Development of classification for bearing system prestressed structures

Stetsko A.A.

Senior lecturer,
Department of cars and carriage facilities,
State Economy and Technology University of Transport

Abstract
The prestressing of structures means various techniques of directional artificial stress regulation or stress-strain state regulation within the structures, performed with the objective to increase their efficiency in the load accommodation during the stages of the service life. Moreover, the interference with the normal work of the object for directional change of its deformation potential energy can be carried out at different stages of its life cycle (during its manufacturing process, mounting, operations or reconstruction) and at different levels.
The current paper is devoted to systematizing information on the classification and application of prestressed structures for bearing systems in various fields of engineering. It also analyzes theoretical and practical peculiarities of modern designs of prestressed structures as well as some specific issues of their use. The capabilities and the analysis of prospects for prestressed bearing structures in railway engineering, particularly in the construction of freight cars, are revealed.
To implement prestressed blocks and elements is rational in the freight cars constructions. However, the effective introduction of the above mentioned is only possible on the basis of scientific grounding for the structure and parameters of appropriate engineering solutions.
Key words: TRANSPORT MECHANICS, BEARING SYSTEMS, PRESTRESSED ELEMENTS, FREIGHT CAR

Introduction

The prestressing of structures stands for various techniques of directional artificial stress regulation or stress-strain state regulation in structures. The prestressing is performed to increase structure's efficiency in the load accommodation on the stages of structure's life cycle. The intervention into the regular work of an object with the directional change of its deformation potential energy can be done both at different stages of the life cycle and at different levels: during manufacturing, erection, operation or reconstruction.

The efficiency criteria to use the prestressing in metal structures can include economic demands for the reduction in the material consumption and the expenses of objects as well as structural and technological issues (increase in stiffness, maintenance of the initial forms of bearing structure elements after the effect of engineering factors such as welding, improvement of dynamic characteristics, etc.).

In this respect, metal constructions are considered to have more opportunities and greater prospects for prestressing to be applied than those of reinforced concrete structures or steel-concrete composite constructions where this technique has been developed primarily as a means to combat low strength of concrete in tension.

In all the cases, regulation of internal forces in struc-

tures requires additional labor costs and there still exists a possibility of loss or restructure of the above mentioned background of internal stresses over time due to the development of processes occurring in materials and connections. Therefore, the introduction of rational methods to regulate the strain-stress state into the practice of contemporary engineering construction designs [1-4] requires the development of appropriate theorization, methodological foundations and practical means for each constructive form.

The purpose of the article and the material

The current paper presents systematic information on the classification and application of prestressed structures of bearing systems in various fields of engineering.

In the field of contemporary engineering, there has been published quite a large number of studies on different types of prestressing. This situation requires classification of the revealed ideas and prestressing developmental techniques in the structures of bearing systems.

In his work, K. Kh. Tolmachev [5] classifies all the techniques of prestress development into three groups: 1 - regulation of stress by bending moments redistribution; 2 – by introduction of longitudinal stress into the construction system; 3 – changes in the internal stress pattern. Y. V. Haidarov tries to classify the prestressing according to the constructive ideas [6]. V. M. Vakhurkin proposes the classification per the techniques to develop prestress and types of structures [7].

One of the most suitable classifications for methods of the prestressed metal structures was represented by P. Ferenchik and M. Tokhacheko [8]. The authors proposed to distinguish two groups within the all the types of the prestressed metal structures: structures prestressed by tie pieces, and structures, in which the stress is produced without the use of tie pieces. The latter is subclassified into: 1 - multilayered constructions; 2 - structures with elements, in which external or own stresses are generated; 3 - structures, reinforced by previous tension to the value which is beyond their material yield strength; 4 – structures prestressed by enforcement action.

Moreover, the classification of prestressed structures of bearing systems can be carried out on several grounds (Fig. 1). In a broad sense, the stress state of structures can be regulated by various methods:

- by prestressing new structures and those that are in operation with introduction of special elements;
- by either partial unloading or partial loading the systems, including the resultants of the external links position change;
- by providing spatial structure work with imposing additional links;
- by incorporating building envelopes into the work produced by the bearing structure (decks, sheets, plates, etc.);
- by changing the static patterns of the structure (change in conditions for support fixation, installation of additional bearings, introduction of temporary or permanent hinges, racks, etc.);
- by changing the mode of operation.

