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METHOD OT THE RESTORING AND REINFORCEMENT OF DAMAGED BENDING REINFORCED CONCRETE ELEMENTS UNDER CYCLIC LOADING

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Abstract. In all the variety of external and internal influences, cyclic loading is often encountered with hardly noticeable external but the large internal changes, as a result of which the building structures receive a significant increasing of deformations, a noticeable decreasing of fatigue strength and crack resistance, that accompanied by premature failure.

In the published literature available to the authors, the reinforcement methods for solving problems, that associated only with the intermittent cyclic load action in one plane were found.

In this paper, we consider a new method of the restoring and reinforcement of damaged bending reinforced concrete elements under low-cycle high-level reversed cyclic loading, using the prestressed metal clips. The operations, the order and conditions of their performance, the devices used in these operations are defined. The variants of connection and the creation of prestressing in reinforcement elements are proposed. The essence of this reinforcement method is the installation of longitudinal and transverse metal reinforcement elements on the damaged reinforced concrete bending element, forming the clip, with the following creation of prestressing in these reinforcement elements. As a result of the prestressing, a triaxial compression of reinforced element is created, the result of which is the restoration of monolithic and the reinforcement of bending reinforced concrete element, that damaged with normal cross-cutting and cross inclined cracks.

Due to the simplicity of prestressed metal clip manufacturing and its inclusion to the work immediately after manufacture, the ability to regulate the complex stress-strain state of reinforced structure during its exploitation and to change, if it is necessary, the static working scheme, especially under alternating cyclic loading, the proposed method of restoring and reinforcement of damaged reinforced concrete structures experiencing the complex types of deformations, is indispensable.

Keywords: method, reinforcement, reinforced concrete element, crack, clip, prestressing.

Introduction. During its “life” cycle structural elements of buildings and structures are exposed to a wide variety of loads that affect the stress-strain state of the entire structural system of the building as a whole and of each of its elements, in particular.

In all the variety of external and internal influences, cyclic loading is often encountered with hardly noticeable external but large internal changes, as a result of which the building structures receive a significant increase in deformations, a noticeable decrease in fatigue strength and fracture toughness, accompanied by premature failure [1, 2]. Undisturbed, but damaged with cross-cutting normal and crossed inclined cracks, emergency structure, according to current standards [3], are subjected to dismantling and replacement, which, in turn, entails stopping the technological process, and additional costs associated with construction and installation work and manufacturing structure. However, the bearing capacity of the reinforced concrete element has reached the pre-emergency or emergency condition as a result of indicated impact load is still possible to recover with strengthening, e.g., concrete [4] mortar block, composite materials [5], prestressed metal casing [6].

Strengthening using the first two of the above methods allows you to restore the construction once. Strengthening the metal casing makes it possible to adjust its stress-strain state by prestressing elements in strengthening both at the initial stage of strengthening, and in the course of its operation. This makes this type of strengthening more attractive and interesting from the standpoint of studying

teamwork, with different types and intensity of loading, damage received, increased requirements for its load-carrying capacity, and so on.

From the point of view of production and operating conditions, strengthening of reinforced concrete structures with mortar mixtures and concretes [4] has such limitations: the inclusion of a reinforcement system is possible only after the strength of the basic materials has been established; the lack of complete control over the joint operation of the reinforced structure and the strengthening system, both at the beginning of the strengthening and in the process of its operation.

The critical factor for the strengthening system of composite materials [5] is the glass transition temperature of its polymer matrix. And these are 60-65ºC. The high cost of composite materials, as well as the lack of direct control of the strengthening system, also limit the wide use of this type of strengthening.

Strengthening with metal elements and cages [6], as well as composite materials, has a limitation on the temperature range of application, although much larger (470 ºC) [7]. But, one of the main advantages of strengthening with the help of metal elements is certainly the multivariance of its use, which in turn makes it possible to regulate the stress-strain state of the structure and to perform constant technical monitoring of the system during its operation.

In this paper, a method of strengthening the damaged through, normal and through-cross the inclined bent cracked concrete elements, strengthening with metal casing pretensioned experiencing low cycle alternating high loading levels were considered.

Published in the accessible to authors literature, the methods of strengthening that are closest to the illuminated problem are solved with problems connected only with the action of a load in one plane and one sign, which imposes limitations on the application of available methods under the action of an alternating load, and also the load acting in different planes.

Thus, a method of strengthening the structure by attaching additional reinforcement to the exposed working armature of the stretched zone, with its preliminary tension "on concrete" and subsequent concreting construction were known [8]. However, in this method, the stretched zone is compressed beforehand and therefore the resistance of only the stretched zone of the bent element increases, which leads to a partial increase in the load-bearing capacity of the reinforced structure, which is not always acceptable (with increased static, pulsating or seismic actions).

