

## Bridge Lesson Plan

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|   |  |   |
|---|--|---|
| <b>21<sup>st</sup> Century Themes:</b> Financial, Economic, Business and Entrepreneurial Literacy |  |   |
| <b>Concepts for STEM Disciplines</b>  | <b>Mathematics</b><br>Ratio and Proportion   | <b>Science</b><br>Measuring force<br>Relationship between human and environment |
|   | <b>Technology</b><br>Research<br>Spreadsheet software<br>Presentation software<br>Simulation | <b>Arts</b><br>Architectural<br>Aesthetics<br>Information about the bridges     |
| <b>Integration</b>  | <b>Prerequisite Knowledge</b>  |   |
|   | <b>Learning Outcomes for Mathematics</b>   |   |
|   | <b>Learning Outcomes for Science Education</b>   |   |
|   | <b>Learning Outcomes for Information Technologies</b>  |   |
| <b>Learning Outcomes</b>  |  |   |
| <b>Grade Level:</b> 6th-grade   |  |   |
| <b>Duration:</b> 10 lesson hours  |  |   |
| <b>Learning Outcomes for Mathematics</b>  |  |   |
| <b>Learning Outcomes for Science Education</b>  |  |   |
| <b>Learning Outcomes for Information Technologies</b>   |  |   |

|                    |  |
|--------------------|--|
|                    | <p><b>Learning Outcomes for Visual Arts</b></p> <ul style="list-style-type: none"> <li>Students are able to use critical thinking skills when describing, analyzing, interpreting and evaluating the artwork.<br/><i>Analyzing an artwork is to explain it in as much detail as possible in relation to what message the artist wants to send and how s/he describes it. At the end of the analysis, the questions like “Is this artwork successful? Why is it successful?” are answered. Values related to learning outcomes should be emphasized.</i></li> <li>Students will be able to explain how the artwork evokes feelings, emotions and aesthetic response.</li> </ul>   |
| Real World Context | <p><b>Problem Situation</b><br/>How to construct a bridge to withstand the greatest force acting on the bridge? What could be the toll for vehicles passing over this bridge?</p>  |
|                    | <p><b>Materials</b><br/>Smartphones or tablets, Appendix 1, Appendix 2, Appendix 3, Appendix 4, Bamboo Sticks or Abeslang, Smartboard, Adhesive material (Silicon gun or glue), dynamometer.</p>   |
|                    | <p><b>Preparations for the lesson</b><br/>The following questions will be sought answers for the preparation of the lesson plan. The answers to these questions will be presented in a separate document:</p> <ul style="list-style-type: none"> <li>How are bridges constructed?</li> <li>What are the materials used in bridge construction?</li> <li>Why do bridges collapse?</li> <li>What information is necessary for bridge construction?</li> <li>What information should be presented for the students?</li> </ul> <p>All of these contents will be prepared in the “create” section. The documents will be printed by the teacher before the lesson and hanged on the classroom walls, doors, windows, cabinets, clipboards, etc.</p>  |
|                    | <p><b>Resources</b></p> <p><a href="https://justfunfacts.com/interesting-facts-about-bridges/">https://justfunfacts.com/interesting-facts-about-bridges/</a><br/> <a href="https://www.kickassfacts.com/bridge-facts/">https://www.kickassfacts.com/bridge-facts/</a><br/> University of NC Charlotte. Learning Activity #5. Design and Build a Model Truss Bridge.<br/> <a href="https://webpages.uncc.edu/~jdbowen/1202/learning_activities_manual/Learning_Activity_5.pdf">https://webpages.uncc.edu/~jdbowen/1202/learning_activities_manual/Learning_Activity_5.pdf</a><br/> <a href="https://www.garrettsbridges.com/design-it/">https://www.garrettsbridges.com/design-it/</a><br/> English, LD (2017). Advancing elementary and middle school STEM education. <i>International Journal of Science and Mathematics Education</i>, 15 (1), 5-24. <a href="https://doi.org/10.1007/s10763-017-9802-x">https://doi.org/10.1007/s10763-017-9802-x</a></p> <p>This lesson plan is conducted within the “STEAM-BOX: Courses, Tools, Resources for Teachers (2020-1-HU01-KA201-078743)” project which has been funded by the Erasmus+ program of the European Union. The European Commission’s support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.</p> |
| STEAM Activity     | <p><b>Ask</b><br/>The teacher starts the lesson by asking questions to the students about bridges: Have you ever seen a bridge before? Where did you see this bridge? What kind of bridge was it? What was the construction material? Did you cross the bridge? How? (On foot, by car, by train?) What are the bridges that you know and do you know the properties of these bridges? Each student is encouraged to respond and participate. Possible answers expected from the students are as follows:</p> <ul style="list-style-type: none"> <li>Chengyang Bridge, no nails were used during its construction.</li> <li>Shiniuzhai Bridge, it is the tallest and longest glass bridge in the world.</li> <li>Gateshead Millennium Bridge, it is the world's first curved bridge.</li> </ul> <p>After receiving the answers from the students, the presentation named <b>Appendix 1. Bridges and Their Properties</b> is shared using the smart board. The teacher briefly gives information about the bridges from different parts of the world and the properties of these bridges to the students.</p> <p>Students are divided into groups of 5-6 people. The print-outs of slides from the presentation with different bridge photos and properties are provided for each group. Sample images:</p>  |