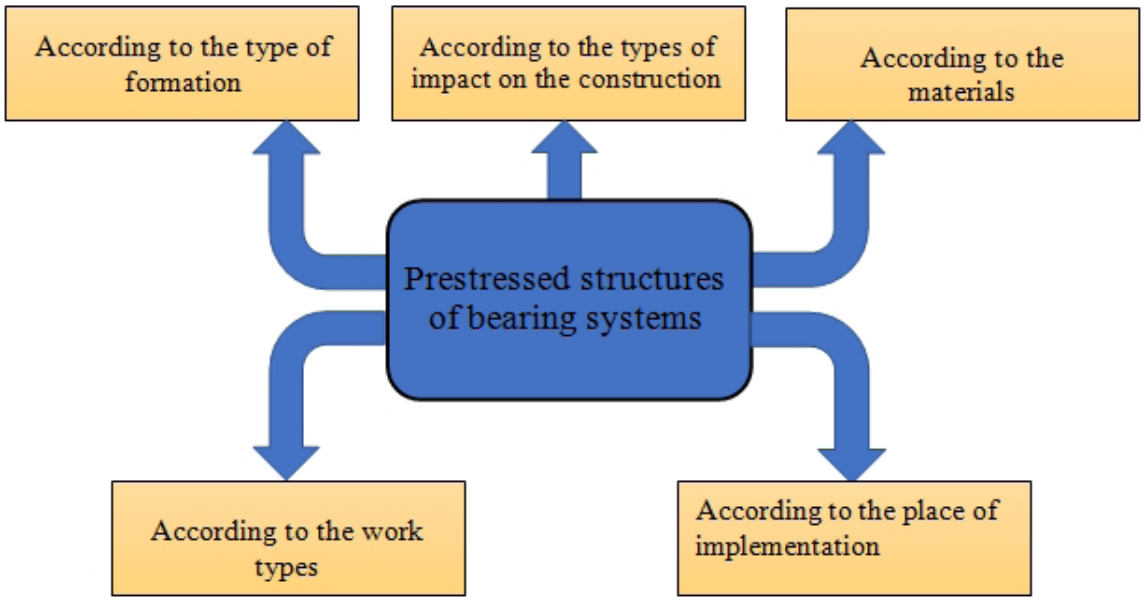

Figure 1. Classification of prestressed structures of bearing systems

All these methods are also suitable for reconstruction.

Furthermore, the prestressed structures can also be divided into two categories - those that can be operated without prestress, and those that cannot exist as unchangeable static objects without prestress. First and foremost, these are several types of hanging systems, guyed poles and others. In such structures, flexible elements can neither take the compression force nor develop mechanisms or instantly changing systems, if they have not been subjected to pre-tension.

If we take into account the means of prestress development, all structures can be divided into two big groups: structures, where prestress is created by means of different high strength elements (tie pieces, strut-framed beams, guy cables, etc.), and the structures, where prestress is created by other means. More detailed classification for the means of prestress development is shown in Fig. 2.

