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TESTING OF MODELS OF BRIDGE DECKS WITH REINFORCED CONCRETE FIXED FORMWORK

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ABSTRACT

In Ukraine, in the second half of the 20th century, the vast majority of highway bridges span structures were built from precast concrete. This was due to the requirement of construction industrialization in the USSR, which required the maximum use of prefab structures. Therefore, the bridge deck slabs had a significant number of longitudinal joints. The experience of maintenance of bridges prefabricated reinforced concrete span structures has shown that a significant number of defects occur in their slabs due to the presence of joints.
Taking into account the above, the current state building regulations of Ukraine for bridge design indicate that in the case of using prefabricated reinforced concrete beams, their surface should be covered with a layer of cast-in-situ reinforced concrete with a thickness of at least 14 cm.
Taking these requirements into account, reinforced concrete span structures of highway bridges are arranged mainly precast and cast-in-situ: installing of precast beams, concreting of the cast-in-situ slab above them. This design requires using of formwork for the slab installation.
A promising direction in cast-in-situ bridge construction is using of various types of permanent formwork [1]. However, their use has not been studied to date. Having studied the experience of using non-removable formwork, it is proposed to test series of samples to determine the suitability for further operation of one or another option, in addition to studying of the joint operation of non-removable formwork plates as part of the combined cross-section of the deck slab.

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INTRODUCTION.

The problem of the slab formwork installation became particularly acute due to the rejection of imperfect types of projects and the transition to individual design using different types of main beams, which requires the creation of individual formwork. During Soviet times one-time wooden formwork became widespread on the territory of Ukraine, attention was hardly paid to the development of unified systems that could be used for different forms [2]. Therefore, the use of rather expensive foreign systems of PERI, Doka, Ulma, etc. companies has become widespread. In addition to the formwork itself, during the construction of cast-in-situ reinforced concrete structures, appropriate supporting structures (scaffolding) were provided. This includes, in addition to wooden ones, stock steel racks of various designs, including telescopic ones, the height of which can be changed depending on the need. Supporting structures have a high cost, and their multiple rotation is not always possible for various reasons. For bridges, in some cases, the use of scaffolding is very complicated, for example, with a significant height of support on bridges over large rivers, overpasses, when crossing railways or existing highways and streets. A promising direction in cast-in-situ bridge construction is the use of various types of permanent formwork.

1. Analysis of literary data and formulation of the problem.

The adoption of the new State Construction Regulations "Bridges and Pipes. Design Rules", caused by the growth of freight flows on the highways of Ukraine, taking into account domestic and foreign experience in the construction and operation of bridges, presented new requirements and tasks to bridge builders that require high-quality and effective solutions. In particular, DBN "Bridges and Pipes" pays a lot of attention to the deck slab complex of highway bridges, since it has a decisive influence on the operational properties of the span structure as a whole. The creation of an effective, reliable and durable deck slab complex has a positive effect on the operational qualities of the span structure as a whole - from the uniform distribution of internal forces between the structural elements to the durability of the structure.

Prefabricated-cast-in-situ structures are a synthesized modification of precast and cast-in-situ reinforced concrete structures. These are united into a single whole and working together prefab elements and cast-in-situ concrete, or reinforced concrete. Prefabricated elements are used either unstressed, or part - unstressed and part of prestressed elements.

Numerous studies and construction practice show that the use of prefabricated-cast-in-situ structures is extremely profitable and effective, especially with using of prestressed elements [3].

The promising directions for improving of the prefabricated-cast-in-situ span structures constructions are:

- maximum simplification of the shape of the prefabricated reinforced concrete beam cross-section;
- execution of completely cast-in-situ deck slab;
- economy in use;
- improvement of manufacturing and installation technologies.

In DerzhdorNDI [State Road Research Institute named after Shulgin] projects of bridge span structures with reinforced concrete beams of the type "3Bet-90" and "3Bet-120" in the span range of 18–33 m, which are designed for new loads in accordance with the requirements of current standards, have been developed. Beams 900 and 1200 mm high, reinforced with pre-tensioned tendons, are designed for the prefabricated-cast-in-situ version of the span structure, which involves the installation of a cast-in-situ deck slab with a thickness of 210-230 mm. The project envisages the use of non-removable formwork - composite plates, which facilitates work related to the installation and dismantling of inventory formwork. The maximum step between beams is 1850 mm [4].

Despite the wide use of factory-made prefab elements, it is necessary to use formwork of various types to concrete the deck slab; at the same time, each bridge project from the point of view of formwork of the deck slab is individual. This creates the need to develop detailed design of formwork structures and processes, requires additional time for both design and installation of formwork and supporting devices; dismantling of the formwork is delayed until the slab of a certain level of strength is set with concrete, etc.

The use of permanent formwork, which has been practiced for a sufficiently long period of time, makes it possible to get rid of these shortcomings.

The construction of chipboard on cement binder is used as a permanent formwork when arranging the slab of the span structure of transport facilities. In the work [5] it is indicated that during the expert assessment, the results of the tests of the BETONYP slab, which were performed by the employees of the DerzhdorNDI in the laboratory and at the factory where they were manufactured. Also, the test of fixed reinforced concrete formwork is partially described in the work [6].

A separate issue related to the use of permanent formwork is the possibility of including them in the work of a continuous section. However, the condition of the strength of the contact seam must be fulfilled here. Until now, sufficiently reliable, physically based and uniform methods of calculating the strength of contact seams under the action of shearing forces have not been developed. Instructions for the calculation of shear contact joints are contained in a number of regulatory and advisory documents. These include both domestic and foreign standards and manuals for the design of concrete and reinforced concrete structures of hydraulic structures, bridges, protective structures of civil defense, prefabricated-cast-in-situ structures, residential buildings, nuclear power plant structures, earthquake-resistant buildings made of cast-in-situ concrete, etc. Guidelines for the calculation of shear contact joints are also contained in international regulatory documents, such as the norms of the European Concrete Committee, as well as in the norms of the USA, England, Germany, France and other countries.

Experimental studies of the shear resistance of contact joints [7] were carried out both on special models simulating the work of a contact joint on shear, and on beam elements separated by contact joints. But the issue is not fully resolved.

Important experimental studies are outlined in [8]. Single-span beams on two supports were made. The test was carried out according to the scheme of pure bending. The tests showed that the strength of the contact seam when using different types of concrete is insufficient. Therefore, the use of concrete with fiber fibers as a material for the manufacture of prefabricated formwork slabs is limited.

A description of options for use and types of reinforced concrete permanent formwork, which are widely used and can become a basis for developing a test program, are given in [9].

All this gives reason to assert that it is appropriate to conduct tests dedicated to the study of the operation of typical constructions of slabs of the carriageway of bridges with reinforced concrete permanent formwork, the possibility of their application and the operation of the contact seam between prefabricated elements and monolithic concrete.

2. The purpose and objectives of the research.

The purpose of the work is to study the operation of typical constructions of bridges deck slabs with reinforced concrete permanent formwork, the possibility of their application, and the operation of the contact seam between prefabricated elements and cast-in-situ concrete.

3. Experimental studies of cast-in-situ reinforced concrete slabs with fixed reinforced concrete formwork.

3.1 Samples and research program.

The object of research is a reinforced concrete bridge deck slab, arranged on a reinforced concrete permanent formwork. Five series of reinforced concrete samples, which differ in construction and reinforcement, are studied (Table 1). Also, only the prefabricated slabs of permanent formwork used for each series tested separately.

Table 1. The working program of studies of roadway slabs concreted with reinforced concrete prefabricated permanent formwork.

Sample type	Formwork type	Marking	Concrete	Number of samples	Test method	Research methods to be used
Cast-in-situ slab excluding formwork	A flat slab with ordinary reinforcement	ПМ-1	B30	2	Single fold $\eta = 0...1$	Microscopy, mech. devices
Cast-in-situ slab including formwork	A flat slab with ordinary reinforcement	ПМ-2	B30	2	Single fold $\eta = 0...1$	Microscopy, mech. devices
Cast-in-situ slab including formwork	A flat slab with pre-stressed reinforcement	ПМ-3	B30	2	Single fold $\eta = 0...1$	Microscopy, mech. devices

3 types of permanent formwork are used for research in this work:

• ПО-1: flat plate with ordinary reinforcement. The plate is not included in the work of the general section, therefore it is designed only for the load from the weight of the concrete;

• ПО-2: flat plate with ordinary reinforcement. The plate is included in the work of the full cross-section of the deck slab, its reinforcement is selected after calculating the model of the deck slab according to the continuous two-span scheme;

• ПО-3: flat plate with prestressed reinforcement. The plate is included in the work of the full section of the deck slab.

