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66
Design Practice in Russia

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66.1   Introduction

Bridge design and construction practice in former USSR, especially Russia, is not much known by foreign engineers. Many advanced structural theories and construction practices have been established. In view of the global economy, the opportunities to apply such advanced theories to practice became available with the collapse of the iron curtain.

In 1931, Franklin D. Roosevelt said, "There can be little doubt that in many ways the story of bridge building is the story of civilization. By it, we can readily measure a progress in each particular country." The development of bridge engineering is based on previous experiences and historical aspects. Certainly, the Russian experience in bridge engineering has it own specifics.
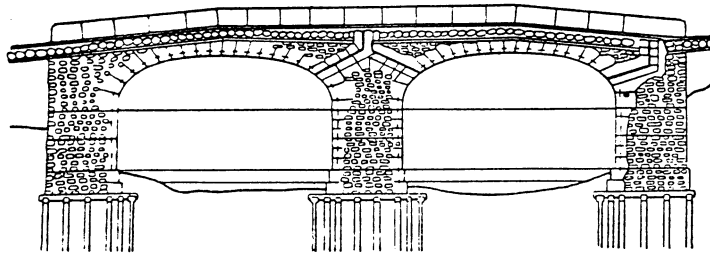
FIGURE 66.1 Typical masonry bridge (1786).

66.2 Historical Evolution

66.2.1 Masonry and Timber Bridges

The most widespread types of bridges in the old time were timber and masonry bridges. Because there were plenty of natural wood resources in ancient Russia, timber bridges were solely built up to the end of the 15th century.

For centuries masonry bridges (Figure 66.1) have been built on territories of such former republics of the USSR as Georgia and Armenia. From different sources it is known that the oldest masonry bridges in Armenia and Georgia were built in about the 4th to 6th centuries. One of the remaining old masonry bridges in Armenia is the Sanainsky Bridge over the River Debeda-chai built in 1234. The Red Bridge over the River Chram in Georgia was constructed in the 11th century. Probably the first masonry bridges built in Russia were in Moscow. The oldest constructed in 1516 was the Troitsky arch masonry bridge near the Troitsky Gate of the Kremlin. The largest masonry bridge over the Moskva River, named Bolshoi Kamenny, was designed by Yacobson and Kristler. The construction started in 1643 but after 2 years the construction was halted because of Kristler's death. Only in 1672 was this construction continued by an unknown Russian master and the bridge was mostly completed in 1689. Finally, the Russian Czar Peter I completed the construction of this bridge. Bolshoi Kamenny Bridge is a seven-span structure with total length of 140 m and width of 22 m [1]. This bridge was rebuilt twice (in 1857 and in 1939). In general, a masonry bridge cannot compete with the bridges of other materials, due to cost and duration of construction.

Ivan Kulibin (Russian mechanics engineer, 1735 to 1818) designed a timber arch bridge over the Neva River having a span of about 300 m, illustrating one of the attempts in searching for efficient structural form [2]. He tested a ¹⁄₁₀ scale model bridge to investigate the adequacy of members and found a large strength in the new structural system. However, for unknown reasons, the bridge was not built.

66.2.2 Iron and Steel Bridges

The extensive progress in bridge construction in the beginning of the 19th century was influenced by overall industrial development. A number of cast-iron arch bridges for roadway and railway traffic were built. At about the same time construction of steel suspension bridges was started in Petersburg. In 1824 the Panteleimonovsky Bridge over the Fontanka River having a span of about 40 m was built. In 1825 the pedestrian Potchtamsky Bridge over the Moika Bankovsky was built, and the Lion's and Egyptian Bridges over the Fontanka River having a span of 38.4 m were constructed in 1827.

The largest suspension bridges built in the 19th century were the chain suspension bridge over the Dnepr River in Kiev (Ukraine), with a total length 710 m including six spans (66.3 and 134.1 m) and
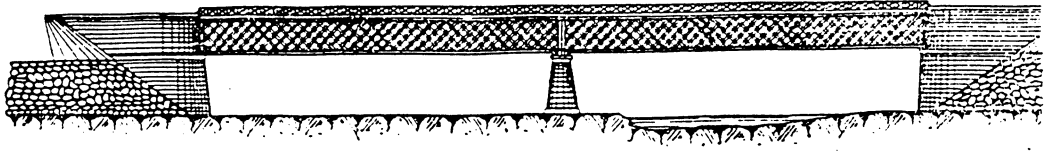
FIGURE 66.2 Bridge over the Luga River (1857).

approaches, constructed in 1853. In 1851 to 1853 two similar suspension bridges were constructed over the Velikaya River in Ostrov City with spans of 93.2 m. The development in suspension bridge systems was based on an invention of wire cables. In Russia, one of the first suspension bridges using wire cables was built in 1836 near the Brest-Litovsk fortress. This bridge crossed the River West Bug, having a span of about 89 m. However, suspension bridges of the first half of the 19th century, due to the lack of structural performance understanding, had inadequate stiffness in both vertical and horizontal directions. This appeared to be the main cause of a series of catastrophes with suspension bridges in different countries. Any occurrence of catastrophes in Russia was not noted. To reduce the flexibility of suspension bridges, at first timber and then steel stiffening trusses were applied. However, this innovation improved the performance only partly, and the development of beam bridges became inevitable in the second half of the 19th century.

The first I-beam bridge in Russia was the Semenovsky Bridge over the Fontanka River in Petersburg constructed in 1857 and the bridge over the Neman River in Kovno on the railway of Petersburg–Warsaw constructed in 1861. However, I-beams for large spans proved to be very heavy, and this dictated a wider application of truss systems.

The construction of the railway line in 1847 to 1851 between Petersburg and Moscow required a large number of bridges. Zhuravsky modified the structural system of timber truss implemented by Howe in 1840 to include continuous systems. These bridges over the Rivers Volga, Volhov, and some others had relatively large spans; e.g., the bridge over the Msta River had a 61.2 m span. This structural system (known in Russia as the Howe–Zhuravsky system) was further widely used for bridge construction up to the mid-20th century.

The steel truss bridges at first structurally repeated the types of timber bridges such as plank trusses or lattice trusses. A distinguished double-track railway bridge with deck truss system, designed by Kerbedz, was constructed in 1857 over the Luga River on the Petersburg–Warsaw railway line (Figure 66.2). The bridge consists of two continuous spans (each 55.3 m.). The P-shape cross sections were used for chord members, and angles for diagonals. Each track was carried by a separate superstructure which includes two planes of trusses spaced at 2.25 m. The other remarkable truss bridge built in 1861 was the Borodinsky Bridge over the Moskva River in Moscow, with span length of 42.7 m. The cornerstone of the 1860s was an introduction of a caisson foundation for bridge substructures.

Up to the 1880s, steel superstructures were fabricated of wrought steel. Cast-steel bridge superstructures appeared in Russia in 1883. And after the 1890s, wrought steel was no longer used for superstructures. In 1884, Belelubsky established the first standard designs of steel superstructures covering a span range from 54.87 to 109.25 m. For spans exceeding 87.78 m, polygonal trusses were designed. A typical superstructure having a 87.78-m span is shown in Figure 66.3. Developments in structural theory and technology advances in the steel industry expanded the capabilities of shop fabrication of steel structures and formed a basis for further simplification of truss systems and an increase of panel sizes. This improvement resulted in application of a triangular type of trusses. By the end of the 19th century, a tendency to transition from lattice truss to triangular truss was outlined, and Proskuryakov initiated using a riveted triangular truss system in bridge superstructures. The first riveted triangular truss bridge in Russia was constructed in 1887 on the Romny–Krmenchug railway line.
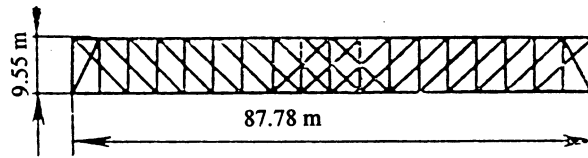
FIGURE 66.3   Standard truss superstructure.

Many beam bridges built in middle of the 19th century were of a continuous span type. Continuous bridge systems have economic advantages, but they are sensitive to pier settlement and have bigger movement due to temperature change. To take these aspects into account was a complicated task at that time. In order to transfer a continuous system to a statically determined cantilever system, hinges were arranged within spans. This was a new direction in bridge construction. The first cantilever steel railway bridge over the Sula River designed by Proskuryakov was built in 1888. The first steel cantilever highway bridge over the Dnepr River in Smolensk was constructed. The steel bridge of cantilever system over the Dnestr River, a combined railway and highway bridge, having a span of 102 m, was designed by Boguslavsky and built in 1894. In 1908, the steel bridge over the River Dnepr near Kichkas, carrying railway and highway traffic and with a record span of 190 m, was constructed. Development of new techniques for construction of deep foundations and an increase of live loads on bridges made the use of continuous systems more feasible compared with the other systems.

In the middle of the 19th century arch bridges were normally constructed of cast iron, but from the 1880s, steel arch bridges started to dominate the cast iron bridges. The first steel arch bridges were designed as fixed arches. Hinged arch bridges appeared later and became more widely used. The need to apply arches in plain areas led to the creation of depressed through-arch bridges.

66.3   Modern Development

The 20th century has been remarkable in the rapid spread of new materials (reinforced concrete, prestressed concrete, and high-strength steel), new structural forms (cable-stayed bridges), and new construction techniques (segmental construction) in bridge engineering. The steel depressed through arch truss railway bridge over the Moskva River built in 1904 is shown in Figure 66.4. To reduce a thrust, arches of cantilever system were used. For example, the Kirovsky Bridge over the Neva River having spans of 97 m was built in Petersburg in 1902. Building new railway lines required construction of many long, multispan bridges. In 1932, two distinguished arch steel bridges designed by Streletsky were constructed over the Old and New Dnepr River (Ukraine) having main spans of 224 m and 140 m, respectively (Figure 66.5).

The first reinforced concrete structures in Russian bridge construction practice were culverts at the Moscow–Kazan railway line (1892). In the early 20th century, the use of reinforced concrete was limited to small bridges having spans of up to 6 m. In 1903, the road ribbed arch bridge over the Kaslagach River was built (Figure 66.6). This bridge had a total length of 30.73 m and a length of arch span of 17 m. In 1904, the road bridge over the Kazarmen River was constructed. The bridge had a total length of 298.2 m and comprised 13 reinforced concrete arch spans of 21.3 m, having ribs of box section.

The existing transportation infrastructure of Russia is less developed compared with other European countries. The average density of railway and highway mileage is about five times less than that of the United States. For the past two decades, railway and highway construction activities have slowed down, but bridge design and construction have dramatically increased.

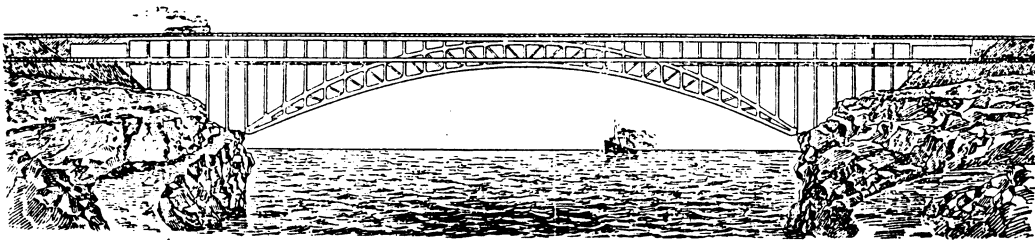**FIGURE 66.4** Steel depressed arch railway bridge over the Moskva River.

FIGURE 66.5 Steel arch bridge with a span of 224 m.

66.3.1 Standardization of Superstructures

An overview of the number and scale of bridges constructed in Russia shows that about 70% of railway bridges have a span length less than 33.6 m, and 80% of highway bridges have less than 42 m. Medium and small bridges are, therefore, predominant in construction practice and standard structural solutions have been developed and used efficiently, using standardized design features for modern bridges.

