it is cheap and high strength weight ratio. Compared with steel hollow sections glass fibre sections has limitation in cross section. In steel wide range of rectangular sections available. Glass fibre is new generation material so, only limited companies providing. In glass fibre assembling the members especially for this frame is difficult. So, I go with structural steel for new design it was the existing material because of its availability.

8.6 ALLOWABLE STRESS

Here we are choosing structural steel as I mentioned earlier for steel yield strength was 250Mpa. From equation three ***(3)*** we can get allowable stress,

$$\text{Allowable stress} = \frac{\text{yield stress}}{\text{factor of safety}} \quad \textbf{(3)}$$

$$\text{Allowable stress} = \frac{250}{3} = 83.33 \text{ Mpa.} \qquad \text{(safety factor = 3)}$$

So, maximum allowable stress is 83.33 Mpa.

9. NEW DESIGNS

As per problem solving process three models were developed and using finite element analysis they were tested.

9.1 MODEL 1

9.1.1 GEOMETRIC MODELLING

Model 1 was created as same as existing model while creation of this model in each stage it is compared with existing model using analysis and model 1 **Fig *18*** was finalised.

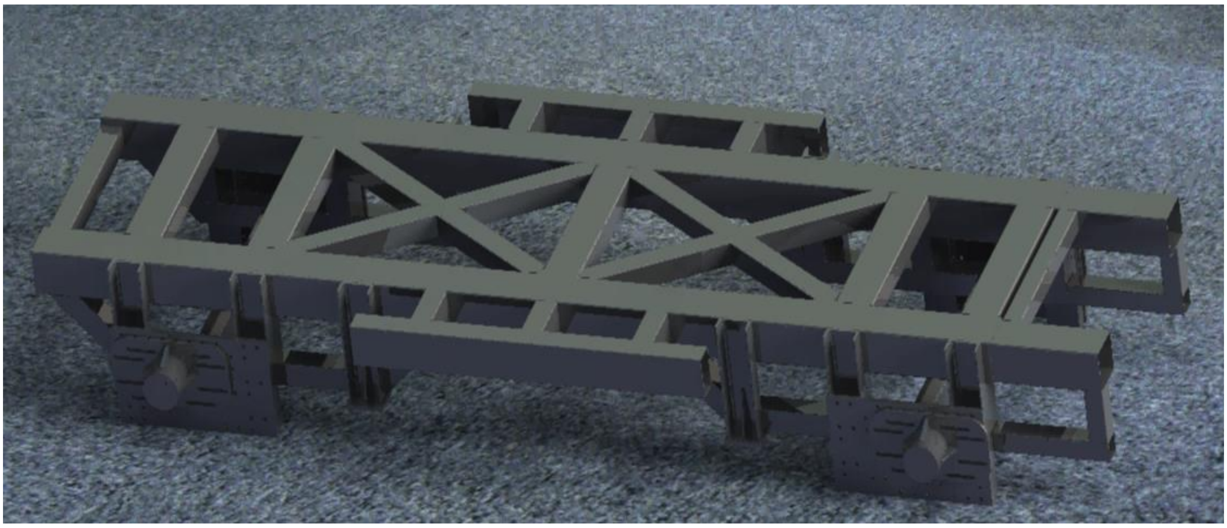


Fig 18 Model 1

Compared with existing model this model has better shape optimization. Because in this model we using two big longitudinal members 150×150×5 used instead of four main members 80×80×3. So, it eliminates all cross members used for supporting in old model. Same for extension assembly also two big members are used. Small cross members 80×80×3 and 70×70×3 also used for supporting.

9.1.2 MASS OF THE FRAME

As per equation ***(1)*** mass of the frame calculated,

We know density of steel = 7850 kg/m^3,

Volume of frame = 0.081 m^3,

Total mass of frame = 7850 × 0.081 = 635.81 kg.

From the equation we found mass of frame is 635.81 kg

So, compared with existing model the mass of the model 1is less than that.

9.1.3 COST OF THE MODEL 1

Same as existing model calculation for price of frame we consider only square sections and rectangular sections they are square sections 150×150×5, 80×80×3, 70×70×3.5 and rectangular sections 140×80×5.

Cross section size (mm)	150×150×5	140×80×5	80×80×3	70×70×3	140×140×4
Total length required (m)	7.1	6.7	14.7	2.2	1.4
Price per metre (€)	24.3	18.3	8.6	7	21
Total price (€)	172.5	122.5	126.5	15.5	29.5

Table 7 Price of the model 1

As per equation ***(2)*** price of the frame was,

Total price of hollow sections = 172.5 + 122.5 + 126.5 + 15.5 + 29.5 = € 466.5.

Prices are taken from F.H.BRUNDLE [38].

9.1.4 STRESS DEVELOPED IN MODEL 1

Maximum stress occurred near to the fixed support. Compared with old model the stress developed was drastically increased, this is because of change in cross section and less crossmembers used for support.

Maximum equivalent stress = 85.99 Mpa.

Minimum equivalent stress = 1.17×10^{-5} Mpa.

The maximum stress is little bit higher than the allowable stress.

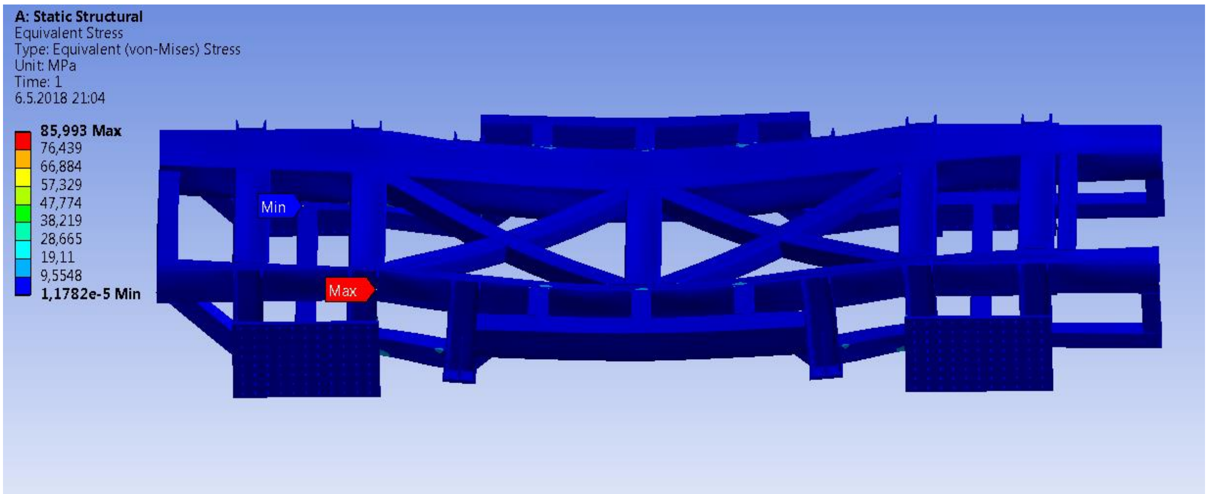


Fig 19 Equivalent stress in model 1

9.1.5 STRAIN DEVELOPED IN MODEL1

Fig 20 shows the equivalent strain developed in model 1. Maximum strain developed near the fixed support.

Maximum equivalent strain = 43.10 × 10^{-5} mm/mm.

Minimum equivalent strain = 7.235 × 10^{-11} mm/mm.

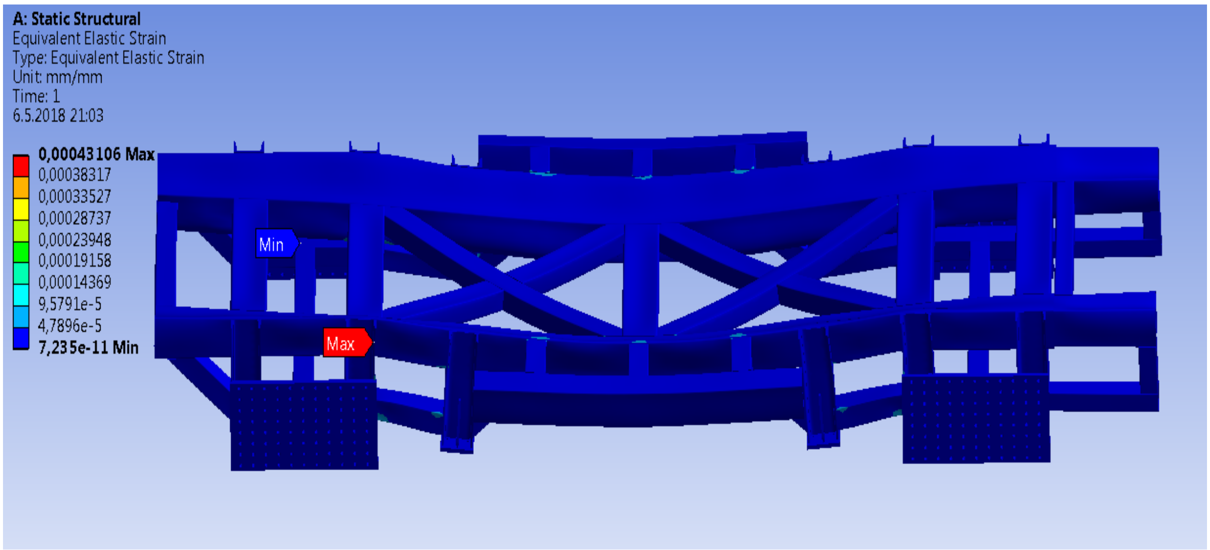


Fig 20 Equivalent strain in model 1

9.1.6 DEFORMATION IN MODEL 1

Maximum deformation occurred in middle as same as old model, compared with old model the deformation little bit higher.

Maximum Deformation = 0.1516 mm.

Minimum Deformation = 0 m.

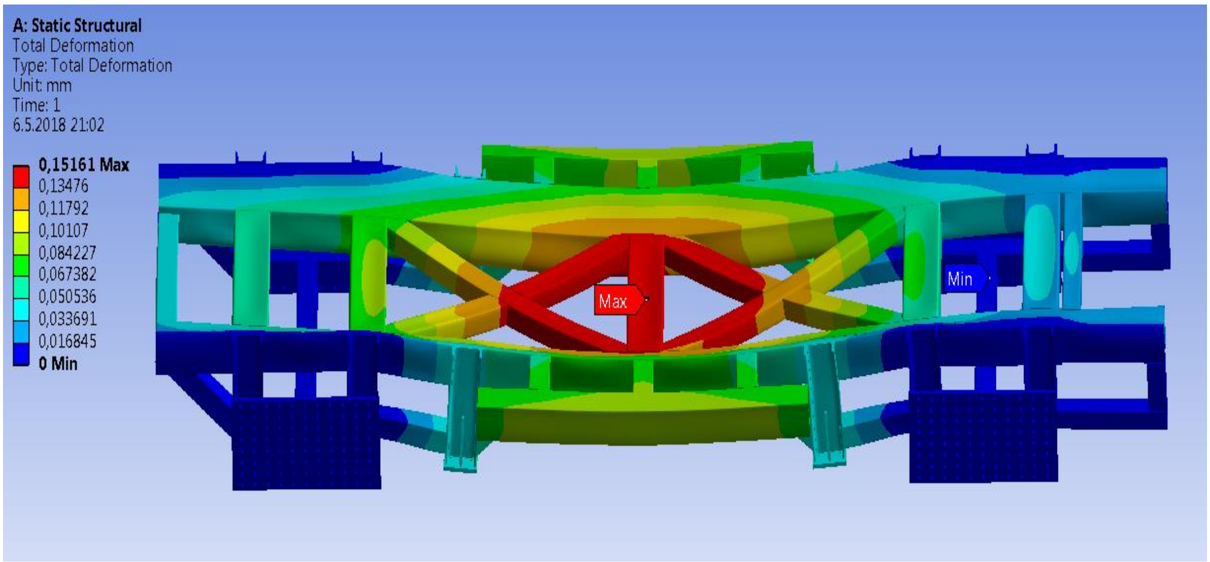


Fig 21 Deformation in model 1

9.2 MODEL 2

9.2.1 GEOMETRIC MODELLING

Model 2 is inspired from existing model, in this model we change the cross section of model from 80×80×3 to 80×60×3 and also, we reduce the height between two longitudinal members so, we can reduce the cross members height. Because of this weight of the frame is reduced. Instead of slanting cross members we using straight member for reducing weight. After finalising the design, we checked with finite element analysis but the results are not favourable. From the study of basic frame types, we got the details about using a backbone to form structure. For increase stiffness of frame, we using 120×60×6 members as back bone to reduce deformation it shown in **Fig *22***. After that, the deformation and stress developed are declined.

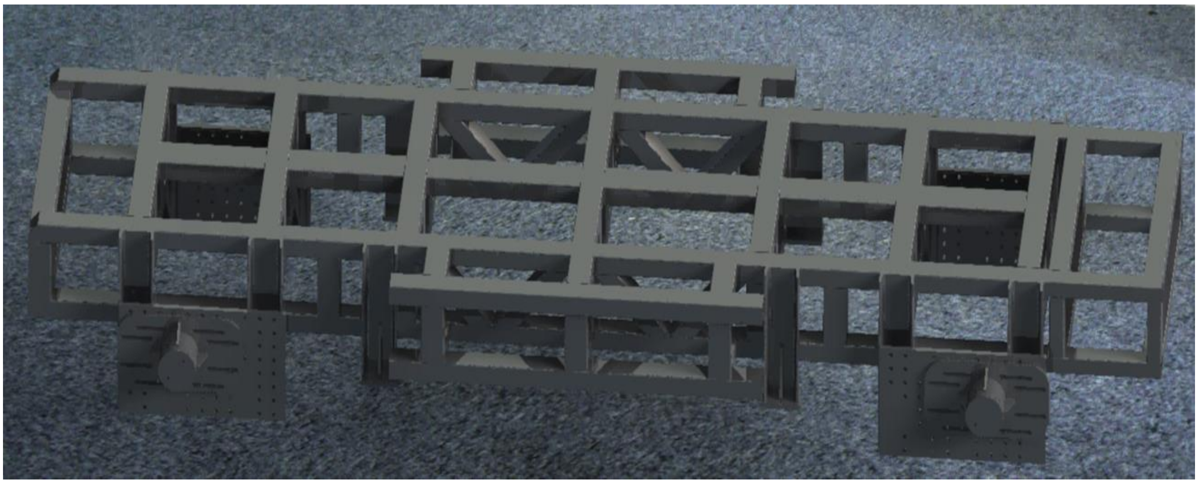


Fig 22 Model 2

9.2.2 MASS OF THE FRAME

Using equation ***(1)*** mass of the frame was,

We know density of steel = 7850 kg/m^3,

Volume of frame = 0.075 m^3,

Total mass of frame = 7850 × 0.075 = 588.75 kg.

From the equation we found mass of frame is 588.75 kg

So, compared with existing model and model1 the mass of the model 2 is less than that. This model is the low mass model from all the three models.

9.2.3 COST OF THE MODEL 2

In this model we are using only rectangular sections they are 80×60×3, 120×60×3, 70×50×3.

Cross section size (mm)	80×80×3	120×60×3	70×50×3
Total length required (m)	44.5	2.7	6.3
Price per metre (£)	8.6	16	6.4
Total price (£)	383	43.2	40.3

Table 8 Price of the model 2

From equation ***(2)*** the price of frame was,

Total price of hollow sections = 383 + 43.2 + 40.3 = € 466.5.

Prices are taken from F.H.BRUNDLE [38].

9.2.4 STRESS DEVELOPED IN MODEL 2

Maximum stress occurred near to the fixed support ***Fig 23*** shows stress developed in model2. Compared with model 1, stress developed was reduced below allowable stress.

Maximum equivalent stress = 79.761 Mpa.

Minimum equivalent stress = 1.13×10^{-5}Mpa.

The maximum stress is less than the allowable stress.

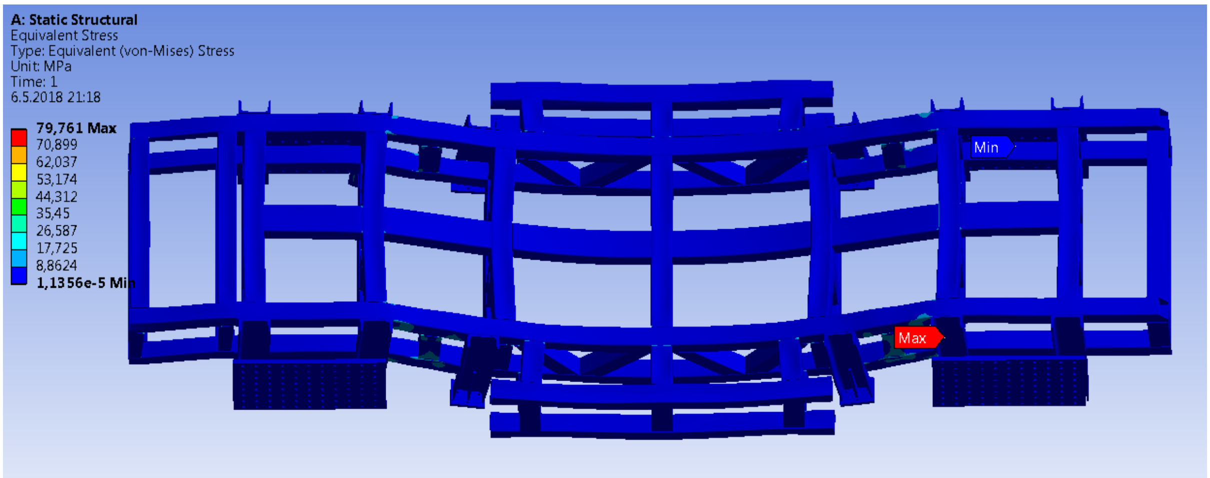


Fig 23 Equivalent stress in model 2

9.2.5 STRAIN DEVELOPED IN MODEL2

Strain developed in model 2 is same as model1 it is shown in ***Fig 24***.

