Structural Elements of Habitable Bridges

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Abstract. This article examines a building type having a long-span aboveground structure also known as a habitable bridge. Habitable bridges provide a useful solution for a number of transportation system limitations and social problems in the urban planning process. Contemporary cities, including Moscow, face problems originating from current structure and missing links in road networks. The missing links appear when an extended barrier such as: a river, a ravine, a highway and railroad track crosses the road. In such cases, habitable bridges serve as vehicle and pedestrian links across these barriers and connect residential, business, cultural and industrial city boroughs. They also offer other feature areas besides a transit function. In this study the author describes the idea of additional feature facilities and operating conditions for habitable bridges in big cities. An investor’s active engagement in the design and building process is key for a successful and productive outcome. In order to attract private investors it is necessary to offer useful commercial areas within the habitable bridge development. Increasing the bridge height to accommodate additional area is one of many ways to provide attractive incentives for investors. General criteria requirements are addressed through standardized construction solutions. One of the most suitable solutions to interconnect local interborough links is with a «short-span habitable bridge». This study addresses the structural components of the habitable bridge building type and its relationship to the road network as well as the surrounding city framework.

1. Introduction
At this time, Moscow agglomeration faces a number of challenges related to urban and suburban growth and development which includes improving links between the city and its suburbs. City traffic results from its historical structure and critical disconnects in the road network [1]. One of the most significant causes of breakdown in the city road network is due to a large amount of prolonged natural and artificial barriers including: rivers, ravines, high-ways and railroad tracks [2]. The prolonged barriers penetrating the city inhibit communication between neighborhoods, result in traffic jams and car over mileages [3] triggering environmental pollution and increase in emission of harmful substances into the atmosphere. City governments, urban planners, and architects are looking for solution of the above problems.

2. Background and status of the problem
Government programs “Transport strategy of the Russian Federation for the period until the year 2030” [4] and “Developing of Moscow transport system” [5] are aimed to improve transportation issues. These programs offer government funding for construction of highways and large capacity overpasses in an attempt to alleviate the issues at hand. Funding more effective solutions with local interborough links provides less incentive for the governmental budgetary policy because it lacks
immediate cost-effectiveness. This short sidedness manifests itself in Moscow’s land-zoning and road-planning projects [6].

Support and interest of private investors is required for construction of the local roadwork links. This funding strategy is successfully implemented at transport hub buildings in Moscow and the rest of the world [7]. The investors’ are enticed to invest into the transport hub projects due to its profit potential of the commercial components offered.

Another solution to transportation issues that could also provide city districts with useful spaces is a building that combines transit and social functions (figure 1). This type of building is called “habitable bridge” and it is a commonly used term. The habitable bridge is a type of a long-span, aboveground structure [8] containing transport and public space components that overcomes natural and artificial prolonged barriers. This type of building has a number of prototypes like horizontal skyscrapers, spatial cities and elevated bridge parks that were explored by Russian and foreign architects and scientists [9-12]: L. Lisitsky, Y. Friedman, A. Razgulova, E. Brooks, J. Genevie, A. Gonski. The key idea of all this researches is the necessity of applying aboveground city spaces. Pedestrian habitable bridge as a method of the aboveground developing was the main object of E.Pokka, N. Plotnikova, I. Symeonidou works [13-15]. Required transport function was introduced in habitable bridge in E. Kocheshkova, T. Zabalueva and A. Zakharov works [16].

![Habitable bridge construction funding principles](image)

**Figure 1.** Habitable bridge construction funding principles.

3. **Theoretical basis and practical significance of the habitable bridge concept**

Different design strategies can be applied to the habitable bridge depending on the width of the barrier to be crossed. Design type A is defined as a multi-level structure constructed of steel and concrete composite slabs. Design type B consists of alternating load bearing floors [17] and open-plan floors. Design type C represents a spatial beam that is made up from a number of multi-storey trusses with slabs leaned on its joints [16] (figure 2).

The height of the bearing construction increases proportional to the square of the span length. The slab height increase of more than 1.5 meters results in transition from design type A to design type B. The slab height of about 4-7 meters results in transition from design type B to design type C. Therefore, design type A is used to accommodate a 15-30 meter span between building supports. Design type B is used to accommodate a 30-50-meter span, and design type C is used to accommodate a span of 50 - 100 meters. Habitable bridges using design type A are classified as “short-span habitable bridges”; the ones using design type B are classified as “middle-span” and the ones using design type B are classified as “long-span”.

2
Figure 2. Habitable bridge constructions.
1 - steel and concrete composite slab; 2 – vertical support; 3 – load bearing floor; 4 – open-plan floor; 5 – suspension, 6 – multi-story truss

Short-span habitable bridges are best suited for local links especially for the links passing over railroad tracks.

In an effort to achieve cost effective design and construction, it is necessary to create standardized elements that fit into an existing road network system with the use of short-span habitable bridges.

A short-span habitable bridge consists of the following primary components (figure 3):
1) span-structure that includes vehicular and pedestrian circulation as well as additional space for other functions;
2) vertical supports to carry the load of the spanning structure;
3) access roads to the vehicular circulation;
4) vertical communication systems required for proper pedestrian use and all other functions at all building levels.