The current existing standardization covers the design of superstructures for certain bridge types. For railway bridges, standard designs are applicable to spans from 69 to 132.0 m. These are reinforced concrete superstructures of slab, stringer types, box girder; steel superstructures of slab, stringer types; composite superstructures; steel superstructures of through plate girder, deck truss, through-truss types. For highway bridges, standard designs cover the span range from 12 to 147 m. These are reinforced concrete superstructures of voided slab, stringer, channel (P-shaped) girder, solid web girder, box girder types, composite superstructures of steel web girder types, and steel super-structures of web and box girder types.

Modern highway bridges having spans up to 33 m and railway bridges up to 27.6 m are normally constructed with precast concrete simple beams. For highway bridges, continuous superstructures of solid web girder types of precast concrete segments are normally used for spans of 42 and 63 m, and box girder type of precast box segments are used for spans of 63 and 84 m. The weight of
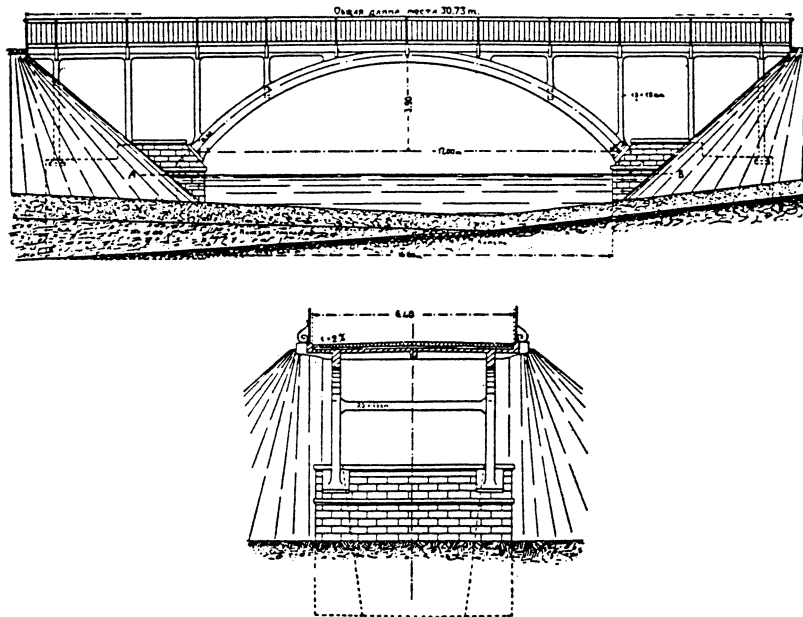
FIGURE 66.6   Reinforced concrete ribbed arch bridge over the Kashlagash River (1903).

precast segments does not exceed 60 tons and meets the requirements of railway and highway transportation clearances. For railway bridges, steel box superstructures of full span (33.6 m) shop-fabricated segments have become the most widespread in current practice.

The present situation in Russia is characterized by a relative increase in a scale of application of steel superstructures for bridges. After the 1990s, a large number of highway steel bridges were constructed. Their construction was primarily based on modularization of superstructure elements: shop-fabricated segments having a length of up to 21 m. Many of them were built in the city of Moscow, and on and over the Moscow Ring Road, as well as the bridges over the Oka River in Nizhni Novgorod, over the Belaya River in the Ufa city, and many others. A number of steel and composite highway bridges having spans ranging from 60 to 150 m are currently under design or construction. In construction of bridges over the Moskva, Dnepr, Oka, Volga, Irtish, Ob Rivers, on the peripheral highway around Ankara (Turkey), on the Moscow Ring Road, and some others, continuous steel superstructures of web and box girder types permanent structure depth are typically used. The superstructures are assembled with modularized, shop-fabricated elements, which are welded at the shop or construction site to form a complete cross section configuration. Erection is normally accomplished by incremental launching or cantilever segmental construction methods.

The extensive use of steel bridges in Russia is based on optimum structural solutions, which account for interaction of fabrication technology and erection techniques. The efficiency is proved by high-quality welded connections, which allow erection of large prefabricated segments, and a reduction in quantity of works and in the construction period. A low maintenance cost that can be predicted with sufficient accuracy is also an advantage, while superstructures of prestressed reinforced concrete in some cases require essential and frequently unpredictable expenses to ensure their capacity and durability.

66.3.2 Features of Substructure

Construction of bridge piers in Russia was mainly oriented on the use of precast concrete segments in combination with cast-in-place concrete. The usual practice is to construct piers with columns

of uniform rectangular or circular sections fixed at the bottom of the foundations. For highway bridges with spans up to 33 m full-height precast rectangular columns of 50×80 cm are of standard design. For longer-span bridges, the use of precast contour segments forming an outer shape of piers and cast-in-place methods has become more widespread.

A typical practice is use of driven precast concrete piles for the pile foundation. Standard types of precast concrete piles are of square section 0.35×0.35, 0.40×0.40, 0.45×0.45 m and of circular hollow section of 0.60 m diameter. Also, in the last two decades, CIDH (cast-in-place drilled holes) piles of 0.80 to 1.7 m in diameter have been widely used for foundations.

An increasing tendency is to use pile shafts especially in urban areas, when superstructures are borne directly by piles extended above the ground level (as columns). The efficiency was reached by implementing piles of square sections 35×35, 40×40 cm, and of circular Section 80 cm in diameter. Bored and cast-in-place piles of large diameter ranging between 1.6 to 3.0 m drilled to a depth of up to 50 m and steel casings are widely employed in bridge foundations. In foundations for bridges over the rivers and reservoirs, bored piles using a nonwithdrawable steel casing within the zone of change in water level and scour depth are normally used. These foundation types were applied for construction of bridges over the Oka River on the peripheral road around Nizhni Novgorod, over the Volga River in Kineshma City, over the Ob River in Barnaul City, over the Volga River in Ulyanovsk City, and some others.

Open abutments are most commonly used for highway bridges. Typical shapes are bank seats, bank seats on piles, and buried skeleton (spill-through). Wall abutments and bank seat on piles are the types of substructure mainly used for railroad bridges. Wingwalls are typically constructed back from the abutment structure and parallel to the road.

66.4   Design Theory and Methods

66.4.1   Design Codes and Specifications

The Russian Bridge Code SNIP 2.05.03-84 [5] was first published in 1984, amended in 1991, and reissued in 1996. In Russia the new system of construction codes was adopted in 1995. In accordance with this system the bridge design must satisfy the requirements of the bridge code, local codes, and industry standards. The Standards introduce new requirements resolving inconsistencies found in the bridge code. The bridge code covers design of new and the rehabilitation of existing bridges and culverts for highways, railways, tramways, metro lines, and combined highway–railway bridges. The requirements specified are for the location of the structures in all climatic conditions in the former USSR, and for seismic regions of magnitude up to 9 on the Richter scale. The bridge code has seven main sections: (1) general provisions, (2) loads, (3) concrete and reinforced concrete structures, (4) steel structures, (5) composite structures, (6) timber structures, and (7) foundations.

In 1995, the Moscow City Department of Transportation developed and adapted "Additional Requirements for Design and Construction of Bridges and Overpasses on the Moscow Ring Highway" to supplement the bridge code for design of the highway widening and rehabilitation of the 50 bridge structures on the Moscow Ring Highway. The live load is increased by 27% in the "Additional Requirements." In 1998 the Moscow City Department issued the draft standard TSN 32 "Regional Building Norms for Design of Town Bridge Structures in Moscow" [6] on the basis of the "Additional Requirements." The new standard specifies an increased live load and abnormal loading and reflects the necessity to improve the reliability and durability of bridge structures. The final TSN 32 was issued in 1998.

66.4.2   Design Concepts and Philosophy

In the former Soviet Union, the ultimate strength design method (strength method) was adopted for design of bridges and culverts in 1962. Three limit states — (1) the strength at ultimate load,

(2) deformation at service load, and (3) cracks width at service load — were specified in the bridge design standard, a predecessor of the current bridge code. Later, the limit states 2 and 3 were combined in one group. The State Standard: GOST 27751-88 "Reliability of Constructions and Foundations" [4] specifies two limit states: strength and serviceability. The first limit state is related to the structural failure such as loss of stability of the structure or its parts, structural collapse of any character (ductile, brittle, fatigue) and development of the mechanism in a structural system due to material yielding or shear at connections. The second limit is related to the cracking (crack width), deflections of the structure and foundations, and vibration of the structure.

The main principles for design of bridges are specified in the Building Codes and Regulations — "Bridges and Culverts" SNIP 2.05.03-84 [5]. The ultimate strength is obtained from specified material strengths (e.g., the concrete at maximum strength and usually the steel yielding). In general, bridge structures should satisfy ultimate strength limit in the following format:

$$\gamma_d S_d + \gamma_l (1+\mu) S_l \eta \le F\left(m_1, m_2, \gamma_n, \gamma_m, R_n, A\right) \tag{66.1}$$

where S_d and S_l are force effects due to dead load and live load, respectively; γ_d and γ_l are overload coefficients; μ is dynamic factor; η is load combination factor; F is function determining limit state of structure; m_1 is general working condition factor accounting for possible deviations of constructed structure from design dimensions and geometrical form; m_2 is coefficient characterizing uncertainties of structure behavior under load and inaccuracy of calculations; γ_n is coefficient of material homogeneity; γ_m is working condition factor of material; R_n is nominal resistance of material; A is geometric characteristic of structure element.

The serviceability limit state requirement is

$$f \le \Delta \tag{66.2}$$

where f is design deformation or displacement and Δ is ultimate allowable deformation or displacement.

The analysis of bridge superstructure is normally implemented using three-dimensional analysis models. Simplified two-dimensional models considering interaction between the elements are also used.

66.4.3 Concrete Structure Design

Concrete structures are designed for both limit states. Load effects of statically indeterminate concrete bridge structures are usually obtained with consideration for inelastic deformation and cracking in concrete. A proper consideration is given to redistribution of effects due to creep and shrinkage of concrete, forces adjustment (if any), cracking, and prestressing which are applied using coefficients of reliability for loads equal to 1.1 or 0.9.

The analyses to the strength limit state include calculations for strength and stability at the conditions of operation, prestressing, transportation, storing, and erection. The fatigue analysis of bridge structures is made for operation conditions.

The analyses to the serviceability limit state comprise calculations for the same conditions as indicated above for the strength limit state. The bridge code stipulates five categories of requirements to crack resistance: no cracks; allowing a small probability of crack formation (width opening up to 0.015 mm) due to live-load action on condition that closing cracks perpendicular to longitudinal axis of element under the dead load is assured; allowing the opening of cracks after passing of live load over the bridge within the limitations of crack width opening 0.15, 0.20, 0.30 mm, respectively.

The bridge code also specifies that the ultimate elastic deflections of superstructures are not to exceed, for railroad bridges, $L/600$ and, for highway bridges, $L/400$. The new standard TSN 32 provides a more strict limit of $L/600$ to the deflections of highway bridges in Moscow City.

66.4.4 Steel Structure Design

Steel members are analyzed for both groups of limit states. Load effects in elements of steel bridge structures are determined usually using elastic small deformation theory. Geometric nonlinearity is required to be accounted for in the calculation of systems in which such an account causes a change in effects and displacements more than 5%. The strength limit states for steel members are limited to member strength, fatigue, general stability, and local buckling. The calculations for fatigue are obligatory for railroad and highway bridges.

For steel superstructures in calculations for strength and stability to the strength limit state the code requires consideration of physical nonlinearity in the elastoplastic stage. Maximum residual tensile strain is assumed as 0.0006, and shear strain is equal to 0.00105.