The closest to our method is the reinforcement of structures, which is described in the description of the invention to USSR copyright certificate No. 1778250 [9]. The method involves securing the reinforcement element in the compressed zone of the reinforced concrete beam and the subsequent two-stage pre-compression: before and after the stress of the reinforcement element of the stretched zone. However, this method has the following drawbacks: in this method, the upper elements for strengthening the reinforced concrete beam are compressed twice, but only in the longitudinal direction, which results in the reinforcement of only normal sections of the integral reinforced concrete beam by the action of only a constant transverse load or bending moment in the main vertical force plane , and does not lead to an increase in the sloping sections and the support sections, in general, to the action of the same sign-constant load. Under the influence of an alternating transverse load (for example, in case of an earthquake), on the contrary, this method of amplification can lead to premature failure both in normal sections that have been pre-stretched with the upper reinforcement elements and crosswise inclined sections at the supports.

In addition to the above written methods for strengthening the bent elements, other methods with similar drawbacks are known.

The purpose and the research objectives. Analysis of literature sources has showed that the issue of reinforcing damaged bent ferro-concrete elements under the influence of a low-cycle alternating load of high levels remains, in practice, were unexplored. In this regard, the purpose of this work is to develop a method for restoring and strengthening damaged bent reinforced concrete structures operating under conditions of low-cycle, alternating high-level load loading, using prestressed metal casing.

The research objectives are: to identify the characteristic features of the proposed method operations, to establish the order and sequence of these operations, to develop a schematic diagram

of the device that provides this method.

Methods of research. Typical features of the method are operations, order and conditions for their execution, as well as the devices used in performing these operations (Fig. 1, 2). We divide the complex operations into simpler ones:

1) Mounting the longitudinal reinforcement elements (1) on a mechanically damaged bending element using a glue mixture, scaffolding and other devices;

2) Connection of longitudinal reinforcement elements (1) with support elements (2);

3) Mounting the parts (5) to create prestressing in the longitudinal reinforcement elements (1);

4) Fixing in the design position of the longitudinal reinforcement elements (1) and supporting elements (2) by fixing the tension of the parts (5);

5) Fastening of transverse vertical reinforcement elements (3) to longitudinal reinforcement elements (1);

6) Fastening of the transverse horizontal reinforcement elements (4) to longitudinal reinforcement elements (1) with subsequent fixing tension on the reinstated or reinforced structure;

7) Sequential stepwise creation of prestressing in longitudinal (1) and transverse (3, 4) reinforcement elements up to the design value.

Thus, to achieve this goal we perform the selected operations in the same sequence, but with the obligatory consideration of the production conditions and the nature of the damage to the structure. In this case, the connection of the transverse vertical (3) and horizontal (4) reinforcement elements with the longitudinal reinforcement elements (1) and the subsequent fixing of their tension on the reconstructed or reinforced structure is performed successively in one of the variants (Table 1).

Table 1 – Sequences and options for creating a metal clip from longitudinal (1), vertical (3), horizontal (4) gain elements

Sequences	Options		
	1	2	3
1	(3)	(3)	(4)+(3)
2	(4)	(4)	

Depending on which faults prevail in the renewable or reinforced bending structure, the creation of alternate stepped prestressing in the longitudinal and transverse reinforcement elements up to the design value can be performed in two stages:

Stage 1 – alignment in the longitudinal direction of the damaged structure and fixing it in the design position according to the recommendations of Table. 2.

Table 2 – Sequences and variants of step-by-step stepwise creation of prestressing in longitudinal (1.1) ... (1.4), transverse vertical (3) and horizontal (4) reinforcement elements according to Fig. 1

Sequences	Variants							
	1	2	3	4	5	6	7	...
1	1.1+1.2	1.3+1.4	1.1+1.3	1.2+1.4	1.1+1.2	1.3+1.4	1.1+1.3	...
2	1.3+1.4	1.1+1.2	1.2+1.4	1.1+1.3	(3)	(3)	(4)	...
3	(3)	(3)	(4)	(4)	1.3+1.4	1.1+1.2	1.2+1.4	...
4	(4)	(4)	(3)	(3)	(4)	(4)	(3)	...

Stage 2 – creation of prestressing pretension in the longitudinal and transverse reinforcement elements up to the design value (Table 3).