Max strain developed = 45.86×10^{-5} mm/mm.

Minimum equivalent strain = 6.45×10^{-11} mm/mm.

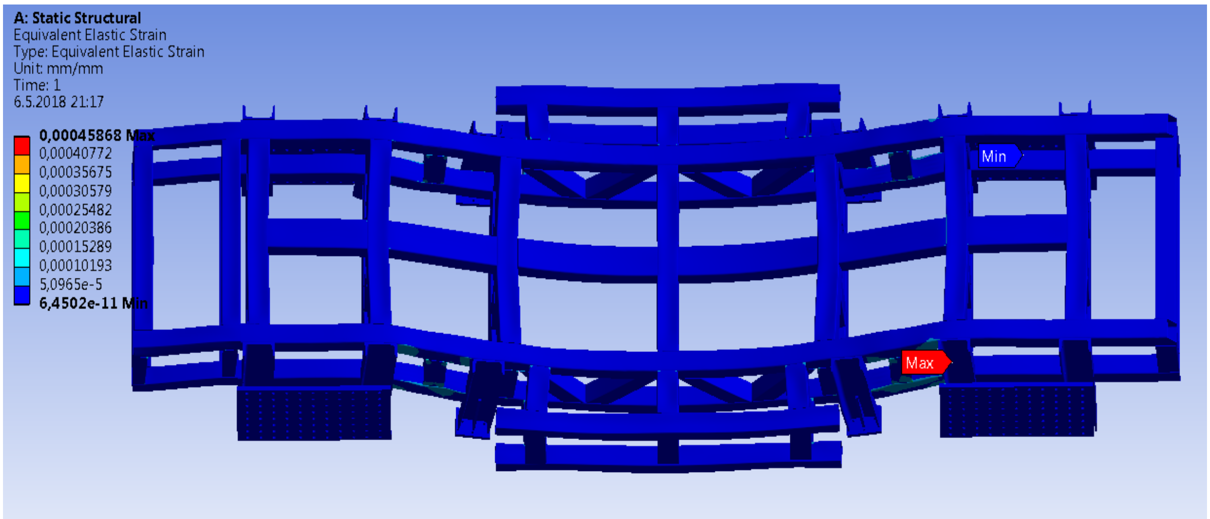


Fig 24 Equivalent strain model 2

9.2.6 DEFORMATION IN MODEL 2

Maximum deformation occurs all parts middle it shown in ***Fig 25*** deformation results same as model 1. Model 1 and model 2 has same deformation.

Maximum Deformation = 0.1513 mm.

Minimum Deformation = 0 m.

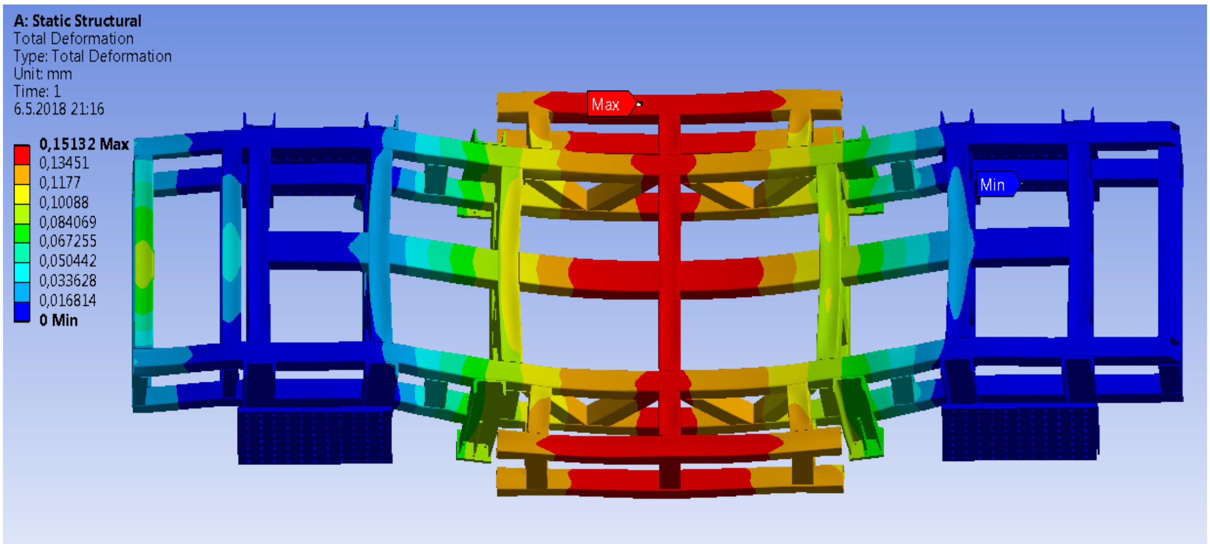


Fig 25 Deformation in model 2

9.3 MODEL 3

9.3.1GEOMETRIC MODELLING

The existing model has good stiffness and robust in construction so completely ignoring the existing model it was not good. So, model 3 was developed from existing model, as per the results from analysis of existing model we removed some members of model and also making some alterations in model. From the results of existing model, the cross members near the plates are removed and some members from top also removed for making the design lighter. After removing the members, we make analysis from that we found the stress developed and deformation in middle was higher so, we add members 80×60×3 in middle to increase stiffness.

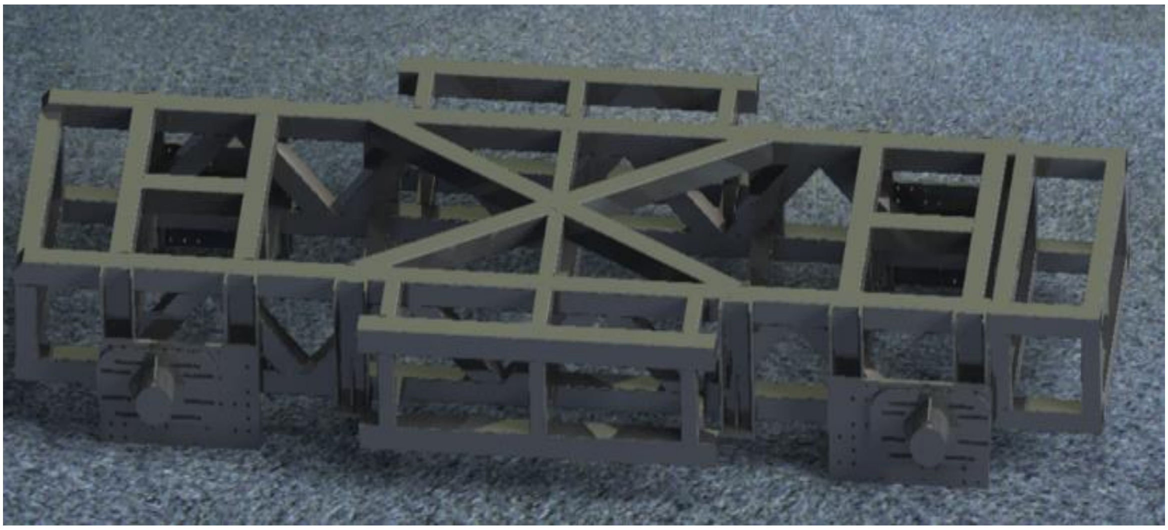


Fig 26 Model 3

9.3.2 MASS OF THE FRAME

Because of reduced members the frame volume also reduced.

From equation ***(1)*** mass of the frame was,

We know density of steel = 7850 kg/m^3,

Volume of frame = 0.082 m^3,

Total mass of frame = 7850 × 0.082 = 643.7 kg.

From the equation we found mass of frame is 643.7 kg

So, compared with existing model the mass of the model 3 is less than that.

9.3.3 COST OF THE MODEL 3

we consider square sections 150×150×5, 80×80×3, 70×70×3.5 and rectangular sections 140×80×5.

Cross section size (mm)	80×80×3	80×60×3	70×70×3
Total length required (m)	39.3	11.5	7
Price per metre (€)	8.6	7	7
Total price (€)	338	80.5	49

Table 9 Price of the model 3

Total price of hollow sections = 338 + 80.5 + 49 = € 467.5.

Prices are taken from F.H.BRUNDLE [38].

9.3.4 STRESS DEVELOPED IN MODEL 3

Maximum stress occurred next to longitudinal member it shown in ***Fig 27*** .

Maximum equivalent stress = 77.083 Mpa.

Minimum equivalent stress = 4.87×10^{-6} Mpa.

The maximum stress is less than the allowable stress.

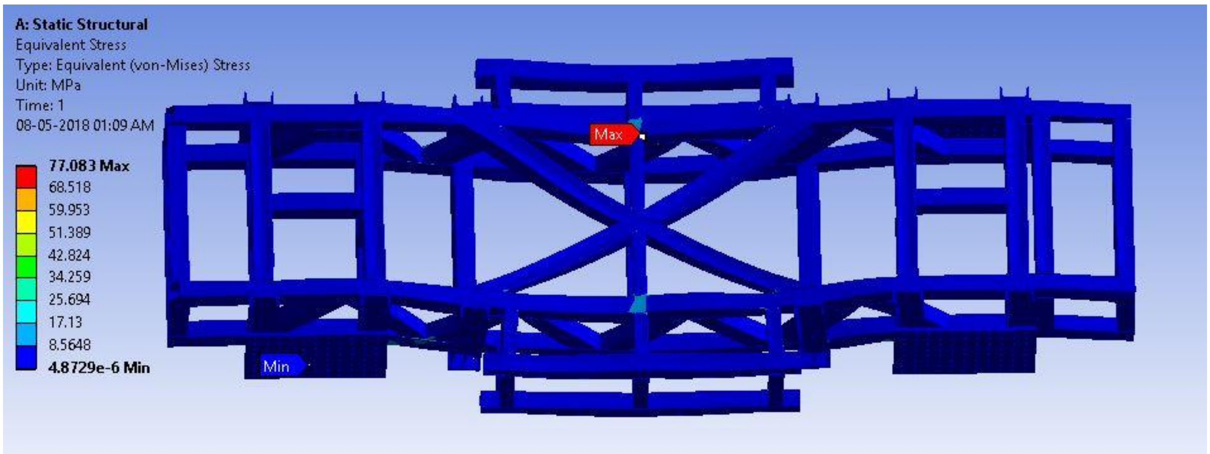


Fig 27 Equivalent stress in model 3

9.3.5 STRAIN DEVELOPED IN MODEL3

Fig 28 shows the equivalent strain developed in model 3.

Max strain developed = 43.10 × 10^{-5} mm/mm.

Minimum equivalent strain = 7.235 × 10^{-11} mm/mm.

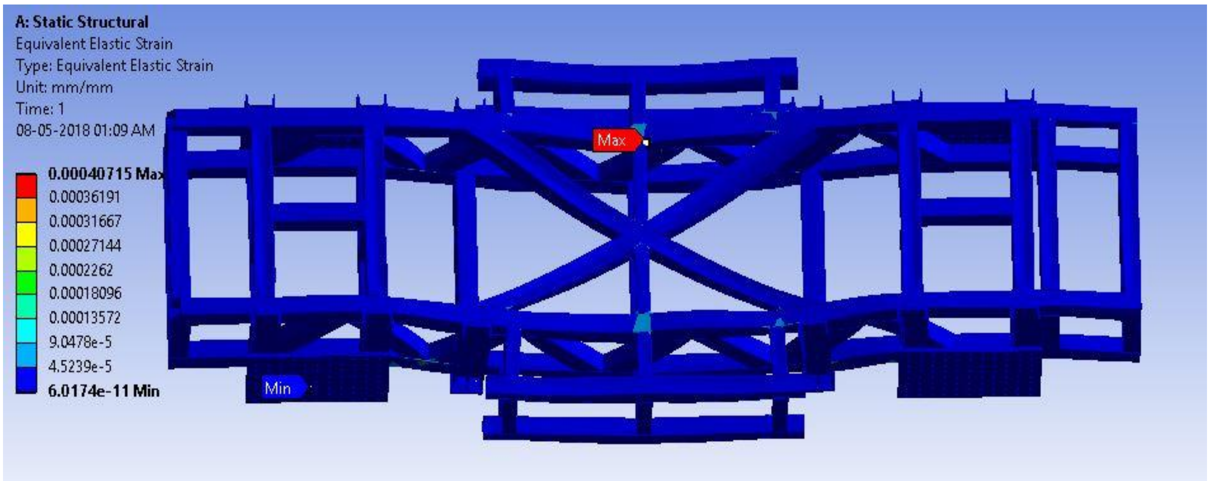


Fig 28 Equivalent strain in model 3

9.3.6 DEFORMATION IN MODEL 3

Fig 29 shows the deformation occurred in model 3. Same as other models maximum deformation developed in middle cross members. Model 3 has least deformation among all the three.

Maximum Deformation = 0.106 mm.

Minimum Deformation = 0 mm.

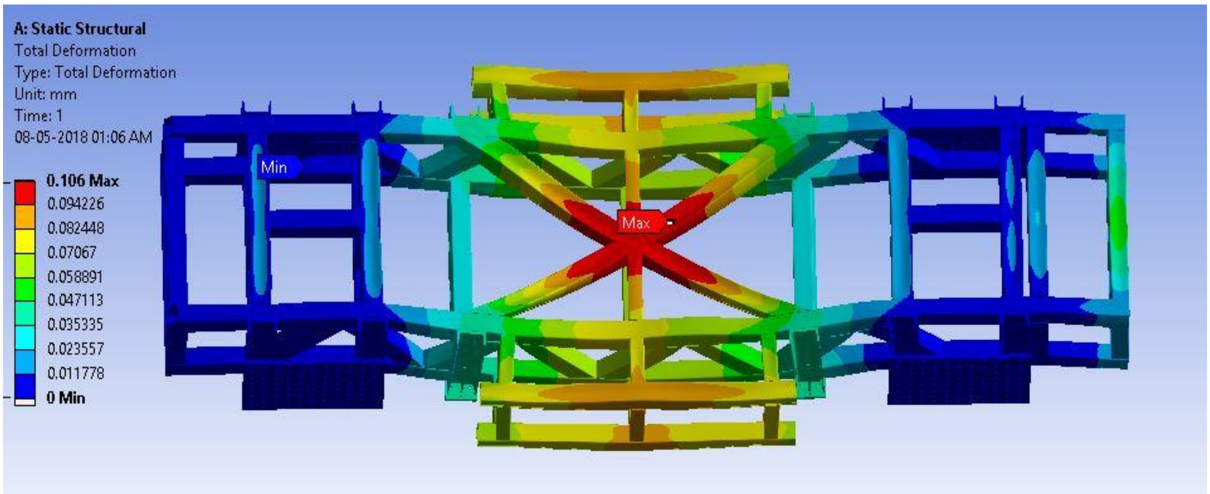


Fig 29 Deformation in model 3

10.RESULTS COMPARISON

10.1 STRESS COMPARISON

	Existing Model	Model1	Model2	Model3
Maximum stress developed (Mpa)	33.646	85.99	79.761	77.083

Table 10 Stress comparison

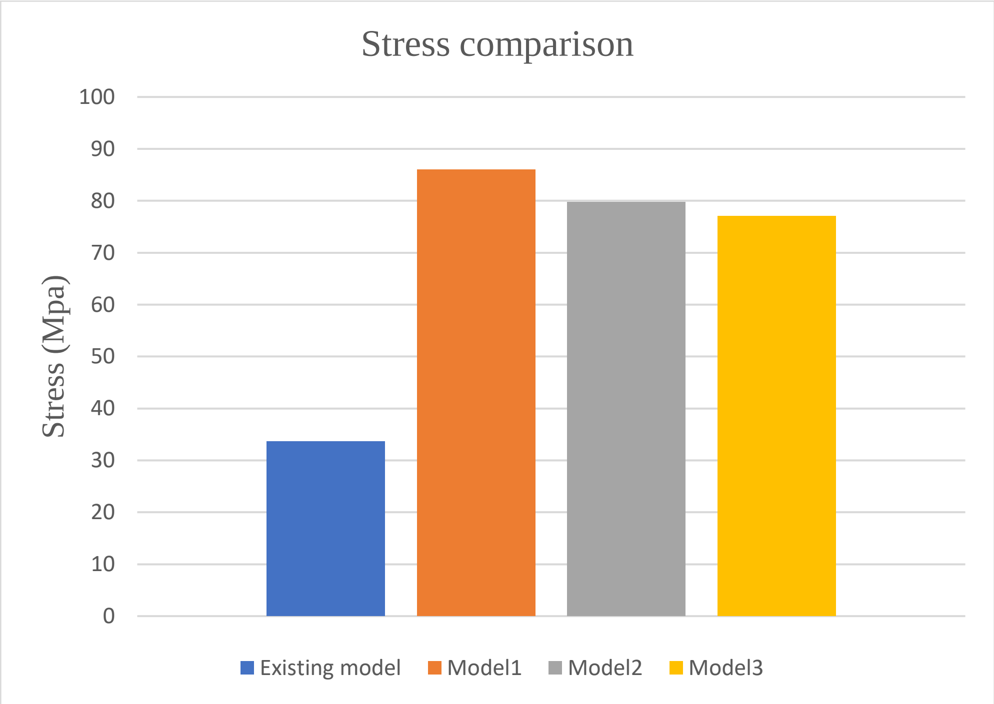


Fig 30 Stress comparison

It is necessary to find critical point which has maximum stress because the critical point is one of the factors that may cause the fatigue failure. Allowable stress in steel was 83.3 Mpa. From the results except model 1 all the three have less stress than allowable. It's clear that from the new models, model 3 have less stress because of it construction.