The net sections are used for strength design of high-strength bolt (friction) connections and the gross sections for fatigue, stability, and stiffness design. A development of limited plastic deformations of steel is allowed for flexural members in the strength limit state. The principles for design of steel bridges with consideration for plastic deformations are reviewed in a monograph [9]. Stability design checks include the global flexure and torsion buckling as well as flange and web local buckling.

A composite bridge superstructure is normally based on a hypothesis of plane sections. Elastic deformations are considered in calculations of effects that occur in elements of statically indeterminate systems as well as in calculations of strength and stability, fatigue, crack control, and ordinates of camber.

66.4.5 Stability Design

Piers and superstructures of bridges are required to be checked for stability with respect to overturning and sliding under the action of load combinations. The sliding stability is checked with reference to a horizontal plane. The working condition factors of more than unity should also be applied for overturning and driving and less than unity for resisting forces.

66.4.6 Temporary Structures

The current design criteria for temporary structures used for bridge construction are set forth in the Guideline BSN (Department Building Norms) 136-78 [10]. This departmental standard was developed mainly as an addition to the bridge code and also some other codes related to bridge construction. The BSN 136-78 is a single volume first published in 1978 and amended in 1984. These guidelines cover the design of various types of temporary structures (sheet piling, cofferdams, temporary piers, falsework, etc.) and devices required for construction of permanent bridge structures. It specifies loads and overload coefficients, working condition factors to be used in the design, and requirements for design of concrete and reinforced concrete, steel, and timber temporary structures. Also, it provides special requirements for devices and units of general purpose, construction of foundations, forms of cast-in-place structures, and erection of steel and composite superstructures.

The temporary structures are designed to the two limit states similar to the principles established for permanent bridge structures. Meanwhile, the overload coefficients and working condition factors have a lower value compared to that of permanent structures. The recent study has shown that the Guideline BSN 136-78 requires revision, and therefore initial recommendations to improve the specified requirements and some other aspects have been reviewed in Reference [11].

The BSN 136-78 specifies a 10-year frequency flood. Also on the basis of technical-economical justification up to 2-year return period may be taken in the design, but in this case special measures for high-water discharge and passing of ice are required. The methods of providing technical hydrologic justification for reliable functioning of temporary structures are reviewed in the Guideline [12]. To widen the existing structures, the range of the design flood return period for temporary structures in the direction of lower and higher probabilities of exceedance is also recommended [12].

66.5 Inspection and Test Techniques

The techniques discussed herein reflect current requirements set forth in SNIP 3.06.07-86, the rules of inspection and testing for bridges and culverts [13]. This standard covers inspection and test procedures of constructed (new) or rehabilitated (old) bridges. Also, this standard is applicable for inspection and tests of structures currently under operation or for bridges designed for special loads such as pipelines, canals, and others. Inspection and testing of bridges are implemented to determine conditions and to investigate the behavior of structures. These works are implemented by special test organizations and contractor or operation agencies.

All newly constructed bridges are to be inspected before opening to traffic. The main intention of inspection is to verify that a bridge meets the design requirements and the requirements on quality of works specified by SNIP 3.06.04-91 [14]. Inspection is carried out by means of technical check up, control measurements, and instrumentation of bridge structural parts. If so required, inspection may additionally comprise nondestructive tests, laboratory tests, and setting up long-term instrumentation, etc. Results obtained during inspection are then compared to allowable tolerances for fabrication and erection specified in SNIP 3.06.04-91. If tolerances or other standard requirements are breached, the influence of these noted deviations on bridge load-carrying capacity and the service state are estimated.

Prior to structural testing, various details should be precisely defined on the basis of inspection results. Load tests require elaborate safety procedures to protect both the structure and human life. Maximum load, taking into account the design criteria and existing structural deviations, needs to be established. The position of structure (before testing is started) for future identification of changes resulting from load tests needs to be recorded (marked up). For the purpose of dynamic load tests, conditions of load passing over the bridge are evaluated.

66.5.1 Static Load Tests

During static load testing, displacements and deformations of the structure and its parts, stresses in typical sections of elements, local deformations (crack opening, displacements at connections, etc.) are measured. Moreover, depending on the type of structure, field conditions, and the testing purpose, measurements of angle strain and load effects in stays or struts may be executed.

For static load tests a bridge is loaded by locomotives, rolling stock of railways, metro or tramway trains, trucks as live loads. In cases where separate bridge elements are tested or the stiffness of the structure is determined, jacks, winches, or other individual loads may be needed. Load effects in members obtained from tests should not exceed the effects of live loads considered in the design accounting for an overload factor of unit and the value of dynamic factor taken in the design. At the same time, load effects in members obtained from the test are not to be less than 70% of that due to design live loading. Weight characteristics of transportation units used for tests should be measured with an accuracy of at least 5%. When testing railroad, metro, tramway bridges, or bridges for heavy trucks, load effects in a member normally should not be less than those due to the heaviest live loads passing over a given bridge.

Quantities of static load tests depend on bridge length and complexity of structures. Super-structures of longer span are usually tested in detail. In multispan bridges having similar equal spans, only one superstructure is tested in detail; other superstructures are tested on the basis of a reduced program, and thus only deflections are measured.

During testing, live loads are positioned on deck in such a manner that maximum load effects (within the limits outlined above) occur in a member tested. Time for test load carrying at each position is to be determined by a stabilization of readings at measuring devices. Observed deformation increments within a period of 5 min should not exceed 5%. In order to improve the accuracy of

measurements, time of loading, unloading, and taking readings is to be minimized as much as possible. Residual deformations in the structure are to be determined on the basis of the first test loading results. Loading of structures by test load should normally be repeated. The number of repeated loading is established considering the results that are obtained from the first loading.

66.5.2 Dynamic Load Tests

Dynamic load tests are performed in order to evaluate the dynamic influence (impact factor) of actual moving vehicles and to determine the main dynamic characteristics of the structure (free oscillation frequency and oscillation form, dynamic stiffness, and characteristics of damping oscillation). During dynamic load testing, overall structure displacements and deformations (e.g., midspan deflections, displacements of superstructure end installed over movable bearings), as well as, in special cases, displacements and stresses in individual members of the structure are measured.

The heavy vehicles that may really pass over the bridge are to be used in dynamic load tests to determine dynamic characteristics of structures and moving impact. Vibrating, wind, and other loads may be used for dynamic tests. To investigate oscillations excited by moving vehicles, the trucks are required to pass over the bridge at different speeds, starting from a speed of 10 to 15 km/h. This allows us to determine the behavior of the structure within a range of typical speeds. It is recommended to conduct at least 10 heats of trucks at various speeds and repeat those heats, when increased dynamic impact is noted. In some cases when motorway bridges are tested, to increase the influence of moving vehicles (e.g., to ascertain dynamic characteristics of the structure), a special measure may be applied. This measure is to imitate the deck surface roughness e.g., by laying planks (e.g., 4 cm thick) perpendicular to the roadway spaced at the same distance as the distance between the truck wheels.

When testing pedestrian bridges, excitation of structure free oscillations is made by throwing down a load or by a single pedestrian or a group of pedestrians walking or running over bridges. Throwing down a load (e.g., castings having a weight of 0.3 to 2 t) creates the impact load on a roadway surface typically from 0.5 to 2.0 m height. The location of test load application should coincide with the section where maximum deflections have occurred (midspan, cantilever end). To protect the roadway surface a sand layer or protective decking is placed. The load is dropped down several times and each time the height is adjusted. The results of these tests give diagrams of free oscillations of superstructures. Load effects in structural members during the test execution should not exceed those calculated in the design as stipulated in the section above.

66.5.3 Running in of Bridge under Load

To reveal an adequate behavior of structure under the heaviest operational loads, running in of bridges is conducted. Running in of railroad and metro bridges is implemented under heavy trains, the bridges designed for AB highway loading run-in by heavy trailers. Visual observations of structure behavior under load are performed. Also, midspan deflection may be measured by simple means such as leveling. A number of at least 12 load passes (shuttle-type) with different speeds are recommended in the running procedures of railroad and metro bridges. The first two or three passes are performed at a low speed of 5 to 10 km/h; if deflections measurements are required, the trains are stopped. Positioning trailers over marginal lane having 10 m spacing between the back and front wheels of adjacent units is recommended in running in bridges designed for AB highway loading of two or more lanes. It is recommended that single trailers pass over the free lane at a speed of 10 to 40 km/h, and a number of passes are normally taken, at least five. When visual observations are completed, trailers are moved to another marginal lane and single trailers pass over the lane, which is set free. For running in of single-lane bridges, the passes of single trailers only are used.

FIGURE 66.7   Typical through-truss bridge of 44 m span on the Baikal-Amour Railway Bridge Line.

66.6 Steel and Composite Bridges

In recent decades, there has been further development in design and construction of steel bridges in Russia. New systems provide a higher level of standardization and reduce construction cost.

66.6.1 Superstructures for Railway Bridges

Most railroad bridges are steel composite bridges with single-track superstructure. Standard superstructures [15] are applicable to spans from 18.2 to 154 m (steel girder spans 18.2 to 33.6 m; composite girder spans 18.2 to 55 m; deck truss spans 44 to 66 m; and through-truss 33 to 154 m). Figures 66.7 and 66.8 show typical railroad bridges. Steel box girders as shown in Figure 66.9 have a span of 33.6 m. Similar box girders can be assembled by connecting two prefabricated units. These units are shop-welded and field-bolted with high-strength bolts of friction type. More details are given in References [3] and [15]. For truss systems, the height of trusses is from 8.5 to 24 m with panels of 5.5 and 11 m. Two types of bridge deck — ballasted deck with roadbed of reinforced concrete or corrosion-resistant steel and ballastless deck with track over wooden ties or reinforced concrete slabs — are usually used. For longer than 154 m or double-track bridge, special design is required.

66.6.2 Superstructures for Highway Bridges

Standard steel superstructures covering spans from 42 to 147 m are based on modularization of elements: 10.5 m length box segment, 21 m double-T segment, and 10.5 m orthotropic deck segment. Typical standard cross sections are shown in Figure 66.10. Main technological features of shop production of steel bridge structures have been maintained and refined. Automatic double arc-welding machines are used in the 90% shop fabrication.

66.6.3 Construction Techniques

Steel and composite superstructures for railway bridges are usually erected by cantilever cranes (Figure 66.11) having a capacity up to 130 tons and boom cranes with a larger capacity. The superstructures of 55-m-span bridges may be erected by incremental launching method using a

FIGURE 66.8 Deck girder composite bridge of 55 m span over the Mulmuta River (Siberia).

FIGURE 66.9 Steel box superstructure of 33.6 m span for railway bridges.

nose. When the cantilever crane is applied to erection of the superstructure of 55 m span, a temporary pier is required. For truss superstructures, cantilever and semicantilever erection methods are widely implemented. Figure 66.12 shows the cantilever erection of bridge over the Lena River (span of 110 + 132 + 110 m) using derrick cranes.

For highway bridges, the incremental launching method has been the main erection method for plate girder and box girder bridges since 1970, although this method has been known in Russia for a long time. Cantilever and semicantilever methods are also used for girder bridges. Floating-in is an effective method to erect superstructures over waterways when a large quantity of assembled superstructure segments are required. The application of standard pontoons simplified the assembly of the erection floating system. Equipping of floating temporary piers by an air leveling system and other special equipment made this erection method more reliable and technological.