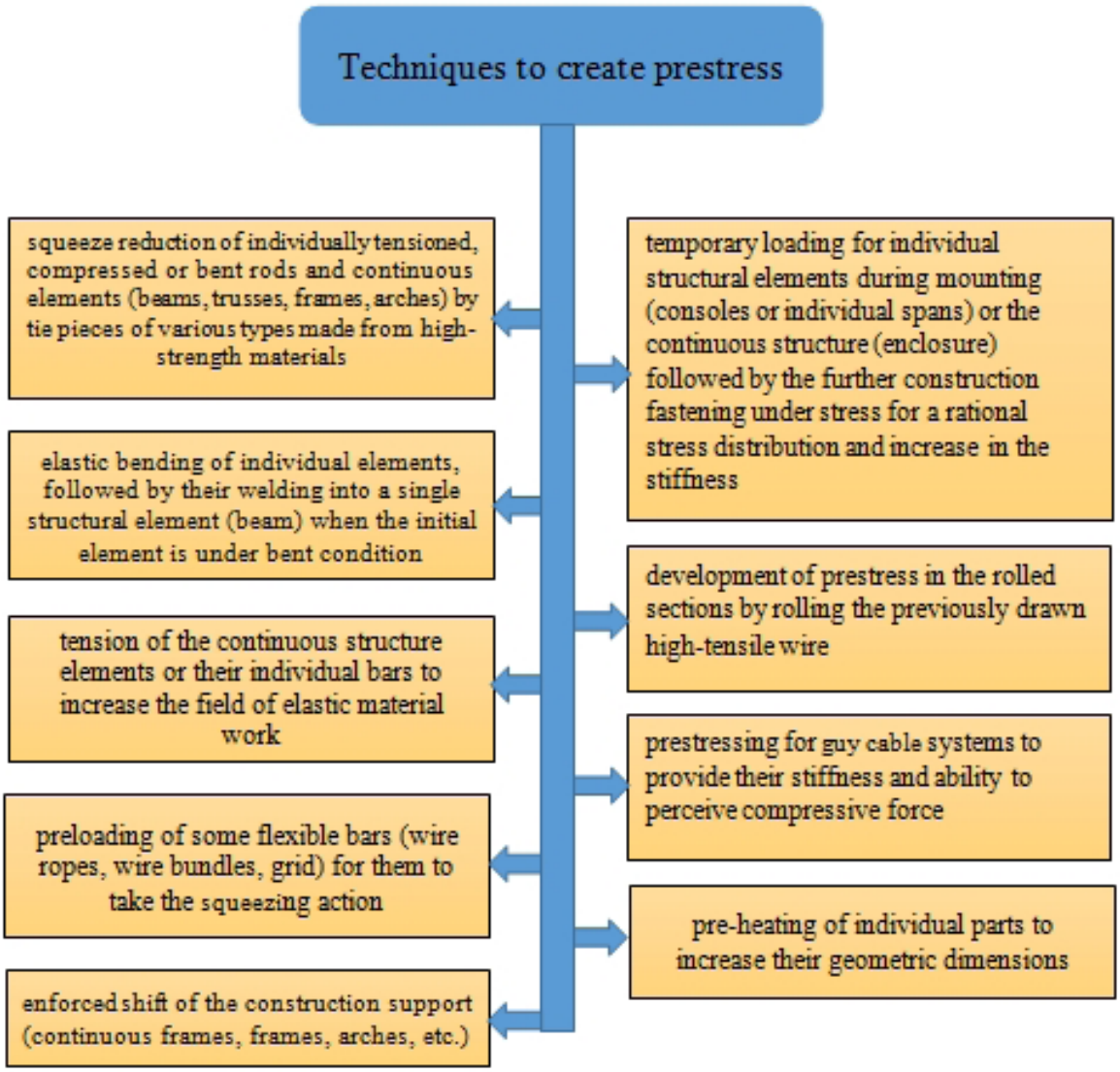

Figure 2. Classification of techniques to create prestress

The group of prestress structures with high strength elements includes as follows:

- simply supported beams and continuous ones with the straight and broken prestressed patterns and strut-framed beams both within the height of the beam (Fig. 3, *a, b, c*) and outside the beam (Fig. 3, *d, e, f, g*);
- trusses with high strength prestressed elements that are arranged in the tension chord zone and other rods (Fig. 4, *a, d*);
- trusses with prestressed strut-framed beams of different shapes, situated both within the truss and outside its dimensions (Fig. 4, *b, c, e*);
- roofing panels reinforced with strut frame;
- frames, arches, vaults and other systems with the inclusion of high prestressed elements (Fig. 5, a, b, c, d, e, f)

