Andrzej JURKIEWICZ
Piotr MICEK
Marcin APOSTOŁ
Dariusz GRZYBEK

KOMPLEKSOWE BADANIA ELEMENTÓW SYSTEMU SPRĘŻAJĄCEGO JAKO PODSTAWA BEZPIECZEŃSTWA SPRĘŻONEJ KONSTRUKCJI

COMPLEX TESTING OF THE PRESTRESSING SYSTEM ELEMENTS AS THE BASE OF PRESTRESSED STRUCTURE SAFETY

Artykuł jest kontynuacją problematyki prezentowanej w artykule „O potrzebie monitorowania procesu sprężania konstrukcji mostowych". Opisany system monitorowania i rejestracji przebiegów sił sprężających i wydłużeń był przeznaczony do pracy w fazie wytwarzania konstrukcji (podczas procesu sprężania). Zapewnienie jakości i bezpieczeństwa sprężonej konstrukcji wymaga również prowadzenia badań elementów systemu sprężającego. Każdy z elementów sprężającego systemu ma wpływ na jakość konstrukcji, ale niektóre z tych elementów mają decydujące znaczenie. Rodzaje i metodologia takich badań są prezentowane w ETAG 13. Jednak prowadzenie takich badań wymaga skomplikowanego stanowiska badawczego. Artykuł prezentuje konstrukcje elementów systemu sprężającego ASIN oraz szczegółowe badania wynikające z instrukcji zawartych w ETAG 13. Instrukcje te obejmują badania zakotwień: badania wytrzymałości statycznej, badania wytrzymałości zmęczeniowej, badania poślizgu, badania strat siły sprężającej wynikających z tarcia. Oprócz badań zakotwień, badania powinny objąć również: cięgna, osłony kanałów, specjalne materiały do wypełnienia wewnętrznych przestrzeni kanałowych. Stanowisko badawcze zostało zbudowane do prowadzenia takich badań. Wytyczne zawarte w ETAG 13 określają ocenę przydatności systemu sprężającego. Na tym polu istotnymi czynnikami są: wytrzymałość mechaniczna, bezpieczeństwo z zapewnieniem bezpieczeństwa pożarowego, ochrona zdrowia, ochrona środowiska, oszczędność energii. System sprężania ASIN, który został opracowany przez pracowników Katedry Automatyzacji Procesów spełnia wymagania ETAG 13. Przykładowe wyniki badań tego systemu z ich oceną są prezentowane w artykule.

Słowa kluczowe: *konstrukcje sprężone, system sprężania, monitorowanie.*

This article is a continuation of the problem presented in article "About the need of the monitoring of the bridge construction prestressing process". The described system of the monitoring and registration of a prestressing forces and elongations courses was destined to the building stage (during prestressing process). A quality and safety assurance of the prestressed structure require also a leading of the testing of prestressing system elements. Each of the elements of prestressing system have influence on the structure quality but some of it have main meaning. A kind and a methodology of such testing are presented in ETAG 13. The leading of such complex research requires a sophisticated laboratory stand. This article presents the elements structures of ASIN prestressing system as well as the detailed researches according to ETAG 13 instructions. This instructions contain a anchorage testing: static strength researches, fatigue strength researches, a slop researches, a researches of force losses from friction. Apart from anchorage testing, researches should also contain a testing of the cable, a testing of the canals shields, a testing of the shield pipes, a testing of the special material to a filling of internal canals space. The laboratory stand was built to the leading of such complex testing. The instructions of ETAG 13 define the assessment of the suitability of the prestressing system. In this field the most important factors are following: a mechanical strength, a system safety with fire safety assurance, a health protection, a environment protection, a energy saving. ASIN prestressing system, which was elaborated by employees of Department of Process Control, fulfil ETAG 13 requirements. A exemplary researches results with its assessments are presented in this article.