66.6.4 Typical Girder Bridges

Pavelesky Railroad Overhead

Design of overpasses in Moscow was a really challenge to engineers. It requires low construction depth and minimum interruption of traffic flow. Figure 66.13 shows the Pavelesky Overhead built
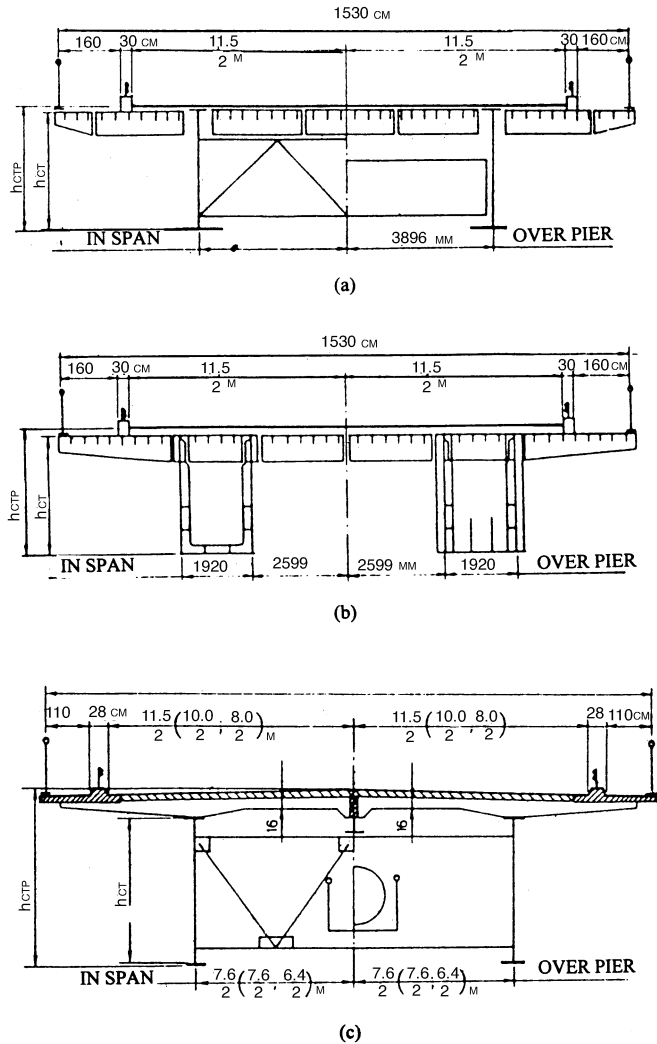
FIGURE 66.10 Typical highway superstructure cross sections. (a) Steel plate sirder; (b) box girder; (c) composite girder.

in 1996 over the widened Moscow Ring Road. The bridge has a horizontal curve of $R = 800$ m and carries a triple-track line. The steel superstructure (Figure 66.14) was designed of low construction depth to meet the specified 5.5 m highway clearance and to maintain the existing track level. This new four-spans (11 + 30 + 30 + 11 m) skewed structure was designed as simple steel double-T girders with a depth of 1.75 m. The orthotropic plate deck of a thickness of 20 mm with inverted T-ribs was used. An innovation of this bridge is the combination of a cross beam (on which longitudinal ribs of orthotropic deck are borne) and a vertical stiffener of the main girder connected to the bottom flange, thus forming a diaphragm spaced at 3 m. A deck cover sheet in contact with ballast was protected by metallized varnish coating.

Moskva River Bridge

Figure 66.15 shows the Moskva River Bridge in the Moscow region, built in 1983. The superstructure is a continuous three-span (51.2 + 96 + 51.2 m) twin box girders (depth of 2.53 m) with orthotropic deck. The bridge carries two lanes of traffic in each direction and sidewalks of 3 m. In transverse
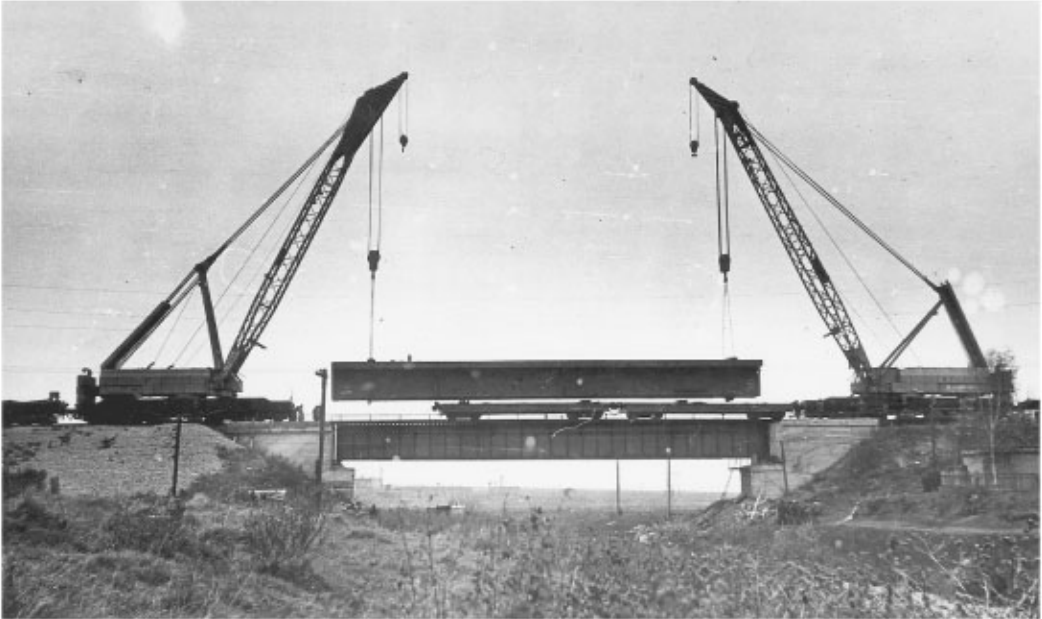
FIGURE 66.11 Erection of steel box superstructure of 33.6 m by boom cranes.

FIGURE 66.12 Cantilever erection of typical truss bridge using derrick cranes.

FIGURE 66.13 Paveletsky Railroad Overhead.
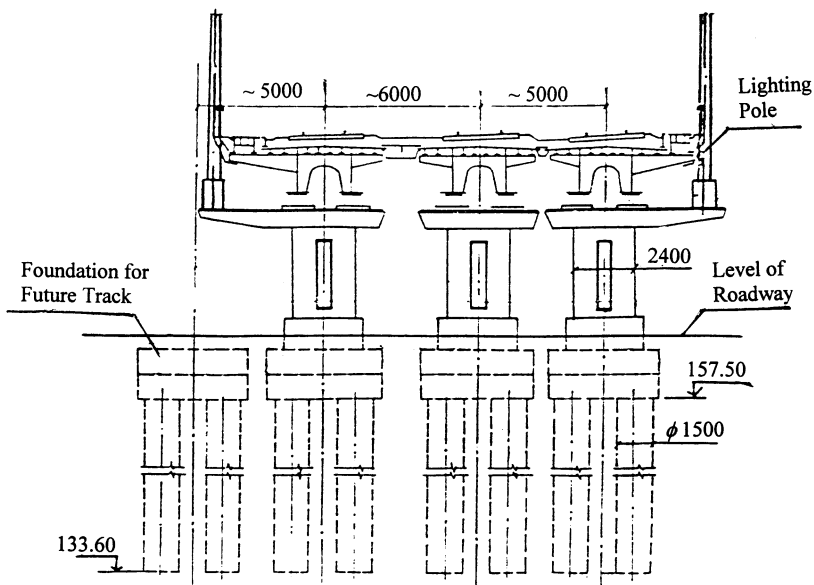
FIGURE 66.14 Typical cross-section of Paveletsky Railroad Overhead (all dimensions in mm).

direction, boxes are braced, connected by cross frames at 9 m. Piers are of reinforced concrete Y-shaped frames. Foundation piles are 40×40 cm section and driven to a depth of 16 m. The box girders were launched using temporary piers (Figure 66.16) from the right bank of the Moskva River. Four sliding devices were installed of each pier. The speed of launching reached 2.7 m/h.

Oka River Bridge

Oka River Bridge, near Nizhny Novgorod City, consisting of twin box section (Figure 66.17) formed with two L-shaped elements with orthotropic deck was open to traffic in 1993. A steel bridge of 988 m length is over the Oka River with a span arrangement of $2 \times 85 + 5 \times 126 + 2 \times 84$ m.

FIGURE 66.15   Moskva River Bridge in Krilatskoe.

FIGURE 66.16   Superstructure launching for Moskva River Bridge in Krilatskoe.
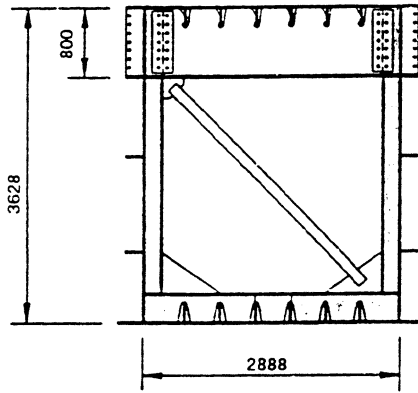
FIGURE 66.17 Cross section of main box girder formed of two L-shaped elements (all dimensions in mm).
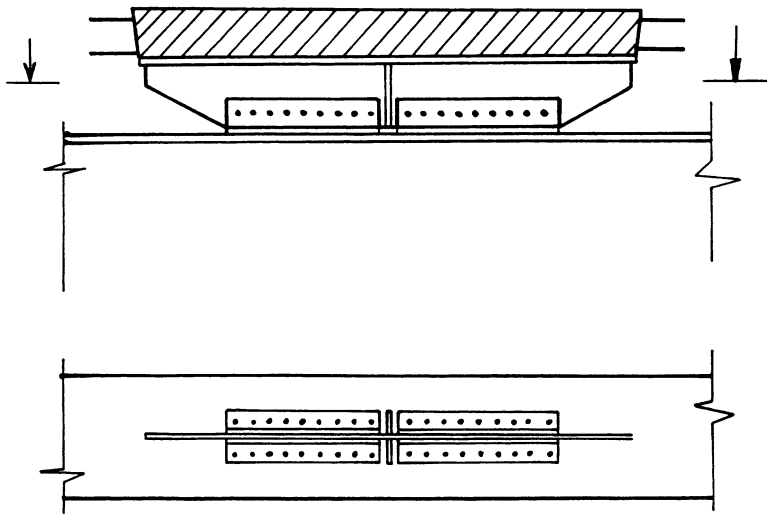
FIGURE 66.18 Connection details of precast reinforced concrete deck and steel girder.

Ural River Bridge

The Ural River Bridge near Uralsk City was completed in 1998. This five-span (84 + 3 × 105 + 84 m) continuous composite girder bridge (depth of 3.6 m) on a gradient of 2.6 m carries a single lane of highway with overall width of 14.8 m. Precast concrete deck segments are connected with steel girders by high-strength friction bolts (Figure 66.18). Connection details are presented in Reference [3].