10.2 DEFORMATION COMPARISON

	Existing Model	Model1	Model2	Model3
Deformation (mm)	0.1495	0.1516	0.1513	0.1060

Table 11 Deformation comparison

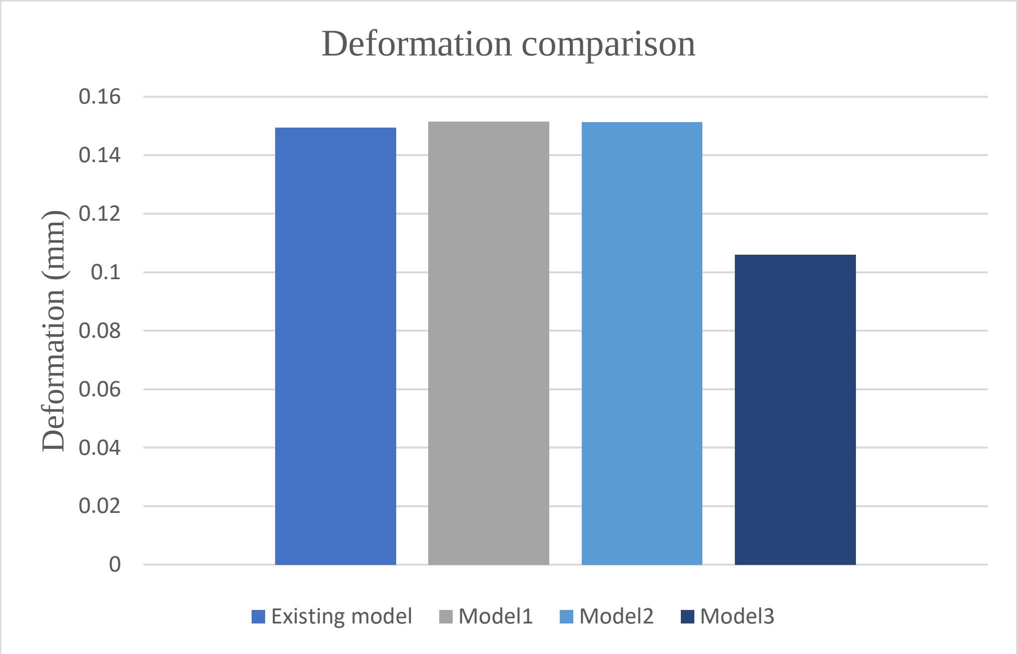


Fig 31 Deformation comparison

Model 3 has less deformation among the four models because of its construction. For all models deformation occurs in middle cross members because fixed supports located at sides of models. Model 3 is altered from existing model but Compared with that it has less deformation.

10.3 MASS COMPARISON

	Existing Model	Model1	Model2	Model3
Mass (Kg)	698.65	635.81	588.75	643.70

Table 12 Mass comparison

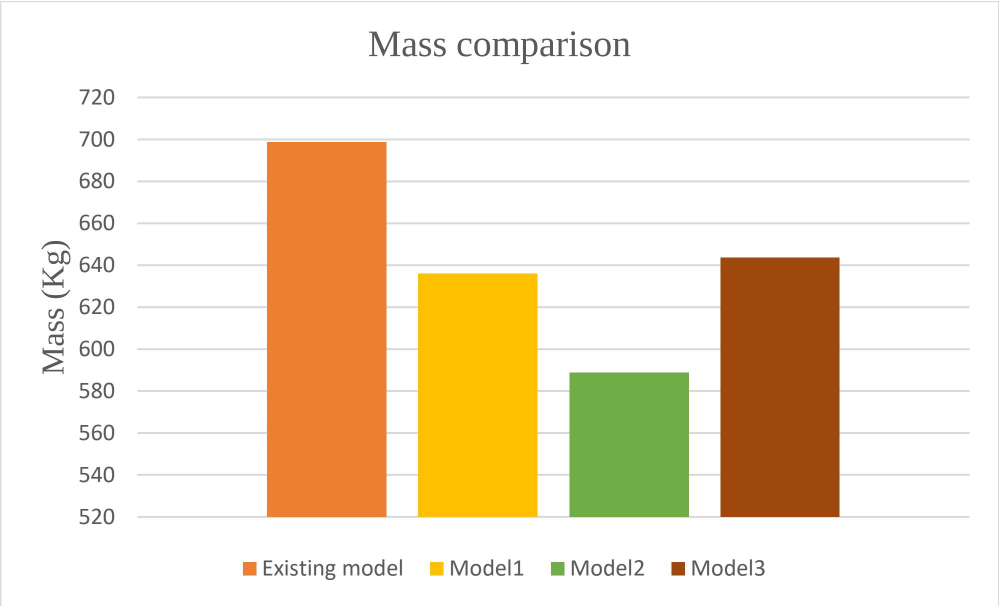


Fig 32 Mass comparison

Model 3 has less mass because of its reduced cross section and reduced height of model. Also, it has good stiffness. Compared with existing model, model 2 mass was reduced 15.7%. Whereas model 1 has 9% reduced mass and model 3 has 7.8% reduced.

10.4 PRICE COMPARISON

	Existing Model	Model1	Model2	Model3
Price (€)	536.2	466.5	466.5	467.5

Table 13 Price comparison

Fig 33 Price comparison

Compared with existing model, Model 1 and model 2 has least price because of cross sections used for construction. Model 1 constructed with two big longitudinal member and model 3 constructed with rectangular cross section, reduced height. Model 3 also have less price with small difference. Model 1 and model 2 have 13% reduced price with existing model and model 3 has 12.8%.

11.CONCLUSION

From the finite element analysis of frames, Model 2 has weighed pros over cons when compared with other two models. Based on results it was inferred that Model 2 has good stiffness properties with 15.7% of reduced weight and 13% of reduced price than existing model. Finally, an ideal frame was found using different product development methodologies and CAD & analysis software, as described and executed in the thesis.

The literature study was carried out for better understanding of the whole process of developing and optimizing a frame. Various topics are researched below

- Types of chassis
- FEM analysis
- Various loading conditions and types of stress acting on the chassis
- Materials used for chassis manufacturing
- Advanced materials

The dimensional specifications of existing model help me to design an accurate frame. From this thesis work I have learned how to approach product development process, how to optimize an existing design and finite element analysis.

12. FUTURE WORK

Even though the design is complete, there is always a room for improvement. There is no end for a new design the possibilities are,

- Design optimization - Change the cross section and thickness, change height of frame, cross member type.
- Material optimization - Choose different materials.
- Change the methodologies were used.

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Appendix

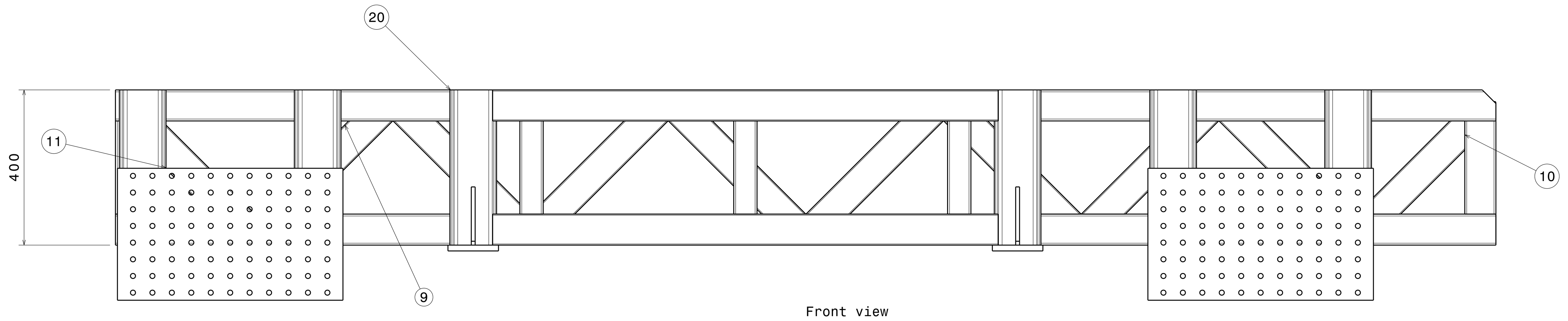
1. Compact Disc with Final thesis reports and drawings.

2. Technical Drawings.

i. Existing model assembly
ii. Existing model extension
iii. Model 1 assembly
iv. Model 1 extension
v. Model 2 assembly
vi. Model 2 extension
vii. Model 3 assembly

3.Rectangular section catalogue.

4. Square section catalogue.



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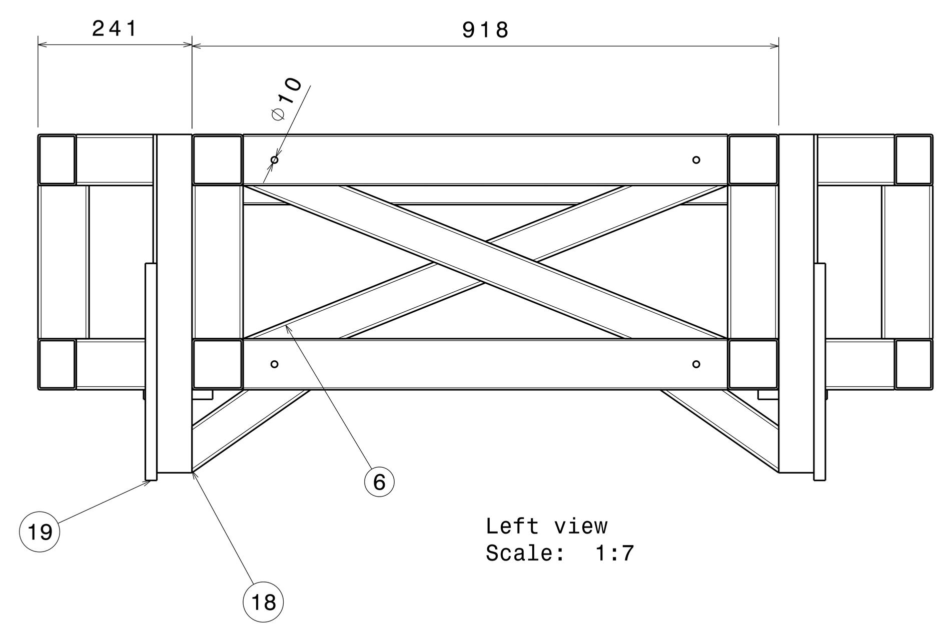

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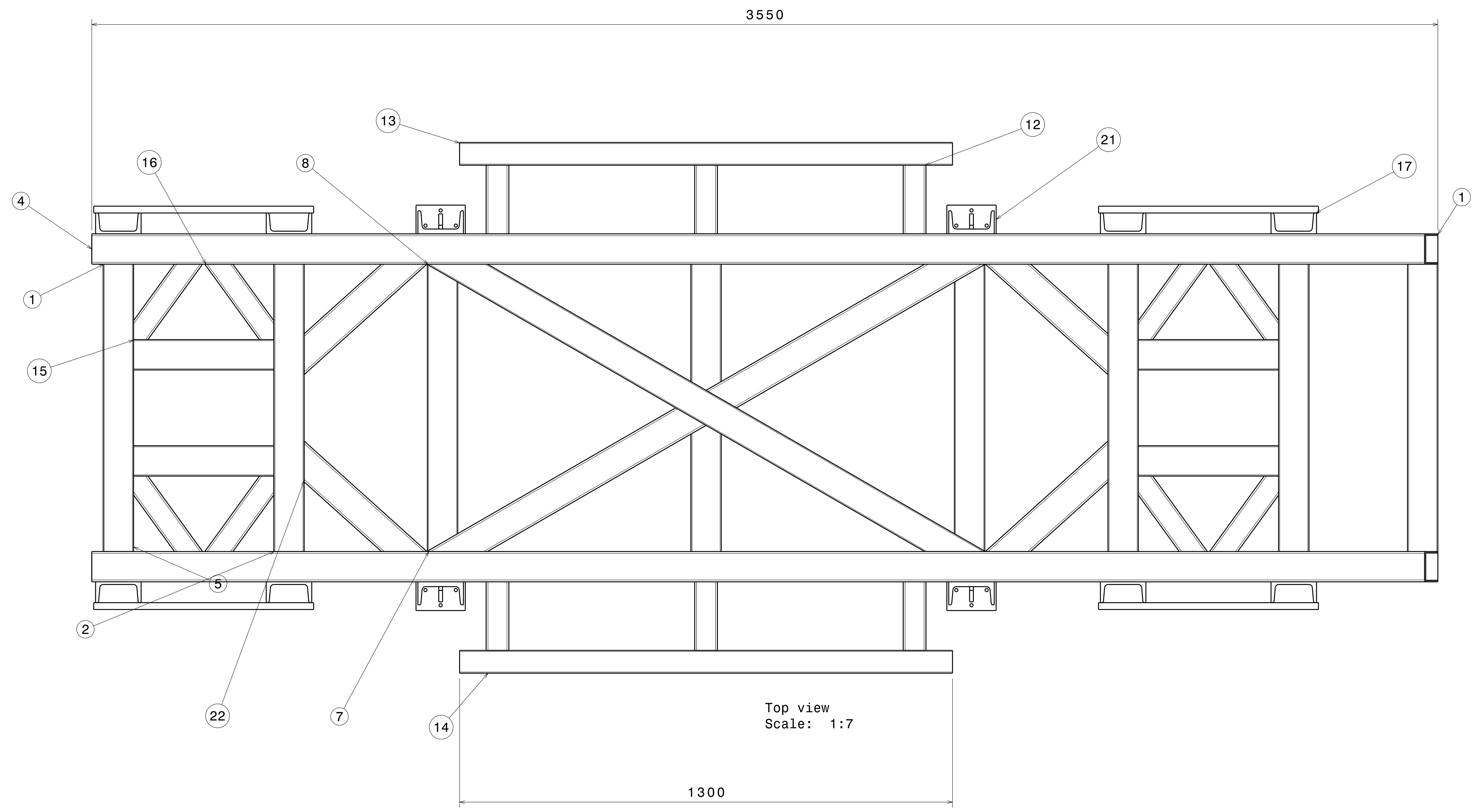

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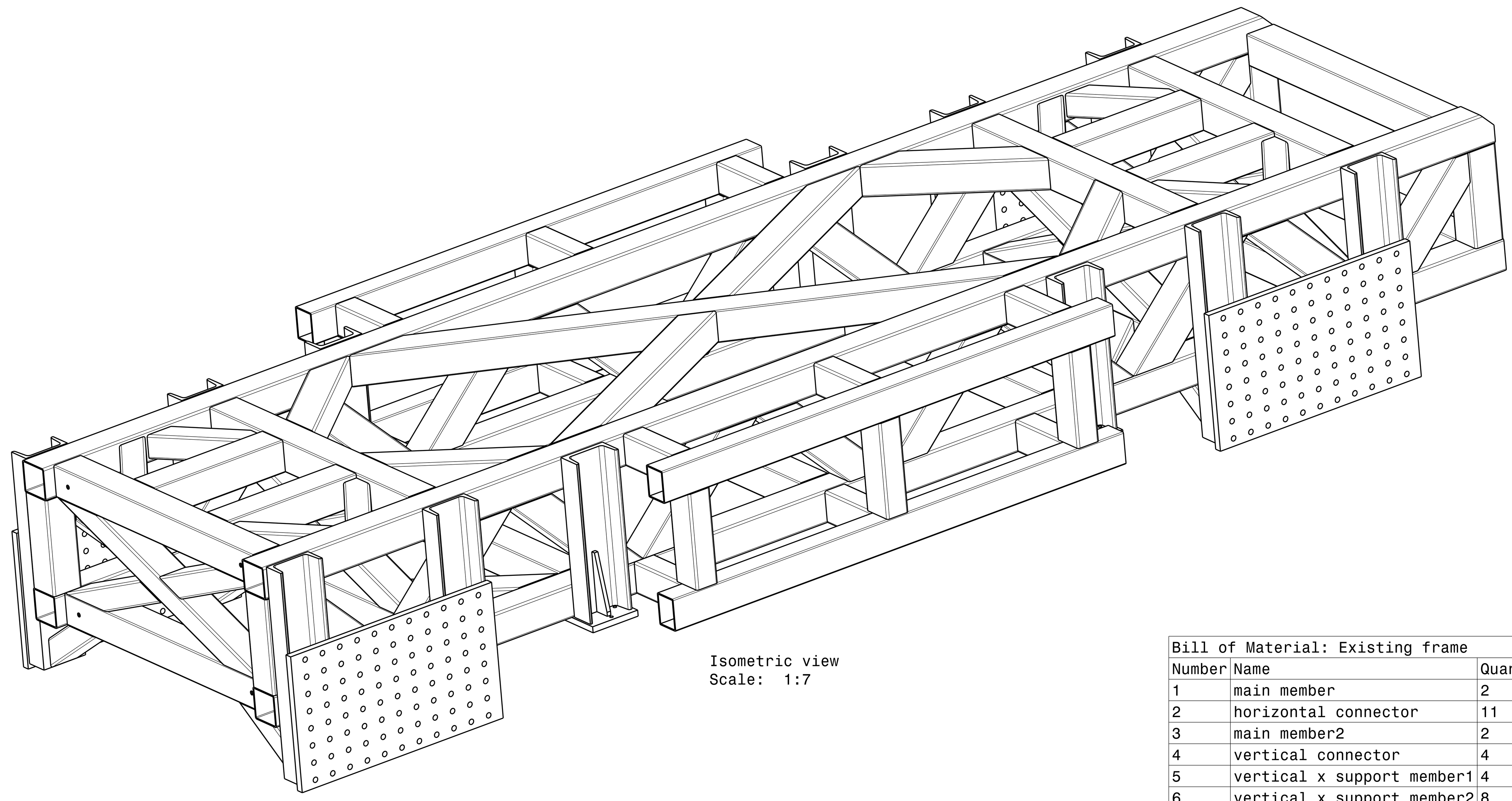

