BRIDGES IN VENICE. ARCHITECTURAL AND STRUCTURAL ENGINEERING ASPECTS

Introduction

With its hundreds of bridges built over the course of centuries, most of which are still in use today, Venice probably has more bridges than any other city without.

It is also a city where the culture of bridges and bridge-building is closely linked to the culture of the town.

From an engineering point of view, it is of particular interest to study certain aspects of Venetian Bridges, specifically the problems that Venetian artisans, artists, engineers and architects encountered over the centuries, and how they overcome these problems.

Soil conditions and foundation work

The subsoil of Venice is not uniform: it is in fact characterised by a certain variability of soil types and alternating strata. Generally speaking, however, the following formations can be identified: a first stratum of fill, 1-5 m thick, with poor load-bearing capabilities; a second stratum, 2-5 m thick, of clay-loam soil with a low-medium consistency, and a high degree of deformability; alternate strata of clay and loamy clay with a medium consistency; sandy silts and fine sands; in some areas, typically at a depth of between 5 and 8 m, there is a formation of over-consolidated loamy-sandy clay, with a good consistency, known as “Caranto”, in several areas, this “Caranto” is also found at greater depths.

Structural types and materials

There are two main types of bridge in Venice: arch bridges and girder bridges. Girder bridges generally have a horizontal arch vector, and therefore require longer access ramps than arch bridges, whose ramps are inclined from the keystone to the abutments; in addition, generally speaking, girder bridges need to have higher structural depth than.

Arch bridges are much more prevalent, as they successfully integrate the need for a continuous pedestrian pathway with the need to leave sufficient space underneath for boats to pass. Arches are designed according to various formal types: semi-circular, horseshoe, segmental, equilateral pointed and elliptical. Typological analysis reveals a strong prevalence of segmental arches, but only rare cases of low segmental arches, as is shown in the figure. These bridges are transpiring structures that transmit large horizontal forces to the foundations, which posed a not-inconsiderable technical problem given the poor quality of the superficial subsoil in Venice.

The “Ponte degli Scalzi”

The “Ponte degli Scalzi”, crosses the Canal Grande near the railway station, between the Chiesa degli Scalzi and the Chiesa di San Simeon Piccolo. The bridge was built, replacing a steel girder truss, between 1932 and 1934 to the design of Eugenio Miozzi, civil engineer, and is an outstanding example of formal elegance, architectural consistency and daring engineering. The bridge has a total length of 55 m, a span of 40.40m, a rise of 6.75m, and a rise-to-span ratio of 1.8; it is 7m wide, and the thickness of the arch varies from 80cm at the key-stone to 1.30m at the imposts. The slenderness ratio at the keystone is 1.50, a figure that would be high for an arch bridge built in reinforced concrete. And yet, the vault of the “Ponte degli Scalzi” is built entirely of stone! More precisely the material is “Pietra d’Istria”, the white, strong and compact limestone used in venetian buildings since 14th century. The construction system was described by its designer as the “compensatory systematic lesion” method, and consisted in the creation of three kinematic joints, which were open when the voussoirs were laid and gradually closed as the construction system was described by its designer as the “compensatory systematic lesion” method, and consisted in the creation of three kinematic joints, which were open when the voussoirs were laid and gradually closed as the formwork was removed. This resulted in a structure that was isostatic during the deformation phase as weight was transferred from the falsework to the actual arch, without causing any bending stresses during these phases. The bridge was completed in 29 months, and required for its foundations 3411 cubic metres of concrete and 225,900kg of steel reinforcements; it also required 321 cubic metres of Istria rock, 324 of which were used for the arch; the total construction cost was 2,550,000 Italian Lire, equivalent to around 4.7 million Euro today, that was a good result when considering the high cost of the valuable material used for the main structure. The bridge didn’t require special maintenance or monitoring in its 76 years life.

Conclusions

The problems associated with the presence of deformable soils, and thus the recurrent problem of countering thrusts and the horizontal yielding of the abutments, initially led to a preference, especially for the larger bridges across the Canal Grande, for isostatic beam structures: in wood for the Rialto and in steel for the Accademia and the Station. Subsequently, the arch bridge became prevalent, built using brick or, preferably, stone. Rise-to-span ratios were high, but always within 1.7, considering this value as a traditional limit for the venetian soil conditions; with gradually increasing slenderness ratios. And, as we have seen, these slenderness ratios were often the result of precise structural and construction solutions, designed to pursue those objectives of formal elegance that the bridges of Venice display to such a considerable extent.

References


Mario de Miranda, Marco Pogacnik, Luka Skansi*

Università IUAV Venezia. Unità di ricerca “Arte del costruire”