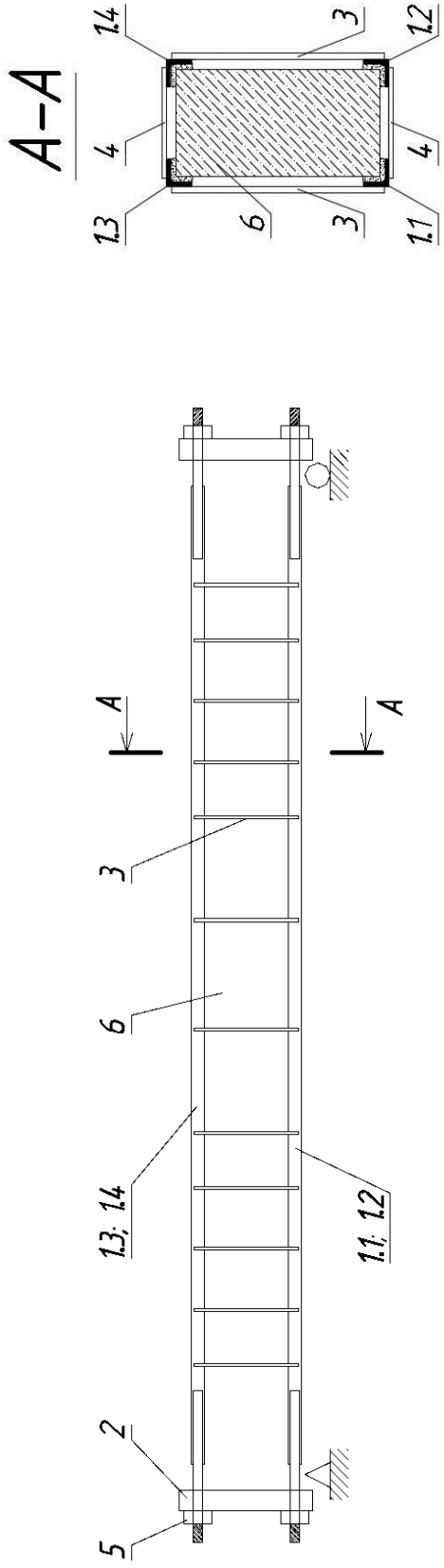

Fig. 1. Schematic diagram (P&ID) of an apparatus for reinforcing a conventional curved reinforced concrete structure mechanically damaged by through normal and crossover cracks by means of a prestressed metal holder

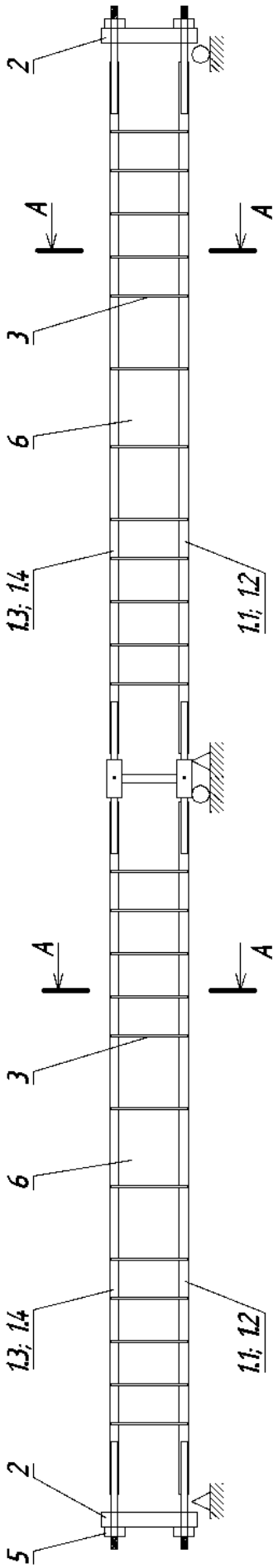

Fig. 2. Schematic diagram of the device for reinforcing mechanically damaged through normal cracks and cross inclined cracks of continuous non-bend reinforced concrete structures using a prestressed metal clip

Table 3 – Sequences and options for creating prestressing in the longitudinal (1) and transverse (3, 4) gain elements at a time to the design value

Sequences	Options							
	1	2	3	4	5	6	7	8
1	(1)	(1)	(3)	(3)	(4)	(4)	(4)	(1)
2	(4)	(3)	(1)	(4)	(1)	(3)	+ (3)	(4)
3	(3)	(4)	(4)	(1)	(3)	(1)	(1)	+ (3)

The conditions for the performance of these operations do not differ from the conditions for performing general construction work, while observing the generally accepted safety rules, as well as the regulations for the use of reinforcement materials and the established production technology.

Results of the researches. The conducted experimental studies confirmed the expediency of using this method for restoration and reinforcement, if necessary, of mechanically damaged reinforced concrete structures. Thus, when reinforced concrete beams with through normal and inclined cracks reinforced by this method, it was possible not only to restore the bearing capacity, but also to increase it up to 1.5 times in comparison with the original ones.

Conclusions and prospects for further research.

1. Restoration of monolithic character and reinforcement (if necessary) of bent reinforced concrete structures damaged by through normal and cross inclined cracks is possible by creating in them a three-axis compression due to prestressing of the elements of the reinforcing metal cage.