Isometric view
Scale: 1:7

Bill of Material: Existing frame

Number	Name	Quantity
1	main member	2
2	horizontal connector	11
3	main member2	2
4	vertical connector	4
5	vertical x support member1	4
6	vertical x support member2	8
7	Top X member1	2
8	Top X member2	1
9	slanting member1	16
10	slanting member2	2
11	slanting member3	2
12	side horizontal member1	12
13	side horizontal member2	4
14	side vertical member	6
15	Top stiffner1	4
16	Top stiffner2	8
17	C section	8
18	C section support	8
19	side plate	8
20	lifting member	4
21	lift stiffner	4
22	main X stiffner	8

Technical University of Liberec	
DRAWN BY: Jayaprakash Lakshmanasamy	DATE: xxx
CHECKED BY: Ing.Petr Zelený, PhD	DATE: xxx
DESIGNED BY: SVOTT.s.r.o	DATE: xxx
DRAWING TITLE	Existing model
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DRAWING NUMBER	OKSAVSTA0100
REV	X
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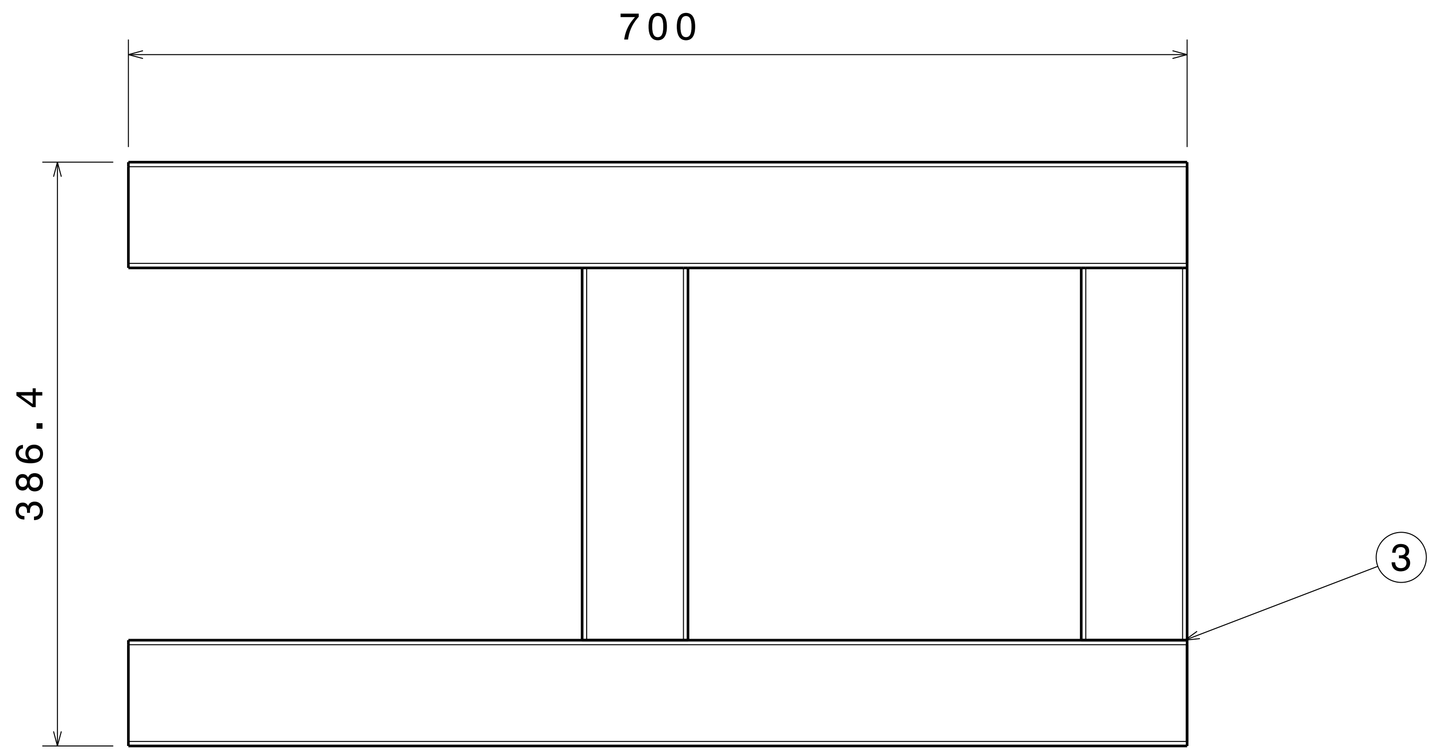
WEIGHT(kg)	XXX
SHEET	1/1



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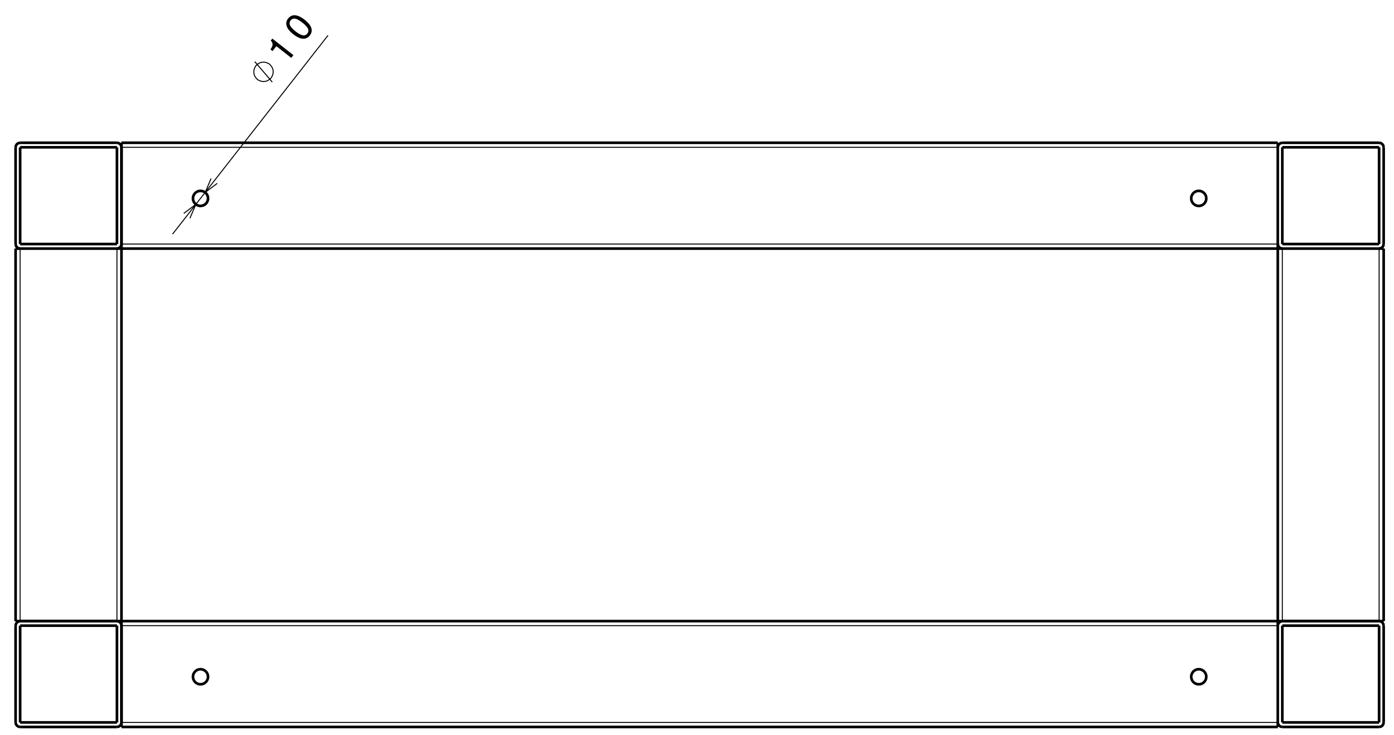

Left view
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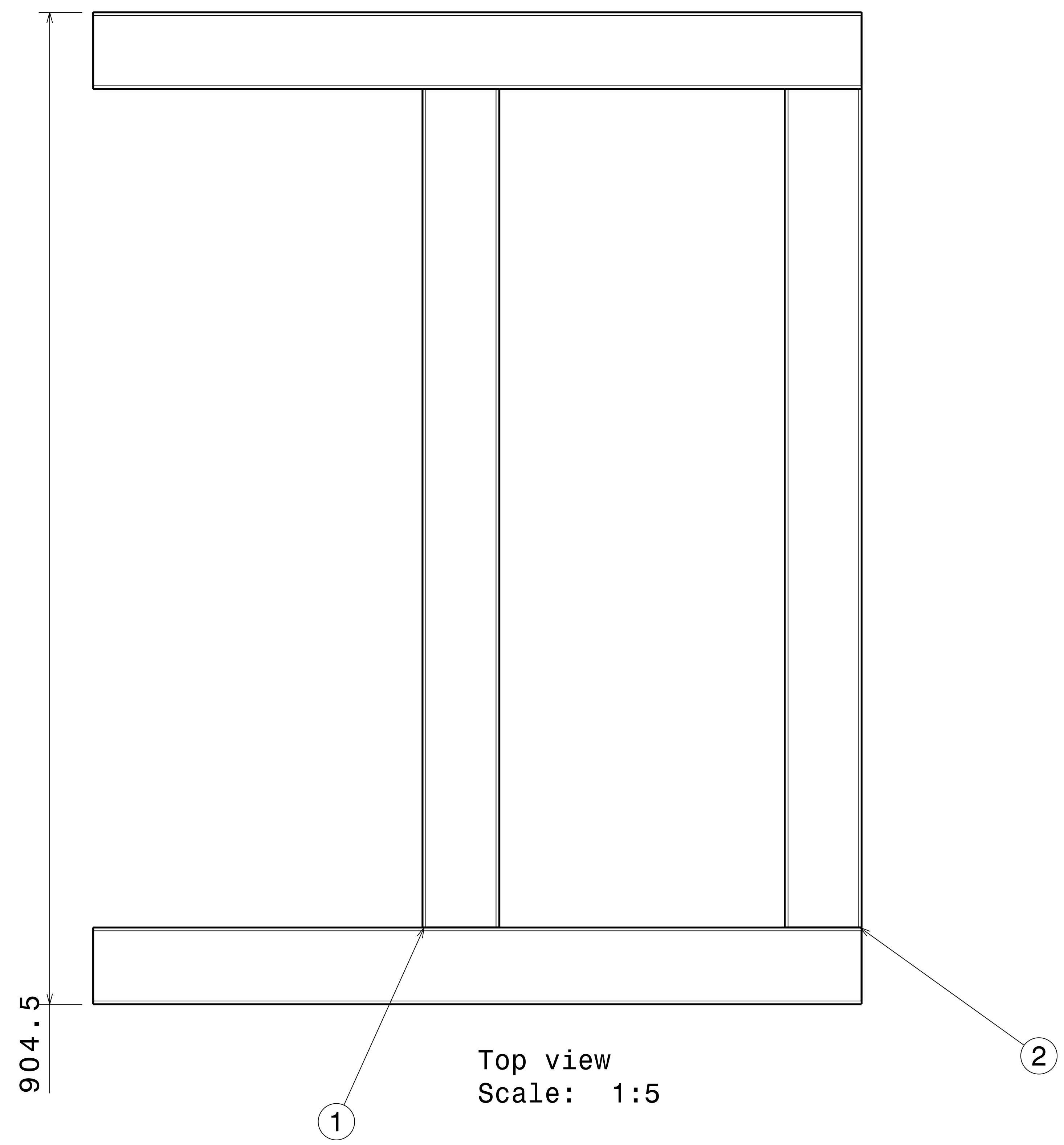

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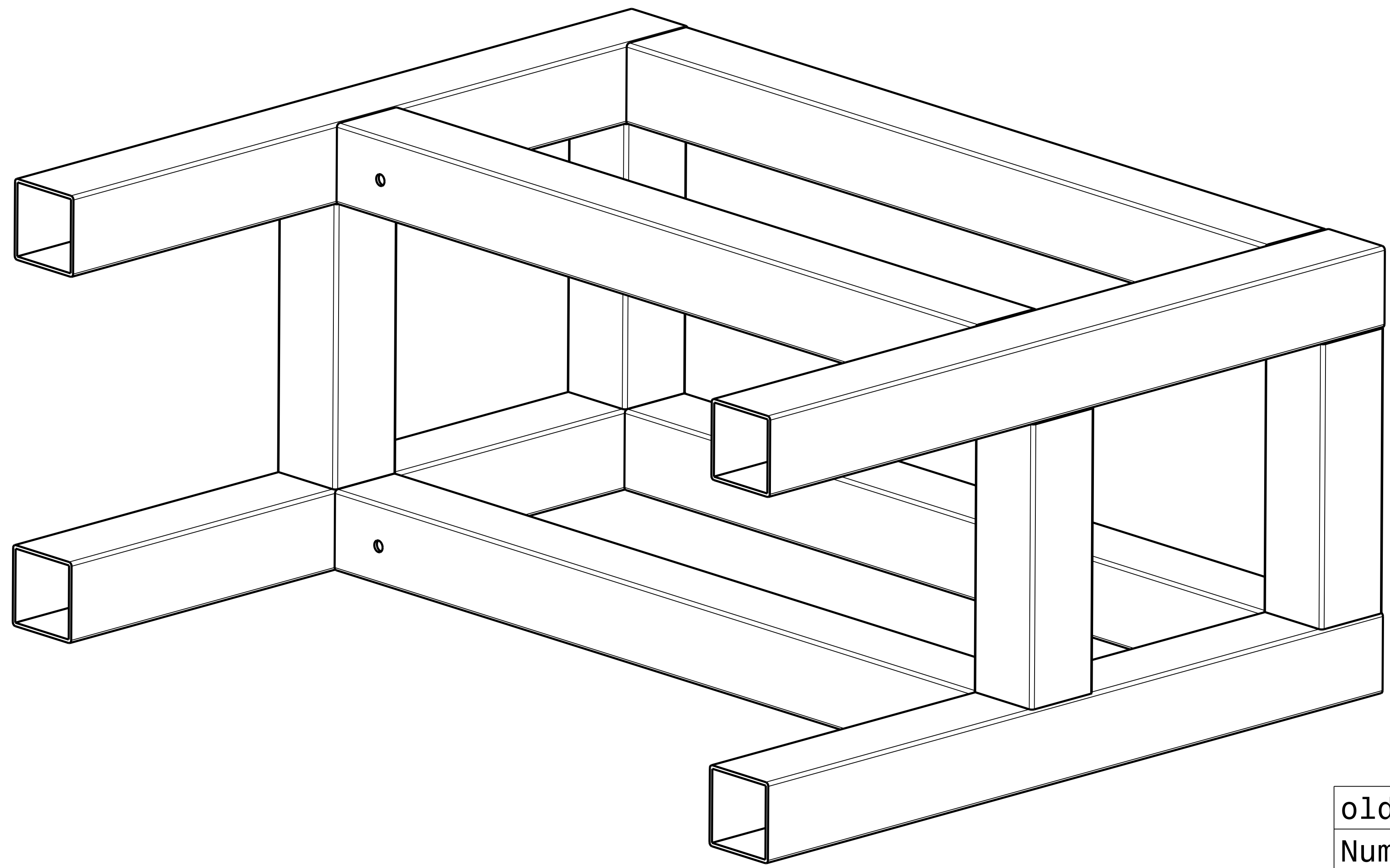

Isometric view
Scale: 1:5

old model extension asembly		
Number	Name	Quantity
1	main member	4
2	horizontal connector	4
3	vertical connector	4

