

BRICO 2020

THE NORDIC STEEL BRIDGE COMPETITION

RULES AND REGULATIONS

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1. MISSION AND PHILOSOPHY

Our mission is to create an opportunity for students from all over the world to come together and compare each other's engineering knowledge and skills in a competitive yet friendly atmosphere. We hope to contribute to a diverse engineering education. This competition gives students a chance to design and produce their own steel bridge, which has to meet certain criteria (see chapter 3). In search of the most efficient design under the given criteria, students have to be innovative and put the knowledge obtained in school into practical use.

We want to encourage all the participants to be innovative and think outside of the box when tackling engineering problems presented to them. When reading through the rules and regulations, at first it might seem that everything is highly regulated but there still are a lot of possibilities that exist inside this set of restrictions. It is tricky...yet interesting. Be clever and open-minded when creating your design, what isn't forbidden is (probably) allowed. Often this kind of approach could lead to a design or assembly strategy, which is borderline non-compliant with the rules and takes advantage of some gray areas in the rules.

Our philosophy in dealing with this kind of situations is to rather favor the clever idea instead of punishing the team for exploiting the gray areas in the rules. Of course everything depends on the exact context and organisers keep the right to judge each case separately, but the general mindset of organisers is favorable towards out of box thinking. This is the way of thinking we want all the participants to adapt as well. After all we are here to learn from each other, share experiences and establish new international contacts.

2. GENERAL

2.1. Organizer

BRICO 2020 is organized by the nonprofit organization BRICO MTÜ formed by engineering students from Tallinn University of Technology.

2.2. Rules

- 1) The Participants of the competition have to follow this document (which contains the Rules and Regulations of the Competition) from the moment of sending an application form till the end of the Competition.
- 2) The Rules of the Competition are posted on the official competition website www.brico.ee.
- 3) The Organizer has a right to make minor changes in the Rules and Regulations in the future if problems/issues concerning the Rules and Regulations appear.

2.3. Date, place and participation fee

- 1) BRICO 2020 will be held on 11-15 May 2020 on the campus territory of Tallinn University of Technology. This includes competition days (13 and 14 May) and social activities.
- 2) Detailed schedule will be sent via e-mail before the competition.
- 3) Participation fee for BRICO 2020 is 250 € per team.

2.4. Participants

- 1) The Participants of the Contest are all students and have to be declared as such in the application form.
- 2) Only students studying on the Bachelor's or Master's level are allowed to attend the competition.
- 3) A Participant can only be involved in one team.

2.5. Team

- 1) Teams consist of 4 university students.
- 2) Teams can have a supervisor.
- 3) Teams have to choose a captain among the 4 members.