Consider the design of ПО-1 plates (Fig. 1). Since the plate is not taken into account in the work of the deck slab, its reinforcement is calculated only for the weight of the concrete mixture. The plate has dimensions in plan of 1200 x 600 mm and is reinforced with a reinforcing mesh with 4 rods Ø8A-I, the pitch of the rods is 100 mm in the longitudinal direction. In the transverse direction, the mesh has 8 rods Ø8A-I with a step of 150 mm. The edges of the reinforcing rods are bent (see Fig. 1, node A.) in order to ensure the reliable transfer of adhesion forces to the concrete, to avoid the formation of longitudinal cracks and splitting. Concrete of plate ПО-1 has class B-40; although the slab is not taken into account in the design work, the use of high-class concrete is due to the small thickness of the slab and the need to ensure the corresponding class of frost resistance. A layer of concrete with a thickness of 200 mm will be placed on the plate, so the estimated uniformly distributed load on the plate is 2.9 kN/m2. Plates are designed with individual reinforcement, but in factory conditions it is possible to make a line for the full length of the reinforcing bar and concrete it. Then the resulting structure can be cut into short plates of the required length, which will increase the production rate of formwork plates for several times.

The construction of the ПО-2 plate, in general, repeats the construction of the plate ПО-1 (Fig. 1). However, the formwork plate is included in the work of the deck slab general section, so the reinforcement of the ПО-2 plate has been changed. The working reinforcement of the ПО-2 plate are 4 rods Ø12A-III.

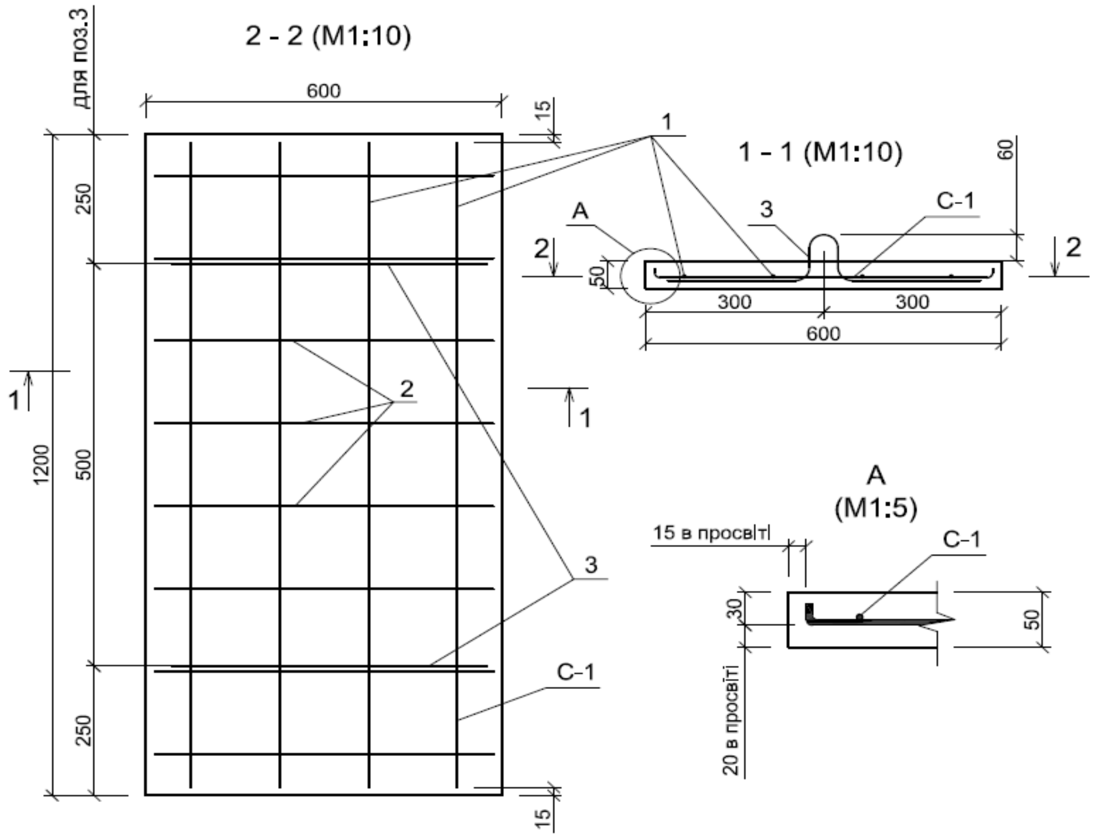

Fig. 1 – Construction of formwork plate ПО-1 (ПО-2)
1 – reinforcement rods Ø8A-I (Ø12A-III); 2 – reinforcement rods Ø8A-I;
3 – mounting loops Ø8A-I.

ПО-3 plates are reinforced with three prestressed tendons K-7 Ø9mm, the cross-section of one tendon is 53mm2. The tension force of one tendon is 4t or 40 kN. The tension force of the tendons is selected taking into account the requirements of norms [3] in accordance with the crack resistance category 2a. The design of the ПО-3 plate is shown in fig. 2.

In addition to non-removable formwork plates, supporting blocks, which are used for mounting ПМ-1, ПМ-2, ПМ-3 plates, are designed. Block marking is B-1 (central) and B-2 (side). They repeat the upper part of the prefabricated reinforced concrete prestressed beams 3Bet-120 produced by the plant "3 betony" (t. Kalush). The blocks have the same rebar releases as the 3Bet-120 beams.

For research in this work, 3 types of construction of a cast-in-situ deck slab, which is concreted on a permanent formwork, are adopted:

• ПМ-1: deck slab with ПО-1 formwork plates. Plate ПО-1 is not included in the work of the structure.

• ПМ-2: deck slab with ПО-2 formwork plates. The ПО-2 plate is included in the work of the deck slab full cross-section;

• ПМ-3: deck slab with ПО-3 formwork plates. The ПО-3 plate is included in the work of the deck slab full cross-section.

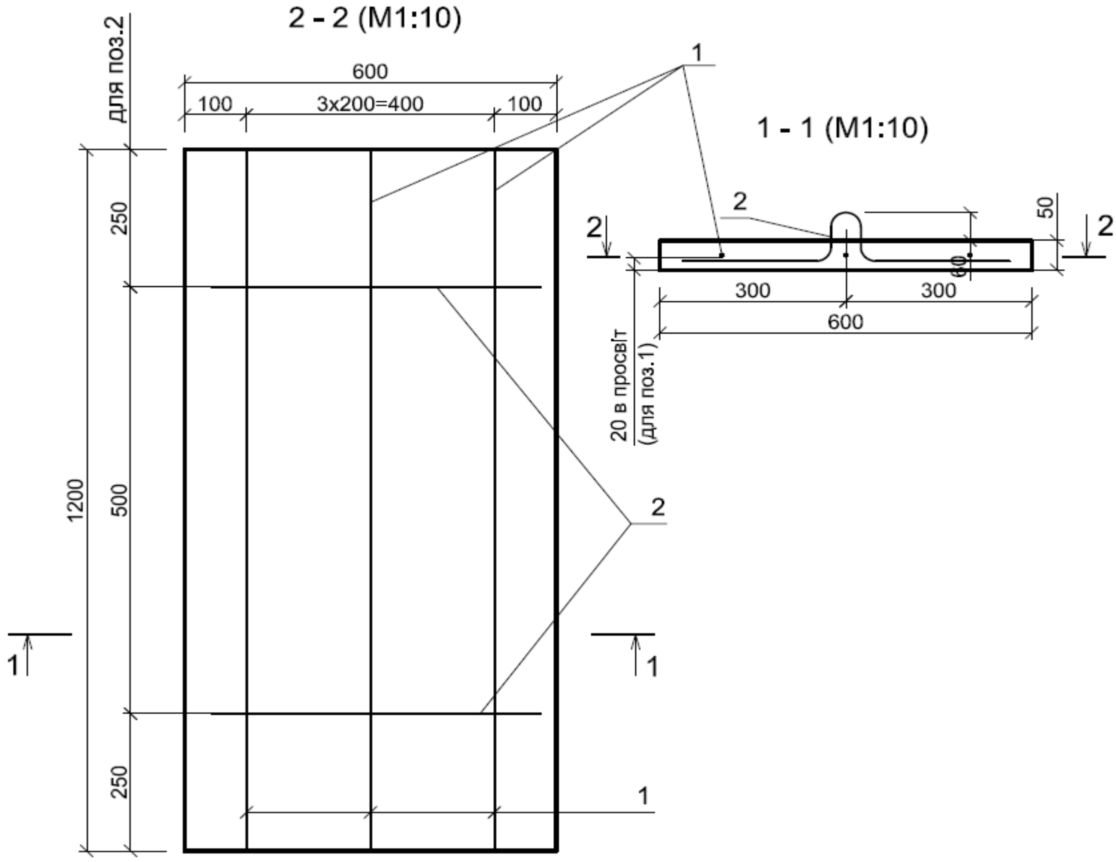

Figure 2. Construction of the ПО-3 formwork plate
1 – ropes K-7 Ø9mm; 2 – mounting loops Ø8A-I.