		Technical university of Liberec				
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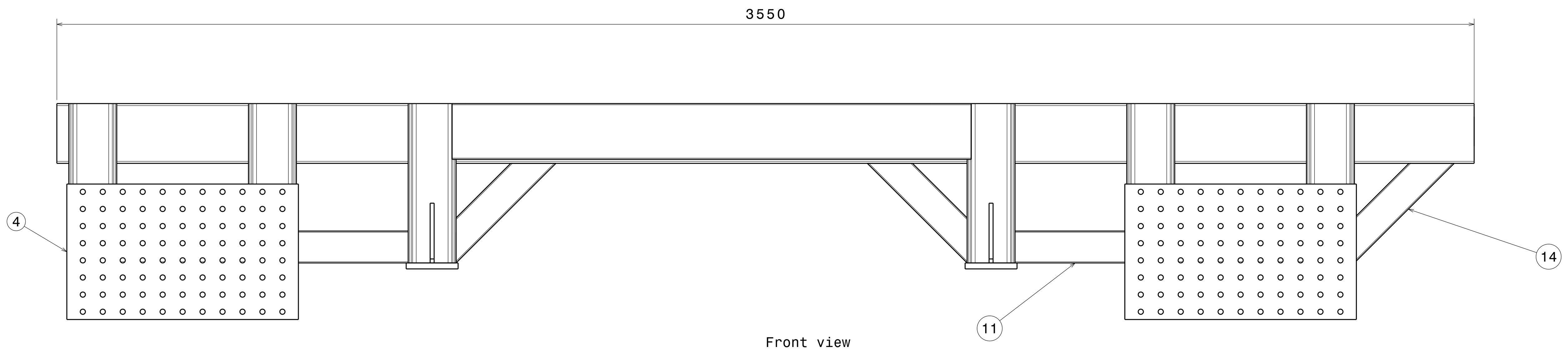
CHECKED BY Ing.Petr Zelený, PhD	DATE xxx	SIZE A2	DRAWING NUMBER 2KSAVSTA0200			REV X
DESIGNED BY SVOTT.s.r.o	DATE xxx	SCALE 1:5	WEIGHT(kg) XXX		SHEET 1/1	



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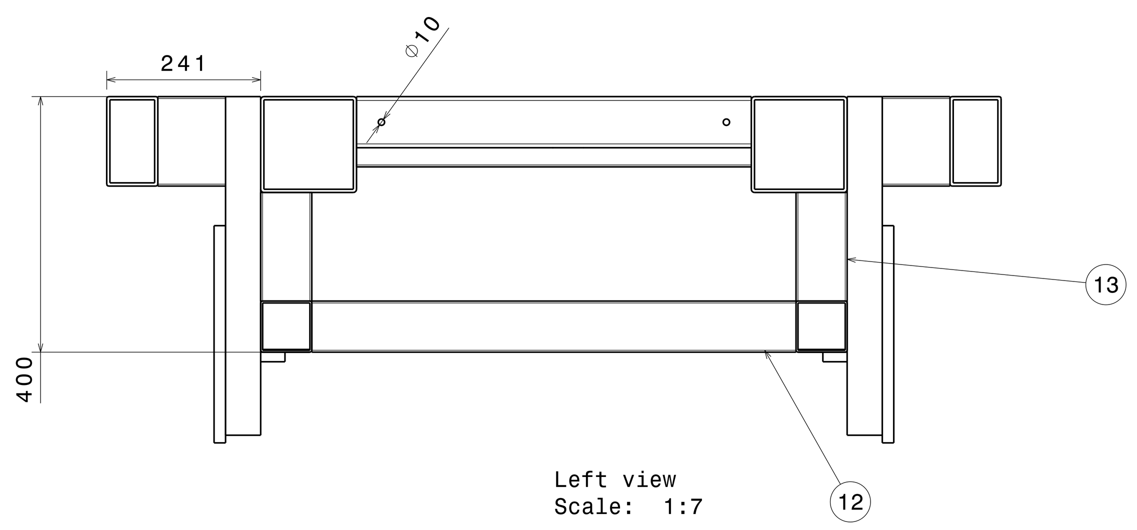

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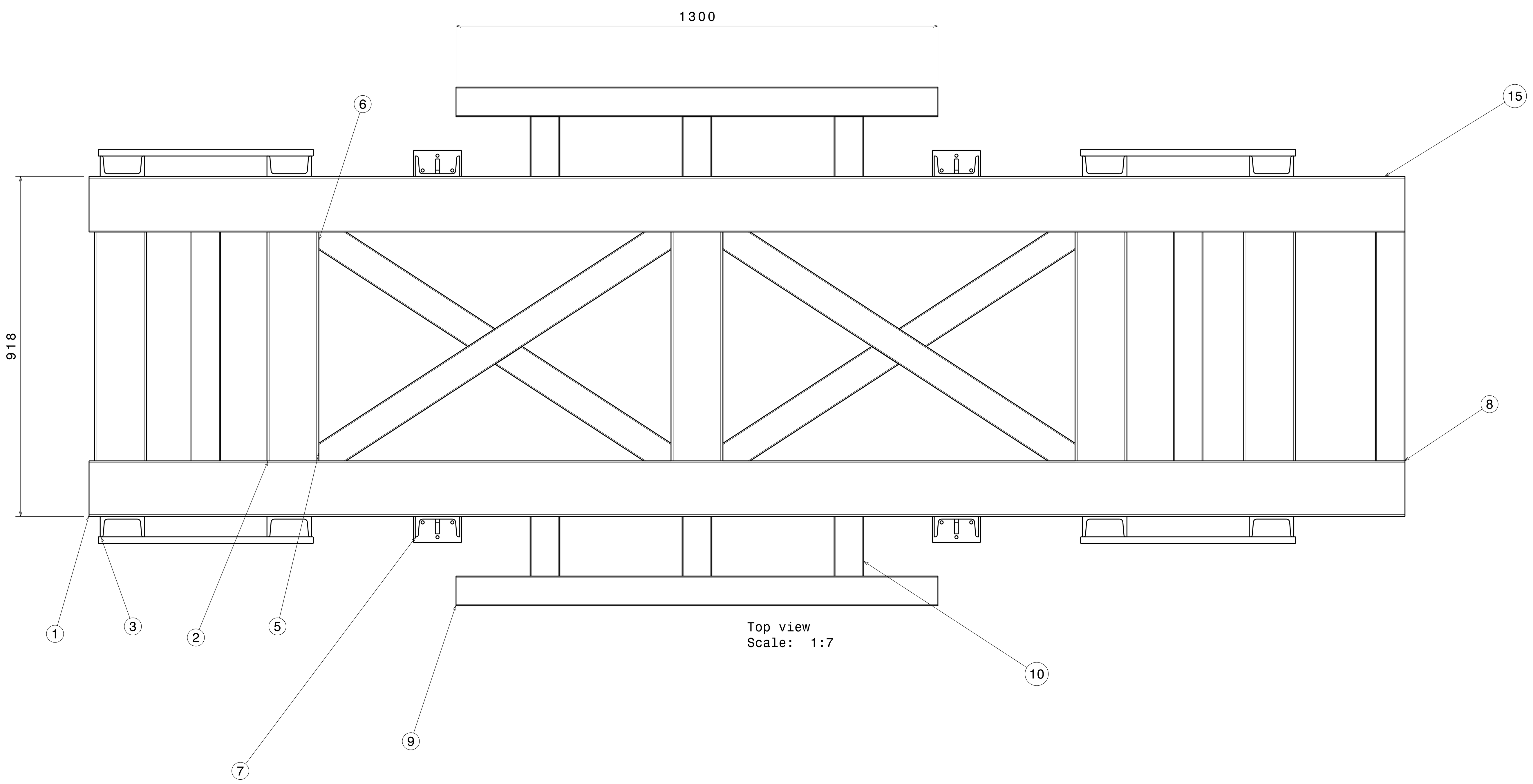

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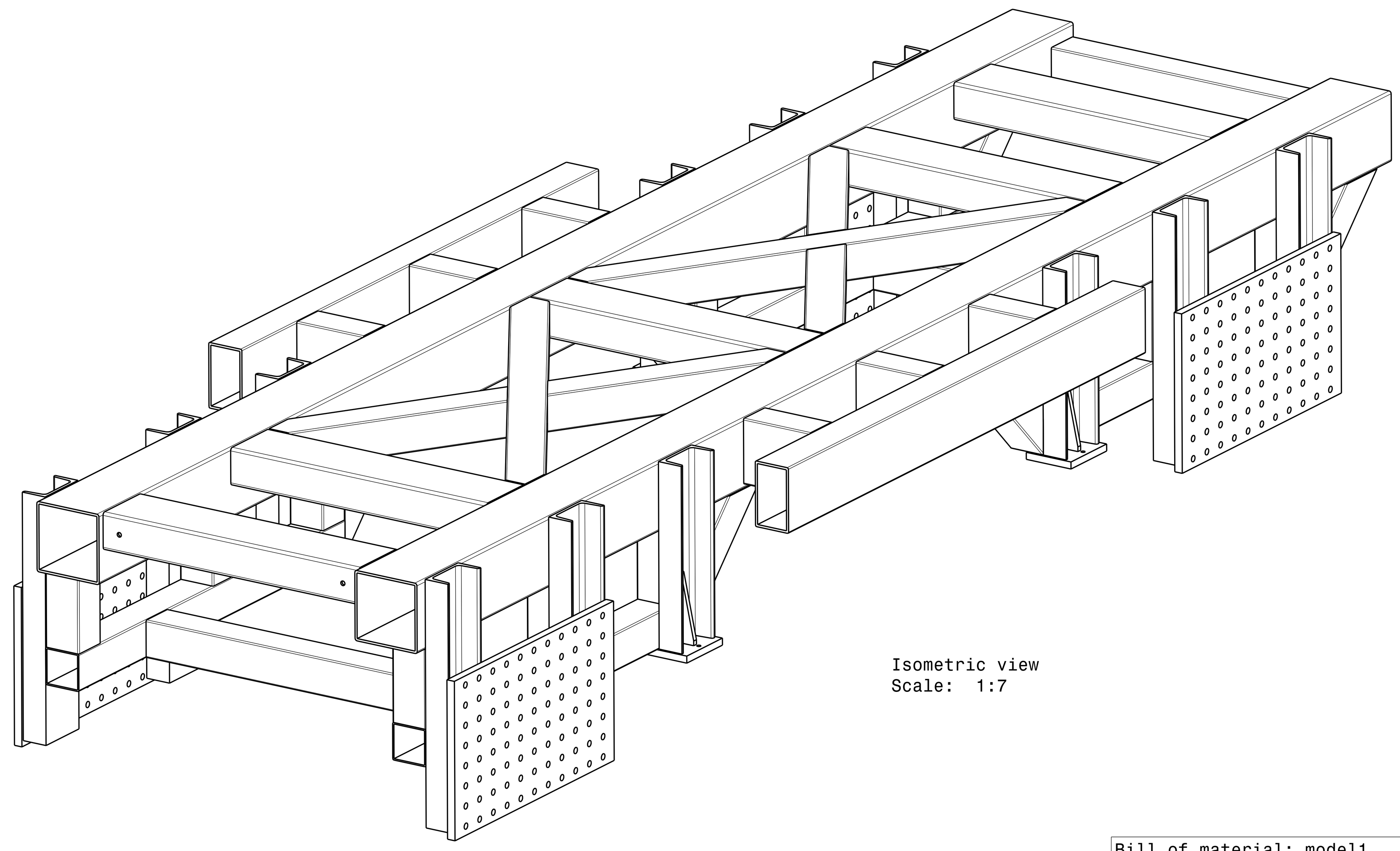

Isometric view
Scale: 1:7

Bill of material: model1

Number	Name	Quantity
1	main member	2
2	horizontal connector1	4
3	plate connector	8
4	plates	4
5	X crossmember1	2
6	X crossmember2	4
7	lifting member	4
8	horizontal connector2	1
9	side member1	2
10	side member2	6
11	support main member	4
12	support horizontal connector	2
13	straight member	12
14	slanting member	6

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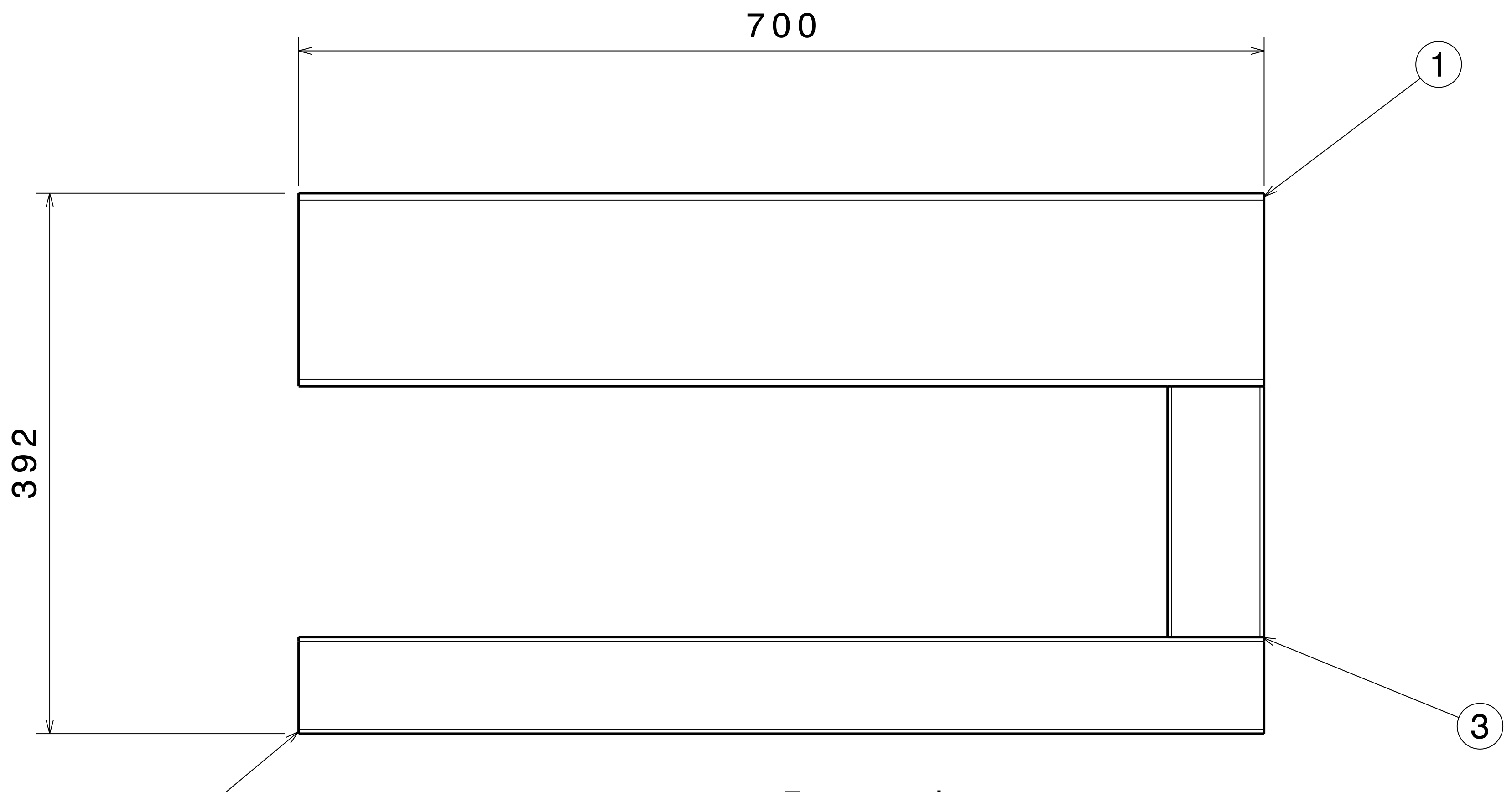
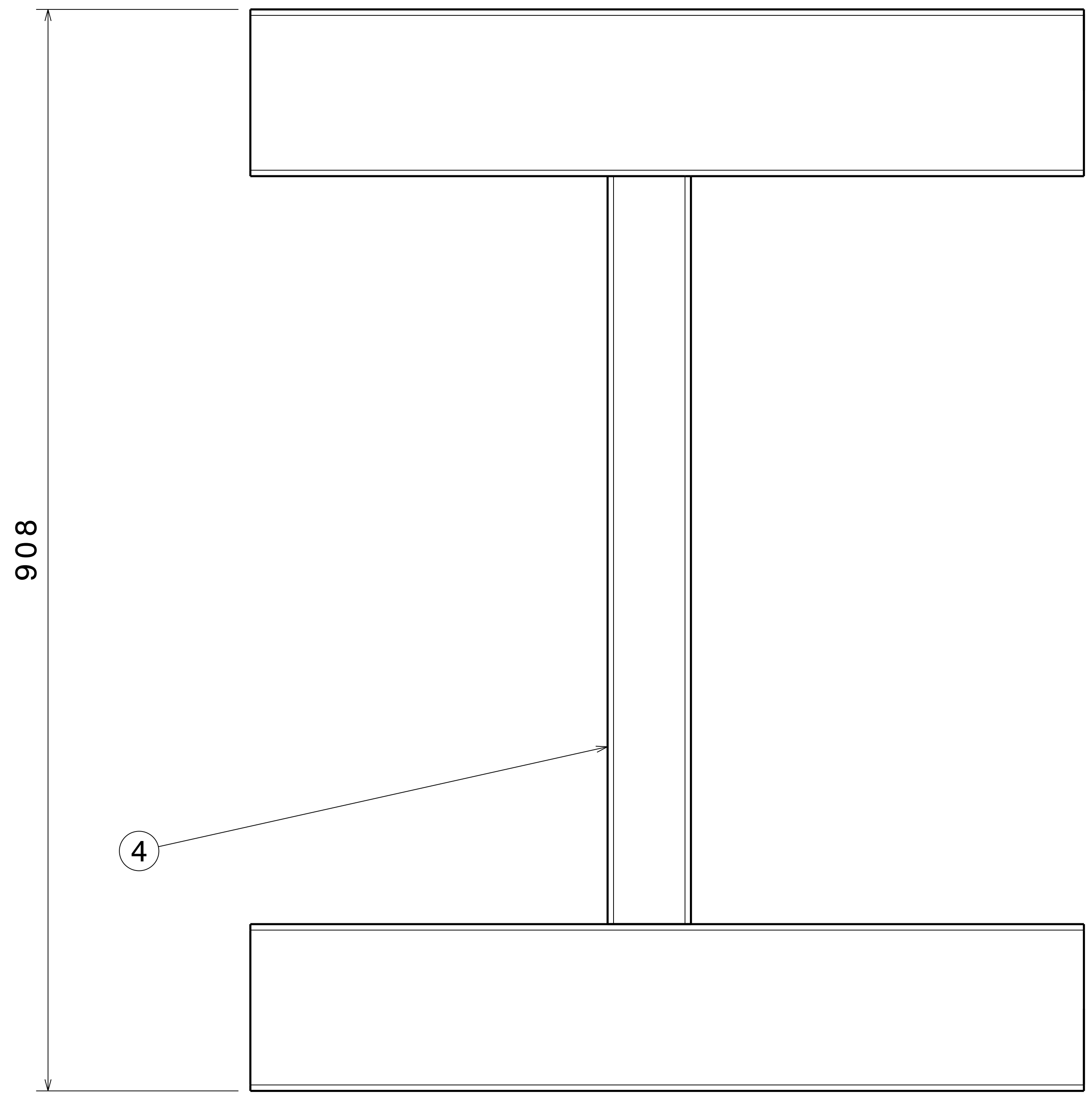