3.PROBLEM STATEMENT

3.1. Restrictions

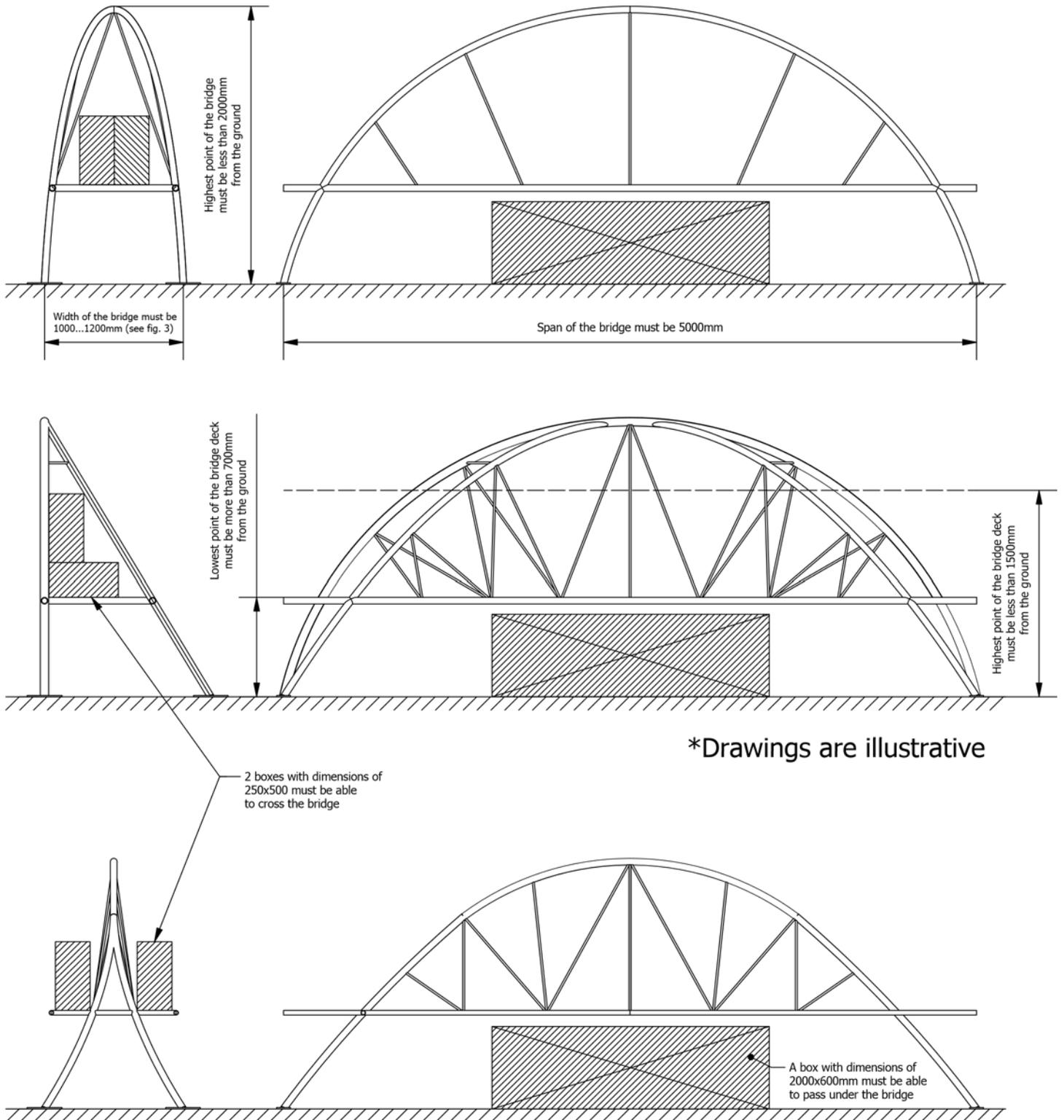
3.1.1. General Restrictions

- 1) The bridge consists of construction elements (hereafter „elements“).
- 2) The number of elements is unlimited.
- 3) All elements have to be made of steel S355 or lower.
- 4) Teams have to send a certificate to organizers 2 weeks before the competition (27.04.2020) to prove that steel used in their bridge is S355 or lower.
- 5) All elements must be stable after the assembly phase.

3.1.2. Restrictions on the geometry of the bridge

- 1) The span of the bridge must be 5000 mm +/-50 mm construction tolerance but teams have to design for span=5000mm. Span is measured as shown in figure 1 and figure 3.
- 2) The distance between steel plates (perpendicular to the axis of the bridge) must be in the range 1000...1200 mm (see figure 1 and figure 3) measured from the center of both plates.
- 3) The highest point of the bridge can be max 2000 mm from the ground (see figure 1).
- 4) A 2000x600 mm box must be able to pass under the bridge (see figure 1).
- 5) Two boxes with dimensions of 250x500 must be able to cross the bridge (see figure 1).
- 6) The deck of the bridge must be horizontal.
- 7) The highest point of the deck has to be less than 1500 mm from the ground.
- 8) The lowest point of the deck has to be higher than 700 mm from the ground.
- 9) Bridge has to be designed so it is possible to perform loading procedure as explained in paragraph 3.2.
- 10) In case of any violations of these restrictions (1-8), penalty 1 (7 +0.1*x points, x=violation in mm) will apply for each violation.

FIGURE 1 – Restrictions on the geometry of the bridge



3.1.3. Restrictions on binding members and single elements

- 1) Elements have to be joined by bolts and nuts from M6 to M16 (grade 8.8).
- 2) Joints between elements must be connected with at least 1 bolt and nut.
- 3) Bolted joints have to be tightened up by hand or by using a mechanical wrench (teams shall have their own set of wrenches).
- 4) Bolts can be integral parts of the element (e.g. can be welded).
- 5) Holes in elements can be threaded.
- 6) The use of washers is allowed.
- 7) Each element of the bridge must fit into a box with the dimensions of 1200x250x250 mm.
- 8) The maximum weight of a single element is 7 kg.
- 9) In case of violation of (7) or (8), penalty $2 (2 + 0.2 * x)$ points, $x = \text{violation in mm}$ or just $2p$ in case of violating (8)) applies for each violating element.
- 10) Flexible tension members such as cables or chains and post tensioning members are not allowed.
- 11) Elements cannot be pre-stressed, meaning that no initial internal force can be introduced.
- 12) Any load carrying members of the bridge which contain moving pieces, hinges or springs are forbidden.
- 13) In case of violation of (10), (11) or (12), the bridge is only eligible for the display award.
- 14) Each leg of the bridge has to have a legplate with outer dimensions of 250x100x8 mm welded to it. Each plate must contain two holes (diameter of 18 mm). The position of the holes is shown in figure 2. The plates have to be perpendicular to the axis of the bridge.
- 15) At midpoint of the span of the bridge there must be a hook or loop made of steel and welded to the bridge. Teams can choose the side for hook/loop. This is used to apply horizontal loading.