Major vertical structural elements incorporate communication systems required to run vertically throughout the building. This combination of systems is called vertical link blocks. The vertical link blocks in the habitable bridge development performs the following functions:
1) connection of all building elevations with each other and the landscape;
2) distribution of pedestrian circulation;
3) pedestrian circulation elevation to the span-structure;
4) operational supply for additional areas in the span-structure;
5) integration of interior engineering network system with the city engineering network system.

The combination of spaces in the vertical link blocks is directly related to the additional function of the habitable bridge, therefore particular types of blocks for each function type is recommended. Vertical elements such as elevators, stairs, escalators, support spaces, entrances lobbies, security rooms and lavatories are common components of vertical link blocks. In most cases, these blocks have an operational purpose used for space organization, import and export of people and services. The span-structure includes vehicular and pedestrian paths located on varied planes and extra-function areas. In the case of trade or exhibition use of the bridge its pedestrian transit ways should be integrated in the commercial areas. This manifests in the vertical link block structure.
Figure 3. Basic components of a habitable bridge.
1 – span-structure; 2 – vertical supports; 3 - access road; 4 – vertical communication systems

The researchers from Moscow State University of Civil Engineering Department of Architecture have already designed more than 40 habitable bridge projects. In depth analysis of numerous habitable bridge projects with varied programs has revealed a wide variety of extra-functions spaces. Extra-function space alternatives depend on the sanitary and hygiene characteristics of the environment, more specifically, the noise and vibrations above the railway, and the social demands of surrounding residential areas. High noise and vibration levels govern the duration of one’s stay in such buildings. Naturally, habitable bridge areas built over-railroads are recommended to be used for parking and storage purposes. When public and commercial programming is desired to be placed over elements that cause noise and vibration, construction and planning strategies could be used to mitigate unwanted side effects. Effective vibration protection may be achieved by reducing vibration level in the contributor (railway track) by special systems [18, 21]:
- under ballast mats;
- continuous rail bearing;
- elastic insertion pads for sleep boots;
- rail pads;
- sleeper pads;
- mass-spring system.

Noise isolation ways involve the use of special elements like floating floors and elastic ceiling hangers in the interior and insulation materials like stone wool. Planning methods involve organization of buffer zones in span-structure inner space between the extended barrier and habitable areas and using a gallery type of design with a gallery between the bridge carriageway and habitable areas.

Habitable bridges built above natural elements such as rivers and ravines are typically programmed for residential development, hotels, cultural centers and congress-halls.

Automobiles enter vehicular circulation areas by access roads. Access roads connect parts of the city road network to the habitable bridge vehicular area in both directions.
The design depends on the site relief, number of traffic lanes, relative position of linked roads and prolonged site barriers. Short-span habitable bridge connecting collector streets may contain one- or two-lanes vehicular roads and one- or two-way traffic. Connector roads running along a barrier can be positioned perpendicular, parallel, across or any hybrid of all types (in the case of a few couples of linked roads). In the case of perpendicular position, it is necessary to extend existing ways until they enter the bridge. One of the major purposes of the habitable bridge construction is to alleviate and prevent traffic jams. It is critical to accommodate proper access road turning radius in order to achieve the decrease of speed necessary to transition from vehicular city circulation onto the bridge.

Two types of access road configuration strategies are proposed relative to the ground elevation. One strategy is to build the road without the rise in elevation when the habitable bridge is situated over a prolonged barrier that is deep enough to encompass the required function (for example – railway traffic). The other access road strategy accommodates a rise in elevation and the habitable bridge is situated on a leveled site.

While with the first option it is clear that reconstructing of the road spans at the ends in order to connect them to the habitable bridge entrance is a viable solution, the second option is less clear on how to accommodate the rise in elevation to the bridge level. There are also three ways of accommodating rise in elevation via access roads: 1 - a spiral ramp, 2 - an elevator and, 3 - an overpass. Option 3 is the only method which provides the development of a straight and simple track to increase a traffic speed as much as possible. The cross section of the overpass depends on its support step. Overpass supports can be separate columns, arches, II-, Y- or V-shaped frames. The choice of support type affects the appearance of the habitable bridge and the type of supports has to be coordinated with the whole composition of the building.

The resulting space beneath the overpass is suitable for different social needs:
1) as an extra level ground open parking;
2) as an area for service station and carwash;
3) as an recreation spaces with commercial stalls;
4) to provide passage for long-length ground level objects

The availability of two-meter height space between the stalls or cars and the overpass bearing constructions is the main requirement of placing these objects below the overpass [19]. Therefore, the space beneath the overpass may be used for different purposes over the distance that meets this requirement.

5. Conclusion
The variety of compositions of particular components in a habitable bridge offers a sufficient number of habitable bridge versions to provide solution to urban-planning problems in different conditions. The wide range of additional functions makes such objects attractive for developers. This universal solution will be useful not only for large cities but for evolving medium-sized towns. The habitable bridges may become the first step in connecting city territories by continuous linear habitable systems [20].

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