Front view
Scale: 1:5

Left view
Scale: 1:5



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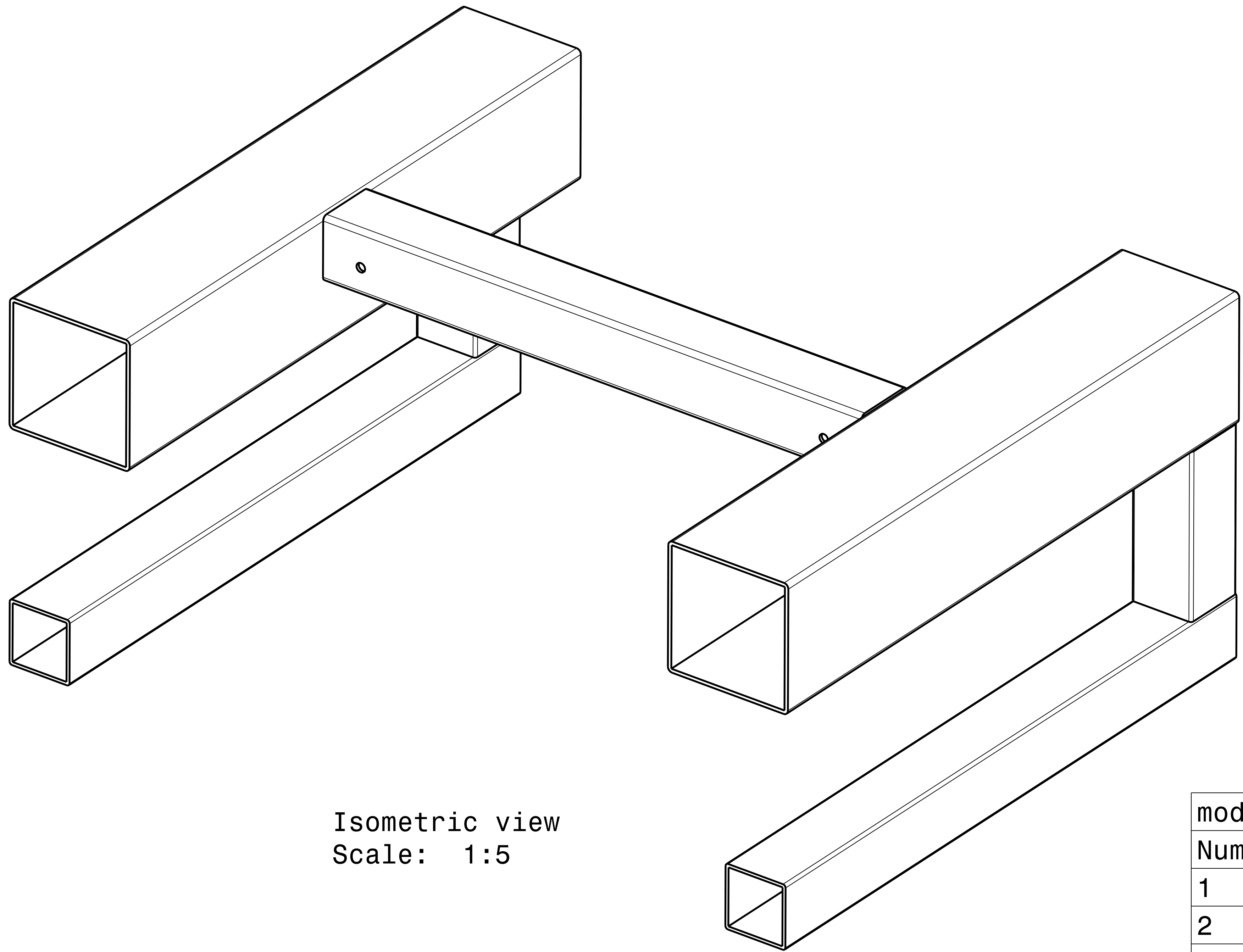

Isometric view
Scale: 1:5

model 1 Extension assembly		
Number	Name	Quantity
1	main member	2
2	horizontal support	2
3	vertical connector	2
4	horizontal connector	1

DRAWN BY: Jayaprakash Lakshmanasamy	DATE: xxx	Technical University of Liberec			
CHECKED BY: Ing.Petr Zelený, PhD	DATE: xxx	DRAWING TITLE: Model 1 Extension			
DESIGNED BY: Jayaprakash Lakshmanasamy	DATE: xxx	SIZE: A2	DRAWING NUMBER: 2KSAVSTA0400		REV: X
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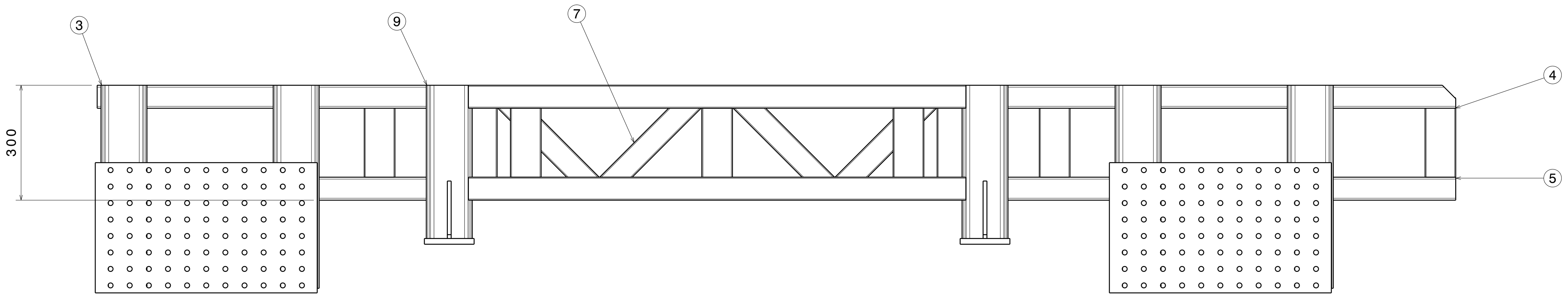

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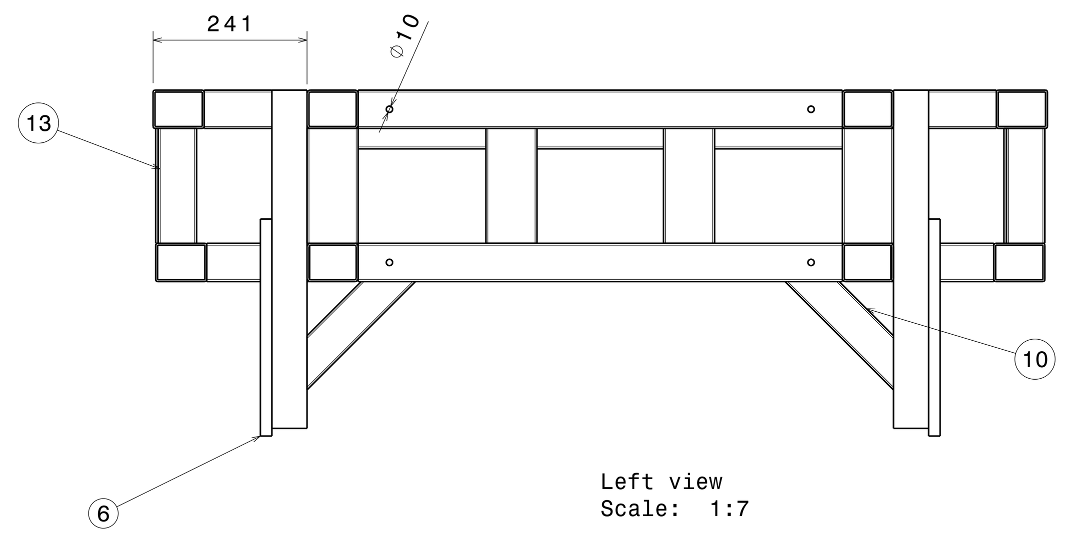

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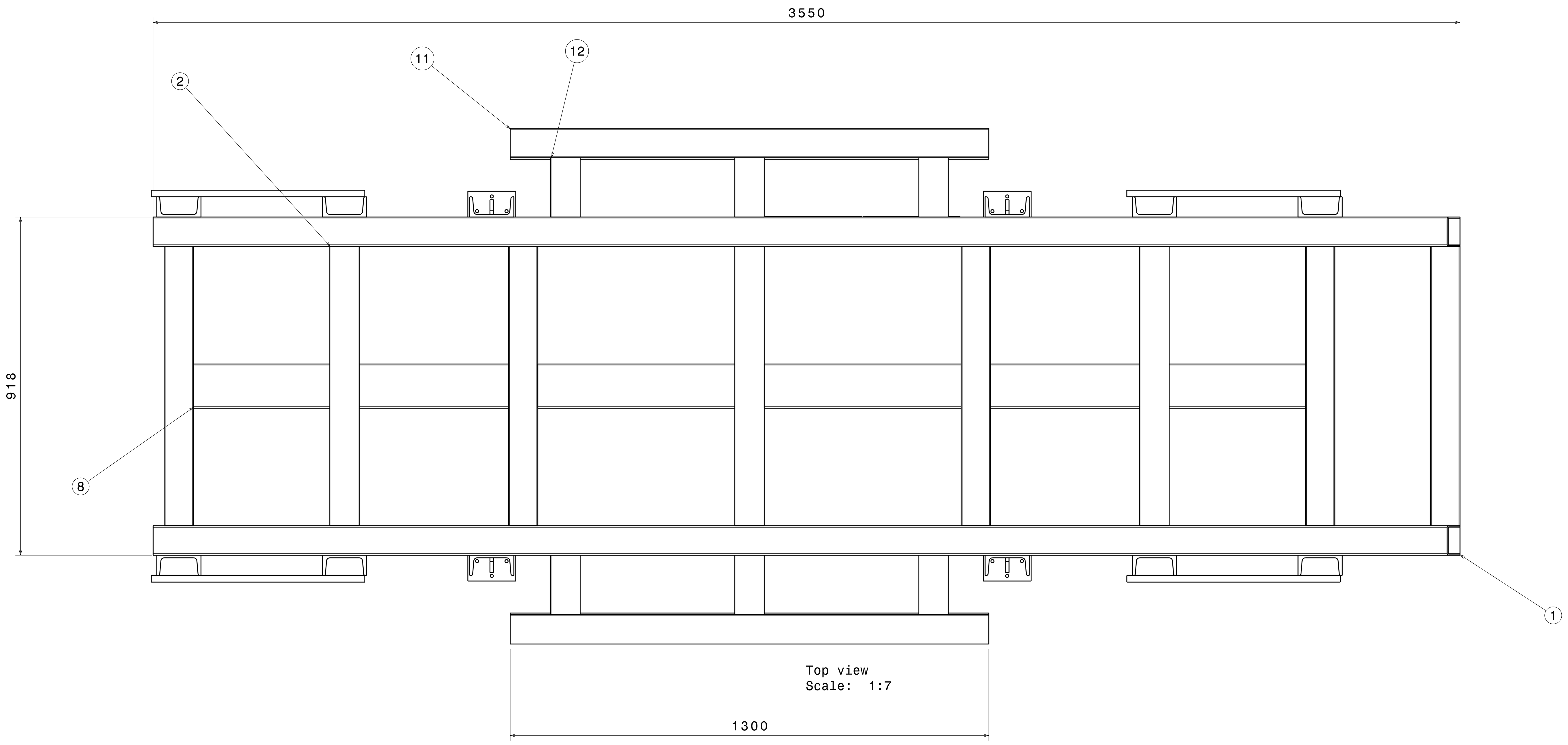

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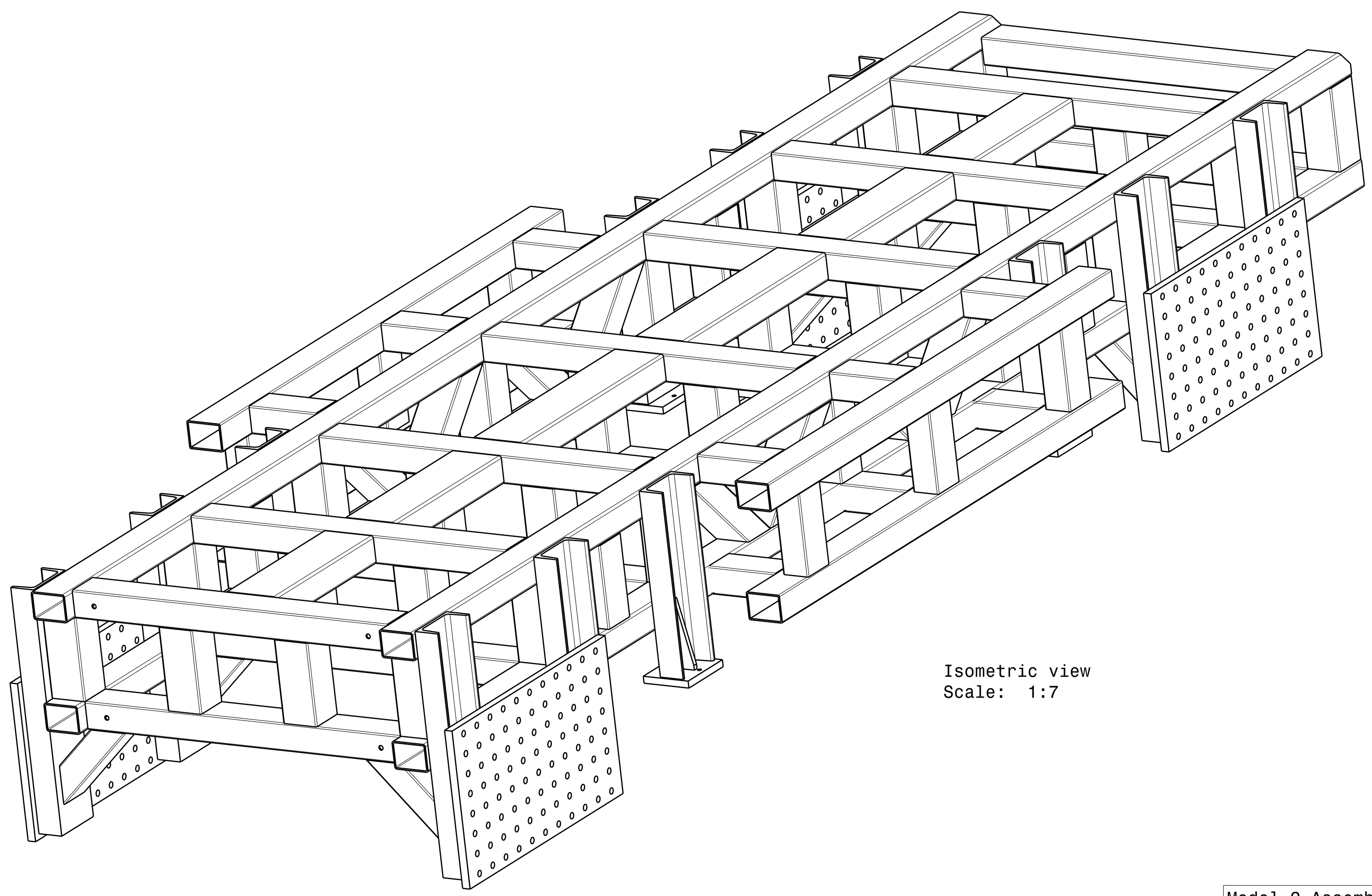

Isometric view
Scale: 1:7

Model 2 Assembly		
Number	Name	Quantity
1	main member	2
2	main connector	16
3	plate connector	8
4	straight member	34
5	main member2	2
6	plates	4
7	slanting member	8
8	backbone member	6
9	lifting member	4
10	support member	8
11	side member1	4
12	side member2	12
13	side member3	6

