**ENGINEERING COMPANY OF CENTRAL AMERICA**

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NEWSLETTER

# Bridge Design

**INTRODUCTION**
Bridges have been and still are the umbilical cords of humankind's progress over the centuries and they have dramatically influenced history of humanity's conquest of nature's barriers – a river, a chasm, an estuary, a valley, and even the sea. From just a few meters wide to many kilometers long, bridges have the same common goal of serving the needs for better access, better transportation links, better trade between communities and in general terms improving the daily life of the people who use them (see fig. 1).

**BRIDGE MATERIALS**
Fundamental progress in the construction sector has always been linked to the application of new materials. In this sense, Paleolithic period (2'000' 000 – 10'000 BC) narrow tree trunk bridges have evolved into the use of cast iron in the eighteen- and nineteen-hundreds as well as the use of reinforced concrete in the first half of the 20th century. In the 1950s and 60s, composite fiber materials[1] experienced their first peak, driven by their low self-weight (approx. 25% less than steel), high strength, good resistance to corrosion and ageing, as well as low thermal conductivity and high sustainability[2].

As stated by many researchers, by looking at the history of construction, certain regularities can be recognized: new building materials are always used first in traditional structural forms (material substitution) before independent, material-adapted forms emerge. In this context when iron was used to replace the stone as a construction material for bridges, bridge geometry initially remained the same as the one used with the stone: the arch (see fig. 2).

The real economic advantage came to light when iron and later steel, discover its own nature and left the arch behind to discover the straight beams and a new world of long span applications started. Similar relations can be found between concrete and steel. In early applications concrete was used predominantly in linear structural elements associated with typical straight steel girders before material-adapted structural forms such as shells and slabs were introduced.

**BRIDGE ENGINEERING AND BRIDGE AESTHETICS**
When designing bridges, the civil engineer assumes the role of a generalist and specialized designer at the same time. In the early days of modern bridge construction, designing a bridge was more an art than a profession.
Today's bridge designers face increasing pressures regarding cost reduction lead to standardized solutions using the advantage of repetitive effects. For most projects the art of bridge engineering has developed into daily business ruled by low cost solutions even in detriment of aesthetic and environmental impact. This development has been fostered through population growth and the consequent need for finer transportation networks, the emergence and proliferation of individual and cargo transport during the past century, the need of bundling transport routes in order to lessen land use and, in many cases, by the lack of education of the local authorities responsible for bridge tendering and acquisition.
It is clear that bridges have to be designed according to a complex framework of rules and norms, implemented in order to grant structural safety, functionality, low maintenance costs and durability. However this approach alone often leads to bridge designs which are relatively poor from both an esthetic and environmental point of view. Since bridges become part of the personality of cities, local authorities should also give their contribution when tendering bridge projects on a turn key basis: Apart from focusing on costs and compliance with structural design norms alone, minimum requirements should be made regarding the esthetic characteristics of the structures in question and their integration into the existing environment, as shown in Fig. 3.

*Fig. 1. Pedestrian bridge built from Toni Rüttimann (Toni "El Suizo"). Driven by humanitarian motivation, Toni helps people in need around the world to build wonderful cable supported bridges. Up to date nearly 400 bridges with up to 270m span have been built in rural areas at very low costs using cables, tubes and plates spent from the oil and steel industry. With his noble actions the bridge builder movement led by Tony has repeatedly demonstrated that a few simple engineering techniques combined with a precise bridge management system are key ingredients to make a better world.*

*Fig.2 Southwark Bridge, London, 1819: Iron in the structural form of stone. The arches of the first iron bridges built approximately 200 years ago were constructed using traditional stone construction methods. In this case, curved iron blocks were used instead of stone, a technique that was used up until the development of the first steel frames.*

*Fig. 3: Abetxuko Bridge over Zadorra River, Vitoria, Spain. This exceptional bridge has been designed by Dr.-Ing. Juan Sobrino.*

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[1] Composite materials are basically GFRP (Glass Fiber Reinforced Polymer) and CFRP (Carbon Fiber Reinforced Polymer) With regards to sustainability, the fabrication of glass fibers and polyester requires only 25% the amount of energy required for that of steel. Even the use of petroleum as a base for the plastic matrix can be seen from a positive angle: When composite fibers are used in building applications, the inherent energy in the raw material is conserved for decades; when the material is recycled, the time frame extends easily to 100 years. This makes the use of composite materials one of the most sustainable uses of petroleum today.

**BASIC STUDIES**

Depending on the size and location of a specific bridge project, a number of basic studies may come necessary as important prerequisites (see Fig. 4), namely:

- Environmental impact study, Traffic Studies
- Seismicity, Geology, Seismic Hazard
- Topography, Hydrology, Hydraulic, Geotechnical Studies
- Geometrical Design (vertical and horizontal alignment definition)

In some cases, specific studies like seismic hazard studies and geophysical investigations may be omitted and replaced by data obtained through norms or other existing basic studies.

**STRUCTURAL DESIGN**

Although the variety of bridge construction known today is immense, one may differentiate between 6 different basic bridge types, as shown in fig. 5: Each bridge type presents its own specific advantages with respect to its location and use.

After reviewing and evaluating the specific site conditions derived from the basic studies, the structural bridge design commences with the evaluation of specific proposals for the structure type to be chosen. In common practice, such evaluation is performed in accordance with the following criteria:

- Cost minimization. This goes for construction costs as well as predicted maintenance and repair costs.
- Quality and safety. The designed structure has to fully comply with the corresponding project norms and specifications.
- Environmental impact. Negative effects on the environment, as well as on the surrounding landscape/infrastructure should be kept at minimum – whilst keeping adequate esthetics.