Keywords: *prestressing, post-tensioning system, monitoring.*

1. Introduction

Works on sliding and prestressing of pre- and post-tensioned concrete constructions original technology are leading in Department of Process Control since 1992. Intensive basic researches resulted in creating of system which includes both tensioning and transporting units as well as interacting with them grips and anchorage series of types. In connection with signing by Poland, European Committee association agreement, as a precondition of prestressing technology development is existence of research laboratory allowing to carrying out static and fatigue tests of all system components. Because testing of anchor blocks of one type in laboratories of Western Europe concerns are very expensive, so that there were decision about making proper research laboratory.

2. Research of the elements of prestressing system

2.1. Static load tests

The anchored tendon (fig. 1) is stressed at one end with representative equipment comparable to the one used on construction site in steps corresponding to 20%, 40%,60% and 80% of the characteristic tensile strength of the tensile elements. The load is increased at a constant rate corresponding to about 100 MPa per minute.

At 80% level, the load is transferred from the equipment to the anchorage and test rig. It is then held constant at 80% level for one and two hours for internal and external tendons, respectively.

Subsequently, the load is gradually increased for both tendon types with the test rig to failure at a maximum strain rate of 0.002 per minute till tendon scarifying [4].

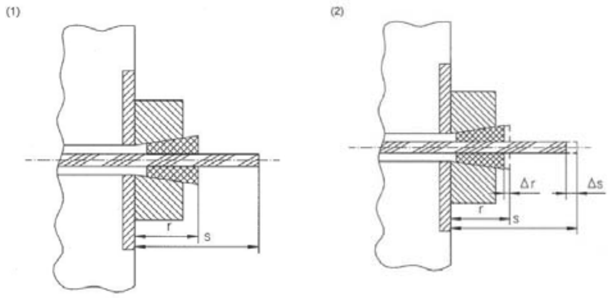

Fig. 1. Slides in the anchorage: a) anchorage before prestressing, b) anchorage after prestressing

2.2. Fatigue tests

The test shall be performed in a tensile testing machine with the pulsator at a constant load frequency of not more than 10 Hz, and with a constant upper load of 65% of the characteristic strength of the tensile elements.

Range of loads *ΔF = max F - min F* shall be maintained constant throughout the testing, at levels corresponding to 80 MPa stress amplitude in the tensile elements for 2 million cycles.

2.3. Load transfer to the structure

Specimen (fig. 2) is loaded by steps: 0.2 Fpk, 0.4 Fpk, 0.6 Fpk, and 0.8 Fpk.

After reaching the load 0.8 Fpk at least ten slow load cycles are to be performed, with 0.8 Fpk and 0.12 Fpk being the upper and the lower load limits, respectively (fig. 3).

Following cyclic loading, the specimen shall be loaded continuously to failure [4]. Measuring set-up for load transfer test is shown in fig. 4.

2.4. Test for friction losses in anchorages

The test specimen shall consist of a prismatic concrete beam (or another device) including the tensile elements, anchorage components including bearing plate, anchor head, wedges or as applicable for other methods of anchoring the tensile elements, etc as well as the jacks and manometers.

The test specimen is assembled in the rig machine according to the envisaged application using the components necessary for anchoring the tendon.

At least three successive loading and unloading cycles will be done, with the jack in its open/middle/closed position, respectively. The linear regression shall be determined from the 20% load level to the maximum load [4].

3. Elements of ASIN system ASIN

3.1. Anchors and anchor blocks

On the basis of Ayre model of contact effect of system string – anchoring jaw – bushing(disc) using the MES environment series of anchors and grips adjustment for post-tensioned technology for series of strings ∅7.8, ∅12.5, ∅15.5 [6]. Exemplary anchoring block is shown in fig. 5 and its application in the bridge construction building is shown in fig. 6.