FIGURE 2 – Steel plate

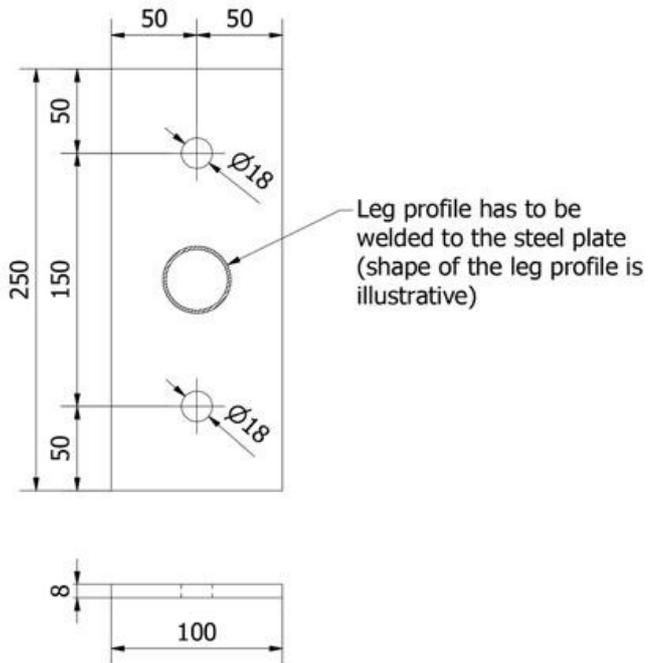
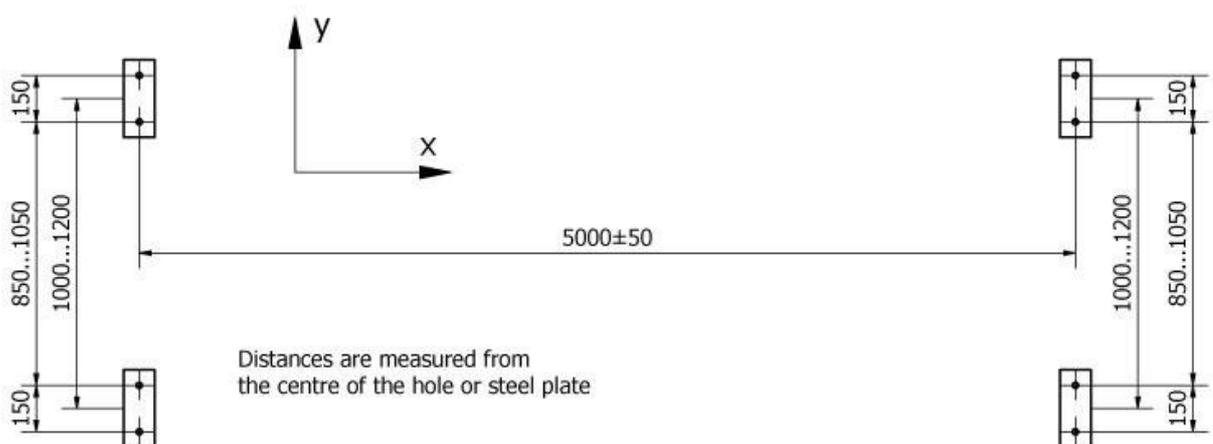


FIGURE 3 – Position of plates



3.1.4. Restrictions on the construction process

3.1.4.1. Before the construction starts

- 1) All binding members (bolts and nuts), tools and hard hats have to be placed in area A (see figure 4) and must fit entirely within the assigned area. Teams are allowed to group bolts, wrenches and hard hats in area A as they wish. Bolts and nuts can be in cups.
- 2) All the elements of the bridge have to be in area B (see figure 4), not touch each other and must fit entirely within the assigned area.
- 3) All members of the team have to stand in area C.

3.1.4.2. During construction

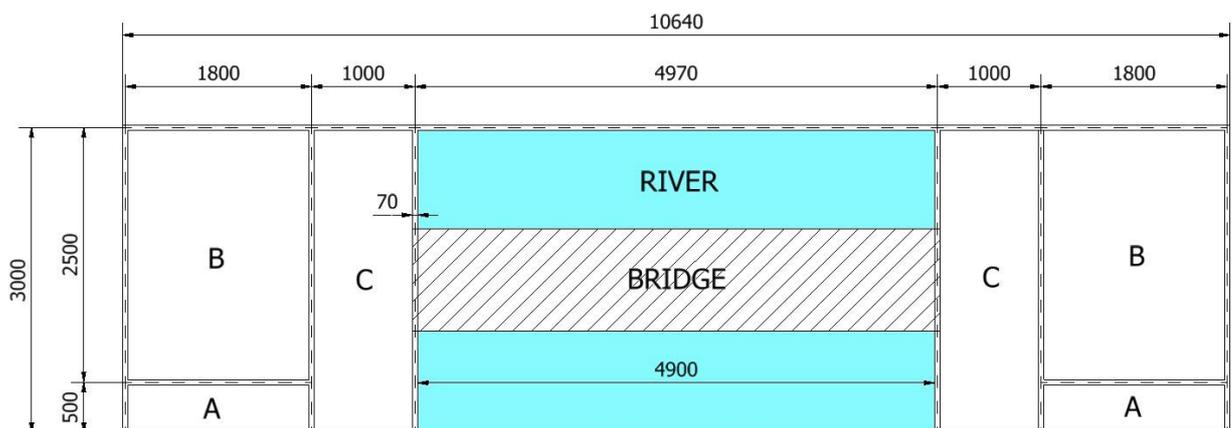
- 1) It is allowed to put together assembled parts and fix them with bolts in area B.
- 2) Assembled parts can consist of 3 elements at most.
- 3) Assembled parts must fit entirely into combined area of A and B during the assembly (use of airspace strictly above area A and B is allowed). Assembled part can only touch ground inside area A or B. Use of temporary supports in area A or B is allowed.
- 4) It is allowed to support the bridge or a single element and tighten the bolts at the same time.
- 5) Teams are allowed to use temporary supports during the construction process. Temporary supports must fit into a box with the dimensions of 1500x250x250 mm. Temporary supports can be made of wood or steel.
- 6) Temporary support members should not collapse. If that happens penalty 3 applies (1 point).
- 7) Two members of the team are „barges“. This means they are only allowed to work in the river area. The moment a barge steps in the river area, he/she is not allowed to step outside the river borders until the end of construction.
- 8) Barges are not allowed to jump over or pass under the bridge in order to cross to the other side after full span of bridge has been connected.
- 9) The other two members can only work inside areas A, B and C.
- 10) No part of the bridge can touch the river.
- 11) No tool, nut, bolt, washer or hard hat can touch the river.
- 12) If a tool, nut, bolt, washer or hard hat falls in the river, barges can pick them up.
- 13) It is forbidden to throw tools, bolts or elements.
- 14) In case of accidents, the judge will stop the time and check the issue.
- 15) If the judge notices any violations, he/she will notify the team immediately.