### Uzunköprü, Türkiye

Located in the district of Uzunköprü (Long Bridge), some arches of the bridge are pointed, while others are in the form of an arc. The bridge is 1392 meters long and 5.5 meters wide. Reliefs and rosettes can be seen on the body of the bridge, which has a triangular flood splitter.



### Golden Gate Bridge, USA

The bridge is a suspension bridge over the Golden Gate Strait at the entrance to San Francisco Bay in California. Currently, it is the seventh longest suspension bridge in the world.



Students do their research in their groups. They note/create a table related to the similarities and differences they notice about the bridges. Possible table contents are as follows:

#### Similarities

- They have piers
- They shorten the distance
- They ease the traveling

#### Differences

- They can be used by pedestrians or vehicles for crossing
- They can be built using different materials
- They can have different heights
- They can have different lengths
- Their designs can be different

All the groups share the similarities and differences they have identified one-by-one, and the teacher writes them on the board for everyone to see. It should be ensured that the students put forward the types of bridges such as "suspension bridges", "stone bridges", "arch bridges". The teacher starts a class discussion to determine what the differences are about these bridges. In addition, the teacher asks which bridges the students like more in terms of design:

- Which bridges are better? Why?
- Do you think it matters whether a bridge looks good or not? Why?

In line with the answers of the students for these questions, it is emphasized that the bridges are also architectural work.

### Research

Teacher distributes **Appendix 2. Bridge Activity - Student Worksheet** to all the students and gives clues about the problem situation. S/he gives time for the students to analyze the sample case. The teacher asks guiding questions to the students in order to limit the topics to be researched. The questions like "What happened? What could be the reasons? What could be the consequences of this case? What can be done?" can guide the students to search for information that will enable them to construct a durable bridge.

Then, the teacher shares the **Appendix 3. Bridge Information** list with the students. At this stage, the students may be asked to do research. The following websites can be used for this purpose:

- <https://listelist.com/tarihte-yikilan-kopru/>
- <https://www.matematiksel.org/tacoma-narrows-koprusu/>
- <https://www.sanalsantiye.com/tacoma-narrow-koprusu/>

In addition to the information given about bridges, the students determine the questions that they are curious about and that they want to investigate. They do individual research to find answers to their questions. During the research, the teacher walks around the classroom, encourages the students to do research and helps them think critically about the information they read. After the research is completed or the allocated time is finished, the students return to their groups and share the research results with their groupmates. By having a group discussion, they synthesize their thoughts and information and prepare a joint group report. A spokesperson from each group presents the group report including their results to the other groups.

### Imagine

While group reports are shared, a class discussion setting can be created. Having completed all groups' presentations, the teacher can draw the students' attention to the news of collapsed bridges and can fine-tune an atmosphere for discussion.