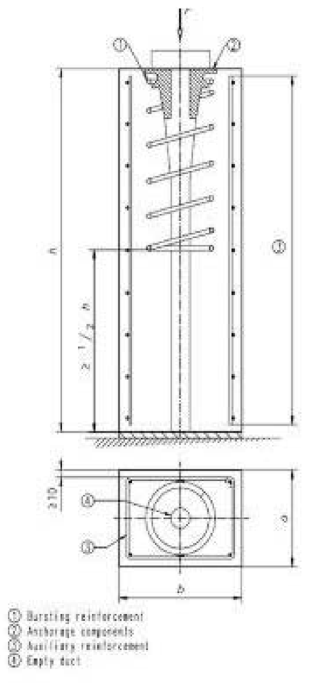

Fig. 2. Test specimen for load transfer test

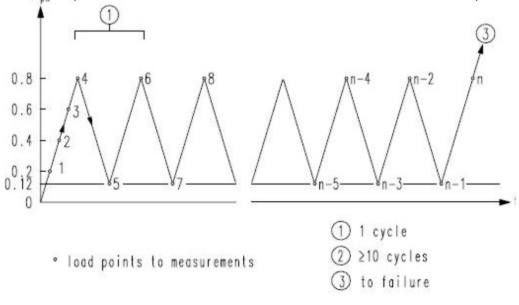

Fig. 3. Course of specimen load

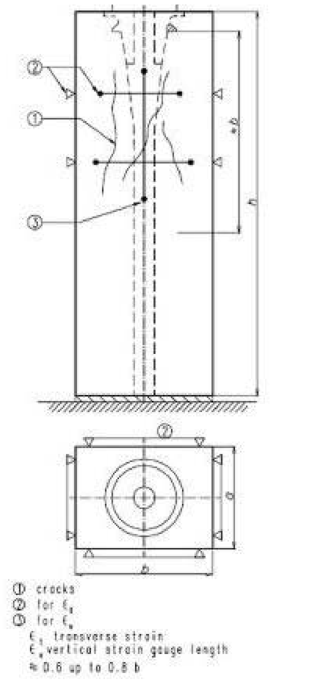

Fig. 4. Measuring set-up for load transfer test

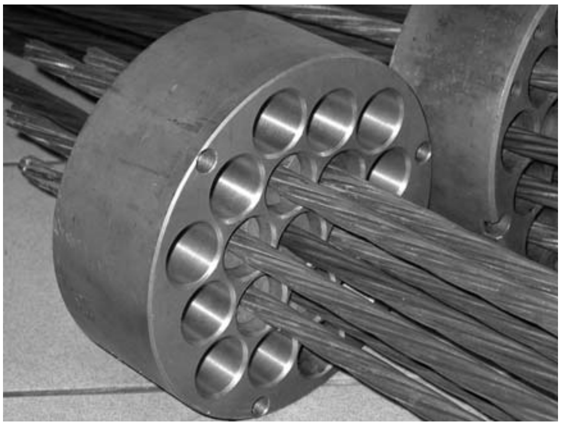

Fig. 5. Anchor blocks

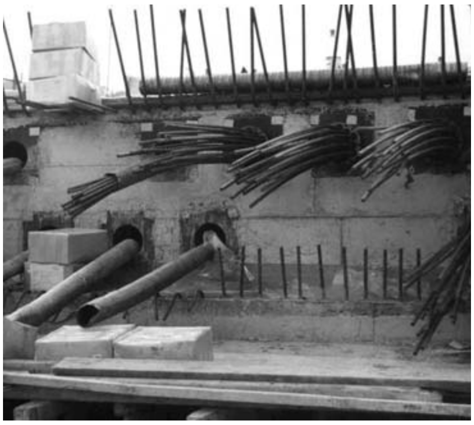

Fig. 6. Application in bridge construction

3.2. Tensioning and transporting devices

Exemplary prestressing device is shown in fig. 7 and its application in the bridge construction building is shown in fig. 8 [6].