The construction of ПМ-1 slabs is shown in fig. 3. A two-span deck slab is selected for the test. Plates ПО-1 are mounted on support blocks B-1 and B-2. A layer of cast-in-situ concrete with a thickness of 200 mm is placed over the plates. The concrete class of the cast-in-situ slab is B30. The reinforcement of the monolithic slab consists of two meshes: upper and lower. Since we have a continuous scheme, both grids are calculated. The cast-in-situ slab is designed for A-15 and NK-100 uniform loads. The total length of the cast-in-situ deck slab is 3600 mm, so only one AK tandem is placed on the slab. Calculations on crack resistance and endurance have been performed. As a result of calculations, the slab reinforcement is:

- upper mesh 3 Ø18 AIII with a step of 200 mm;
- lower mesh 3 Ø18 AIII with a step of 200 mm.

The following ПМ-2 and ПМ-3 slabs have the same design. Plates ПО-2 and ПО-3 are mounted on support blocks B-1 and B-2. A layer of cast-in-situ concrete with a thickness of 200 mm is placed over the plates. The concrete class of the cast-in-situ slab is B30. The reinforcement of the cast-in-situ slab consists of only one mesh - the upper one. The reinforcement, calculated for the positive moment in the span of the deck slabs, is embedded in the permanent formwork plates. For ПМ-2, permanent formwork plates are reinforced with ordinary reinforcement, and for ПМ-3 pre-tensioned tendons are used. The inclusion of non-removable formwork plates in the work resulted in an increase in the working height of the section by 50 mm, which, in turn, leads to a decrease in the amount of necessary reinforcement in the middle of the flight of the deck slab part of the bridge. The forces arising in slabs ПМ-2 and ПМ-3 are identical to ПМ-1, because the calculation schemes of all three types of samples are the same. Calculations on crack resistance and endurance have been performed. Since ПМ-2 and ПМ-3 slabs do not have a lower mesh, the samples are designed for the forces that occur during sample transportation. Each sample has four loops. The distance between the loops is calculated in such a way that when the sample is lifted, the latter works according to the scheme of a split beam with two cantilevers. In this way, the formation of tensile forces in the area of the B-1 support block, where there is no reinforcement to absorb this moment, is prevented.

It is clear that the main object of study of ПМ-2 and ПМ-3 samples will be the contact zone of precast and monolithic concrete.

3.2. Testing flat plates with conventional reinforcement.

Flat plates with conventional reinforcement are represented by two samples ПО-1 and ПО-2. Plates were tested for one-time bending according to the pure bending scheme.

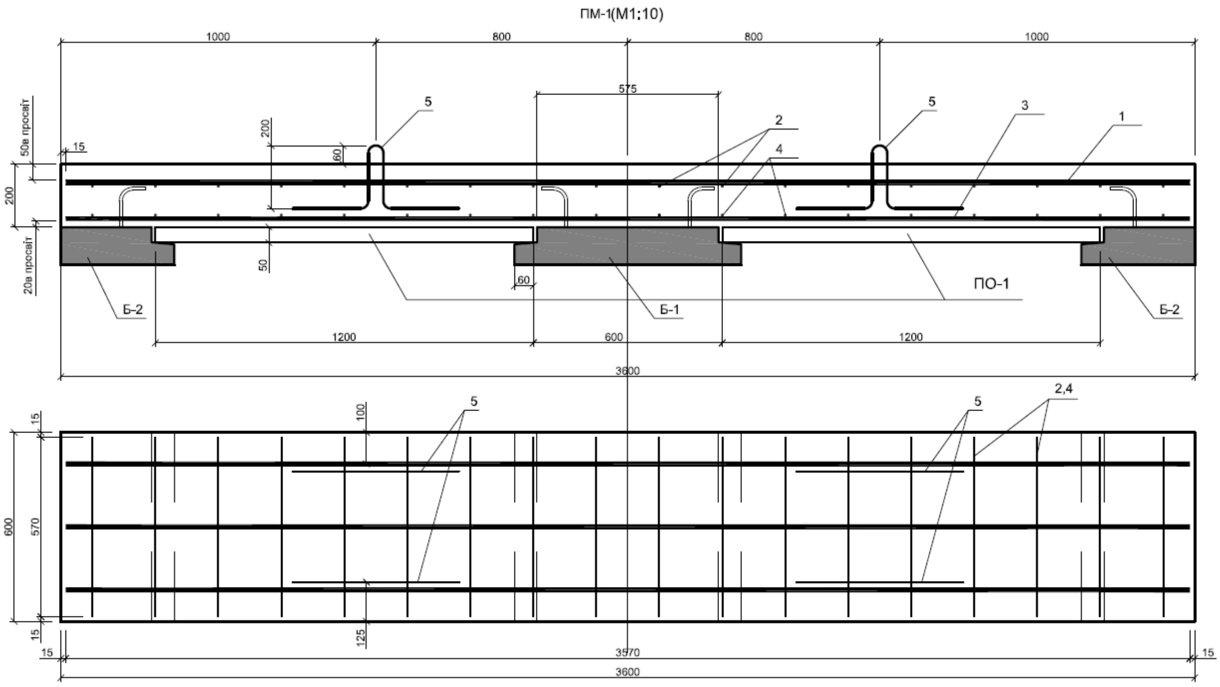

Fig. 3. Construction of a cast-in-situ deck slab ПМ-1.
1 – reinforcement rods Ø18A-III; 2 – reinforcement rods Ø8A-I;
3 – reinforcement rods Ø18A-III; 4 – reinforcement rods Ø8A-I; 5 – mounting loops Ø12A-I.

The tests were carried out on a force stand (Fig. 4) with two concentrated forces. The loading device was controlled by a 10-ton hydraulic jack complete with a pumping station. The general view of the test setup is presented in fig. 5.

During the test, deflections of the plate under load were determined. Fibrous deformations of plate concrete were measured using watch-type micro-indicators with a base of 200 mm.

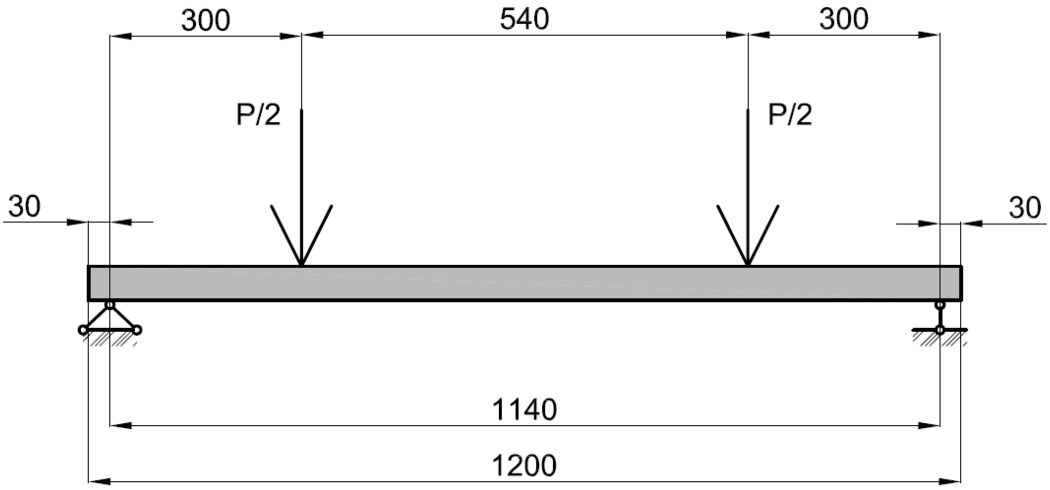

Fig. 4. Test scheme of non-removable reinforced concrete plates formwork ПО- 1, 2, 3.