- Why do bridges collapse?
- What precautions can be taken to prevent them from collapsing?
- How to construct safe, durable and economical bridges?
- What should be taken into consideration in order to construct an aesthetic bridge?
- How can the structure and appearance of the bridge be harmonized with its surroundings?

- If you were to construct a bridge, what would you pay attention to?

Receiving the answers from the students, the teacher says to the students that they can construct a bridge on a mobile game based on a set of criteria they want, asks them to download the mobile game called “Bridge Constructor Playground” (App Store <https://apps.apple.com/us/app/bridge-construction-sim/id1073594113> and Google Play <https://play.google.com/store/apps/details?id=pl.aidemmedia.RealisticBridge&hl=en&gl=US>), and tells them to examine the mobile game. The main aim here is to integrate technology by enabling the students to experience the bridge construction process. The mobile game can be played individually or as a group.

#### **Plan**

Students determine the properties of the bridge they will create on the mobile game. To this end, the question “What would you pay attention to if you were to construct a bridge?” is detailed by the teacher with the following questions:

- What are the requirements to prevent the bridge from collapsing?
- How to construct a bridge that withstands the most force?
- What materials should you use?
- What kind of a shape should your bridge have in order to be durable?
- How wide should it be?
- How many vehicles can cross?
- How should it look?
- What should we do to make it environmentally-friendly?

Students, in groups, discuss how the potential bridge will be constructed. In this process, the teacher walks around the classroom and helps the students with guiding questions. Students are encouraged to think and discuss possible solutions and create a bridge construction plan.

Another question, “How can a bridge withstanding the most force be constructed so that it does not collapse?”, is directed to the students. Students are asked to discuss how bridges can be constructed within their groups. At this stage, the students are presented with the materials they will use and they are asked to both familiarize with the materials and think about the solution proposals. Doing that, the teacher walks around the classroom and helps the students with guiding questions. Students are expected to think and discuss different solutions and create a bridge construction plan. The teacher shows the students the objects that are going to be used by being placed on the bridges to test the constructed bridges. While planning the solution proposals, Mathematics is used to calculate how many cars can pass over the bridge depending on the width of it and how much toll these cars can be charged.

#### **Create**

Initially, students construct and test the bridge with the properties they have determined in the mobile game. Then, the process of construction of a real bridge, which is modeled and tested in the mobile game, starts using the materials provided to the students in the classroom environment. Following the completion of solution proposals, the students are asked to construct the bridge they have planned. Students measure the force with a dynamometer and determine what magnitude of the force the bridge they will construct should be able to withstand.

In this process, students who cannot create their plans are given the opportunity to return to the previous stage and plan a solution again. Students utilize from Mathematics when calculating how wide the bridge can be to compensate for the given cost, how many cars can fit on the bridge (min. / max.), how many cars can cross the bridge on average per day, and how many lanes the bridge can have (whether there will be a pedestrian crossing, how wide the lanes can be). The toll will be found by dividing the cost by the number of the cars determined. Doing that, the arithmetic mean will be used while finding the number of cars and ratios will be utilized when calculating the toll. By this way, the teacher can direct the ideas of the groups in the solution process.

#### **Test**

The bridges are placed in the determined range and the objects are placed upon them. In case of a collapsed bridge, the groups with these bridges identify the deficiencies in their models. Following this, a class discussion is held about why the bridge that carries the most force is successful, what the reasons for collapsing are for the collapsed bridges, and what can be done to prevent the bridges from collapsing.