Chusovaya River (Perm-Beresniki) Highway Bridge

The Chusovaya River Bridges, with a length of 1504 m and on convex vertical curves in radius of 8000 and 25,000 m was completed in 1997. The superstructure comprises two continuous steel composite girders (4 × 84 + 84 + 126 + 5 × 147 + 126 + 84 m). One main problem of bridge construction is the construction of pier foundations within the river under complex geologic and hydrologic conditions. All river piers were constructed under protection of sheet pilling with the use of scows. Piers were constructed using floating cranes. The superstructure segments having lengths of 94.8, 84, and 99.7 m were assembled on the right bank, and then slipped to the river and placed over the floating pier.
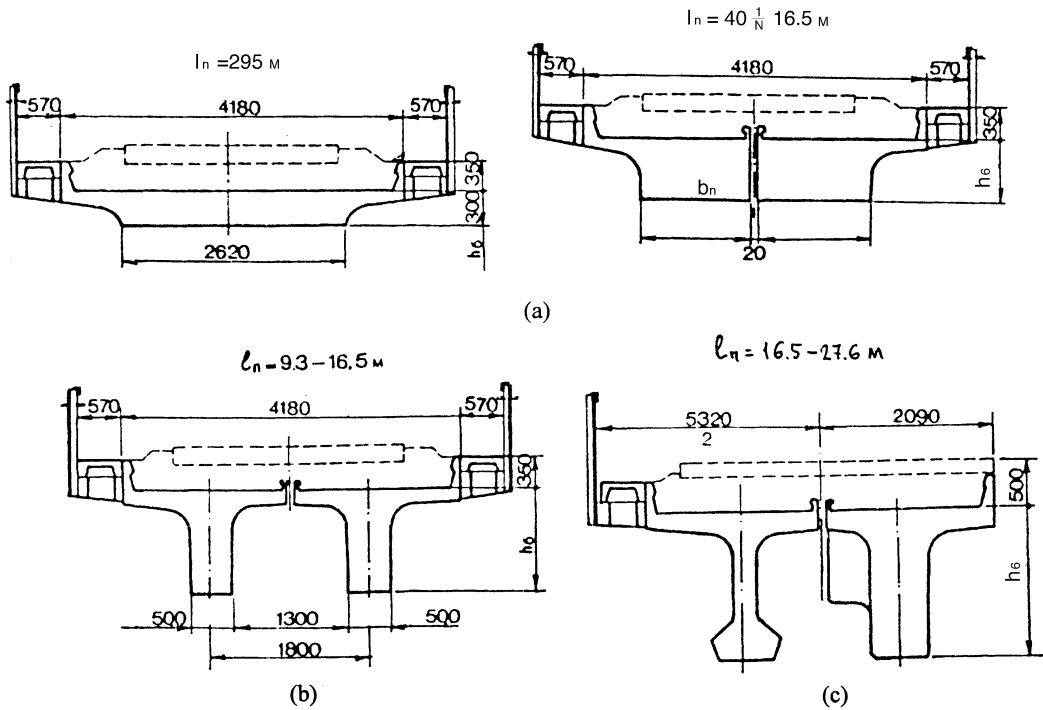
FIGURE 66.19 Typical cross sections of concrete superstructures for railway bridges (all other dimensions in mm).
(a) Nonprestressed reinforced concrete slab; (b) nonprestressed reinforced concrete I-beam; (c) prestressed concrete
T-beam.

66.7 Concrete Bridges

About 90% of modern bridges are concrete bridges. The recent decades have been characterized by intensive development of standardized precast concrete bridge elements. Main operational requirements and various conditions of construction are taken into account by the existing standardization. This allows a flexible approach in solving architectural and planning tasks and construction of bridges of various span lengths and clearances. Precast concrete bridges, both railway and highway, have been built in many environments, ranging from urban to rural areas. General characteristics of the common types of concrete bridge structures are provided in the following subsections.

66.7.1 Superstructures for Railway Bridges

For railway bridges, standardized shapes for girders and slabs have been widely used for span lengths of 2.95 to 27.0 m. The simplest type of bridge superstructure is the deck slab, which may be solid or voided. The standard structures are designed to carry live load S14 (single-track) and may be located on curved sections of alignment having a radius of 300 m and more. Typical nonprestressed concrete slabs with structural depth from 0.65 to 1.35 m are applicable for spans ranging 2.95 to 16.5 m. Nonprestressed precast T-beams with depth from 1.25 to 1.75 m are used for spans ranging from 9.3 to 16.5 m. Prestressed concrete T-beams with depths from 1.75 to 2.6 m are applicable for spans from 16.5 to 27.6 m. Single-track bridges consist of two precast full segments connected at diaphragms by welding of steel joint straps and then pouring concrete.

All three types of precast superstructure segments are normally fabricated at the shop and transported to a construction site. The waterproofing system is shop-applied. Longitudinal gaps between the segments are covered by steel plates. All superstructure segments starting from 1 to 5 m
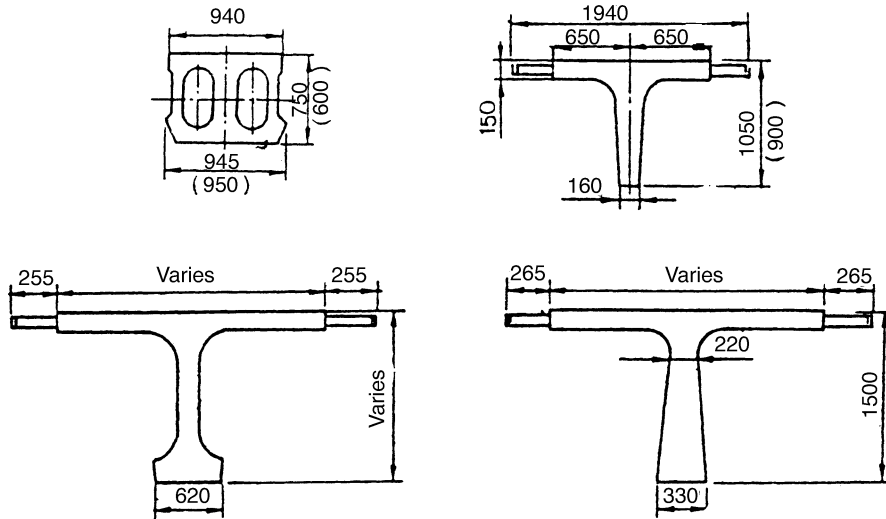
FIGURE 66.20   Standard precast beams for highway bridges (all dimensions in mm).

FIGURE 66.21   Typical section of overhead on the Moscow Ring Road.

length are placed on steel bearings. Superstructures may be connected into a partially continuous system, thus allowing adjustment of horizontal forces transferred to piers.

66.7.2   Superstructures for Highway Bridges

More than 80% of bridges on federal highway networks have span lengths not exceeding 33 m. Figure 66.20 shows typical standard cross sections for highway bridges. Nonprestressed concrete void slabs with structural depth from 0.6 to 0.75 m are applicable for spans ranging 12 to 18 m. Nonprestressed precast T-beams with depth from 0.9 to 1.05 m are used for spans ranging from 11.1 to 17.8 m. Prestressed concrete T-beams with depths from 1.2 to 1.7 m are applicable for spans from 32.3 to 41.5 m. Figure 66.21 shows a construction site of precast concrete beams on the Moscow Ring Road.
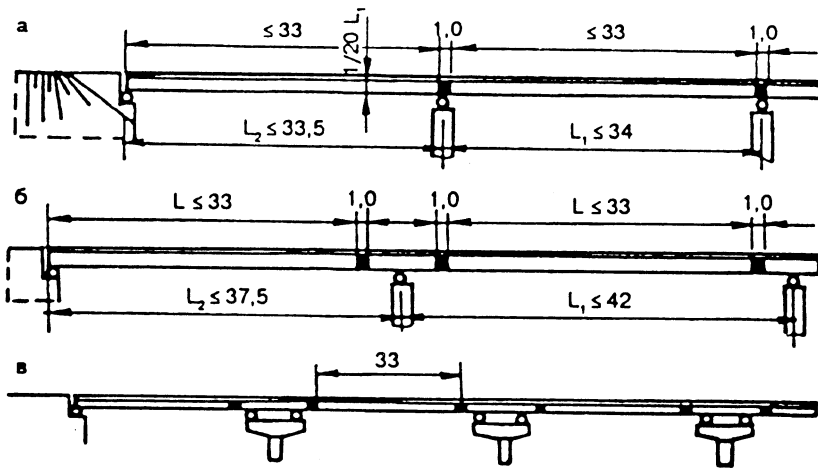
FIGURE 66.22 Typical continuous bridge schemes composed of standard beams (all dimensions in mm).

Fabrication of pretensioned standard beams are conducted at a number of specialized shops. However, by experience some technological difficulties have been noted. These are operations related to installation of reinforcement (space units) into molds of a complex configuration, e.g., bulbous bottom of the girder section, placing of concrete into and taking off the beam from these molds. To improve the fabrication procedure, a special shape of the beam web in the form of a drop has been developed. The standard design of a beam having a 27 m length has been elaborated. Precast prestressed T-beams which are the most widespread in the current construction practice have structural depth from 1.2 to 1.7 m with typical top width of 1.8 m and weight of one beam from 32.3 to 59 tons.

Where special transport facilities are not available or transportation limitations exist or manufacturing facilities such as stressing strands are expensive, precast-in-segment post-tensioned beams are considered to be beneficial. The designs of standard T-beams have been worked out considering both prestressing systems: post-tensioning and pretensioning. The standard T-beams have been designed precast in segments with subsequent post-tensioning for the span lengths of 24, 33, and 42 m.

Due to transportation limitations or restrictions or other reasons, a rational alternative for the post-tensioned beams is beams with transverse joints. In this case the beam consists of segments of limited length and weight (up to 11.8 tons) which may be transported by the usual means. Such segments may be precast either on site or in short lengths at the factory with subsequent post-tensioning at the site. The joints between segments may be implemented by filling the joint gap of 20 to 30 mm thickness with concrete (thin joint); by placing concrete of a minimum thickness of 70 mm (thick joint); or epoxy glued having a 5 mm thickness.

To reduce expansion joints and improve road conditions, the partially continuous system — simple beams at the erection stage and continuous beams at service stage — has been widely used for superstructure; spans up to 33 m. The girders are connected by casting the deck slab over support locations slabs are connected by welding of steel straps on the top of deck. Figure 66.22 shows a typical continuous bridge scheme composed of standard precast slabs or T-beams.

Figure 66.23 shows a standard design for continuous superstructures with double-T beams. The overall width of the precast segment may reach 20 m, but its length is limited to 3 m due to transportation constraints. Ducts for prestressing cables are placed in the web only.

In 1990, another standard design for box-girder continuous systems was initiated. A typical box section is shown in Figure 66.24. Each segment has 1.4 m at bent and 2.2 m within spans with weight up to 62 tons. Using standard precast segments, superstructures can have spans of 63, 71.8, 84, and 92.8 m. Due to financial difficulties the design work on standard box segmental superstructures has not been completed. However, the general idea has been implemented at a number of bridges.
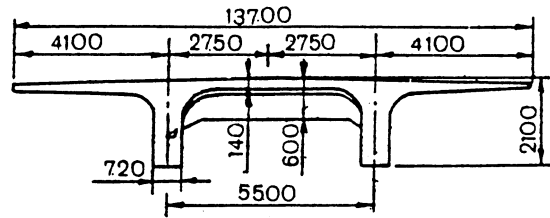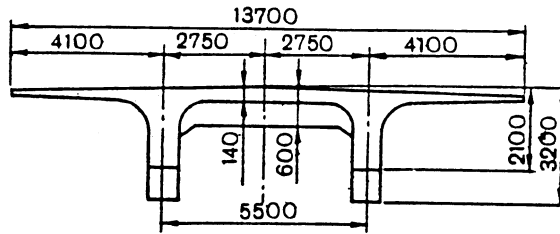
FIGURE 66.23   Typical cross sections of standard solid web girders. (a) For span arrangement of 33 + *n*(42) + 33 m; (b) for span arrangement of 42 + *n*(63) + 42 m (all dimensions in mm).
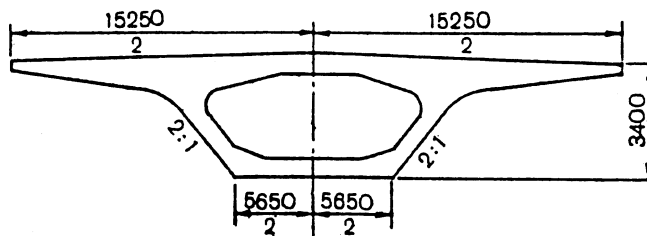

FIGURE 66.24   Typical cross section of precast box segment (all dimensions in mm).

66.7.3   Construction Techniques

The precast full-span beam segments are fabricated at specialized shops on the basis of standard designs. The erections of solid girder segments up to 33 m are conducted by mobile boom cranes of various capacities, gantry cranes, and launching gantries. Special scaffoldings have been designed to erect the solid girder of 24 to 63 m (Figure 66.25).