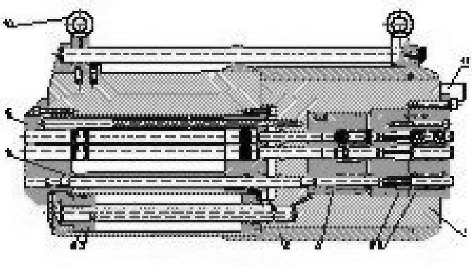

Fig. 7. Multi-cables press: 1 – major piston, 2 – cylinder, 3 – succor pistons, 4 – front block, 5 – front rosette, 6 – back rosette, 7 – disc of disanchor pistons, 8 – disc of inner jaws, 9 – pistons of the anchor external jaws (in the anchor block), 10 – respite, 11 – sensor of the protrusion of piston

3.3. Hydraulic driving and control unit

Requirements and assumptions:
1. ability of fluent steering of the aggregate's efficiency,
2. ability of steering of the working sequences from aggregate UNTM 13,

Fig. 8. Application in bridge construction

3. ability of steering of tensioning speed,
4. ability of stabilizing of the force in the tendon at a given level,
5. ability of choosing the way of steering, e-g: manual, servo-automatic, automatic (depending on the requirement),
6. ability of the registration of the selected parameters of work.

The hydraulic unit, which fulfill mentioned above assumption is shown in fig. 9 and its application in the bridge construction building is shown in fig. 10 [6].

Fig. 9. Hydraulic unit

Fig. 10. Application in bridge construction

4. Laboratory stand

Taking assumptions of fulfilling conditions included in valid standards during project stage for laboratory stand were the basic problem. Those requirements apply not only to construction of the stand but also stand working conditions. In according with recommendations of research institutes looking after laboratory certification assumptions and working conditions were established:

- construction should transmit force of ca. 8000kN, what is imposing by the force needed to break full cable (in our case for 19 strings with maximum breaking force 350kN),
- maximum linear displacement of the stand during maximum load shouldn't exceed 0.8mm,
- stand driving system (hydraulic unit) should be characterized by chokeless type of work (energy saving system – according to ISO 14000),
- stand construction and instrumentation should allow to lead static and dynamic (fatigue) tests of prestressing systems with needed precision.

On the basis of the above assumptions laboratory stand, which scheme is shown at figure 11 and 12, were design and made [5].

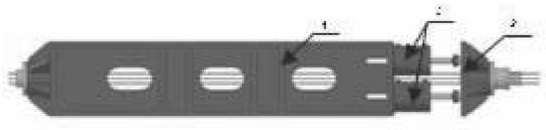

Fig. 11. Schema of laboratory stand: 1- body,2- hydraulic cylinders, 3 – moving disc

Fig. 12. General view of the test stand for pre-tensioned

5. Laboratory research

Testing of force distribution in the cable is conducted by individual sensors ts20 (fig.13).

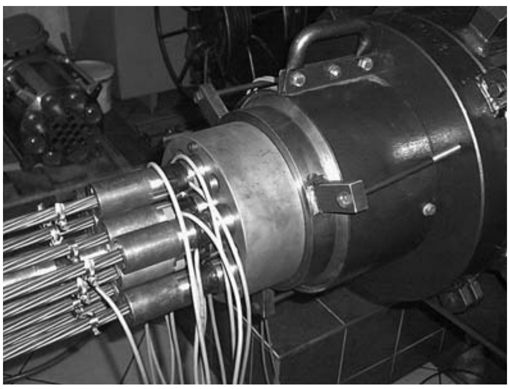

Fig. 13. View of sensor localization

Strength researches of the anchoring block was conducted at the design level of new anchoring blocks. Exemplary researched anchoring block is shown in fig. 14.

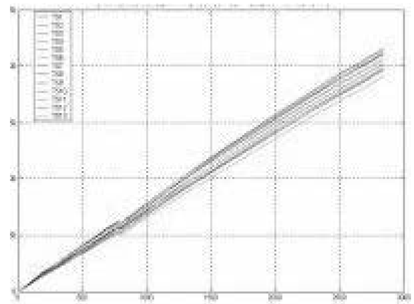

Fig. 14. Distribution of the force in cable

Individual anchorage of ASIN 45 with the force sensor of TS20 were set up at active side of laboratory stand. Anchoring block of ASIN 13 was set up at passive side of laboratory stand. 13 strand of characteristic load capacity of 279 kN were used in this research. Jaws in grips were preliminary anchored by force of 10 kN. Extensometers of EA-06-120LZ-120 were glued on the anchoring block (fig. 15). The extensometers were connected to full bridge system and were connected with measurement system of Spider 8. The value of stresses, which were obtained in the research are presented in fig. 16.

