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Innovative Structural Solutions and Construction Techniques for Deep Foundations of Large Bridges Over Rivers.

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SUMMARY
This paper deals with the development of new structural solutions adopted for deep foundations of bridges over the large rivers Volga and Kama. The innovative structural solutions called for new efficient construction techniques which were based on the use of rising floating platforms. Also some typical practice of quality control of downhole enlargement and concrete strength of bored piles are discussed.

1. INTRODUCTION

The design and construction of large bridge crossings over the rivers and reservoirs in the basin of the Volga river have their own specifics. Specific geological and hydrological conditions are characterized by low air temperature, reaching minus 35°C; intensive action of ice drift, having a thickness of up to 1 m; water depths of up to 30 m; a significant variability in water levels, a river bottom composed of sands susceptible to scours, and underlying by clays of low bearing capacity. By experience the construction of piers in such complicated conditions takes about 70% of labor intensity and time compared to that of the whole bridge and typically 60% of overall bridge cost. To improve this situation a new structural solution and construction techniques have been developed.

2. NEW STRUCTURAL SOLUTION AND CONSTRUCTION TECHNIQUES

2.1 Structural solution details

Compared to the traditional single pilework option, a new structural solution comprises two separate pilecaps. This resulted in a reduction of ice effect on foundation. Raising a base of pile cap above working water level and adoption of ice protective shell allowed to avoid construction of sheet piling and subaqueous concreting.

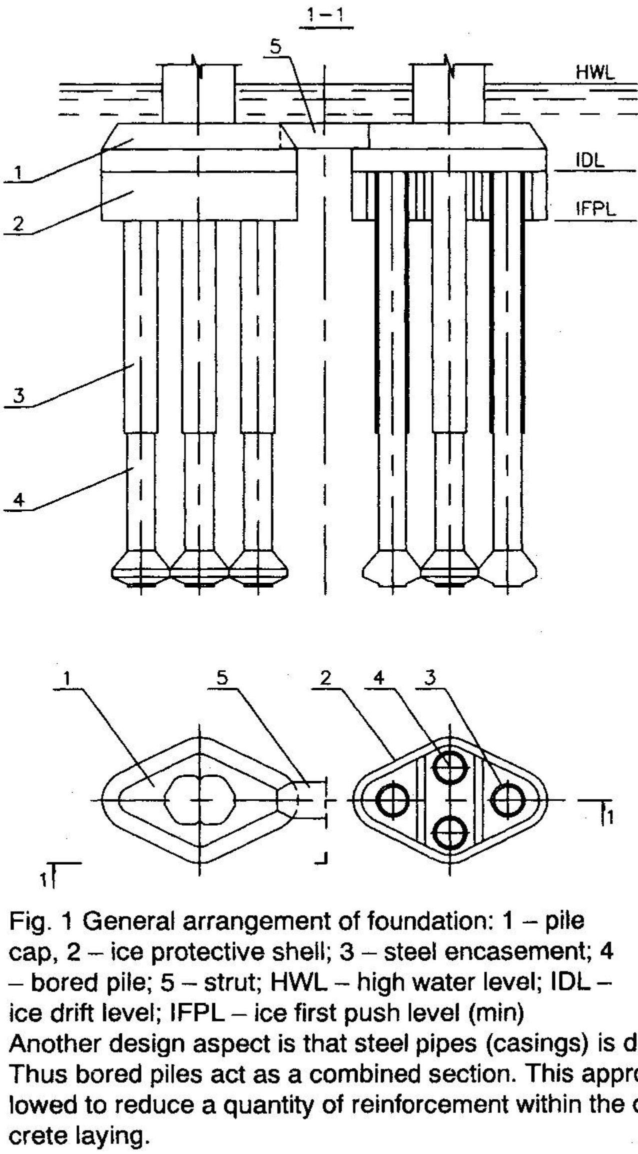

Fig. 1 General arrangement of foundation: 1 – pile cap, 2 – ice protective shell; 3 – steel encasement; 4 – bored pile; 5 – strut; HWL – high water level; IDL – ice drift level; IFPL – ice first push level (min)

At the same time the pile cap is located within the water level of possible ice floating and therefore the rhombus, streamlined shape is given to the cap. The ice protective shell repeats a form of pile cap. The purpose of this structural detail is to eliminate some concrete volume (to reduce the pier weight) and to protect against floating of ice. Special structural arrangements in the foundation with shell do not allow formation of ice inside of it. Positive temperatures inside the shell are maintained for a long period of time. Therefore a number of freezing/thawing cycles for concrete of piles is reduced. Another additional purpose of this cover is for aesthetic appearance of pier at low water levels.