When large-span bridges are constructed, different cranes may be used simultaneously. At a low-water area of rivers, gantry cranes may be applied, but at deep water, cranes SPK-65 or others may be used. A typical erection scheme of precast cantilever bridge over the Volga River built in 1970 is shown in Figure 66.26.

Although concrete bridge superstructures are constructed mainly by precast segments, in recent years cast-in-place superstructure construction has been reviewed on a new technological level. By this method, construction of superstructure is organized in the area behind the abutment on the approaches to a bridge. The successive portion of the superstructure is cast against the preceding segment and prestressed to it before proceeding to erection by the method of incremental launching.

Cast-in-place concrete main girders and modified precast concrete decks are usually used. Traditionally, when precast deck slabs were used for bridge construction, these precast elements were fabricated with provision of holes for shear connectors that were later filled with concrete. This
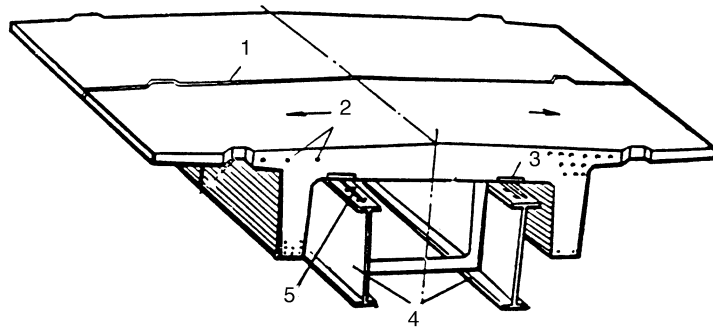
FIGURE 66.25 Position of precast segments of solid web girders over special scaffoldings. 1–glued joints; 2–ducts; 3–embeds; 4–movable special scaffoldings; 5–rails for segment moving.
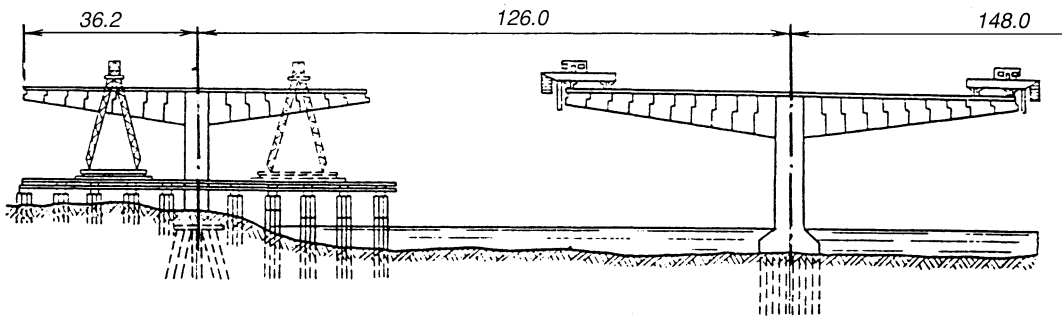

FIGURE 66.26 Typical erection scheme of the bridge over the Volga River (all dimensions in mm).

solution has several disadvantages. To improve the practice, new types of joint between structural members were introduced. The use of steel embeds in precast slabs allows connection of main girders by means of angles and high-strength bolts [3].

66.7.4 Typical Bridges

Komarovka Bridge

A railway bridge over the Komarovka River has recently been built in Ussuryisk (far east of Russia). The bridge of 106.85 m length has a span arrangement of 6 × 16.5 m (Figure 66.27). The super-structure is of reinforced concrete beams of standard design. The intermediate piers are of cast-in-place reinforced concrete. Abutments are spill-through type of precast elements and cast-in-place concrete. Foundations are on bored 1.5-m-diameter piles. Steel casings of 1.35 m diameter were placed in the top portion of the piles. Separate connections of the superstructure into the two systems reduced the temperature forces in the girt. Structurally, the girt (Figure 66.28) consists of two angles of 125 × 125 × 10 mm, which are jointed to the bearing nodes by means of gussets, installed between the bottom flange of superstructure and the sole plate of the fixed bearings. The girt is attached to each gusset plate by high-strength bolts. To reduce the temperature stresses, the girts were fixed to the superstructure and embeds over the abutments at 0° C.

Kashira Oka River Bridge

In 1995, a bridge of total length of 1.96 km crossing over the Oka River near Kashira was constructed. The main spans over the navigation channel are 44.1 + 5 × 85.5 + 42.12 m. The bridge carries three traffic lanes in each direction. Seven-span continuous superstructures are precast concrete box
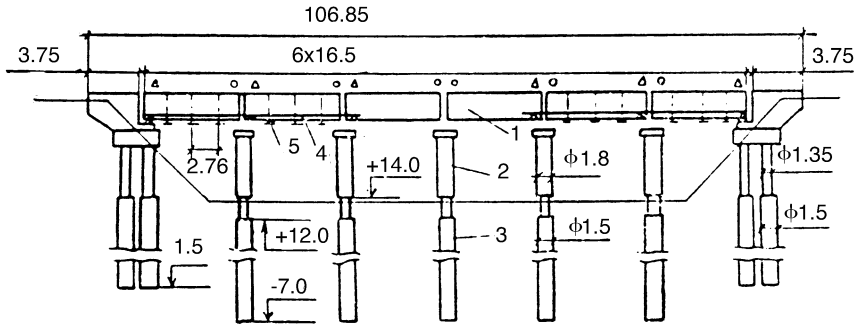
FIGURE 66.27 General arrangement of bridge over the Komarovka River. 1–RC super structure; 2–cast-in-place pier; 3–bored pile; 4–special girt; 5–key to limit sideward movement (all dimensions in mm).
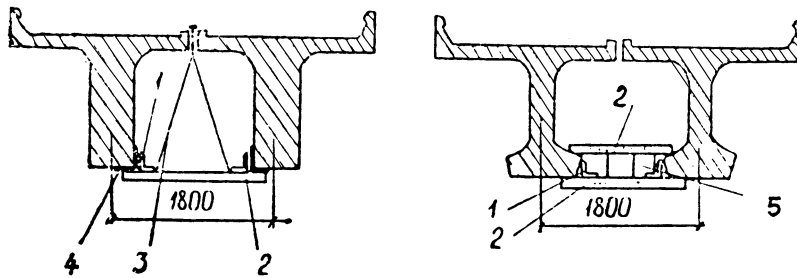

FIGURE 66.28 Special girt details. (Left) Nonprestressed and (right) prestressed girder. 1–girt; 2–Crosstie; 3–anchor element; 4–noftlen pad; 5–jointing plank (all dimensions in mm).

segments with depth of 3.4 m and width of 16 m constructed using a cantilever method with further locking in the middle of the spans. A typical cross section is shown in Figure 66.29. The precast segments vary from 1.5 to 1.98 m and are governed by a capacity of erection equipment limited to 60 tons. Piers are cast-in-place, slip-formed. Foundations are on bored piles of 1.5 and 1.7 m diameter.

Frame Bridge with Slender Legs

Development of structural forms and erection techniques for prestressed concrete led to a construction of fixed rigid frames for bridges. Compared to continuous-span frame bridge systems it is less commonly used. To form a frame system, precast superstructure and pier elements are concreted at overpier section (1 m along the bridge) and at the deck section (0.36 m wide in a transverse direction). Figure 66.30 shows a typical frame bridge with slender legs. The design foundations need an individual approach depending on the site geologic conditions. Simple forms of precast elements, low mass, clear erection scheme, and aesthetic appearance are the main advantages of such bridge systems.

Buisky Perevoz Vyatka River Bridge

This highway bridge (a nonconventional structure) as shown in Figure 66.31 was open to traffic in 1985. The bridge is a cantilever frame system with a suspended span of 32.3 m. The superstructure is a single box rectangular box girder with depth of 3.75 m and width of 8.66 m. Overall deck width is 10 m. The river piers are of cast-in-place concrete and the foundations are on bored 1.5 m piles penetrated to a depth of 16 m. One of the piers is founded on a caisson placed at a depth of 8 m. The 32-mm-diameter bars of pile reinforcement were stressed with 50 kN force per bar for better crack resistance.
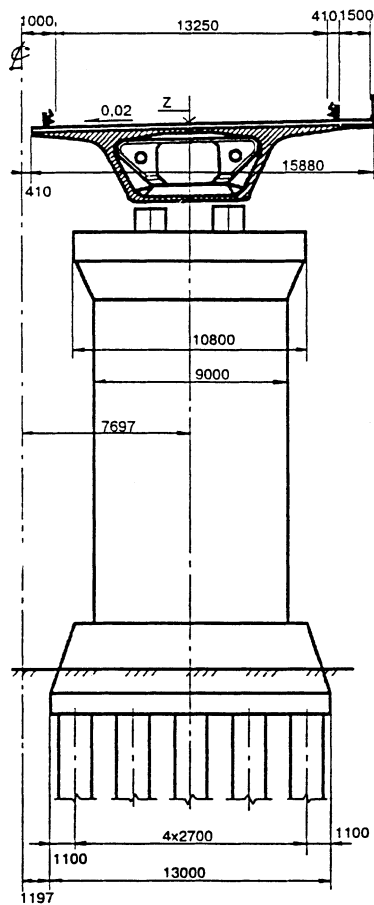
FIGURE 66.29 Typical section of Kashira Oka River Bridge (all dimensions in mm).

Penza Sura River Bridge

This highway bridge comprises a precast prestressed concrete frame of a two-hinge system (Figure 66.32) built in 1975. The superstructure is three boxes with variable sections (Figure 66.33) with a total of 66 prestressing strands. The inclined legs of frames have a box section of 25 × 1.5 m at the top and a solid section 1.45 × 0.7 m at the bottom. The legs of each frame are reinforced by 12 prestressing strands. Each strand diameter of 5 mm consists of 48 wires. Piers are cast-in-place concrete. Foundations are on driven hollow precast concrete piles of 0.6 m. Each frame structure was erected of 60% precast segments. These segments are 5.6 m wide and 2.7 to 3.3 m long. Each frame system superstructure was erected with 12 segments in a strict sequence, starting from the center of the span to the piers, The span segments are placed into the design position, glued, and prestressed. Leg segments are connected with span segments by cast-in-place concrete. A special sequence, as shown in Figure 66.34, for tensioning the strands was established for this bridge.