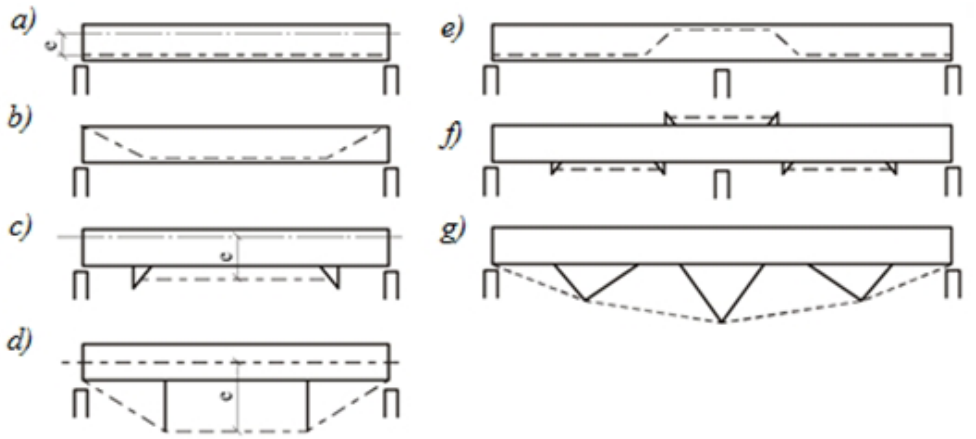

Figure 3. Beams with prestressed tie pieces and strut-framed beams

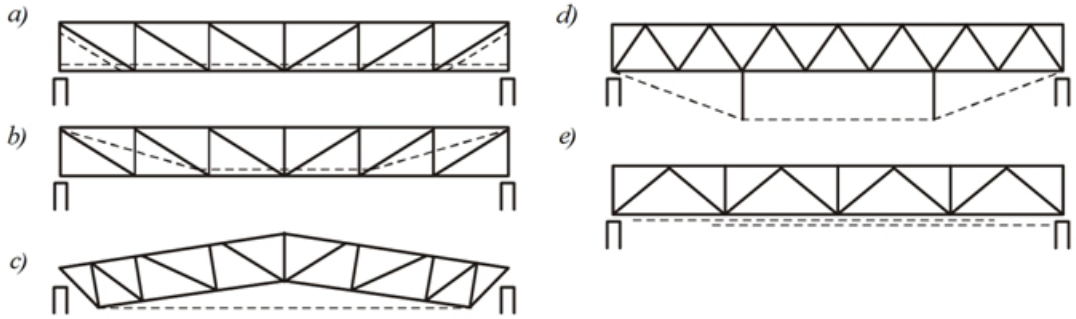

Figure 4. Trusses with prestressed patterns and strut-framed beams

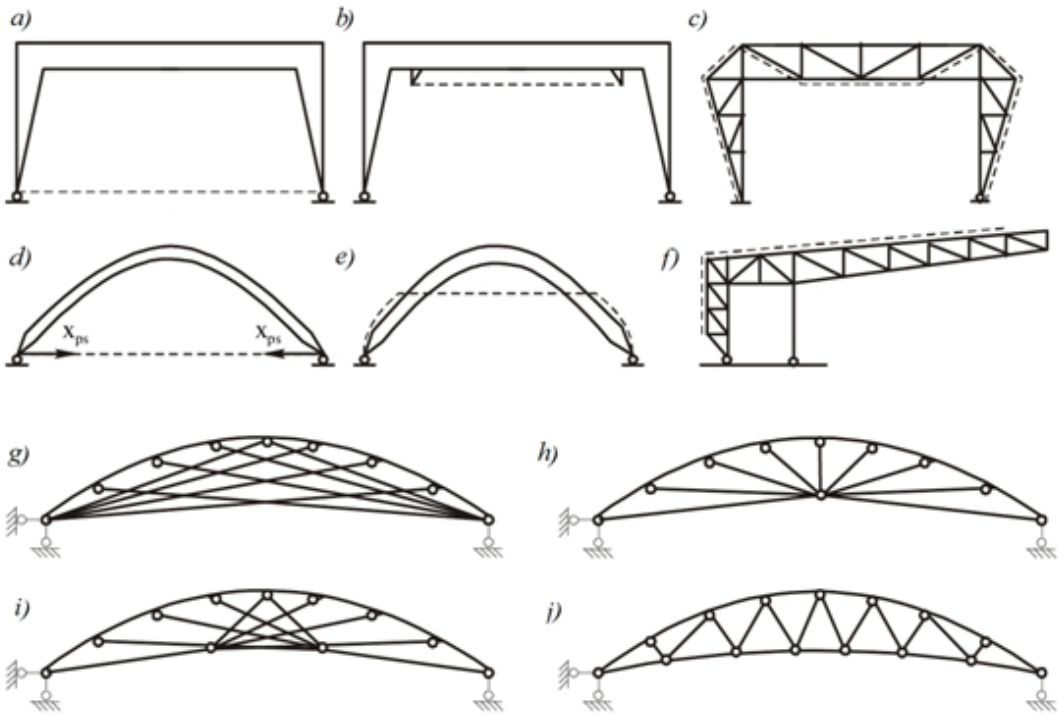

Figure 5. Frames, arches, console systems with prestressed flexible elements

- cable-stayed girder of combined systems with prestressed stay cables;
- hanging two-zone suspension structural systems with stabilizing cable strain or one-zone suspension structural systems with guys tension;
- hanging cross cable systems with stabilizing cable strains;
- multi-storey buildings with prestressed suspended floors;
- multi-storey buildings, reinforced with prestressed high-stregnth elements;
- poles and prestressed support guys;
- poles made from strut-framed beams;
- prestressed mesh towers;
- plate structures with prestressed high-strength cables or straps.