Typical pier foundations comprise reinforced concrete bored piles of 1.5m in dia penetrated to a depth of up to 50 m protected by a steel casing of 2.0 m in dia within the probable depth of scour, and 1.7 m in dia at a lower part between the scour level and the level of bearing stratum. To increase the bearing capacity and reduce a number of piles in foundation, the enlarged up to 3.5 m pile base is normally adopted. In the recent bridge projects, where bridges were designed with spans of up to 160 m, normally four bored piles of large diameter (2m dia typical) were adopted for each pilework. A general arrangement of pier foundation adopted for the bridge over the Volga river near Saratov is shown in Fig. 1. To reduce a magnitude of pier top displacement due to the ice loads, a strut between pilecaps have been designed. This element provides for load distribution between upstream and downstream pilecaps.

Another design aspect is that steel pipes (casings) is designed as contributing to the resistance of bored piles. Thus bored piles act as a combined section. This approach increased design characteristics of piles and allowed to reduce a quantity of reinforcement within the casing length, and provided an improved quality for concrete laying.

2.2 Construction techniques

Construction of deep foundations is based on the use of floating platforms PMK and techniques of installation of bored piles with casings and enlarged to a 3.5m base. The floating platforms are formed of pontoons and have a stiff bearing on river or reservoir bottom by means of lowered posts (columns) which are connected to the platforms (Fig. 2). Placement of bored piles is conducted from top of floating platforms. First, the columns are lowered to a river bottom and driven in soil using a vibrator to a depth ensuring stability of platforms. Installation of steel casings (typically of 2.02 m in diameter) is implemented by the vibrator from operating bridge installed over the platform. To construct bored piles with enlarged bases a boring rig "Kato-50" is adopted which is placed over the platform.

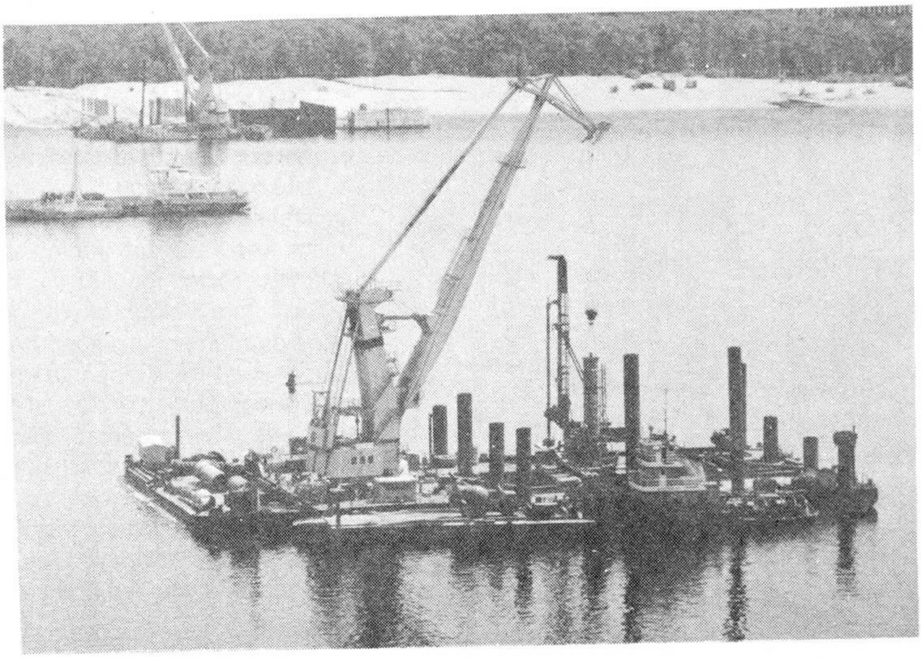

Fig. 2 Typical floating platform

Pilework comprises two elements – pile cap and ice protective shell which are constructed in dry conditions above working water level. Construction of ice protective shell is conducted above the water over a bearing mould fixed on top of steel casings. The sequence of operations is as follows: 1 - two precast reinforced concrete diaphragms of the shell are installed at the mould, 2 - external steel forms are placed to form a circle section, 3 - reinforcement of the shell is placed, 4 - internal steel forms are installed, 5 - ice protective shell is concreted and when the concrete is hardened, the forms are removed. Final configuration of ice protective shell constructed for the bridge over the Volga river near Saratov is shown in Fig. 3.