The evaluation process is often performed in the form of a selection matrix that gives each alternate a rating, based on the basic criteria that are satisfied. An overall rating is then calculated for each bridge type option and a final comparison made to determine the bridge type option that best satisfies all of the criteria and provides the best overall value to the project.

The structural design of a particular bridge itself, involves a number of different stages, as depicted schematically in figure 6. Based upon the geometrical requirements and design criteria, dimensions and spatial distribution of the elements of the chosen bridge type are defined. In a subsequent step, advanced, specialized tools are used in order to model the behavior of the structure to the different applied loads.

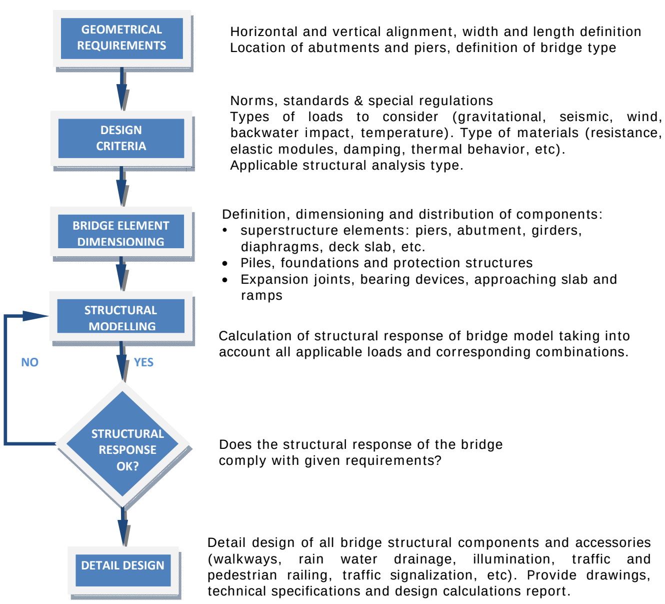


*Fig. 6. Simplified flowchart of the structural bridge design process.*
*In an iterative process, the structural response is calculated by the means of specialized models. The design is optimized until it complies with the applicable norms and project specifications.*

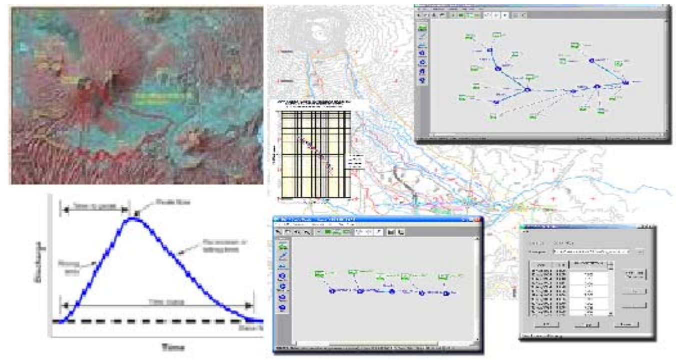

*Fig. 4: Examples of different graphical outputs resulting from a hydrological study performed by EC, on the eastern slope of the San Salvador Volcano. This study was performed within the frame of the design of San Salvador's 1st urban freeway, "Boulevard Diego de Holguín Tramo II". The scope of works included: Traffic, Geotechnical, Hydrological studies and Hydraulic, Geometrical, Concrete Pavements and Bridge Design.*

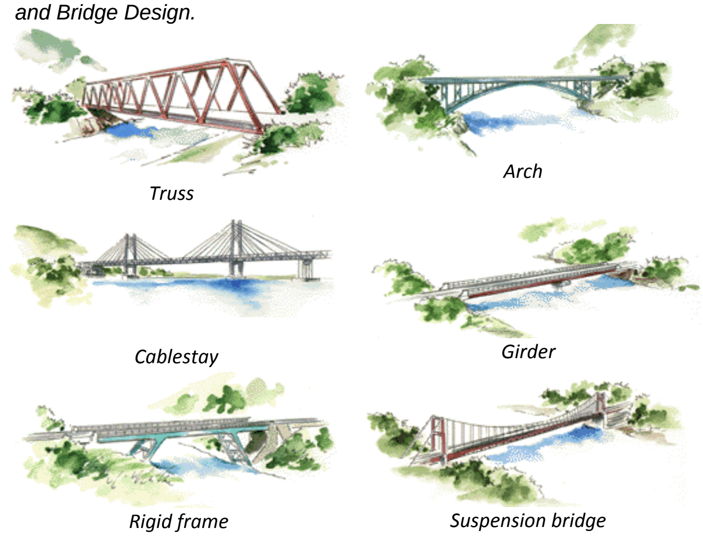


*Fig. 5: Schematic illustration of basic bridge types*

### EC SCOPE OF SERVICES IN BRIDGE DESIGN

Based on over 25 years of experience, EC together with it's partner network offer full bridge design services, including:

**Basic studies**: review geotechnical studies, hydrological reports, topography, geophysical investigations, inspection of existing structures, and definition of suitable structure type**.**

**Structural analysis and design:** Structural modeling of substructures and superstructures based on latest bridge design norms (e.g. AASHTO Standard Specifications for Highway Bridges). Structural Design of new structures, seismic retrofit and structural repair/modification of existing bridges.

**Construction assistance** from EC includes both on-site supervision services, as well as consultancy during the execution of the different construction processes.

**Construction drawings, specifications, calculation reports:** The issuance of these documents is coordinated via our web-based communication system.