At this stage, if possible, the test process can be recorded via a camera. Thus, a brainstorming setting can be created in the class discussion by watching the recordings again. The bridges created by the students are evaluated in terms of aesthetics using their critical thinking skills. Thus, for the discipline of Visual Arts, the targeted critical thinking skills and the contents of the aesthetics of the artworks are enacted. The groups are asked to select a spokesperson and s/he is expected to present their group’s calculations for the toll in the class. The students also discuss how their groups formulate the toll regarding the variables, concepts and similarities and differences of the models. (During this stage, students will create mathematical models. The concepts of arithmetic mean and ratio will be used in these models. The results will be different based on each student's assumption and the variables used).

|                  |   |
|------------------|---|
|                  | <p><b>Improve</b><br/>After the testing stage, students finalize their reports including the strengths and weaknesses of the bridges they have constructed, the performance of the bridges, the force they withstand, how much the tolls are and how they do this calculation. The groups complete the changes they want to make related to their work during this process.</p>   |
| <b>Materials</b> | <p>In the presentation, <b>named Bridges and their properties</b>, it is aimed to introduce the bridge activity for students and help them think about the bridges. For this purpose, the presentation includes different bridges, interesting properties and visuals of these bridges.</p> <p>In the student worksheet, <b>named Bridge Activity</b>, it is aimed to present the problem situation to the students. For this purpose, a piece of news was selected as the problem situation to be given to the students and a scenario was created for this real-life situation. Students are asked to find a solution for this problem situation.</p> <p>In the "<b>Bridge Constructor Playground</b>" mobile game, the main purpose is that the students realize the important points that require attention regarding the bridge construction process. To this end, the accessible mobile games were examined. A mobile game by which students can construct different bridges, test the bridges that are created on the game, and get an idea about the lengths using graph paper was chosen. The reason for specifically selecting the game "Bridge Constructor Playground" is because it is accessible for both IOS and Android devices, free of charge and suitable for the purpose of the study in addition to its Turkish language support.</p> |
| <b>Test</b>      | <p><i>This part will be completed by the teacher after the lesson plan is implemented in the classroom.</i></p>   |
| <b>Improve</b>   | <p><i>This part will be completed by the teacher after the lesson plan is implemented in the classroom. This activity has been developed for secondary level education. The activity can be implemented at the secondary level education in relation to the parabola subject in Mathematics lesson and endurance in the Science Education lesson.</i></p>   |

## Appendix 1. Bridges and Their Properties

### Gold Bridge, Vietnam

Built 1.4 km above sea level, Gold Bridge, opened in Bà Nà Hills, is the perfect spot to enjoy the mountain views to the fullest.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

### Magdeburg Water Bridge, Germany

Unlike the bridges we are used to crossing by land vehicles or pedestrians, ships pass through the Magdeburg Bridge, which is built over the Elbe River! Before the bridge near Berlin was built, crossing the two canals was a long and arduous process. When Magdeburg opened in 2003, it started to serve as a shortcut for ships.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>



## Ponte Vecchio, Italy

What makes this bridge interesting is not only its history, but the buildings on it and the shops inside. In fact, such bridge designs were once very common, but unfortunately, many of them succumbed to history. Ponte Vecchio, on the other hand, is a bridge that survived even World War II, and that's why it's so special. You can shop while crossing the Arno River!



<http://www.brandlifemag.com/dunyanin-en-iliginc-kopruleri/>

## Irgandı Bridge, Turkiye

It differs from its counterparts with its rows of shops rising above an arched structure. The bridge, which was the center of handicrafts of its time with nearly thirty shops, a mosque and two barns, was also a bazaar. This bazaar, which has a structure suitable for the guild system, was an important trade area where travelers and merchants often frequented many years ago.



<https://abcgazetesi.com/14-yuzyilda-kopruler-nasil-yapilirdi-362975>

## Millau Viaduct, France

The Millau Viaduct, the highest bridge in the world with a height of 342 meters, was opened in 2004. The bridge, which you cross as if you were floating above the clouds, crosses the Tarn River Valley from one end to the other. It is a modern time architectural marvel stretching for approximately 2.5 km on seven pillars.