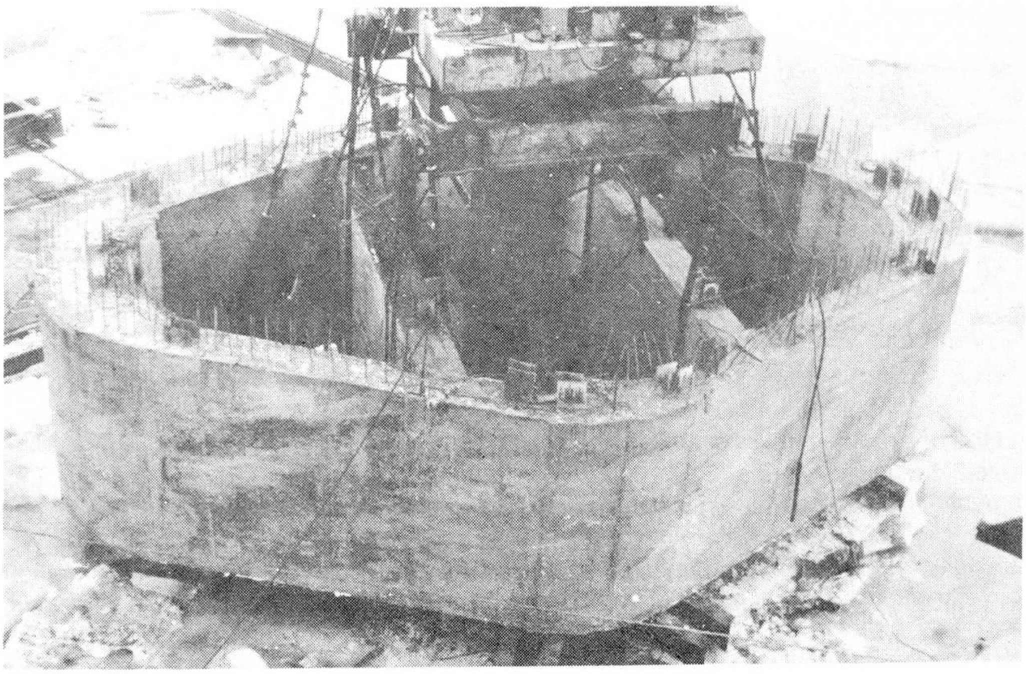

Fig. 3. Ice protective shell

To lower the ice protective shell, typically having a mass of 240 t, into its final position, a special builder's lift have been adopted. This builder's lift consists of bearing frame, fixed on top of casings and a post fabricated of the column of floating platform (Fig. 4). Columns are embraced by ties, between which electro jacks are placed. When the shell is lowered to a final elevation by means of these jacks, the builder's lift is dismantled.