- 16) In case of violation of (2), (3) or (9), the judge interferes and stops the action. The situation before the violation must be restored to continue construction.
- 17) In case of violation of (5), penalty 2 ($2 + 0.2 \cdot x$ points, x =violation in mm) applies for each violating element
- 18) In case of violation of (6) or (10), penalty 3 (1 point) applies for each single case
- 19) In case of violation of (7), (8), (9) or (11), penalty 4 (0.2 points) applies for each single case
- 20) In case of violation of (13), penalty 5 (1 point) applies for each single case

3.1.4.3. After construction

- 1) All temporary supports have to be returned to area B.
- 2) There should be no tools or excess bolts/nuts left on the working site.
- 3) If a team has finished assembling the bridge, the team must notify the judge and the time will be stopped.
- 4) After the judge stops the time, teams have 3 minutes to check their bridges (they are allowed to observe but not to touch). If they find any loose bolts or some other issues, they have to notify the judge and tighten the bolt. Penalty 6 (0.2 points) applies for each loose bolt. The judge will also observe the bridge to make sure that everything is tight and secure (this includes rechecking the bolts).

FIGURE 4 – Plan of the working site



- A - Zone for bolts, tools and hard hats
- B - Assembly zone
- C - Construction zone

3.2. Loads applied during load tests

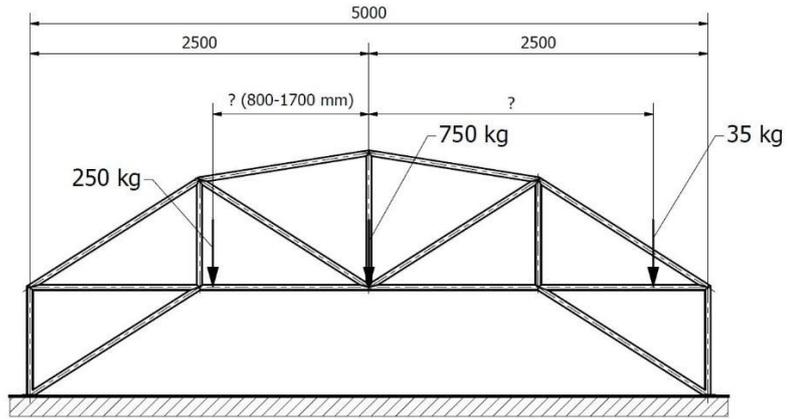
3.2.1. Horizontal load test

- 1) Before loading begins, the bridge is fixed to a special steel frame. This frame is used to simulate the fixed support conditions.
- 2) A 28 kg lateral load is applied at the mid-span of the bridge deck while a 104 kg vertical load is placed on the bridge deck.
- 3) Horizontal deflection is measured at mid-span from the same constructive element that the lateral load is applied to. The aim of horizontal loading is to assess global stiffness of the bridge against horizontal loads.
- 4) Horizontal load is applied to the side where the hook/loop is.
- 5) To pass the horizontal load test, deflection must not exceed 10 mm.

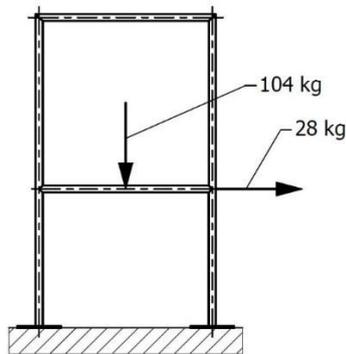
3.2.2. Vertical load test

- 1) A 750 kg load will be applied at the mid-span of the bridge (see figure 3).
- 2) A 250 kg load will be applied at a random location between 800 mm to 1700 mm from midpoint of the span (see figure 5). The exact location will be decided in the beginning of the competition by using a random number generator (<https://www.random.org/>) and this location will be the same for all bridges.
- 3) A 35 kg vertical load can be applied anywhere on the deck if necessary to check local stiffness of the deck. The position of the load is chosen by the organizers. If deflection exceeds 4 mm penalty 7 applies (3 points).
- 4) Loads include the weights and loading grates.
250 kg = weight of grate + loading bars + weights
750 kg = weight of grates + loading bars + weights