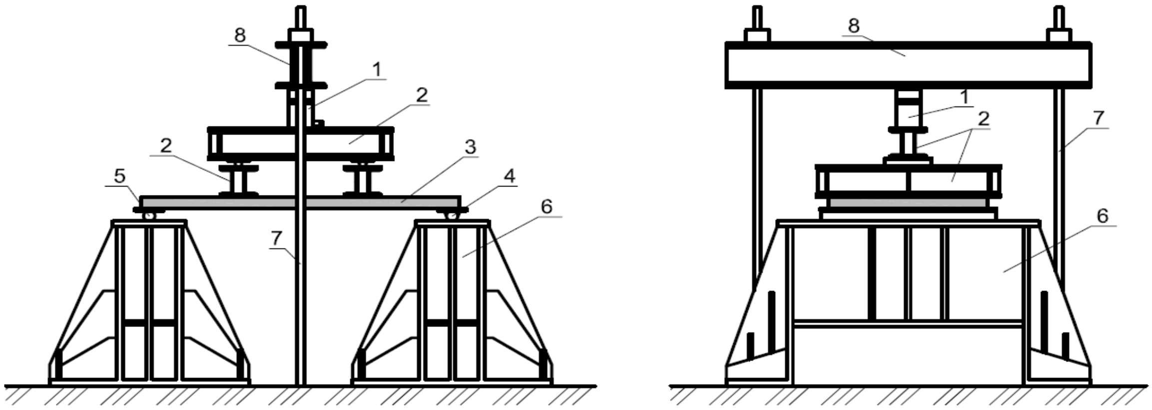

Fig. 5. Stand for testing reinforced concrete plates of permanent formwork
1 – hydraulic jack 10 t; 2 – distribution traverses; 3 – experimental sample; 4 – fixed support; 5 – movable oplra; 6 – supporting pedestal; 7 – traction;8 – upper support traverse.

The crack opening width was determined using an MPB-2 microscope with a resolution of 0.05 mm. Measurements were carried out at each load level from the moment cracks appeared. The width of the opening of "old" cracks, their development and position, as well as the appearance of "new" cracks at each load level were fixed. The load level was controlled by the pressure gauge readings of the pumping station. See the general view of the plate test stand. Fig. 6.

Fig. 6. General view of the slab testing stand permanent formwork.

As part of the tests, 4 plates (2 ПО-1 and 2 ПО-2) were tested.

3.3. Testing of test samples of bridges deck slabs with reinforced concrete permanent formwork.

The cast-in-situ deck slab ПМ-1 is presented as a two-lane continuous system. The support is made through three planes: two lateral 360 x 600 mm and the central 720 x 600 mm. To prevent uneven subsidence, rubber gaskets were installed between the support planes and the stand's pedestals. The wheel load (A15) was located on both spans to create maximum bending moments in the slab. ПО-1 plates were used as permanent formwork in these slabs. The ПО-1 plate is not included in the operation of the entire structure.

Slabs were tested for one-time bending. The purpose of the tests was to determine the bearing capacity of the above-mentioned structures, as well as to determine deflections and stresses in concrete and reinforcement. The test scheme is shown in fig. 7.

The general view of the test setup is presented in fig. 8. The tests were carried out on a force bench with four concentrated forces. The scheme of the bench is shown in fig. 9. The loading device consisted of four 50-ton hydraulic jacks complete with a pumping station. During the test, deflections of the slab under load were determined. Fibrous deformations of slab concrete were measured using watch-type micro-indicators with a base of 200 mm.

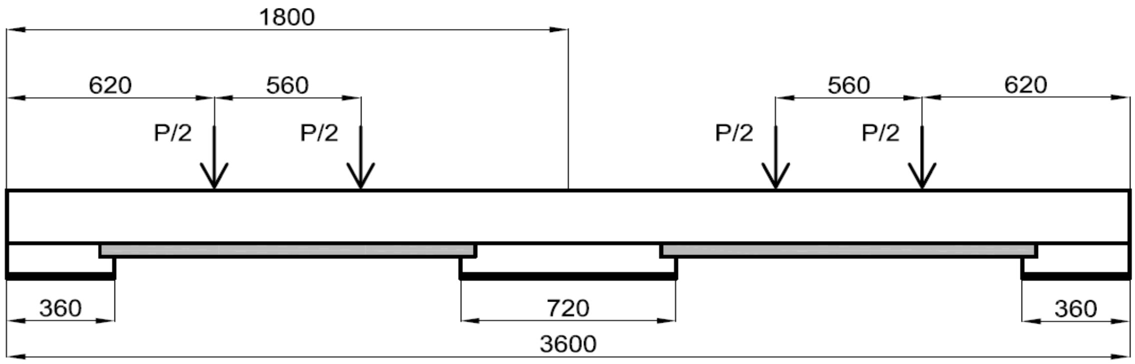

Fig. 7. Test scheme of non-removable reinforced concrete plates formwork ПМ – 1, 2, 3.

The crack opening width was determined using an MPB-2 microscope with a resolution of 0.05 mm. Measurements were carried out at each load level from the moment cracks appeared. The width of the opening of "old" cracks, their development and position, as well as the appearance of "new" cracks at each load level were fixed.

The load level was controlled by the pressure gauge readings of the pumping station.

As part of the tests, 2 plates were tested.

Fig. 8 – General view of the test stand.

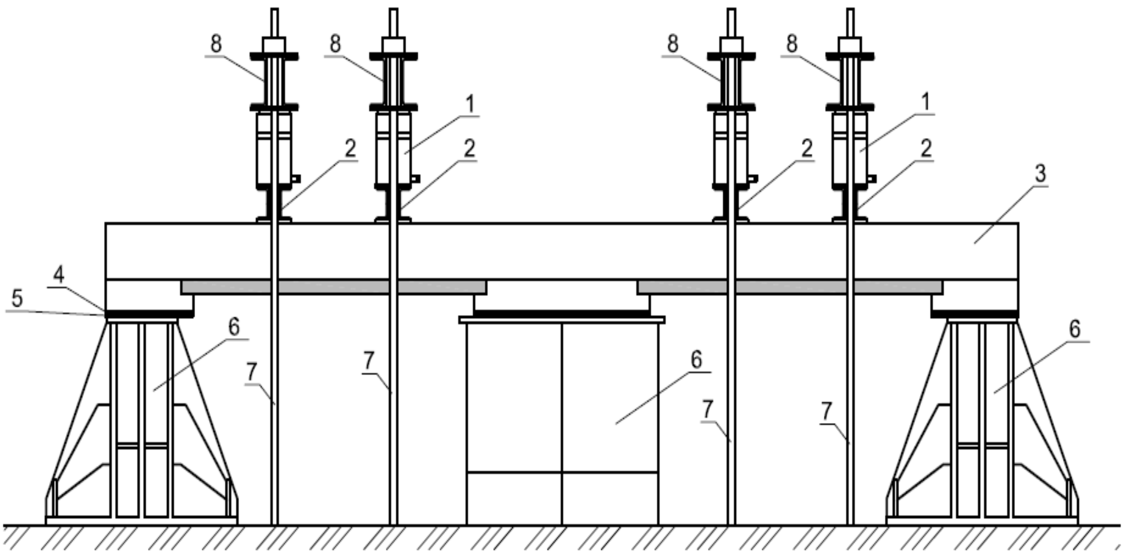

Fig. 9 – Stand for testing reinforced concrete slabs of permanent formwork
1 – hydraulic jack 50 t; 2 – distribution traverses; 3 – experimental sample; 4 – rubber gasket; 5 – metal plate t = 10 mm; 6 – supporting pedestal; 7 – traction; 8 – upper support traverse.

4. Test results.

4.1 Test results of experimental samples of permanent formwork.

During static tests of plates of the ПО-1 series, it was established that the permanent formwork held out the calculated load in terms of bearing capacity and crack resistance. Before reaching the load level of 400 kg, there was a slight proportional increase in the deflections and readings of the clock-type indicators installed on the slabs, which indicated the elastic operation of the structure. When the load level of 400 kg was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop in the central zone and under the distribution traverses, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. In total, 4 cracks formed in the plate. The destruction of the structure occurred after reaching the load level of 1800 kg.