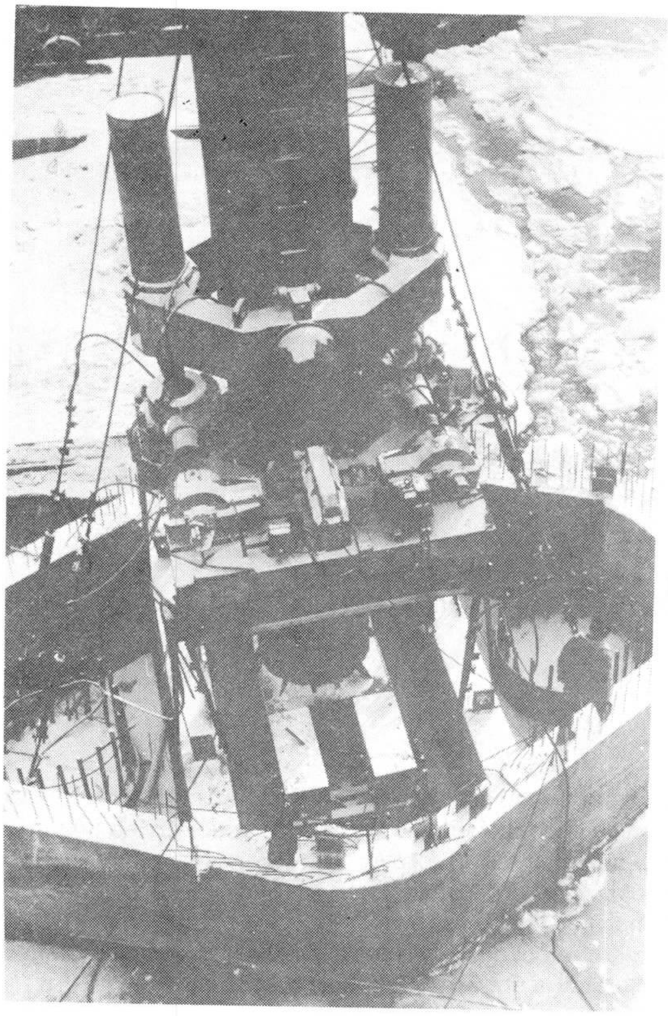

Fig. 4 Builder's lift used for lowering ice protective shell

Final position of ice protective shell is geodetically controlled in plan and elevation. Internal void of shell is spanned by scaffolding formed of concrete plates fixed by embeds on top of shell. These precast plates repeat the shape of internal contour of shell. Reinforcement of pile cap is placed in two stages. At the first stage, steel vertical panels of forms for lower pile cap portion are installed over erected mould and connected by bolts into a single circle section. Then reinforcement is placed in this pile cap portion. After that panel forms for top pile cap portion are installed and placement of reinforcement is completed. Concreting of pile cap is implemented continuously by inclined layers. To prevent thermal losses, moisture protective mats is normally used for covering a surface of pile cap and panel forms.

5. QUALITY CONTROL

The quality of construction of pile foundations is thoroughly controlled. It includes, but is not limited to, checking straightness, tilt of the borehole and enlargement shape if applicable, determining the continuity and strength of concrete in bored piles, confirming the strength of bearing stratum (load tests, etc). Some specific areas are discussed below.

To control a design shape, dimensions and concentricity of downhole enlargement of the bored piles, a special control system has been developed. Lowered into a borehole device provides information on shape, dimensions and volume of the enlargement to a computer. A typical computer graph, showing measurement results of borehole enlarged to 3.5 m is given in Fig. 5. If required the enlargement may be adjusted to a design configuration and measurements are repeated. When satisfactory results are achieved, piles are allowed to be concreted.

To control continuity and strength of concrete in bored piles, an ultrasonic device is used. Control measurements are normally implemented at one pile of each foundation. Channels are arranged in a controlled bored pile using steel pipes. A typical scheme of channels location for ultrasonic control in a bored pile is shown in Fig. 6. Results of control are presented in a form of table-graph. An illustration of measurement results, showing values of concrete strength at one of the bored piles at pier # 18 for the bridge crossing over the Volga river near Volgograd, is given in Fig. 7.