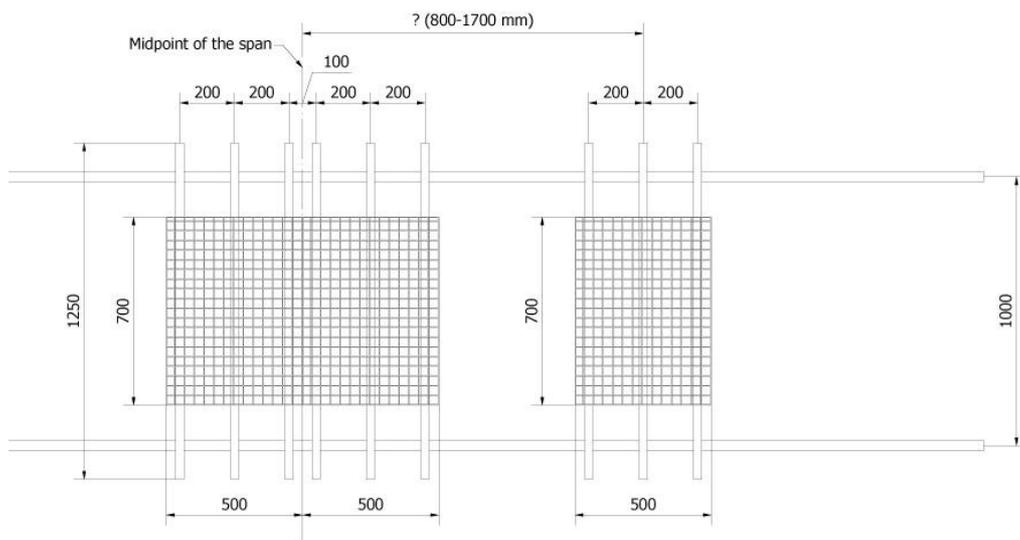
FIGURE 5 – Schemes for loading

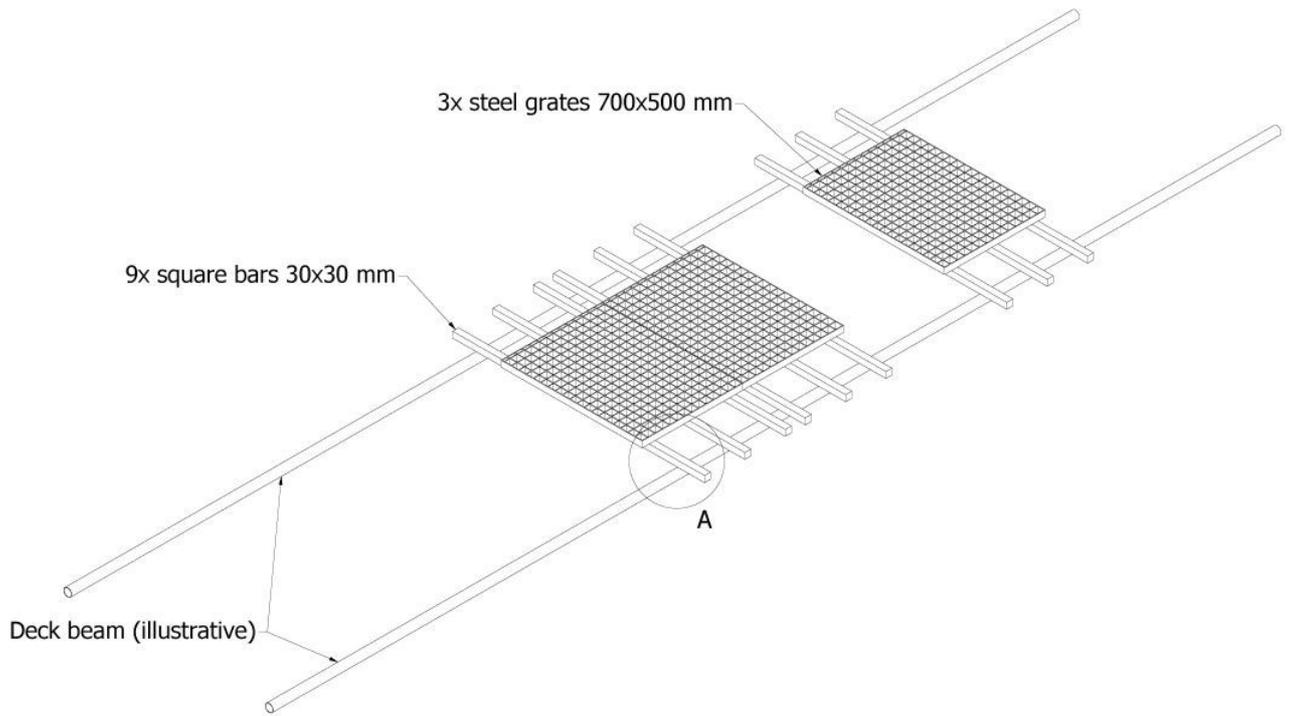


Vertical load test

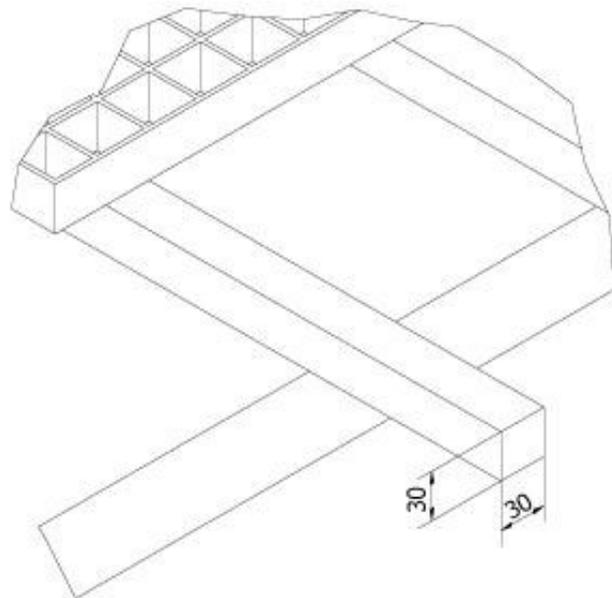


Horizontal load test





DETAIL A



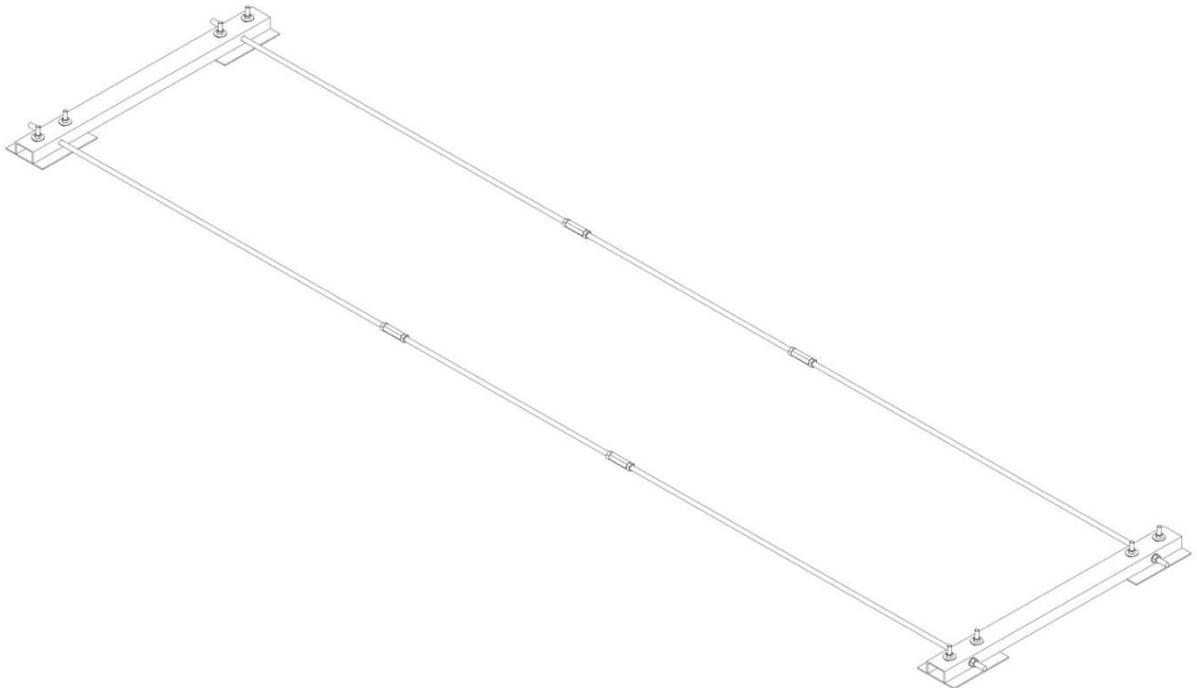
3.3. Supports

The legs of the bridge are fixed as follows (see figure 3):

Displacement in x direction	=	fixed*
Displacement in y direction	=	fixed
Displacement in z direction	=	fixed
Rotation around x axis	=	fixed
Rotation around y axis	=	semi-fixed
Rotation around z axis	=	fixed

*We can assure it will be less than 2-3 mm.

FIGURE 6 – Drawing of the steel frame



4. STAGES OF THE COMPETITION

4.1. I STAGE – DESIGN OF THE BRIDGE

During this stage, teams should first try to find several efficient bridge designs and in the end choose the best one. We encourage all team members to try and figure out their own designs. This already creates a sense of competition and in the end, you as a team end up with a better design to send to BRICO. For structural analysis teams can use any commercially available structural analysis software (RFEM, RSTAB, SAP2000, Robot, STAAD, Sofistik...). Since the small deflection under the applied loads is not the only aspect influencing the final score, you should also think about how you are going to divide your bridge into pieces, whether your bridge is light and easy to assemble etc. Furthermore, bear in mind that it should be possible to place the loading bars on the deck with an interval of ~200 mm. Take into account that in structural analysis software, there might be many steel profiles to choose from, but that does not mean your local companies have them all in stock. Problems can occur especially with smaller profiles. A good thing to do at this stage is scoring system analysis. Everything written in this paragraph is optional and only serves as a description of one way things can be done.