DRAWN BY: Jayaprakash Lakshmanasamy	DATE: xxx	Technical University of Liberec	
CHECKED BY: Ing.Petr Zelený, PhD	DATE: xxx	DRAWING TITLE: Model 1	
DESIGNED BY: Jayaprakash Lakshmanasamy	DATE: xxx	SIZE: A0	DRAWING NUMBER: OKSAVSTA0500 · REV: X
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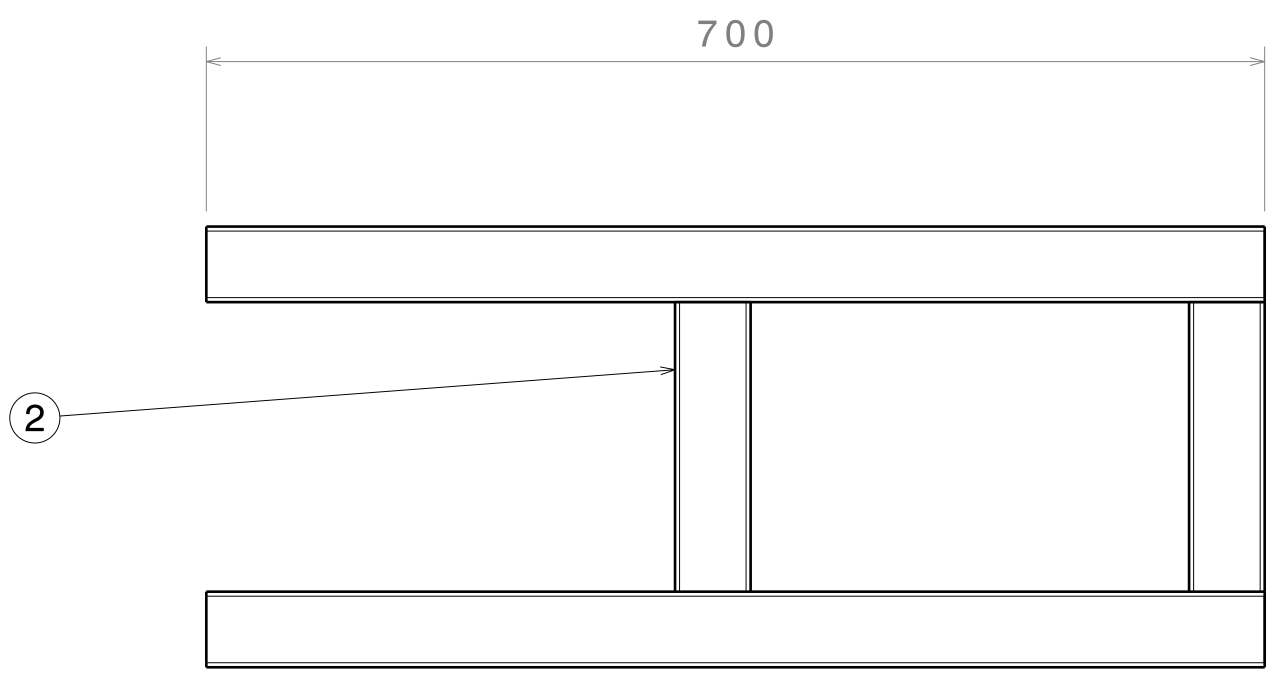

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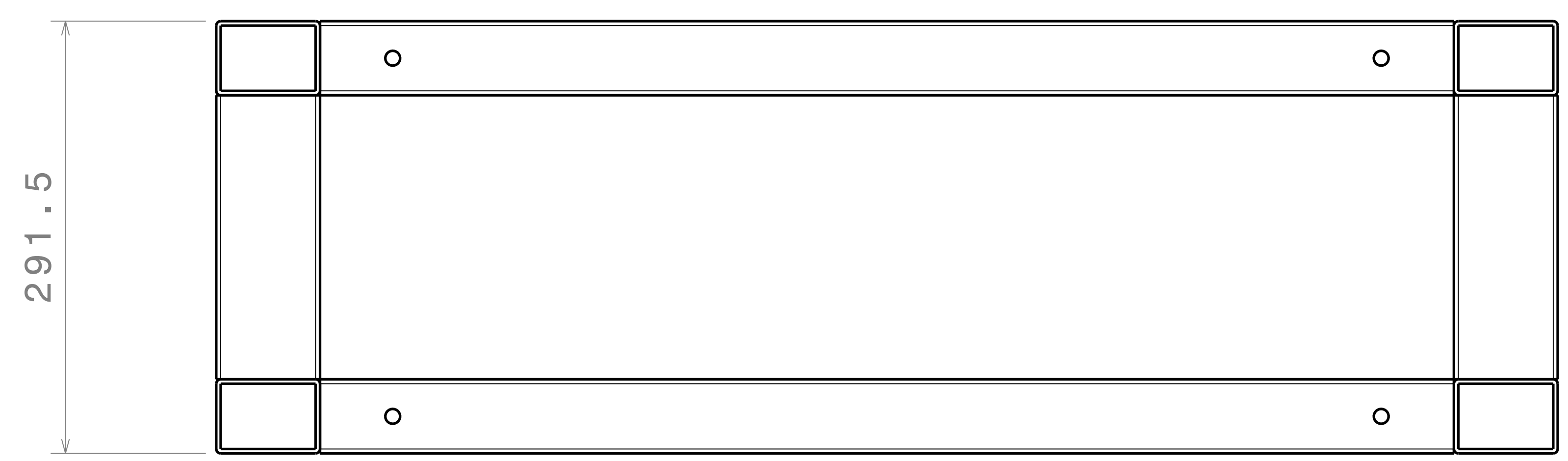

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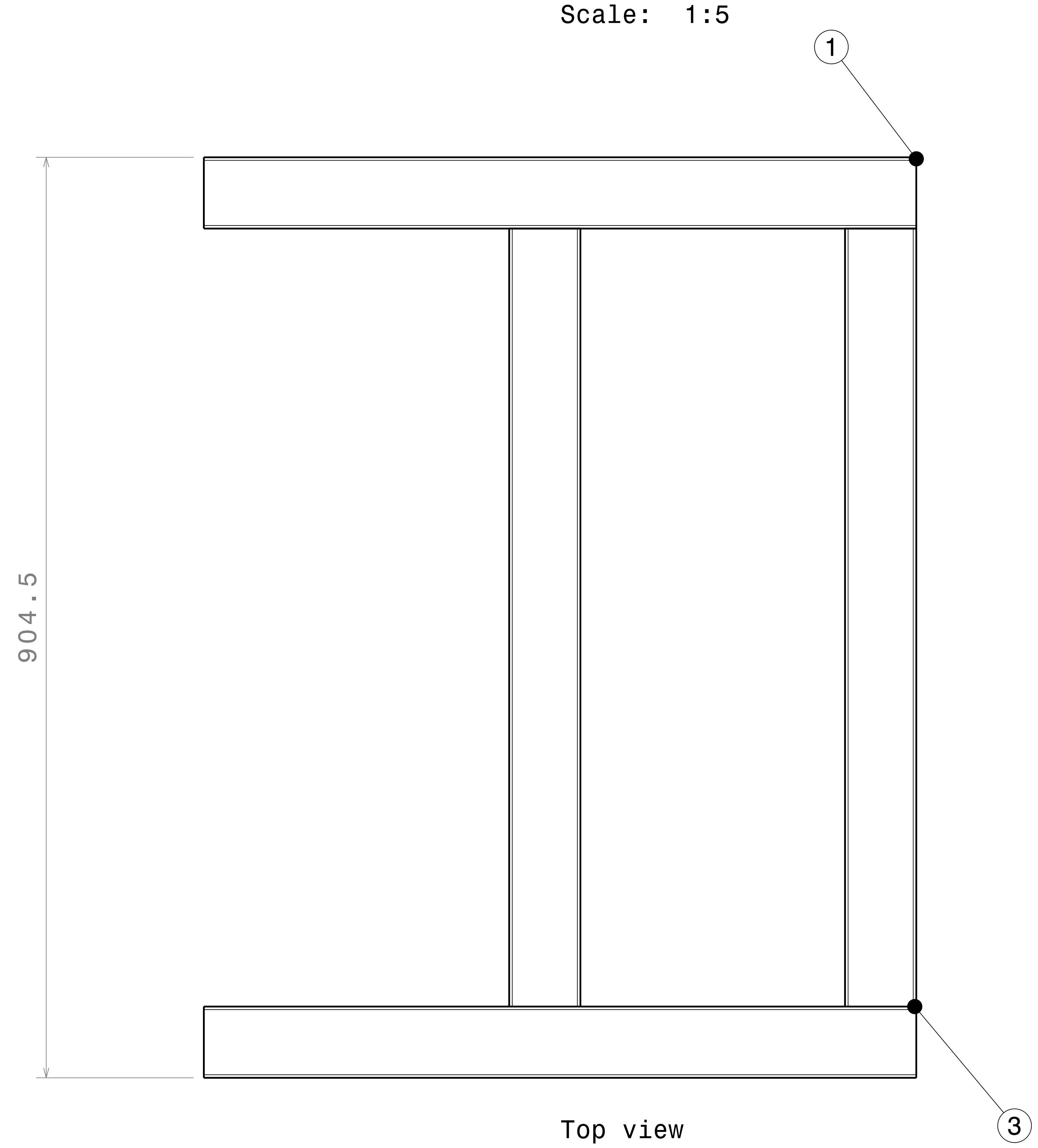

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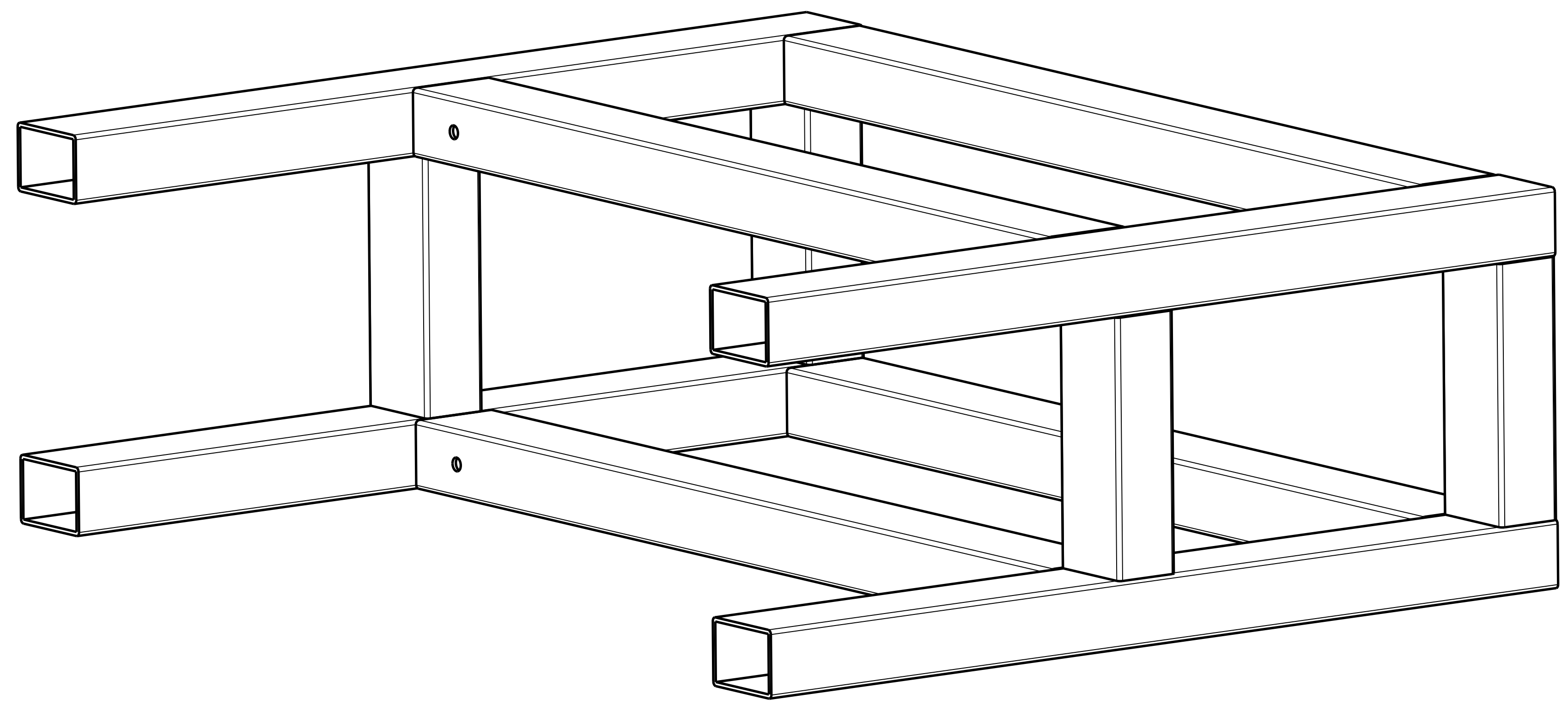

Isometric view
Scale: 1:5

Model 2 Extension Assembly		
Number	Name	Quantity
1	main member	4
2	vertical connector	4
3	horizontal connector	4

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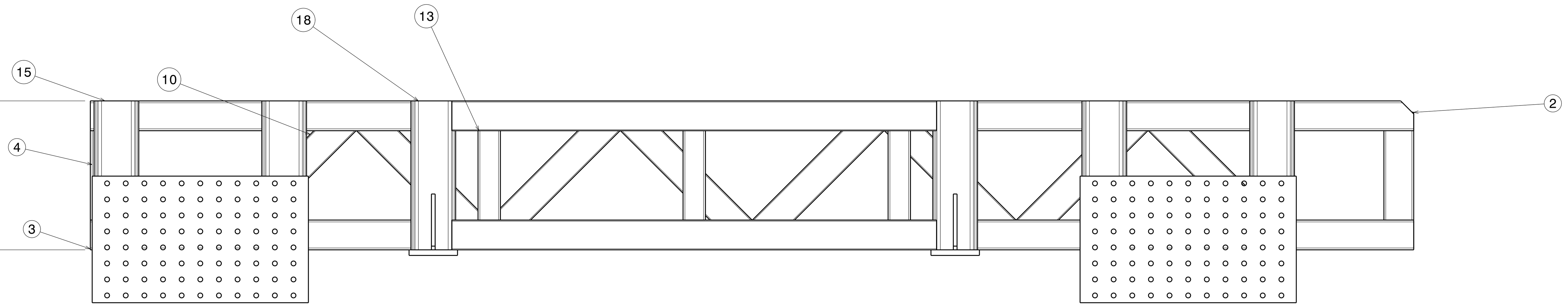

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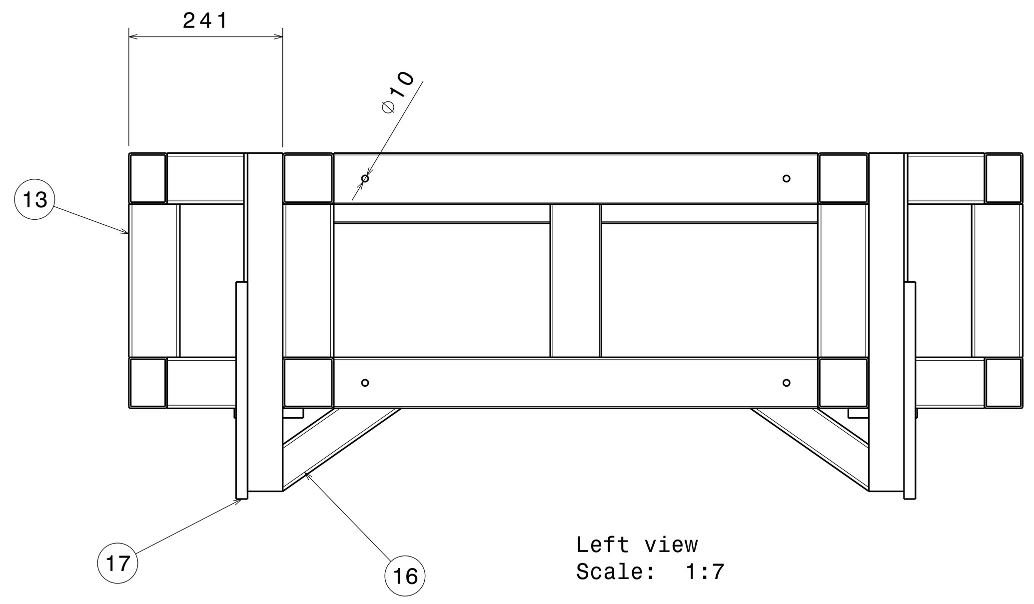