<http://www.brandlifemag.com/dunyanin-en-iliginc-kopruleri/>

## Capilano Cliffwalk, Canada

This 213-meter bridge, which allows you to watch the canyon formed by the Capilano River from 70 meters high, is fixed to the sides of the cliff. With its curved design, it maximizes the adrenaline and the scenic pleasure to the top.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

## Khaju Bridge, Iran

Built by Shah Abbas I in the 17th century, this elegant bridge is located in Isfahan. Khaju Bridge, one of the rarest examples of Iranian architecture, was also designed to act as a dam. With its two-storey arched structure and colorful tiles, it looks spectacular, especially when illuminated at night.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

## Chapel Bridge, Switzerland

Located in Lucerne, Switzerland, the 204-meter Chapel Bridge was built in 1333. It is also the oldest covered wooden bridge in Europe. One of the purposes of the bridge, built over the Reuss River, was to help for the defense of the city from attacks.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>



## Chengyang Bridge, China

The traditional bridge architecture of the Dong people living in China is called the 'Wind and Rain Bridges', because these wooden bridges offer shelters where people can be protected from wind and rain while resting and socializing. Chengyang Bridge, the largest of these bridges and still in use, was built in 1916 and not a single nail was used while this 65-meter bridge was built.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

## Helix Bridge, Singapore

The design of this pedestrian bridge that connects Singapore's Marina district, of course, surpasses its function and becomes one of the most unusual symbols of the city. The spiral architecture of the bridge, which pushes the boundaries of mathematics and engineering, has a dreamlike appearance, especially when illuminated at night.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

## Shiniuzhai Bridge, China

Shiniuzhai in China's Hunan province is the tallest and longest glass bridge in the world. The bridge, which is at an altitude of 523 meters above the sea, attracts hundreds of thousands of tourists every year.



<https://www.bbc.com/turkce/haberler-dunya-38909636>

## Gateshead Millennium Bridge, England

The Gateshead Millennium Bridge in England was opened in 2001. The height of the 127-meter-long "world's first inclined bridge" is 50 meters.



<https://www.bbc.com/turkce/haberler-dunya-38909636>

## Pont du Gard Bridge, France

Pont du Gard, which you can visit in the Languedoc-Roussillon region in the south of France, is an aqueduct built by the Romans.



<https://www.bbc.com/turkce/haberler-dunya-38909636>

## Brooklyn Bridge, USA

When the construction of the bridge was completed, it became the widest suspension bridge in the world. In fact, the towers of the bridge were mentioned as the tallest structures in the USA for several years.



<https://www.haberturk.com/htgastro/kesfet/dunya-uzerindeki-en-iliginc-kopruler-2467135>



## Golden Gate Bridge, USA

The bridge is a suspension bridge over the Golden Gate Strait at the entrance to San Francisco Bay in California. Currently, it is the seventh longest suspension bridge in the world.



[https://www.baike.com/wikiid/3312042740556371218?view\\_id=hbnkuyhc04w00](https://www.baike.com/wikiid/3312042740556371218?view_id=hbnkuyhc04w00)

## Fatih Sultan Mehmet Bridge, Turkiye

The Bosphorus Bridge and the Highway constitute a very important link in Turkiye's transportation network as the first fixed link between Europe and Asia.



<https://www.hurriyet.com.tr/gundem/fatih-sultan-mehmet-koprusunde-13-agustosta-asfaltlama-calismasi-42116876>

## Yavuz Sultan Selim Bridge, Turkiye

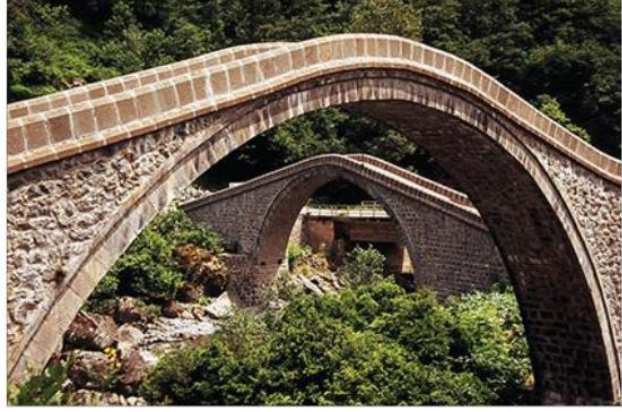
The bridge is the world's widest suspension bridge with a width of 59 meters, the world's highest in the inclined suspension bridge class with a tower height of 322 meters, and the suspension bridge with the second highest tower in all bridge classes.