Remember that it is not hard to design a heavy bridge with a small deflection, but it takes true engineering skills to design a light bridge with a low deflection!

4.2. II STAGE – PRE-EVALUATION

Before qualifying to the final competition teams have to pass pre-evaluation. Pre-evaluation consists of two levels. For level 1 pre-evaluation teams have to send their applications as well as the required files and drawings before the deadline. For level 2 pre-evaluation teams have to send all joint designs and data sheet before the deadline. The pre-evaluation committee looks through each application and decides which teams will qualify for the final competition.

The decision is based on three criteria:

1. Safety of the bridge (most important criteria)
2. Compliance with competition rules
3. Originality/aesthetics of the bridge

After level 1 pre-evaluation max 18 teams are qualified for level 2 pre-evaluation.

After level 2 pre-evaluation max 16 teams are qualified for final competition in Tallinn.

The pre-evaluation committee consists of professors from the Faculty of Civil Engineering of Tallinn University of Technology and members from the organizing team.

4.2.1. Files and drawings to be sent with the application (level 1 pre-evaluation)

- 1) Model of the bridge
 - a) Native format of the analysis software (robot, rfem, sap2000, sofistik, step, iges, x_b etc)
 - b) If possible also .step format
- 2) Drawings (dwg and pdf)
 - a) Front view with dimensions
 - b) Top view with dimensions
 - c) Side view with dimensions (view along the axis of the bridge)
- 3) Certificates of student status

4.2.2. Files and drawings to be sent with the application (level 2 pre-evaluation)

- 1) Design of all different types of joints used in the bridge (dwg and pdf). This can include top view, side view, 3D view of the joint etc... whatever is necessary to clearly understand the design of joint.
- 2) Data sheet about the bridge and the team. Blank file will be sent to all qualified teams after level 1 pre-evaluation results are announced.