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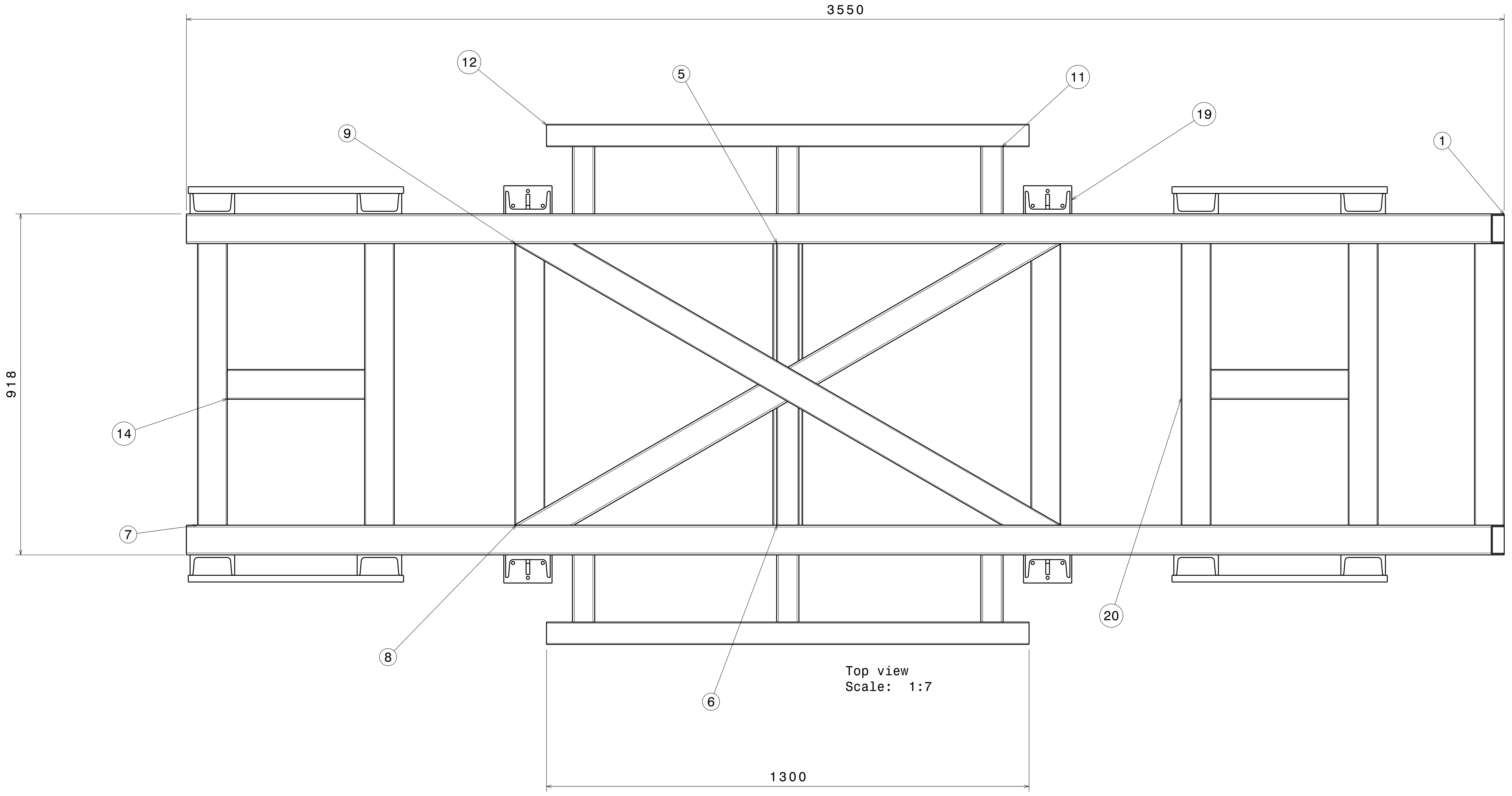
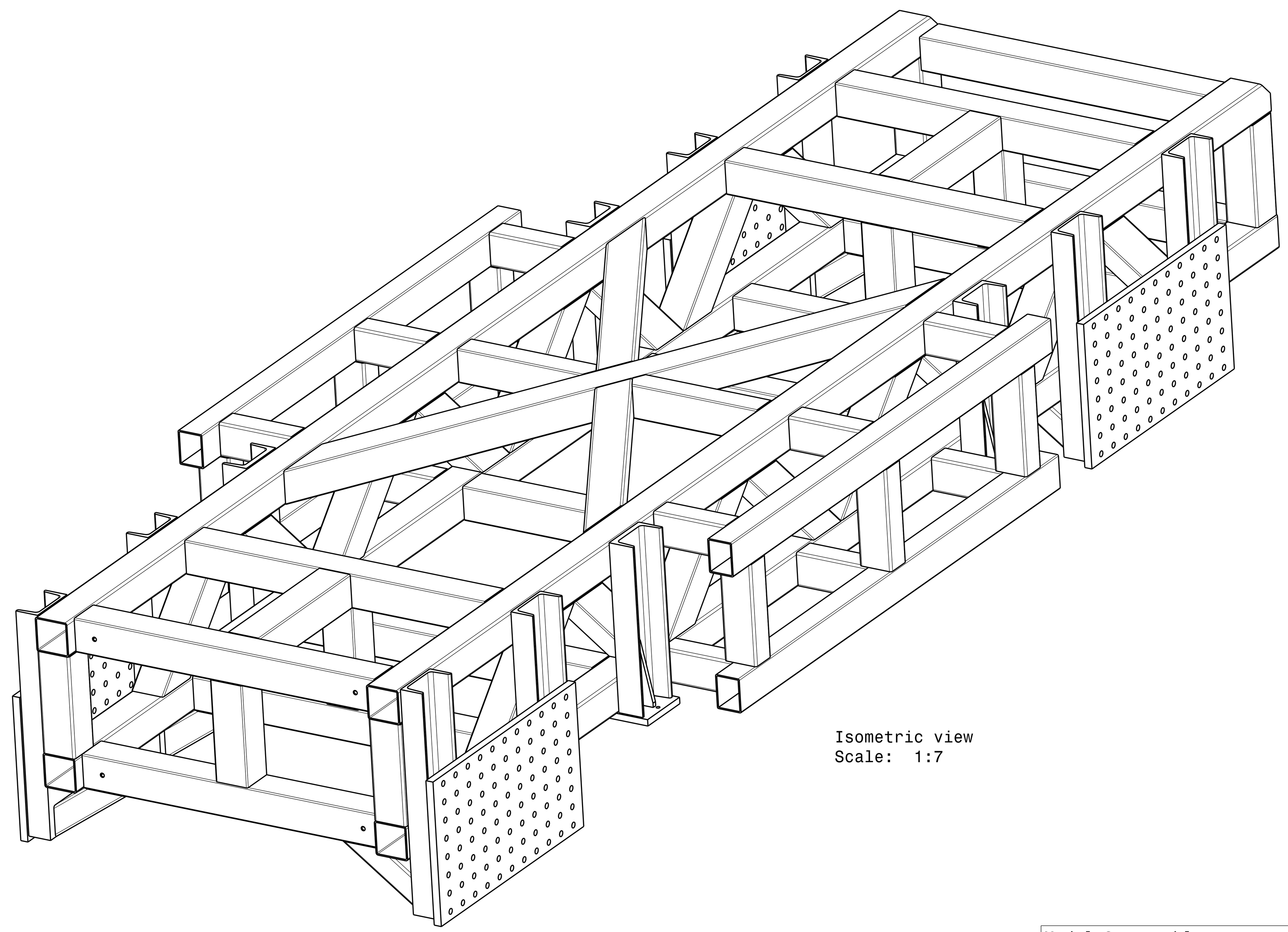


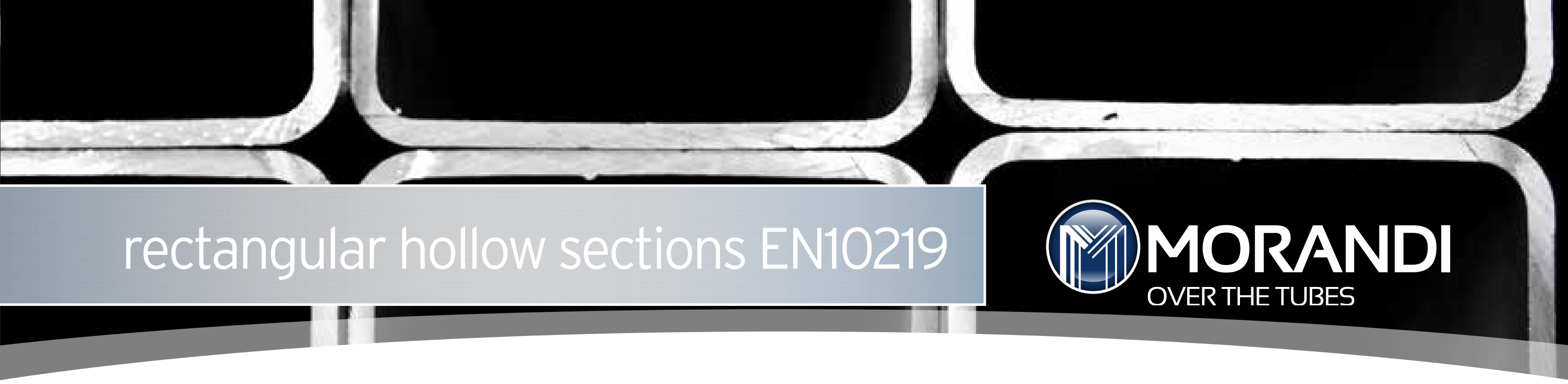
Top view
Scale: 1:7



Isometric view
Scale: 1:7

Model 3 assembly		
Number	Name	Quantity
1	main member1	2
2	horizontal connector1	13
3	main member2	2
4	straight member	8
5	X stiffner	2
6	X crossmember1	2
7	Xcross member	1
8	slanting member	16
9	side member1	12
10	side member2	4
11	side member3	6
12	horizontal connector2	2
13	plate connector-C	8
14	C-support	8
15	plate	4
16	lifting member	4
17	lifting stiffner	4

DRAWN BY Jayaprakash Lakshmanasamy	DATE xxx	Technical University of Liberec			
CHECKED BY Ing.Petr Zelený, PhD	DATE xxx	DRAWING TITLE Model 3			
DESIGNED BY Jayaprakash Lakshmanasamy	DATE XXX	SIZE A0	DRAWING NUMBER 0KSAVSTA0700		REV X
		SCALE 1:7	WEIGHT(kg) XXX		SHEET 1/1



rectangular hollow sections EN10219

MORANDI
OVER THE TUBES

DIMENSION (mm)		THICKNESS (mm)										
		3,00	4,00	5,00	6,00	6,30	8,00	10,00	12,50	14,20	16,00	20,00
60	30	3,77	4,83	-	-	-	-	-	-	-	-	-
60	40	4,25	5,45	6,56	7,56	7,57	-	-	-	-	-	-
70	40	4,72	6,08	7,34	8,50	8,56	-	-	-	-	-	-
70	50	5,19	6,71	8,13	9,45	9,55	-	-	-	-	-	-
80	40	5,19	6,71	8,13	9,45	9,55	-	-	-	-	-	-
80	50	5,66	7,34	8,91	10,39	10,54	-	-	-	-	-	-
80	60	6,13	7,97	9,70	11,33	11,53	-	-	-	-	-	-
90	50	6,13	7,97	9,70	11,33	11,53	-	-	-	-	-	-
100	40	6,13	7,97	9,70	11,33	11,53	-	-	-	-	-	-
100	50	6,60	8,59	10,48	12,27	12,52	-	-	-	-	-	-
100	60	7,07	9,22	11,27	13,21	13,51	16,36	-	-	-	-	-
100	80	8,01	10,48	12,84	15,10	15,49	18,87	-	-	-	-	-
120	40	7,07	9,22	11,27	13,21	13,51	-	-	-	-	-	-
120	50	7,54	9,85	12,05	14,16	14,50	-	-	-	-	-	-
120	60	8,01	10,48	12,84	15,10	15,49	18,87	-	-	-	-	-
120	80	8,96	11,73	14,41	16,98	17,47	21,39	25,56	29,08	-	-	-
120	100	9,90	12,99	15,98	18,87	19,44	23,90	28,70	33,00	-	-	-
140	40	8,01	10,48	12,84	-	-	-	-	-	-	-	-
140	60	8,96	11,73	14,41	16,98	17,47	21,39	-	-	-	-	-
140	70	9,43	12,36	15,19	17,92	18,46	22,64	-	-	-	-	-
140	80	9,90	12,99	15,98	18,87	19,44	23,90	28,70	33,00	-	-	-
150	50	8,96	11,73	14,41	16,98	17,47	-	-	-	-	-	-
150	60	9,43	12,36	15,19	17,92	-	-	-	-	-	-	-
150	75	-	-	16,37	19,34	-	-	-	-	-	-	-
150	100	11,31	14,87	18,33	21,69	22,41	27,67	33,41	38,89	-	-	-
160	60	9,90	12,99	15,98	18,87	19,44	23,90	-	-	-	-	-
160	80	10,84	14,25	17,55	20,75	21,42	26,41	31,84	36,93	-	-	-
160	90	11,31	14,87	18,33	21,69	22,41	27,67	33,41	38,89	-	-	-
160	120	12,72	16,76	20,69	24,52	25,38	31,43	38,12	44,78	-	-	-
180	60	10,84	14,25	17,55	20,75	21,42	26,41	31,84	36,93	-	-	-
180	80	11,78	15,50	19,12	22,63	23,40	28,92	34,98	40,85	-	-	-
180	100	12,72	16,76	20,69	24,52	25,38	31,43	38,12	44,78	-	-	-
180	120	13,67	18,01	22,26	26,40	27,36	33,95	41,26	48,70	-	-	-
200	80	12,72	16,76	20,69	24,52	25,38	31,43	38,12	44,78	-	-	-
200	100	13,67	18,01	22,26	26,40	27,36	33,95	41,26	48,70	-	-	-
200	120	14,61	19,27	23,83	28,29	29,34	36,46	44,40	52,63	58,22	-	-
200	150	16,02	21,15	26,18	31,11	32,30	40,23	49,11	58,52	64,90	-	-
220	120	-	20,53	25,40	30,17	31,31	38,97	47,54	56,55	62,67	-	-
250	100	16,02	21,15	26,18	31,11	32,30	40,23	49,11	58,52	-	-	-
250	150	-	24,29	30,11	35,82	37,25	46,51	56,96	68,33	76,05	-	-
260	140	-	24,29	30,11	35,82	37,25	46,51	56,96	68,33	76,05	-	-
260	180	-	26,81	33,25	39,59	41,20	51,53	63,24	76,18	84,97	-	-
300	100	-	24,29	30,11	35,82	37,25	46,51	56,96	68,33	-	-	-
300	150	-	27,43	34,03	40,53	42,19	52,79	64,81	78,14	87,20	-	-
300	200	-	30,57	37,96	45,24	47,14	59,07	72,66	87,95	98,34	-	-
350	150	-	-	37,96	45,24	47,14	59,07	72,66	87,95	98,34	-	-
350	250	-	-	-	54,66	57,03	71,63	88,36	107,58	120,64	134,06	-
400	200	-	-	45,81	54,66	57,03	71,63	88,36	107,58	120,64	-	-
400	250	-	-	49,73	59,37	61,98	77,91	-	-	-	-	-
400	300	-	-	-	64,08	66,92	84,19	104,06	127,20	142,93	159,18	-
450	250	-	-	-	64,08	66,92	84,19	104,06	127,20	142,93	159,18	-
500	200	-	-	-	64,08	66,92	84,19	104,06	127,20	142,93	-	-
500	300	-	-	-	-	-	96,75	119,76	146,83	165,23	184,30	225,00

square hollow sections EN10219

DIMENSION (mm)		THICKNESS (mm)										
		3,00	4,00	5,00	6,00	6,30	8,00	10,00	12,50	14,20	16,00	20,00
30	30	2,36	2,94	-	-	-	-	-	-	-	-	-
35	35	2,83	3,57	-	-	-	-	-	-	-	-	-
40	40	3,30	4,20	4,99	-	-	-	-	-	-	-	-
45	45	3,77	4,83	5,77	-	-	-	-	-	-	-	-
50	50	4,25	5,45	6,56	-	-	-	-	-	-	-	-
60	60	5,19	6,71	8,13	9,45	9,55	-	-	-	-	-	-
70	70	6,13	7,97	9,70	11,33	11,53	-	-	-	-	-	-
80	80	7,07	9,22	11,27	13,21	13,51	16,36	-	-	-	-	-
90	90	8,01	10,48	12,84	15,10	15,49	18,87	-	-	-	-	-
100	100	8,96	11,73	14,41	16,98	17,47	21,39	25,56	29,08	-	-	-
110	110	9,90	12,99	15,98	18,87	19,44	23,90	28,70	33,00	-	-	-
120	120	10,84	14,25	17,55	20,75	21,42	26,41	31,84	36,93	-	-	-
130	130	11,78	15,50	19,12	22,63	23,40	28,92	34,98	40,85	-	-	-
140	140	12,72	16,76	20,69	24,52	25,38	31,43	38,12	44,78	-	-	-
150	150	13,67	18,01	22,26	26,40	27,36	33,95	41,26	48,70	-	-	-
160	160	14,61	19,27	23,83	28,29	29,34	36,46	44,40	52,63	-	-	-
175	175	16,02	21,15	26,18	31,11	32,30	40,23	49,11	58,52	-	-	-
180	180	16,49	21,78	26,97	32,05	33,29	41,48	50,68	60,48	-	-	-
200	200	-	24,29	30,11	35,82	37,25	46,51	56,96	68,33	76,05	-	-
220	220	-	26,81	33,25	39,59	41,20	51,53	63,24	76,18	84,97	-	-
250	250	-	30,57	37,96	45,24	47,14	59,07	72,66	87,95	98,34	108,94	-
260	260	-	31,83	39,53	47,13	49,12	61,58	75,80	91,88	102,80	113,96	-
300	300	-	-	45,81	54,66	57,03	71,63	88,36	107,58	120,64	134,06	162,00
350	350	-	-	-	64,08	66,92	84,19	104,06	127,20	142,93	159,18	194,00
400	400	-	-	-	73,50	76,81	96,75	119,76	146,83	165,23	184,30	225,00
500	500	-	-	-	-	-	121,87	151,16	186,08	209,81	234,54	288,00