The destruction of the plate was accompanied by the impossibility of reaching a new load level and a sharp increase in deflections; it was also noted that the stresses in the reinforcement had reached the yield point.

During static tests of plates of the ПО-2 series, it was established that the permanent formwork held out the calculated load in terms of bearing capacity and crack resistance. Before reaching the load level of 800 kg, there was a slight increase in the deflections and readings of the clock-type indicators installed on the plates, which indicated the elastic operation of the structure. When the load level of 850 kg was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop in the central zone and under the distribution traverses, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. In total, 12 cracks formed in the plate. The deflection schedule of ПО-2 plates is shown in fig. 10.

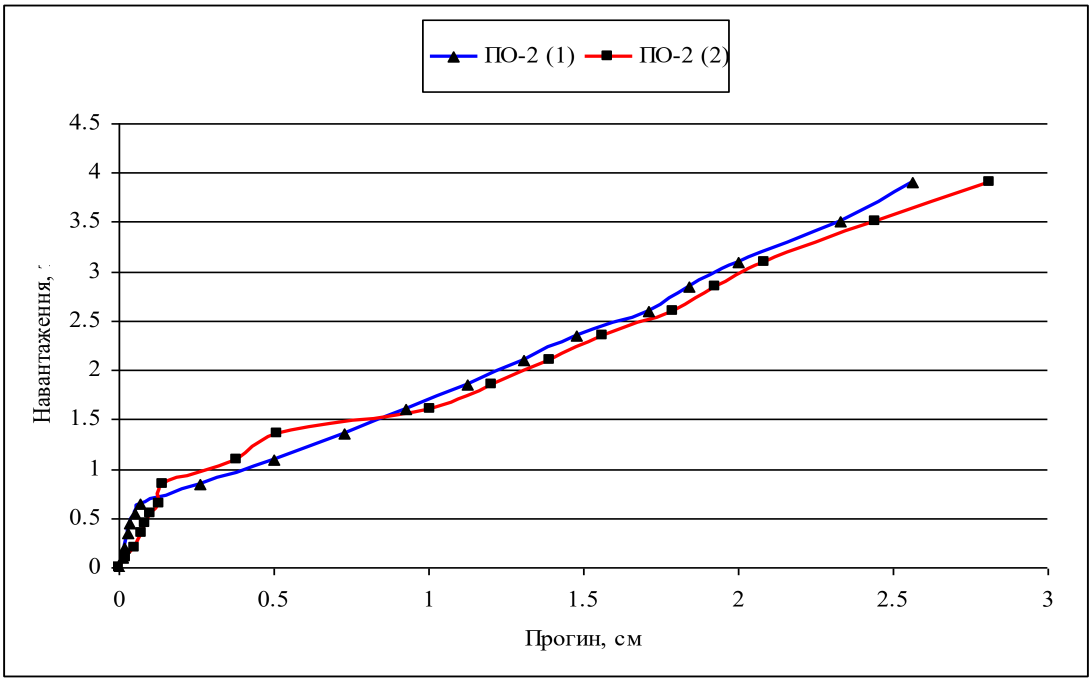

Figure 10. Obtained deflections of plates of non-removable formwork ПО-2.

The destruction of the structure occurred after reaching the load level of 3900 kg. The destruction of the plate was accompanied by the impossibility of reaching a new level of load and a uniform increase in deflections.

It should be added that with a relatively small working height of the ПО-2 plate section, the stresses in the reinforcement did not exceed the yield point, but after the formation of cracks in the stretched zone, the plate lost the necessary stiffness, which led to a uniform increase in deflections due to the flexibility of the plate. Thanks to the fact that the stresses in the reinforcement did not exceed the yield point, after the load was removed, the plates partially compensated for the deflection caused by the load due to the elasticity of the reinforcement.

During static tests of plates of the ПО-3 series, it was established that the non-removable formwork did not hold out the calculated load-bearing capacity (due to the lack of anchoring of the cable reinforcement - see below), but showed excellent crack resistance. Before reaching the load level of 1700 kg, there was a minimal increase in the deflections and readings of the clock-type indicators installed on the plates, which indicated the elastic operation of the structure. When the load level of 1700 kg was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop sharply under the distribution traverses, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. In total, 6 cracks formed in the plate. The destruction of the structure occurred after reaching the load level of 2300 kg. The destruction of the plate was accompanied by the impossibility of reaching a new load level and the uniform increase of deflections. Also slippage of the K7 reinforcing tendons, which led to the accelerated opening of the formed cracks, was noted during the plate testing. The deflection schedule of ПО-3 plates is shown in Fig. 11.

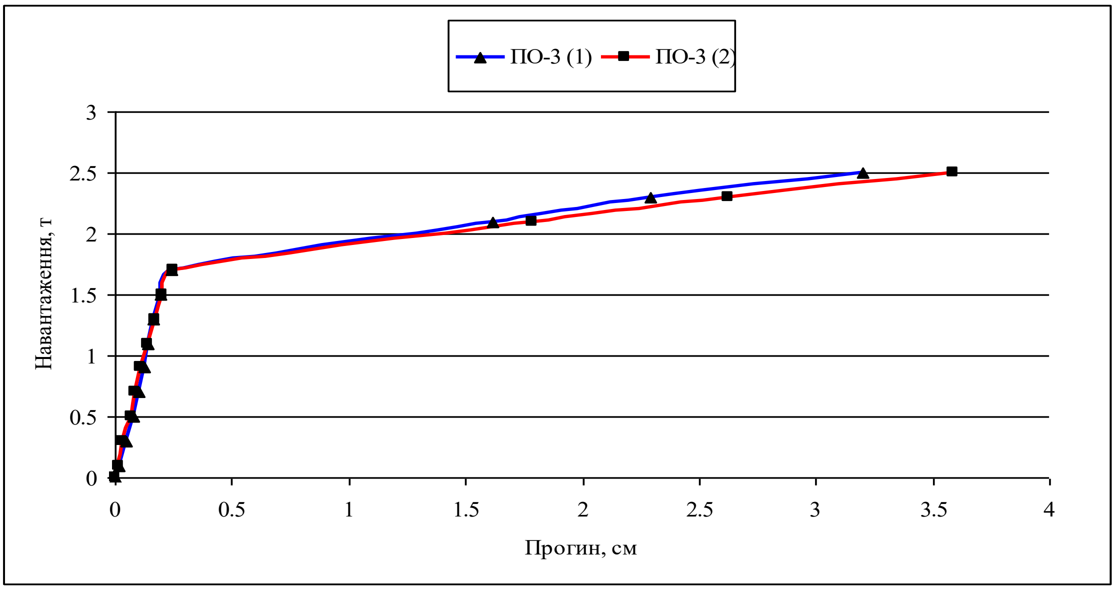

Figure 11. Obtained deflections of plates of non-removable formwork ПО-3.

4.2 Test results of test samples of bridge deck slabs with reinforced concrete permanent formwork.

During static tests of slabs of the ПМ-1 series, it was established that the non-removable formwork ПО-1 was included in the joint operation of the structure as a whole until the stresses in the working reinforcement of the prefabricated plate of the non-removable formwork reached the yield point. The cast-in-situ deck slab held out the calculated load in terms of bearing capacity and crack resistance. Until the load level of 22 t was reached, there was a uniform increase in the deflections and readings of the clock-type indicators installed on the plates, which indicated the elastic operation of the structure. In total, up to 6 cracks formed in the slab span. The deflection schedule of ПМ-1 slabs is shown in fig. 12.