<http://www.brandlifemag.com/dunyanin-en-iginc-kopruleri/>

## Çifteköprü, Türkiye

One of the bridges is over Kamilet Stream and the other is over Soğucak Stream. Both bridges are 35.5 meters long and 2.8 meters wide . Due to their narrow width, the bridges are only open for pedestrian passage.



<https://abcgazetesi.com/14-yuzyilda-kopruler-nasil-yapilirdi-362975>

## Uzunköprü, Türkiye

Located in the district of Uzunköprü (Long Bridge), some arches of the bridge are pointed, while others are in the form of an arc. The bridge is 1392 meters long and 5.5 meters wide. Reliefs and rosettes can be seen on the body of the bridge, which has a triangular flood splitter.



<https://abcgazetesi.com/14-yuzyilda-kopruler-nasil-yapilirdi-362975>

## Malabadi Bridge, Türkiye

The bridge on the Diyarbakır-Silvan road is one of the works of the Artuqids, who once ruled the region. The Malabadi Bridge over the Batman Stream, which joins the Tigris River, is 160 meters long and 7 meters wide.



<https://abcgazetesi.com/14-yuzyilda-kopruler-nasil-yapilirdi-362975>



## Taşköprü, Türkiye

The historical Taşköprü on the Seyhan River, which divides Adana city center into two, is a Roman period monument. Built by the architect Auxentius during the reign of Roman Emperor Hadrian, the bridge is 310 meters long and 11.5 meters wide.



<https://abcgazetesi.com/14-yuzyilda-kopruler-nasil-yapilirdi-362975>

## Appendix 2. Bridge Activity - Student Worksheet

Hundreds of people fell into the river as a result of the collapse of a suspension bridge in the Indian state of Gujarat, killing at least 132 people. The suspension pedestrian bridge connecting the two sides of the river collapsed. It is stated that 400-500 people were on the bridge at the time of the collapse. It was announced that at least 132 people died as hundreds of people on the bridge fell into the Macchu River.



<https://www.normhaber.com/hindistanda-asma-kopru-coktu-132-olu-392405>

Works will be done to reconstruct the bridge. While the bridge is being constructed, it will be ensured that it is a bridge that will withstand the greatest force acting on the bridge. You have been hired as an engineer at a construction company that will construct the bridge. You are expected to design and construct a model bridge with a length of at least 30 cm.

To cover the cost of the bridge, you were asked to develop a model that shows how much the bridge toll should be based on the number of vehicles that will cross the bridge daily. You are requested to find out how much the bridge toll should be and submit a report to the construction company stating how you reached this toll. In this report, you are expected to include information about the process of creating your model.

## Appendix 3. Bridge Information

# Notes for Teachers

- Print all pages.
- Hang all the pages you have printed out on different parts of the classroom (wall, door, window, board, etc.) before the lesson.
- Have students discover information during the research phase.