Fig. 15. Research of the anchoring block

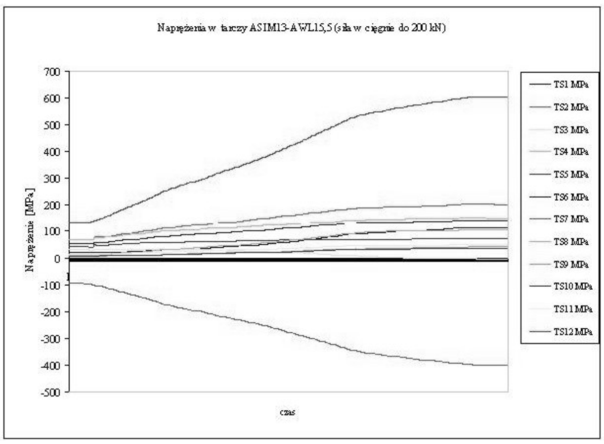

Fig. 16. Distribution of stresses in the anchoring block

Obtained laboratory results of stresses were used to a verification of a simulation model of the anchoring block, which was made in FEM [2] (fig. 17).

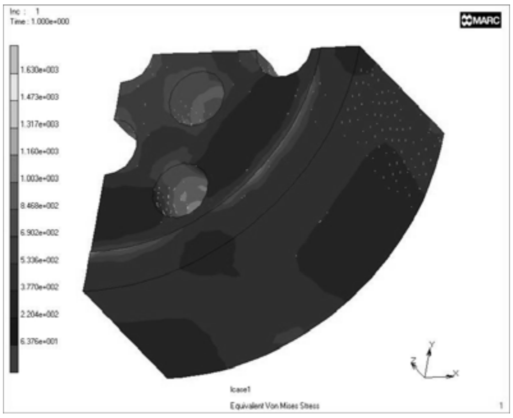

Fig. 17. Distribution of stresses in the anchoring block

Tracing of the prestressing force losses, which were caused by a friction between cable and shield, was made in real construction (fig. 18), which enables a taking into consideration real conditions during prestressing process.

Fig. 18. Research of the prestressing force losses

The researches include the measurements of the forces at passive and active sides. Coefficients of the frictions for a linear segments and bends were defined by iterative method [1,3] (fig. 19).

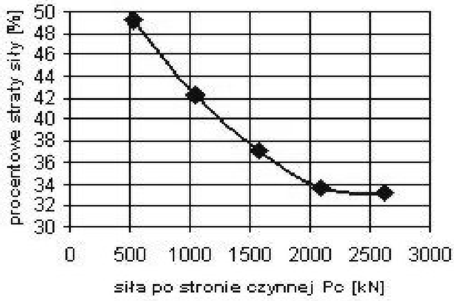

Fig. 19. Distribution of prestressing force losses

6. Conclusions

1. The quality of the prestressing system elements decides about an operating characteristics of prestressed structure. This quality can be checked by specific testings:
   - testing of the static strength of anchorage-jaw-tendon system,
   - fatigue testing
   - testing of system characteristics such as: friction coefficients, slides, prestressing devices characteristics.
2. Testing of elements of prestressing systems (such as static load testing) can be a base of prestressed construction safety if this testings are conducted in the conditions simulating work of tested elements in real constructions.
3. Creation of such conditions demand building special stands. These stands have to enable an obtaining of high values of parameters, for example: force needed to testing anchorage is dependant on a number of tendon which are anchored. The needed force to scarifying one tendon amounts to 350 kN. Hence, if the research includes the testing of anchorage of 31, the needed force amounts to 31 x 350 kN = 10850 kN.

7. References

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Dr inż. Andrzej JURKIEWICZ
Dr inż. Piotr MICEK
Mgr inż. Marcin APOSTOŁ
Mgr inż. Dariusz GRZYBEK
Department of Process Control
AGH University of Science and Technology
Kraków, Poland,
Tel/fax: 0048 12 617 30 80
e-mail: jurkand@agh.edu.pl