Moscow Moskva River Arch Bridge

The cantilever arch bridge (Figure 66.35) over the Moskva River on the Moscow Ring Road was built in 1962. The bridge is a three-span structure with 48.65 + 98 + 48.64 m. The overall road width is 21 m and sidewalks are 1.5 m on each side. Half arches are connected by a tie of 10 prestressing strands at the level of the roadway. The erection of the superstructure was implemented on steel scaffoldings. Arches are erected of precast elements weighing from 10 to 20 tons.
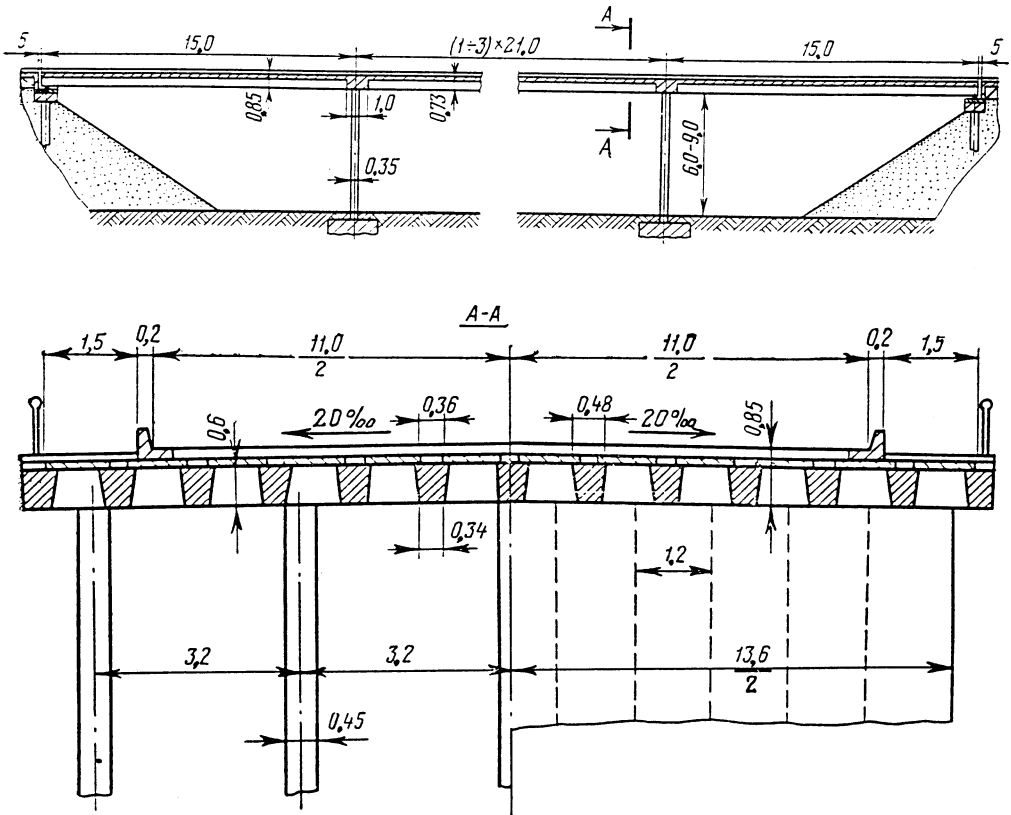
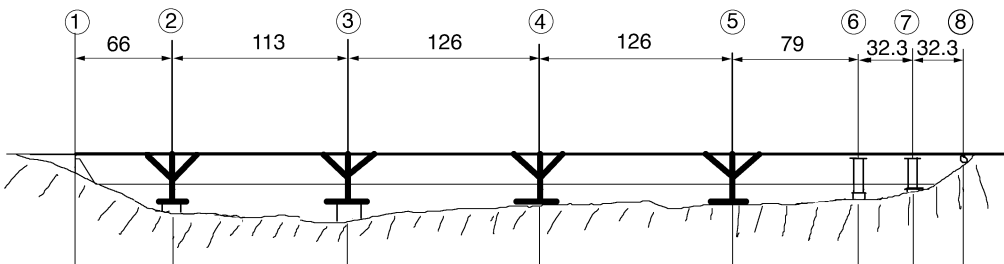**FIGURE 66.30** Typical bridge frame with slender legs (all dimensions in mm).

FIGURE 66.31 General scheme of Buisky Perevoz Vyatka River Bridge (all dimensions in mm).

66.8 Cable-Stayed Bridges

The first cable-stayed bridges were constructed in the former USSR during the period 1932–1936. The cable-stayed highway bridge with a span of 80 m designed by Kriltsov over the Magna River (former Georgian SSR) was constructed in 1932. The bridges over the Surhob River, having a span of 120.2 m, and over the Narin River, having a span of 132 m, were constructed in 1934 and 1936, respectively. Figure 66.36 shows a general view of the Narin River Bridge. A stiffening girder of steel truss system was adopted in these bridges.
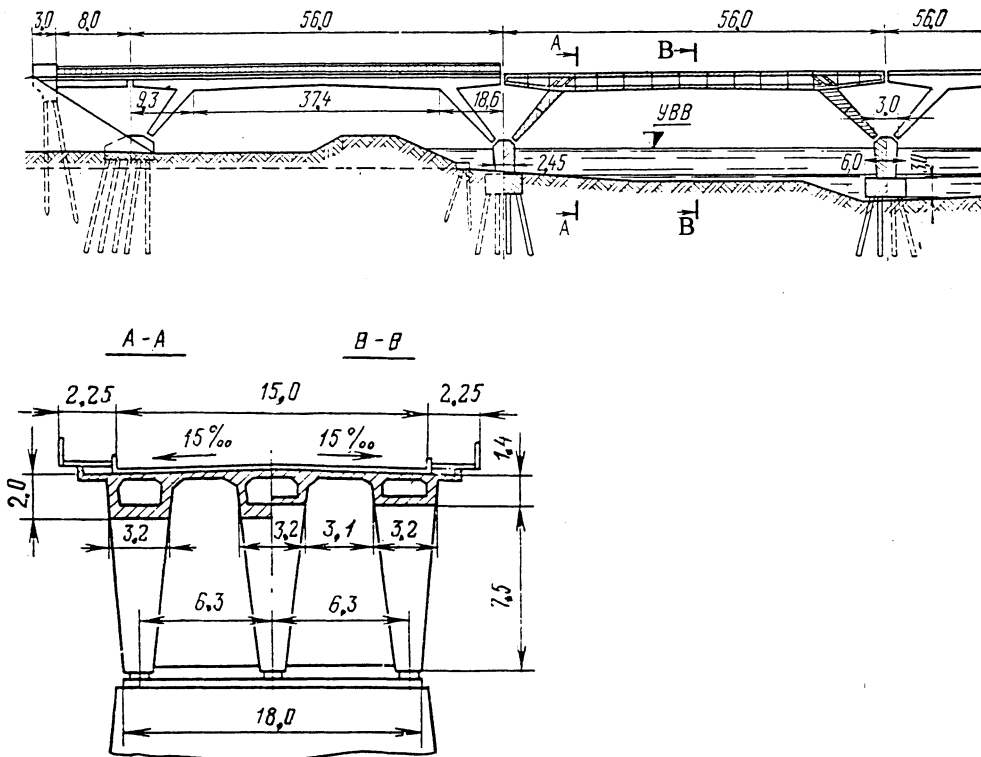
FIGURE 66.32   Penza Sura River Bridge.

FIGURE 66.33   Typical cross section of Penza Sura River Bridge (all dimensions in mm).

The modern period of cable-stayed bridge construction may be characterized by the following projects: the Dnepr River Bridge in Kiev (1962), the Moscow Dnepr River Bridge in Kiev (1976), Cherepovets Scheksna River Bridge (1980), Riga Daugava River Bridge (1981), the Dnepr River South Bridge in Kiev (1991). Two cable-stayed bridges over the Volga River, Uiyanovsk, and over the Ob River near Surgut are currently under construction.
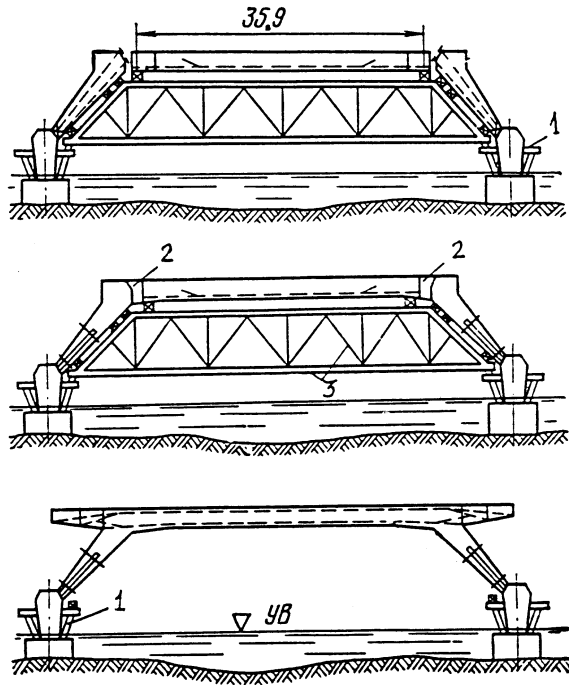
FIGURE 66.34 General sequence of frame structure erection (all dimensions in mm).

FIGURE 66.35 Moscow Moskva River arch bridge.

Kiev Dnepr River Bridge

The first concrete cable-stayed bridge (Figure 66.37) crossing over the harbor of the Dnepr River in Kiev was constructed in 1962. The three-span cable-stayed system has spans of 65.85 + 144 + 65.85 m. The bridge carries highway traffic having a width of roadway of 7 m and sidewalks of 1.5 m on each side. The superstructure comprises two main II-shaped prestressed concrete beams of 1.5 m deep, 1.4 m wide, and spaced at 9.6 m. Cable arrangement is of radiating shape. The stays are composed of strands of 73 and 55 mm in diameter. Towers are cast-in-place reinforced concrete structure.
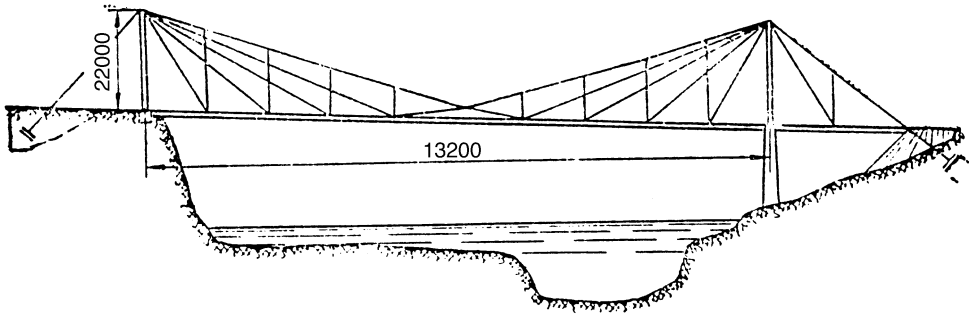
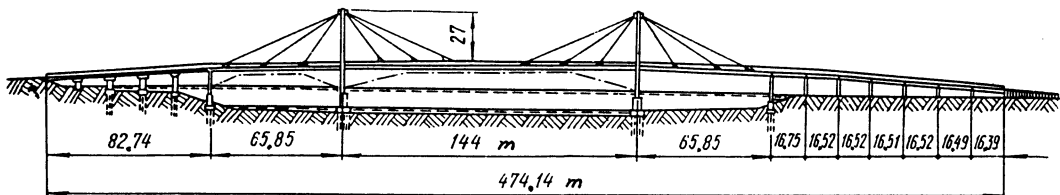**FIGURE 66.36**   Narin River Bridge (all dimensions in mm).

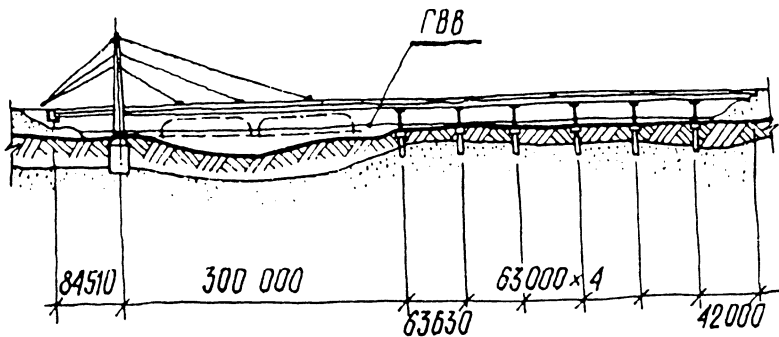**FIGURE 66.37**   Kiev Dnepr River Bridge.

FIGURE 66.38   Moscow Dnepr River Bridge (all dimensions in mm).