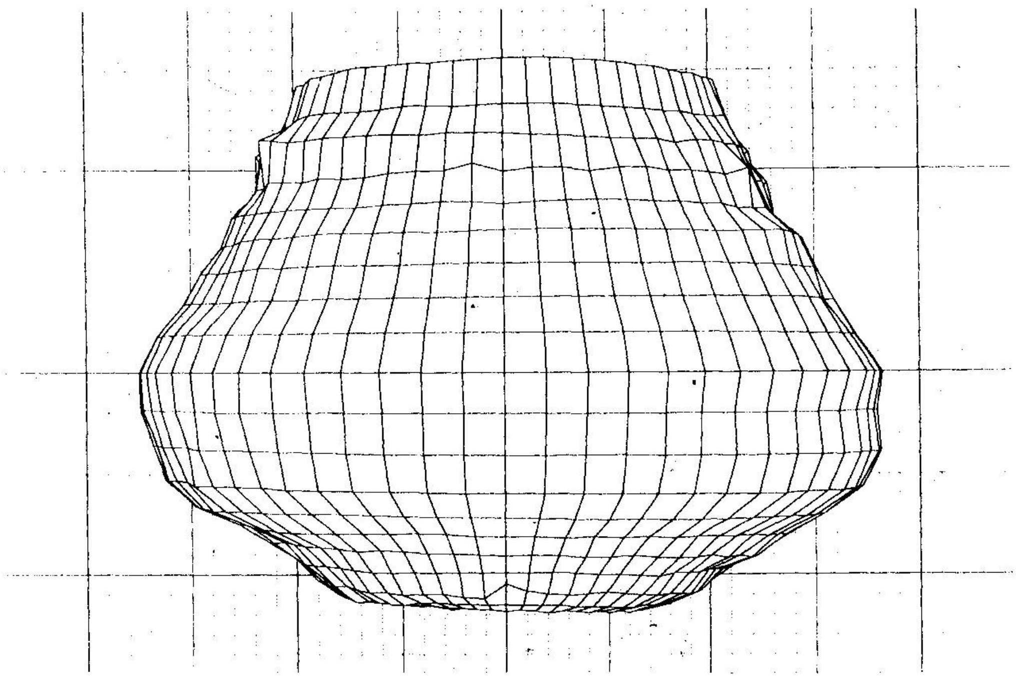

Fig. 5 Graph showing dimensions and shape of borehole enlargement

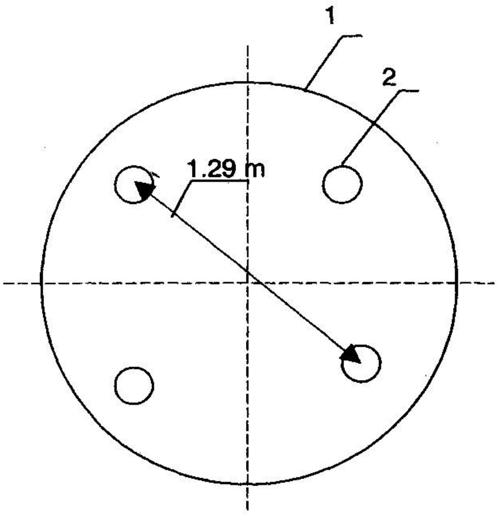

Fig. 6 Scheme of channels for determination of concrete strength in bored pile: 1 – bored pile, 2 – channels (coreholes exaggerated)

Distance from top to point of measurement, m	Device readings		Standard strength B30 (240)
	at base of 1.29 m	adjusted to base of 1.0 m	
0.5	328	254	
1.5	326	253	
2.5	315	244	
3.5	312	242	
...	...	...	
11.5	324	251	
12.5	325	252	
13.5	325	252	
14.5	320	248	
...	...	...	
25.5	342	265	
26.5	336	260	
27.5	318	247	

Fig. 7 Table-graph resulted from ultrasonic control of bored pile

6. CONCLUSION

The abovediscussed innovative structural solutions and construction techniques have been implemented for a number of bridge foundations and proved their efficiency in practice. Bridge projects currently under construction are as follows. The bridge over the Volga near Saratov has a length of about 2.2 km (main span of 157.5 m) and allows traffic of two lanes in each direction. The bridge over the Volga river in Volgograd has a length of about 1.2 km (main span of 155 m) and allows traffic of three lanes in each direction. The bridge over the Kama river is of about 1.6 km in length, having a main span of 150.5 m, and accomodates traffic of two lanes in each direction.

Thirty pier foundations for the bridge over the Volga river near Saratov have recently been built. A final configuration of piers constructed for this bridge is shown in Fig. 8. The similar type of pier foundations for the bridges over the Volga river near Volgograd and over the Kama river near Kazan are currently under construction.

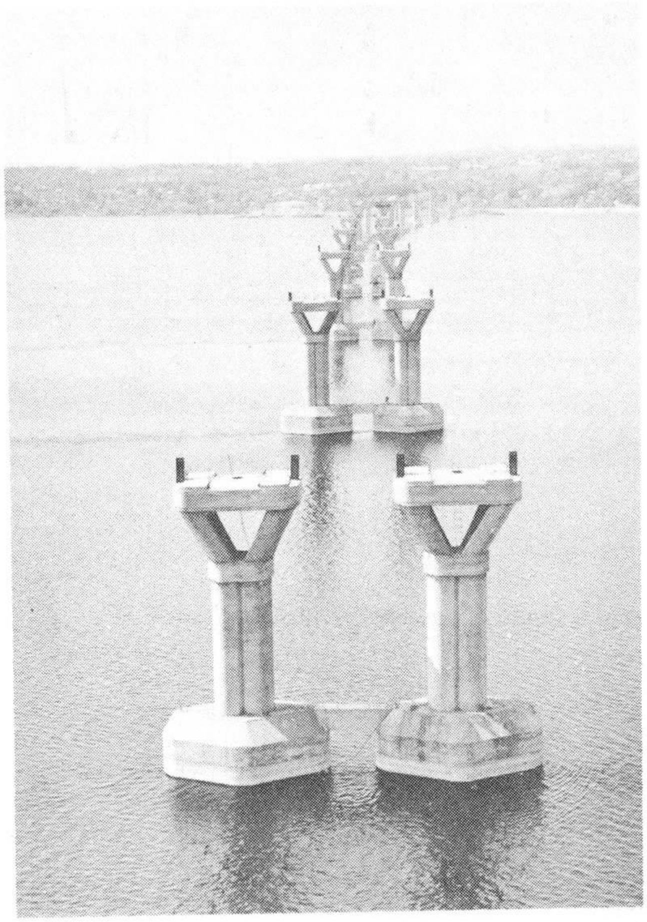

Fig. 8 View of constructed piers for the bridge over the Volga river near Saratov