## Why Do We Need Bridges?

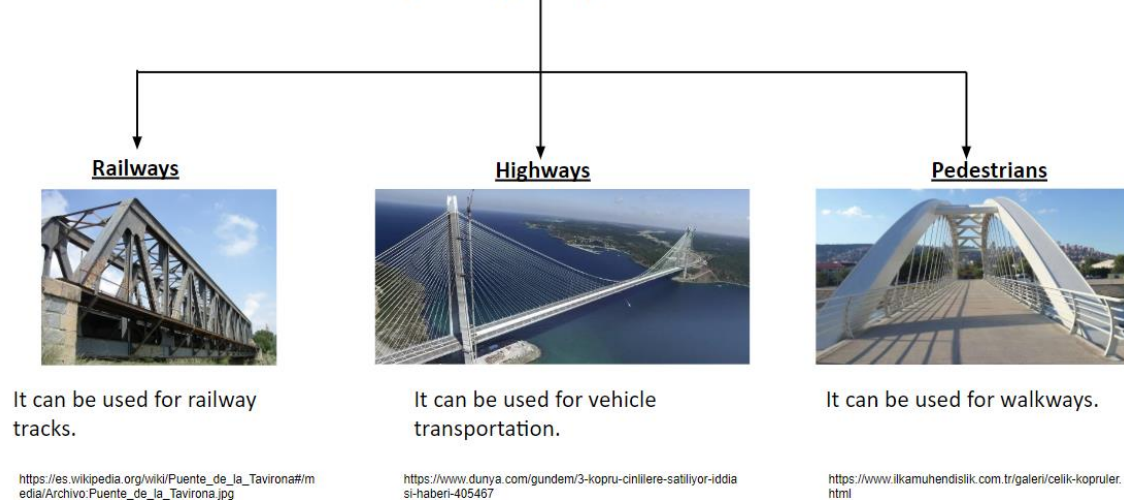
- Generally, the first bridges in forested areas were constructed by lengthening one or more wooden logs. Bridges are constructions built to carry road traffic or other moving loads to cross an obstacle or other structures. Required transitions; pedestrian road, highway, railway, canal, pipeline, etc., or a bridge is a way to cross a stream, river, or valley. They are the constructions that connect two separate sides and allow the traffic flow to pass over the top without interrupting another traffic flow. Bridges are essential constructions in modern road and rail transport systems.



Koyunbaba Bridge, Türkiye

<https://www.flickr.com/photos/sinandogan/4800161394>

## Bridges by Purpose of Use

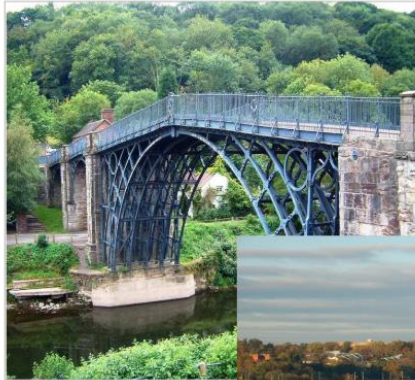


## Bridge Types 1 – Arch Bridges

The essence of arch bridges is that there is no bending except for moving loads. They only act under pressure and for this reason, they can be made of structural elements with weak tensile strength, such as stone cast steel concrete. Arch bridges made of brick, wood, aluminum and forged steel are also available today.

Arches are, in a sense, the simplest structure for a bridge, because if it is made of stone or rock, nothing is needed besides to create the arch form. If the stones are properly cut and the appropriate angles are caught, they will automatically work as abutments.

<https://modelsanstone.com/en/mimari-sanati>



<https://www.flickr.com/photos/ableman/283068075>

## Types of Bridges 2- Girder Bridges

The girder bridge is the most common type of bridge used in the world. In simple terms, even a piece of wood thrown over a 2-3 meter trench creates a bare girder bridge. Wood, concrete or steel can be used as material for girders.

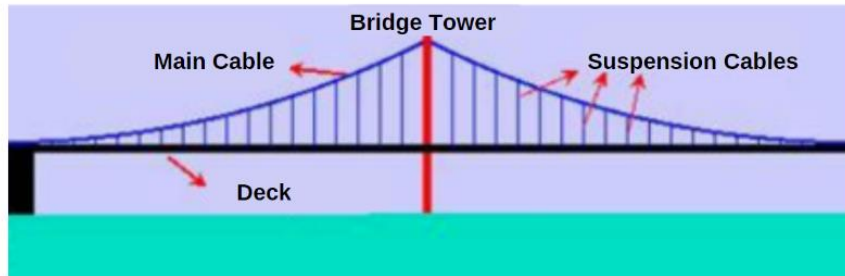


<https://www.erbakan.edu.tr/storage/files/department/insaatmuhendisligi/editor/DersSayfaları/IMG/img3.pdf>



## What is a Deck?

- The deck is the element that provides the distribution and is the first to receive the load. In bridges, the deck is the part of the building that carries the railway or the highway.



## Bridge Types 3 - Cable Tension Bridges

The bridge towers are usually made of reinforced concrete, and sometimes steel. During the construction of a large and long tensioned bridge, possible oscillations are a major problem until the two end beams meet in the middle.