2. The simplicity of manufacturing a prestressed metal cage and its inclusion in the work immediately after manufacturing, the ability to regulate the complex stress-strain state of the reinforced structure during its operation and to change, if necessary, the static scheme of its operation, especially under alternating cyclic loading, make the proposed the method of restoration, as well as reinforcement of damaged reinforced concrete structures experiencing complex types of deformation, is indispensable.

A logical continuation of the ongoing research is the development of a device for the restoration and reinforcement of damaged reinforced concrete bent structures.

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СПОСІБ ВІДНОВЛЕННЯ ТА ПІДСИЛЕННЯ ПОШКОДЖЕНИХ ЗГИНАЛЬНИХ ЗАЛІЗОБЕТОННИХ ЕЛЕМЕНТІВ ЗА ДІЇ ЦИКЛІЧНОГО НАВАНТАЖЕННЯ

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Анотація. В усьому різноманітті зовнішніх і внутрішніх впливів циклічне навантаження є таким, що часто зустрічається з малопомітними зовнішніми, але великими внутрішніми змінами, в результаті яких будівельні конструкції отримують значний приріст деформацій, помітне зниження втомної міцності та тріщиностійкості і яке супроводжується передчасним руйнуванням. Опубліковані в доступній авторам літературі найбільш близькі до проблеми, що висвітлюється, способи посилення вирішують завдання, пов'язані тільки з дією навантаження в одній площині і одного знаку.

У даній роботі розглядається новий спосіб відновлення та підсилення пошкоджених згинальних залізобетонних елементів, які працюють в умовах впливу малоциклового знакозмінного навантаження високих рівнів, за допомогою попередньо напружених металевих обойм. Визначені операції, порядок та умови їх виконання, а також пристрої, які використовуються при виконанні цих операцій. Запропоновані варіанти з'єднання та створення попереднього напруження в елементах підсилення. Суттю даного способу посилення є установка на пошкоджену залізобетонну конструкцію повздовжніх та поперечних металевих елементів, які утворюють обойму, з подальшим створенням попереднього напруження в них, у результаті якого пошкоджена наскрізними нормальними та перехресними похилими тріщинами конструкція зазнає тривісного обтиснення, підсумком якого є відновлення її монолітності та посилення (за необхідності).

Простота виготовлення попередньо напруженої металевої обойми і включення її в роботу відразу ж після виготовлення, можливість регулювати складний напружено-деформований стан посилюваної конструкції в процесі її експлуатації та змінювати, за необхідності, статичну схему роботи, особливо при знакозмінному циклічному

навантаженні, роблять запропонований спосіб відновлення, а також посилення пошкоджених залізобетонних конструкцій, що зазнають складних видів деформацій, незамінним.

Ключові слова: спосіб, посилення, залізобетонна конструкція, тріщина, обойма, попереднє напруження.

СПОСОБ ВОССТАНОВЛЕНИЯ И УСИЛЕНИЯ ПОВРЕЖДЕННЫХ ИЗГИБАЕМЫХ ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ ПРИ ЦИКЛИЧЕСКОМ ДЕЙСТВИИ НАГРУЗКИ

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Аннотация. Во всем многообразии внешних и внутренних воздействий циклическая нагрузка является часто встречающейся с малозаметными внешними, но большими внутренними изменениями, в результате которых строительные конструкции получают значительный прирост деформаций, заметное снижение усталостной прочности и трещиностойкости, сопровождающееся преждевременным разрушением. Опубликованные в доступной авторам литературе наиболее близкие к освещаемой проблеме способы усиления решают задачи, связанные только с воздействием нагрузки в одной плоскости и одного знака.

В данной работе рассматривается новый способ восстановления и усиления поврежденных изгибаемых железобетонных элементов, работающих в условиях воздействия малоцикловой знакопеременной нагрузки высоких уровней, с помощью предварительно напряженных металлических обойм. Сутью данного способа усиления является установка на поврежденный железобетонный изгибаемый элемент продольных и поперечных металлических элементов усиления, образующих обойму, с последующим созданием предварительного напряжения в них, в результате которого создается трёхосное сжатие усиливаемого элемента, итогом которого является восстановление монолитности и усиление (при необходимости) поврежденных сквозными нормальными и перекрёстными наклонными трещинами изгибаемого железобетонного элемента.

Простота изготовления предварительно напряженной металлической обоймы и включение её в работу сразу же после изготовления, возможность регулировать сложное напряженно-деформированное состояние усиливаемой конструкции в процессе её эксплуатации и изменять, при необходимости, статическую схему работы, особенно при знакопеременной циклической нагрузке, делают предлагаемый способ восстановления, а также усиления поврежденных железобетонных конструкций, испытывающих сложные виды деформаций, незаменимым.

Ключевые слова: способ, усиление, железобетонная конструкция, трещина, обойма, предварительное напряжение.

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