4.2.3. Deadline for sending the application. Results of pre-evaluation

Level 1 pre-evaluation	05.01.2020 <u>before</u> 21.00 CET
The results of level 1 pre-evaluation will be published on our website on 09.01.2020.	
Level 2 pre-evaluation	26.01.2020 <u>before</u> 21.00 CET
The results of level 2 pre-evaluation will be published on our website on 30.01.2020.	
All the application documents can be sent to email address: info@brico.ee	

4.3. III STAGE – MANUFACTURING, PRACTICE, ADMIN

If you are already at this stage, you know that your design made it to the final competition in Tallinn in May 2020. This stage begins right after the results of level 2 pre-evaluation have been published on our website (www.brico.ee) on 30.01.2020. All teams will also receive a personal message about whether they qualified to the final competition or not.

Now it is time to start producing your bridge. In general, there are two options. The first is to find a professional company or a sponsor to produce the bridge for you. In this case, we encourage the teams to try to be present as much as they can during the production phase. You will form a better understanding of steel works and all the problems, tolerances and limitations involved in this process. Usually you need to provide workshop drawings of your bridge to the steel company. Those drawings have to be very exact and detailed. Take into consideration that making these drawings can be time-consuming and may even involve learning new software. For example, Autodesk Inventor is widely used to produce detailed 3D models and drawings of steel structures.

The second option is to produce the bridge yourself. This is a more educative option, but it also means you need to have all the proper facilities at your university along with the practical know-how (e.g. different welding techniques, use of specific tools). REMINDER! You should be careful and take all the safety precautions seriously! It is advised to always have someone with a wealth of experience around when producing your bridge.

It is recommended to paint your bridge (e.g. powder coating), but it is not compulsory.

When you finish producing your bridge, the next step is to try and assemble it. The more you train, the faster you will get!

Finally, you also have to think about how you are going to transport your bridge to Tallinn. Of course, this depends a lot on the location. One option is to use a courier company (DHL, UPS etc.). In this case, you also have to pack the pieces properly for transportation purposes.

Everything written in this paragraph is optional and only serves as a description of one way things can be done.

4.4. IV STAGE – COMPETITION

4.4.1. Display

- 1) On the first day of the competition, the bridges will be erected for public viewing and will be evaluated for display near the parking lot of the university campus.
- 2) Teams will have ~2 hours to assemble their bridges and set up necessary posters.
- 3) The poster should include:
 - a) The name of the team
 - b) The name of the university
 - c) A dimensioned side-view
 - d) Additional information about the bridge
- 4) The size of the poster should be A2 or bigger
- 5) The bridge should be presented exactly the way it will be erected during timed construction. (No additional non-constructive elements can be attached to the bridge)
- 6) During the display evaluation judges, including lecturers, representatives of the sponsors and members of construction club will visit each bridge. The teams will give them a brief presentation about their bridge. The jury members are allowed to ask additional questions
- 7) The jury members take into consideration the following aspects:
- 8) Originality
 - a) Aesthetics
 - b) Quality of the presentation
 - c) Content and design of the poster
- 9) The jury members evaluate each bridge with a score from 0 to 100. The arithmetic average of all the scores gives the final display score

4.4.2. Lightness

- 1) After the display, bridges will be weighed by lifting the bridge on scales, one scale under each leg. Readings from the scales will be added to get the total weight of the bridge. It is normal to have different reading under each leg. Stiffness of the bridge is usually not evenly distributed
- 2) After teams have disassembled their bridges, elements are tested to see if they meet the geometrical requirements stated in paragraph 3.1.2.

4.4.3. Assembly

- 1) Timed construction will take place on the university campus parking lot on the second day of the competition
- 2) Only builders and judges are allowed on the construction site during timed construction
- 3) Builders shall wear hard hats, work gloves and protective eyewear at all times during timed construction
- 4) Before construction begins, bridge members, fasteners, temporary piers and tools must be in contact with the ground and must fit entirely within the assigned area (see figure 4 under 3.1.4.3.)
- 5) During construction, each team has one judge with them. All clarifying questions about the rules should be asked before the construction starts

4.4.4. Loading

- 1) The loading tests take place after the timed construction at the same location
- 2) Load tests are applied after the bridge's legs are fixed as explained under 3.3.
- 3) All competitors participating in load testing shall wear hard hats, work gloves, protective eyewear and steel toe work boots/shoes
- 4) Safety equipment must be provided by the competitors
- 5) Judges will not allow competitors without the specified safety equipment to perform load testing
- 6) Competitors not involved in loading, supervisors and other spectators are not allowed to enter the loading area to minimize the risk on personal injuries
- 7) Deflections are measured using digital devices

4.4.4.1. Horizontal loading

- 1) The first part of load testing is a horizontal load test.
- 2) A 28 kg lateral load is applied to the mid-span of the bridge deck while a 104 kg vertical load is placed on the bridge deck at the mid-span.
- 3) Horizontal deflection is measured from the same constructive element that the lateral load is applied to.
- 4) To pass the horizontal load test, the deflection must not exceed 10 mm.
- 5) If the bridge does not pass the horizontal load test, it will not undergo further testing and is only eligible for the display award.

4.4.4.2. Vertical loading

- 1) Vertical loading is the second part of load testing.
- 2) Safety supports and measuring devices are placed under the bridge deck before the weights are applied.
- 3) The loading process is performed by the team members, using the weights and loading grates provided by organizers.
- 4) Deflection is measured at mid-span.
- 5) The vertical load test consists of three parts. First, loading grates are placed on the bridge deck at mid-span and at random location determined using www.random.org. After that, measuring devices are set to „0.0“. Then, a 750 kg weight is loaded onto the loading grates at mid-span, followed by a 250 kg weight at a random location (explained under 3.2.2.).
- 6) A coin throw decides which end of the bridge deck is used for the off-center loading.
- 7) Vertical deflection value is read from the measuring device 30 seconds after loading is finished.
- 8) If the vertical displacement measured exceeds 25 mm (the absolute value), the bridge is only eligible for the display award.