Moscow Dnepr River Bridge

In 1976 the Moscow bridge (Figure 66.38) with a cable-stayed system was constructed. The bridge carries six lanes of traffic and five large-diameter pipes below the deck, and has an overall width of 31 m. The three-span continuous structure has a span arrangement of 84.5 + 300 + 63 m. The stiffening girder comprises twin steel box beams with orthotropic deck fabricated of 10 XCND low-alloyed steel grade. To meet the transportation clearances, the depth of the girder was limited to 3.6 m. In a cross section the main beams are 5.5 m wide with a distance between inner webs of adjacent girders equal to 20.2 m and diaphragms spaced at 12.5 m. The stiffening girder has a fixed connection to the abutment and movable connections at the pylon and intermediate pier. A shaped single reinforced concrete pylon 125 m high has a box section of its legs. Each stay is formed from 91 parallel galvanized wires (diameter 5 mm). The stays have a hexagonal section of 55 × 48 cm and are installed in two inclined planes.
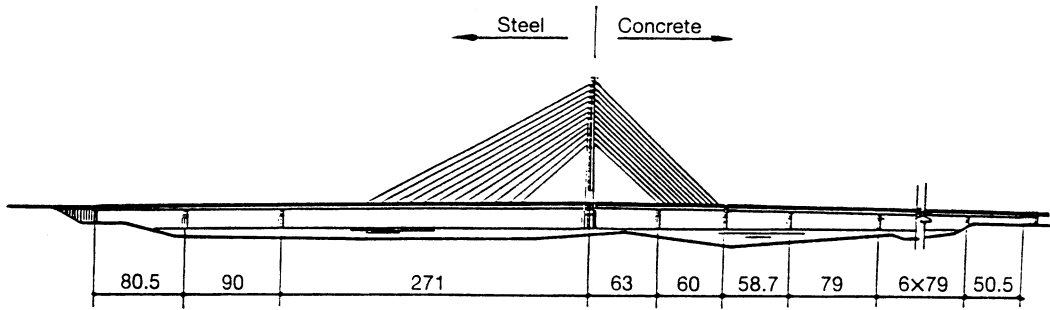
FIGURE 66.39 Dnepr River South Bridge (all dimensions in mm).

Dnepr River South Bridge

The south bridge crossing over the Dnepr River in Kiev (Ukraine) was opened to traffic in 1993. This bridge crossing includes a cable-stayed bridge of a length of 564.5 m and a concrete viaduct of a length of 662 m. A general scheme of the bridge is shown in Figure 66.39. The bridge allows traffic of four lanes and two rail tracks. The bridge also carries four large-diameter water pipes. The design and construction features of this bridge have been presented in Reference [19].

The superstructure comprises steel and concrete portions. The steel portion is a three-span continuous box girder formed of vertical I-beams with orthotropic deck. The concrete portion provides the required counterweight and was constructed of segmental prestressed concrete box sections. The pylon is a two-column cast-in-place concrete frame structure having cross struts between the columns. Cables stays are positioned in two planes, thus torsional rigidity of the bridge is effectively provided.

Ulyanovsk Volga River Bridge

The bridge crossing over the Volga River near Ulyanovsk City is more than 5 km long and includes the cable-stayed bridge. This bridge is currently under construction and will carry combined traffic: highway traffic of four lanes and two tracks for streetcar lines. A span arrangement of this cable-stayed bridge is based on spans of $220 + 2 \times 407 + 220$ m with a single pylon. The scheme of the cable-stayed bridge is shown in Figure 66.40.

The stiffening girder is of trapezoidal configuration comprising two planes of truss interacting with an orthotropic top and bottom deck plate. The steel orthotropic deck for highway traffic is located on top of the truss superstructure. Truss members are hermetically sealed; therefore their inner surfaces are not required to be painted. A peculiarity of structural detailing for the joints is that the node in a form of hermetically sealed welded box was fabricated at the shop. Connections of flanges and diagonals are moved from the node center. Longitudinal ribs of the orthotropic deck system are of box section; transverse beams are spaced at 5.5 m. The stiffening girder is supported by two planes of stays. Each stay includes cables of parallel wires with diameter of 7 mm. The number of wires in the cables varies from 127 to 271. The weight of stiffening girder of cable-stayed bridge is 20,115 t, and stays, 1900 t. The superstructure is erected by the cantilever method.

The approach steel superstructure is also of truss system with continuous spans of 2×220 m. This steel superstructure differs from that of the main span by a transverse rectangular shape only. The structural details are similar to the main-span superstructure. The weight of 2×20 m superstructure is 7640 t. The superstructure is assembled on the bank and then erected by 220 m spans using the floating-in method.

The cast-in-place pylon of 204 m height has an inverted Y-shape in the direction along the bridge and a frame of 2 h (H configuration) with cross struts in the transverse direction. For a general
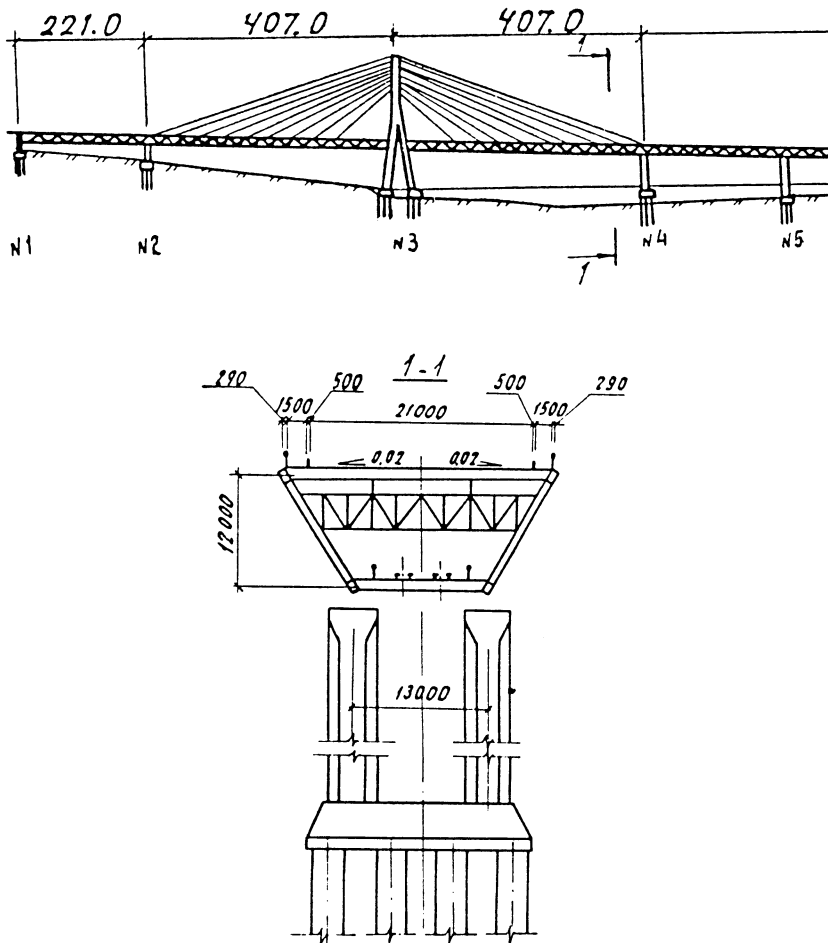
FIGURE 66.40 Ulyanovsk Volga River Bridge (all dimensions in mm).

view of the design alternative for the pylon see Figure 66.41. Towers have a hollow box section with thickness of walls equal to 0.8 to 1.0 m. This type of the pylon structure was influenced by symmetrical side spans of 407 m and absence of permanent guys. The pylon interacts with the superstructure under the unsymmetrical loading by means of its bending stiffness. Foundations are on bored piles of 1.7 m diameter having a bell shape of 3.5 m in diameter at the end.

Surgut Ob River Bridge

Recently, the construction of new bridge crossing the River Ob near Surgut City has started. The overall length of this bridge crossing is a little more than 2 km. A general scheme of the bridge is shown in Figure 66.42. The bridge has an overall width of 15.2 m and will allow traffic of two lanes. It is located in profile on a convex curve having a radius of 120,000 m. The superstructure is a single steel box girder with orthotropic deck. A single pylon of 146 m high is to be constructed in the bottom portion of precast segments forming an outer shape and cast-in-place concrete core, and in the upper portion of two parallel steel towers (transverse section) with struts creating a frame. Intermediate piers are constructed of precast segments with cast-in-place concrete core and with foundation on bored piles with steel casing of 1420 mm in diameter. Abutment are of cast-in-place concrete with foundation on reinforced concrete piles of hollow section 0.6 m in diameter and filled by concrete.
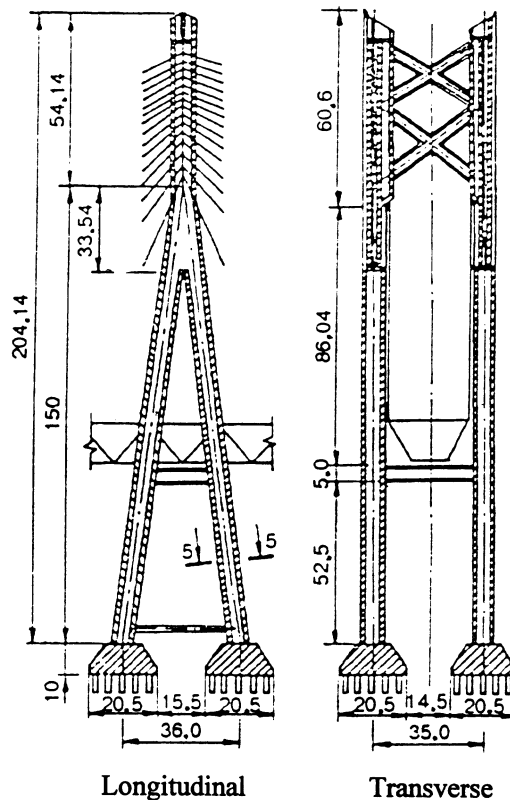
FIGURE 66.41 Ulyanovsk Volga River Bridge pylon (design alternative) (all dimensions in mm).

66.9 Prospects

In recent years, fewer new bridges have been designed and constructed in Russia. The demands for rehabilitation and strengthening of bridge structures are increasing every year. The future directions of bridge design practice are

- Revision and modification of national standards considering Eurocode and standards of other leading countries;
- Considerations for interactions of structural solutions with technological processes considering aesthetic, ecological, and operational requirements;
- Development of new structure forms such as precast or cast-in-place reinforced concrete and prestressing concrete, steel and composite structures for piers and superstructures to improve reliability and durability;
- Redesign of standard structures considering practical experience in engineering, fabrication, and erection practices;
- Unification of shop-fabricated steel elements ready for erection to a maximum dimension fitting the transportation requirements, improvement of precast concrete decks, improvement of corrosion protection systems to a life span up to 12 years; and
- Development of relevant mobile equipment and practical considerations of cast-in-place concrete bridges.
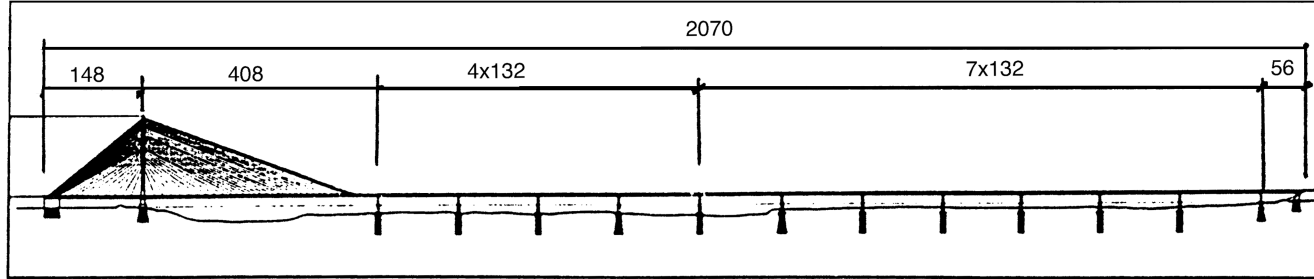
FIGURE 66.42 Surgut Ob River Bridge (all dimensions in mm).

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