<https://m.mobile01.com/topicdetail.php?f=204&t=131044>

## Examples of Bridge Types

### Girder Bridges



### Arched Bridges



### Cable Tension Bridges



### Suspension Bridges



## Bridge Spans

| Bridge Span | Values that the Bridge Span Can Take |
|-------------|--------------------------------------|
| Short       | minimum 6 m and maximum 40 m         |
| Middle      | min 40 m and max 125 m               |
| Long        | at least 125 m                       |

*m: represents meters.*

## Comparison of Bridge Types

| Bridge type            | Advantages  | Disadvantages   | Span  | Material Used   | Design Challenge   |
|------------------------|---|---|---|---|--|
| <b>Girder</b>          | <ul style="list-style-type: none"> <li>Strong and solid frame</li> <li>Works well with most applications</li> </ul>     | <ul style="list-style-type: none"> <li>Cannot be used on bridges with curves.</li> <li>Materials are expensive</li> </ul> | <ul style="list-style-type: none"> <li>Short</li> <li>Middle</li> </ul>               | <ul style="list-style-type: none"> <li>Iron</li> <li>Steel</li> <li>Any substance for the foundation</li> </ul> | <ul style="list-style-type: none"> <li>Low</li> </ul>    |
| <b>Arch</b>            | <ul style="list-style-type: none"> <li>Used for longer bridges with aesthetic curves</li> <li>Long-lasting</li> </ul>   | <ul style="list-style-type: none"> <li>Long span arches are difficult to construct</li> </ul>                             | <ul style="list-style-type: none"> <li>Short</li> <li>Middle</li> <li>Long</li> </ul> | <ul style="list-style-type: none"> <li>Stone</li> <li>Cast iron</li> <li>Wood</li> <li>Steel</li> </ul>         | <ul style="list-style-type: none"> <li>Low</li> </ul>    |
| <b>Suspension</b>      | <ul style="list-style-type: none"> <li>Aesthetic</li> <li>Light and flexible</li> </ul>                                 | <ul style="list-style-type: none"> <li>Unstable against the wind</li> <li>Materials are expensive</li> </ul>              | <ul style="list-style-type: none"> <li>Long</li> </ul>                                | <ul style="list-style-type: none"> <li>Steel rope</li> <li>Any substance for the foundation</li> </ul>          | <ul style="list-style-type: none"> <li>Middle</li> </ul> |
| <b>Cable Tensioned</b> | <ul style="list-style-type: none"> <li>Economic</li> <li>The construction process is fast</li> <li>Aesthetic</li> </ul> | <ul style="list-style-type: none"> <li>Durable cables should be used for long-lasting bridges.</li> </ul>                 | <ul style="list-style-type: none"> <li>Middle</li> </ul>                              | <ul style="list-style-type: none"> <li>Steel rope</li> <li>Any substance for the foundation</li> </ul>          | <ul style="list-style-type: none"> <li>High</li> </ul>   |

## Properties of Materials Used in Bridges

| Materials           | Against fire, earthquake, natural disasters | Combustion properties | Lifetime        | Harmful/Harmless                       | Span                | Cost   |
|---------------------|---|-----------------------|-----------------|--|---------------------|--------|
| Wood                | Flimsy                                      | Flammable             | Short-lived     | Harmless                               | Short               | Medium |
| Iron                | Resistant                                   | Non-flammable         | Long lasting    | There are harmful and harmless aspects | Medium and long     | High   |
| Concrete            | Resistant                                   | Non-flammable         | Long lasting    | There are harmful and harmless aspects | Very big            | High   |
| Steel               | Resistant                                   | Non-flammable         | Medium lifetime | There are harmful and harmless aspects | Long                | Low    |
| Stone               | Resistant                                   | Non-flammable         | Long lasting    | Harmless                               | Short, Medium, Long | Low    |
| Reinforced concrete | Medium durable                              | Non-flammable         | Short-lived     | Harmful                                | Short and medium    | Medium |