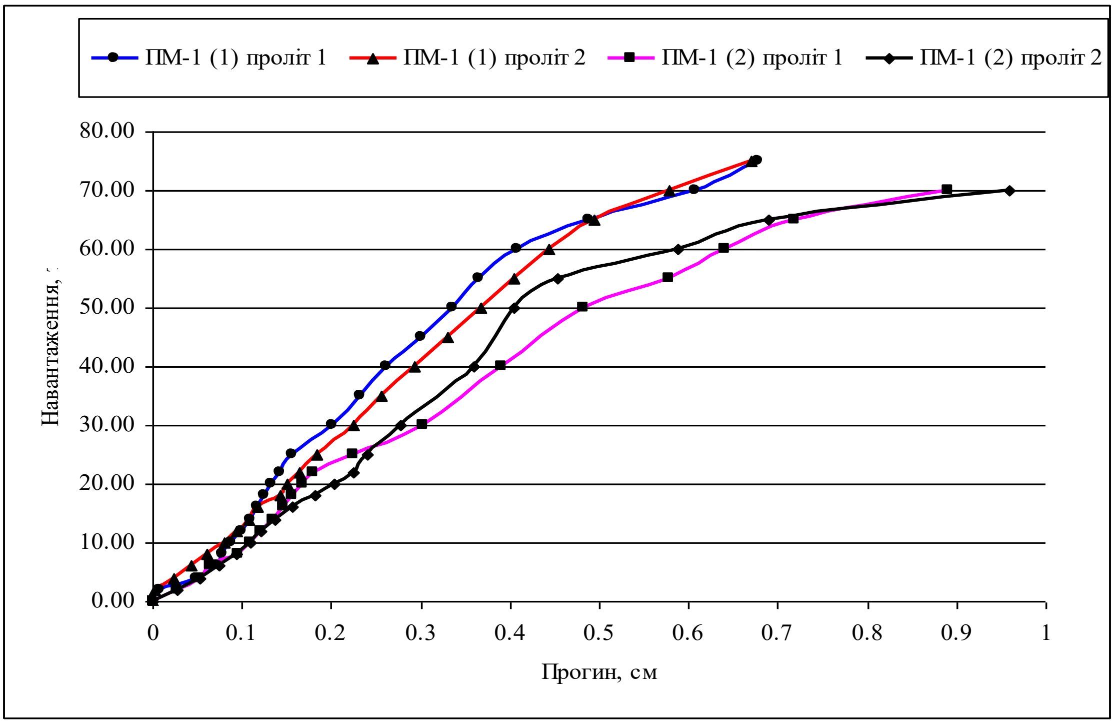

Fig. 12 – The obtained deflections of the deck slabs ПМ-1.

When the load level of 22 t was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop in the span and on the support, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. The collapse of the structure occurred after the load level of 70 and 75 t was reached. The slabs were destroyed by transverse force. Also detachment of ПО-1 non-removable formwork plates from cast-in-situ concrete after removal of the load was noted in some cases during testing of ПМ-1 slabs. This is explained by the fact that the deck slab ПМ-1 was not brought to momentary failure, therefore the stresses in the work reinforcement of the deck slab did not reach the yield point, and all the elastic deformations in the prefabricated part passed, the reinforcement reached the yield point and ceased to perceive tensile forces, which was the cause of the destruction in the form of separation of the assembled part (permanent formwork) from the monolithic one.

During static tests of slabs of the ПМ-2 series, it was established that permanent formwork ПО-2 was fully included in the joint operation of the structure as a whole. The cast-in-situ deck slab held out the calculated load in terms of bearing capacity and crack resistance. Until the load level of 18 t was reached, there was a uniform increase in the deflections and readings of the clock-type indicators installed on the slabs, which indicated the elastic operation of the structure. When the load level of 20 tons was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop in the span and on the support, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. In total, up to 6 cracks were formed in the slab span. The collapse of the structure occurred after reaching the load level of 55 and 65 tons. The collapse of the slabs occurred due to the transverse force. The deflection schedule of ПМ-2 slabs is shown in fig. 13. During the static tests of ПМ-3 series slabs, it was established that the non-removable formwork ПО-3 was fully included in the joint operation of the structure as a whole. The cast-in-situ deck slab held out the calculated load in terms of bearing capacity and crack resistance. Until the load level of 24 t was reached, there was a uniform increase in the deflections and readings of the clock-type indicators installed on the slabs, which indicated the elastic operation of the structure. When the load level of 24 t was reached, the processes of crack formation began - cracks normal to the horizontal faces began to develop in the span and on the support, which was accompanied by an increased growth of deflections and an increase in the compressive stresses of the compressed zone. In general, only one crack was formed in the slab span, which is explained by the slippage of the reinforcing tendon K7 when a certain load level is reached. The collapse of the structure occurred after reaching the load level of 55 and 65 tons. The collapse of the slabs occurred due to the transverse force. The deflection schedule of ПМ-3 slabs is shown in fig. 14.

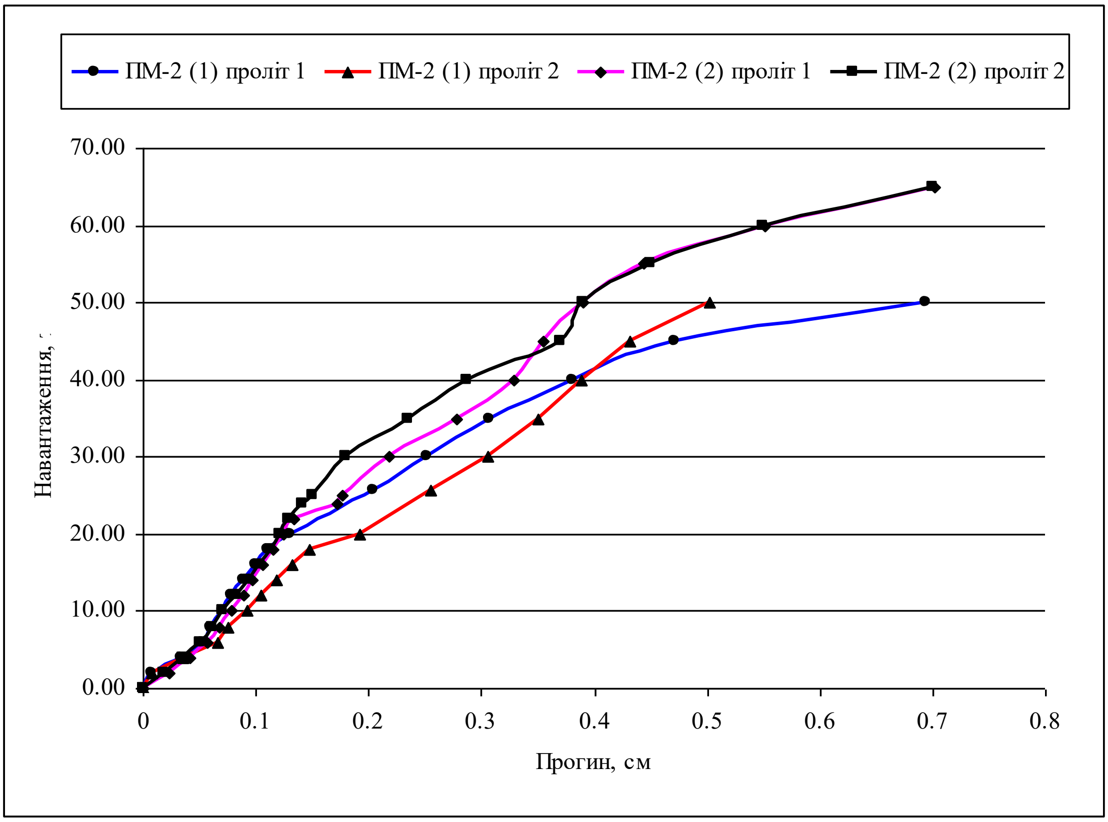

Figure 13. The obtained deflections of the deck slabs ПМ-2.