4.4.5. Objections

- 1) Objections can be made about any violation of the rules.
- 2) Teams can voice their objections when the results are discussed (see 7.7.).
- 3) When making objections about other teams bare in mind the “Mission and philosophy” paragraph of this document.

4.4.6. Equipment provided by the host

- 1) Equipment for fixing the bridge’s legs to the ground
- 2) Equipment and weights for horizontal loading
- 3) Equipment for measuring deflection and horizontal displacement
- 4) Loading grates and weights for vertical loading
- 5) Safety supports to arrest a falling load in case the bridge collapses

4.4.7. Discussion of results

- 1) After team finishes their vertical load testing, there will be a short discussion between each team and jury members. The results of the measured weight, timed construction, horizontal and vertical deflections as well as the added penalties will be announced to the teams. In case of any dissension, issues will be discussed and resolved.
- 2) Objections will be discussed
- 3) Safety
- 4) Safety has the highest priority during the competition



- 5) In case of a serious violation of any safety precautions, the competitor will be disqualified immediately
- 6) In case of a smaller violation of safety precautions, penalty 5 (1 point) will be applied
- 7) Builders shall wear hard hats, work gloves and protective eyewear at all times during timed construction
- 8) Only builders and judges are allowed on the construction site during timed construction
- 9) All competitors participating in load testing shall wear hard hats, work gloves, protective eyewear and steel toe work boots/shoes. Judges will not allow competitors without the specified safety equipment to perform load testing
- 10) Competitors not involved in loading, supervisors and other spectators are not allowed to enter the loading area to minimize the risk on personal injuries
- 11) Bridges that are clearly damaged shall not be accepted for load testing
- 12) During the competition, any activity shall be halted if a judge considers it to be hazardous

4.5. V STAGE – ANNOUNCING THE WINNERS

- 1) On the 3rd day of the competition, winners will be announced in the following categories:
 - a) Display
 - b) Structural efficiency
 - c) Construction economy
 - d) Overall (first, second and third place)
- 2) The winning teams will receive a considerable monetary prize.

5. SCORING SYSTEM

- 1) Winner of each category (display score, lightness, assembly time, ver+hor displacement) gets -1p (CW = Category Winner).
- 2) Team who beats competition records of each category gets -1p (CR = Competition Record)

Scores to beat:

Display:	93.8 p (ktuBulls, 2019)
Lightness:	43 kg (Dimensionless, 2017)
Assembly:	10.92 min (with penalties) (Steel Eagle, 2016) 1.6 min (disqualified: deflection) (ktuBulls, 2019)
Ver+hor displacement:	1.38 mm (RTU Steelbusters, 2017)

Formula for calculating display cost (lowest score wins):	$C_1 = dx + e$ Where x = final display score Upper limit: 25p
Formula for calculating lightness cost:	$C_2 = ax^4 + bx^3 + cx^2 + dx + e$ Where x = kg Lower limit: 0p Upper limit: 25p
Formula for calculating assembly cost:	$C_3 = ax^4 + bx^3 + cx^2 + dx + e$ Where x = minutes Lower limit: 0p Upper limit: 25p
Formula for calculating cost of horizontal displacement:	$C_4 = ax^4 + bx^3 + cx^2 + dx + e$ Where x = mm Lower limit: -5p Upper limit: 10p
Formula for calculating cost of vertical displacement:	$C_5 = ax^4 + bx^3 + cx^2 + dx + e$ Where x = mm Lower limit: -5p Upper limit: 15p
Formula for calculating construction economy (lowest score wins):	$C_c = C_3$
Formula for calculating structural efficiency (lowest score wins):	$C_s = C_2 + C_4 + C_5$
Formula for calculating overall performance (lowest score wins):	$OVERALL = C_1 + C_c + C_s + penalties (-CW points - CR points)$

PARAMETERS FOR SCORING SYSTEM

	AEST	TIME	VER	HOR	WEIGHT
a	-	0.0000785516	0.000351266	0.00373505	0.0000416048
b	-	-0.00412489	-0.00827857	-0.037341	-0.0091437
c	-	0.0451241	-0.00867151	-0.080446	0.724244
d	-0.4	0.741882	1.43864	1.93450	-23.8896
e	40	0	0	0	278.557

6. PENALTIES

Penalty 1	7+0.1*x points x = violation in mm	Applies to violations of restrictions on the geometry of the bridge (3.1.2.)
Penalty 2	2+0.02*x points x = violation in mm	Applies to violations of restrictions on geometry of single elements (3.1.3.)
Penalty 3	1 point	Applies if temporary support or the bridge collapses during construction (3.1.4.2.)
Penalty 4	0.2 points	Dropping tools, bolts, nuts, washers or hard hats; passing under or jumping over the bridge (barge); stepping into restricted area (3.1.4.2.)
Penalty 5	1 point	Throwing tools, bolts or elements (3.1.4.2.)
Penalty 6	0.2 points	Applies to every loose bolt (3.1.4.3.)
Penalty 7	3 points	Applies when local stiffness of the deck is too low (displacement under 35 kg load is bigger than 4 mm)