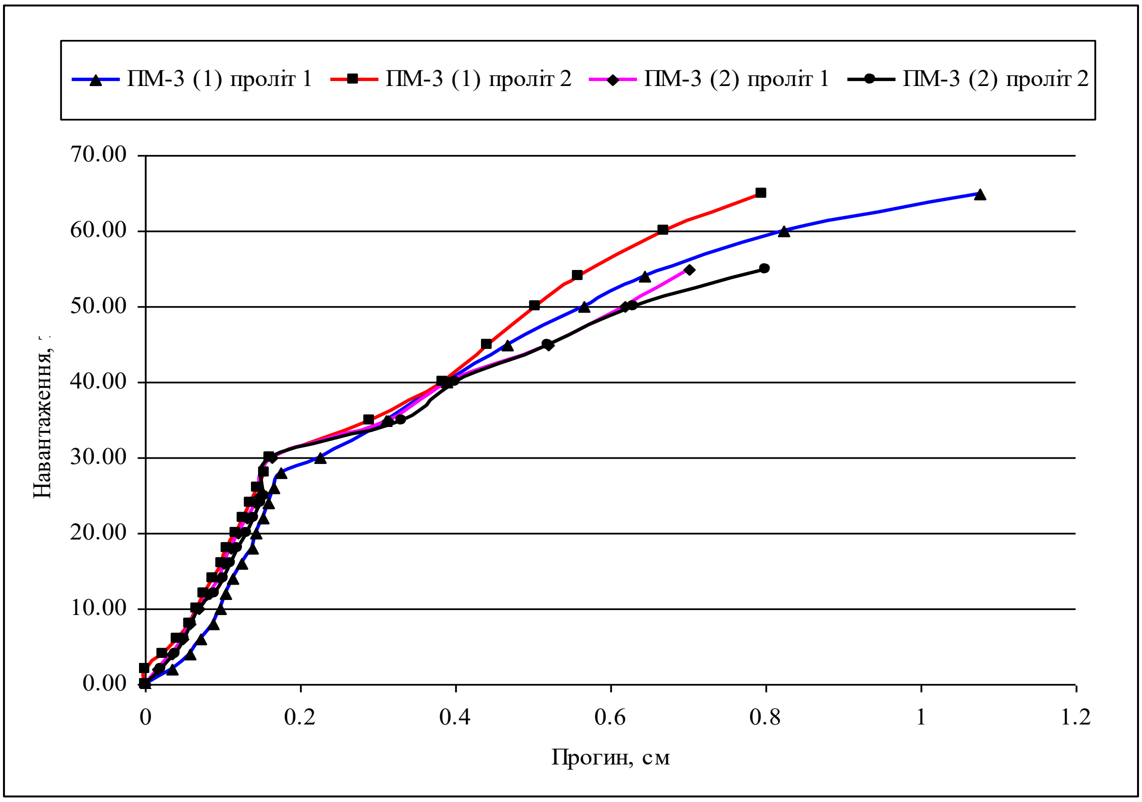

Fig. 14. Obtained deflections of the deck slabs ПМ-3.

5. Conclusions.

5.1 Analysis of test results of test samples of permanent formwork.

According to the results of tests of permanent formwork plates, it is possible to note the excellent performance of ПО-1 and ПО-2 plates. It was found that ПО-2 plates reinforced with reinforcing bars for the design moment in the deck slab, compared to ПО-1 plates (designed to take only the weight of the deck slab concrete), demonstrated greater bearing capacity and crack resistance. Also, in both series of samples ПО-1 and ПО-2, the method of anchoring the ends of the reinforcing rods proved itself well, which made it possible to avoid slippage of even smooth reinforcement (in samples ПО-1). As for plates of the ПО-3 series, these samples can be distinguished only by increased crack resistance, which is clearly due to the use of prestressed reinforcement. However, the plates showed a bearing capacity on par with the ПО-1 series plates. Such a low bearing capacity is explained by the slippage of the K7 tendons when a certain level of loads is reached; in this regard, it is possible to draw a conclusion about the need to create an effective and low-cost method of anchoring prestressed reinforcement in concrete plates of permanent formwork.

5.2 Analysis of test results of test samples of bridge deck slabs with reinforced concrete permanent formwork.

According to the test results of deck slabs, it is possible to note the excellent performance of ПМ-1 and ПМ-2 slabs. It is clear that ПМ-1 slabs, which are reinforced with two reinforcing meshes for the calculated moment in the span and at the support, have a greater bearing capacity. However, as a result of the further increase in the load, and then its decrease, the delamination of the prefabricated permanent formwork ПО-1 was noted. In the future, this factor will have a strong influence on the operational qualities of the real structure - on the durability and aesthetic appearance of the structure. In the ПМ-2 slabs the ПО-2 plate is included in the joint operation, the destruction of the contact seam between the monolithic and precast reinforced concrete was not recorded by visual inspection and instruments. Reliable methods of anchoring reinforcement in prefabricated slabs provide sufficient load-bearing capacity and crack resistance.

It is also possible to note the characteristic cracking in the constructions of ПМ-1 and ПМ-2 samples. The opening of cracks did not significantly increase with the growth of deflections and load, sometimes it can be noticed that some redistribution of the opening of cracks took place, namely when "new" ones appeared, closing of "old" ones took place. The dependence graph of "load - opening of cracks" for ПМ-1 samples is shown in Fig. 15. The dependence graph of "load - opening of cracks" for ПМ-2 samples is shown in fig. 16.

Although the ПМ-3 slabs showed excellent crack resistance and sufficient load-bearing capacity, compared to the first two series, the recorded slipping of the reinforcing tendon does not allow us to draw a full conclusion on its operation. It should also be noted that ПМ-3 slabs were tested only for one-time bending; it is possible to hypothesize that during the operation of the structure under the action of low-cycle and repeatedly repeated loads due to the slippage of the tendons, the destruction of the structure may occur earlier than can be determined by calculations. Opening of cracks with increasing deflections and load increased significantly. The dependence graph of "load - opening of cracks" for ПМ-3 samples is shown in fig. 17.

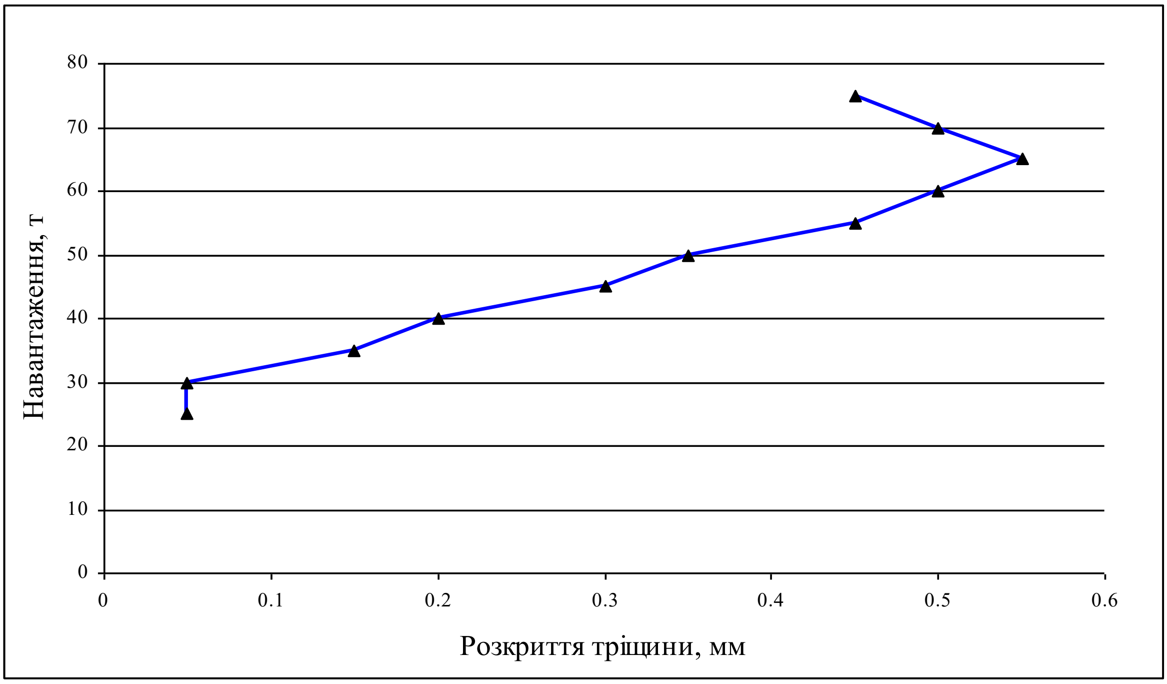

Figure 15. Graphs of the dependence of "load - opening of cracks" of deck slabs ПМ-1.

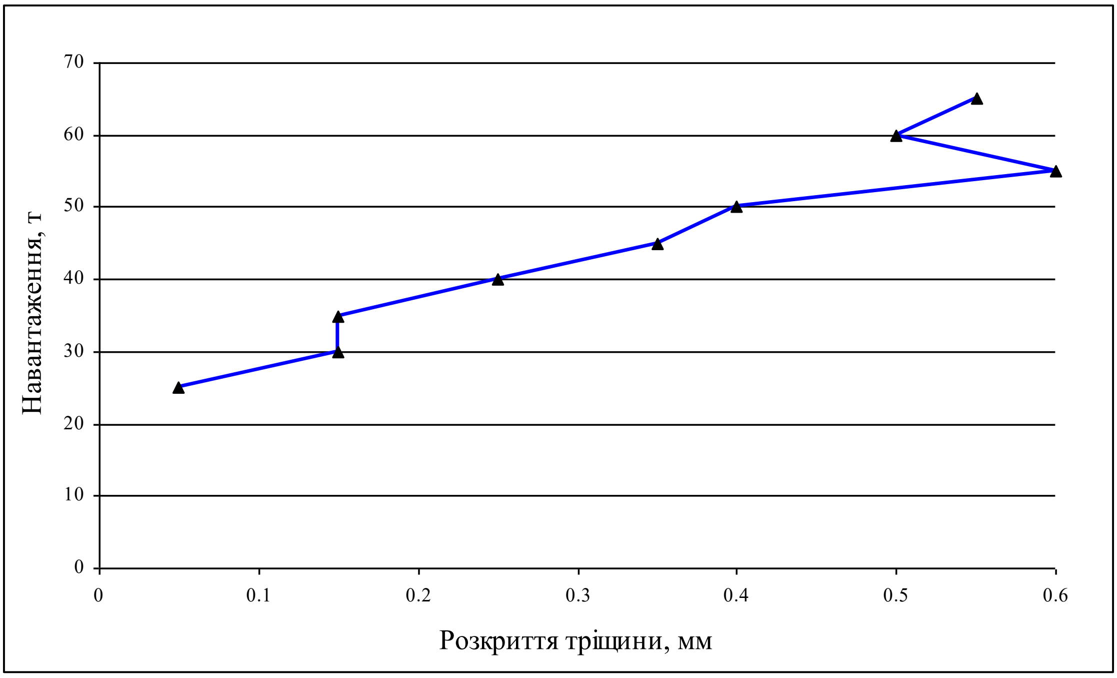

Figure 16. Graphs of the dependence of "load - opening of cracks" of deck slabs ПМ-2.

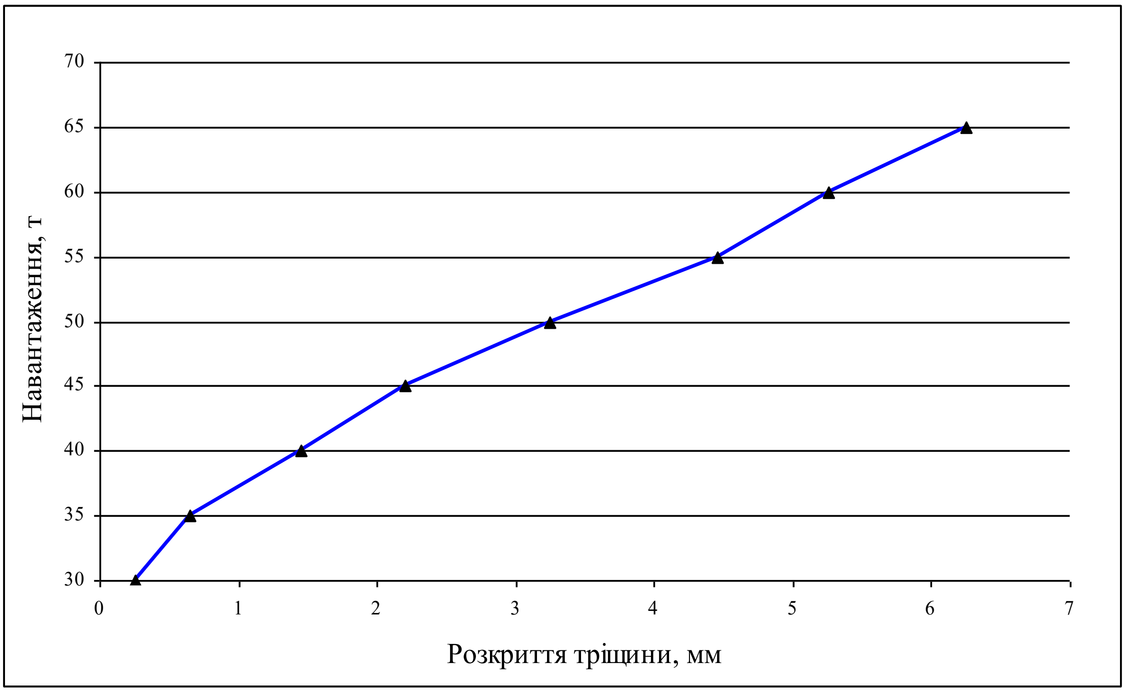

Figure 17. Graphs of the dependence of "load - opening of cracks" of deck slabs ПМ-3.

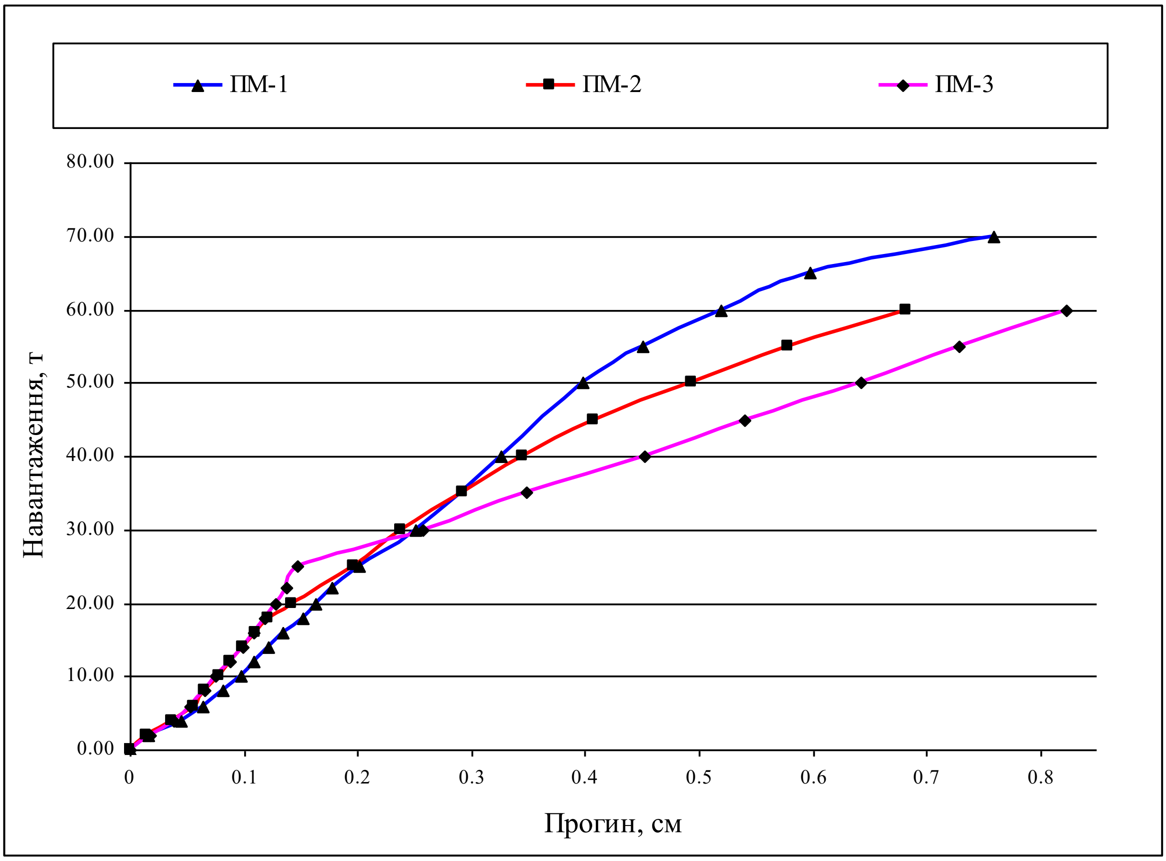

Figure 18. Comparison graph of deflections of cast-in-situ deck slabs.

Comparison of average deflections of all three series (see Fig. 18). From the diagram, it can be seen that ПМ-2 and ПМ-3 series slabs show better performance in the elastic stage. Their deflections almost coincide, it is clear that before the appearance of the first cracks, the slabs have greater bending stiffness compared to ПМ-1. At higher load levels, it becomes clear that in the case of slippage of the tendon in ПМ-3, its deflections are 25-30% greater compared to ПМ-1. If we compare ПМ-2 and ПМ-1 samples, it becomes clear that due to the larger amount of reinforcement in the stretched zone, ПМ-1 has smaller deflections than ПМ-2, although the difference is about 10-15%.

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