There are also constructions for which alternative prestressed techniques are applicable:

- beams with previously curved elements (Fig. 6);

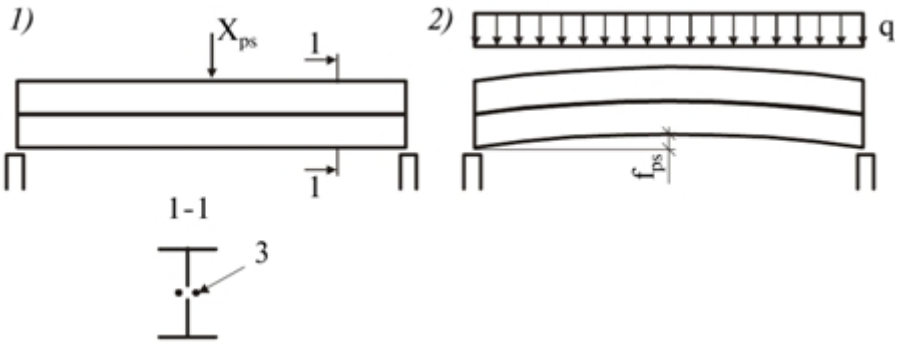

Figure 6. Precurved beams

1 –pre-curve of beam elements by force X_{ps}; 2 – beam in operational position under load q; 3 – overlaps welded after the pre-curve of beam elements

- beams with pre-tensioned thin walls or one of the flanges;
- columns with pre-tensioned thin walls;
- continuous structures with supporting structure level shift;
- frames and arches with the horizontal shift of supporting structures;
- spatial structural plates with supporting structures level shift;
- systems with introduced additional supporting structures or hinges;
- structures closed by tensioning or wedging out adjacent cross sections of elements;
- continuous, console, frame and other structures with partial loading or unloading (Fig. 7);

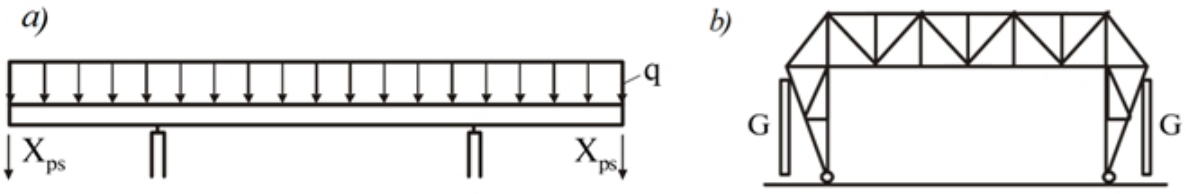

Figure 7. Console loader (X_{ps}) and suspension of walls to the frame

- trusses with precurved rods;
- panels and shells with tensioned thin sheets.

According to the types effect on the structure the following cases may be distinguished:

- internal prestress: the balance within the system, reactions of support are unchangeable (beams and other structures with ties, strut-framed beams, beams with precurved or tensioned elements, etc.);
- external prestress: the balance due to the changes of reactions (beams and other systems with supporting structures level shift, guyed structures, etc.);
- static pattern change during the stress adjustment process.

According to the materials of elements imposing effect: metal rolled profiles (including thin sheets); flexible elements (steel wires and strand bundles, cables, reinforcement bars, strips and bars of fiberglass and other materials for special construction).

According to the type of work performed, the following classification is possible: constructions with previous axial and non-axial tension; with previous axial and non-axial compression; with previous curving.

According to the place of implementation: at the manufacturer's factory; during the installation of subassemblages; during the installation after lifting and installing including cases of single and multiple previous tension; during being under reconstruction – at the facility or on a special platform when replacing with new ones.

The use of prestress allows one to enhance steel savings by 15-18% (at elastic behaviour) and 19-23% (the elastic-plastic behaviour) and to reduce the costs by 8-14% [9] while providing the similar or even improved carrying capacity.

Conclusions and recommendations

As a result of analyses performed on the existing widely-spread ideas and the techniques to generate prestress in bearing systems structures, we have developed a classification of prestressed structures of bearing systems according to the certain characteristics. Given in the paper examples of prestressed structures application in general engineering demonstrate their economic efficiency and significantly positive impact on the structural and technological qualities of the corresponding objects.

However, this approach has not found a decent implementation in the railway engineering designs, particularly, in the car building. But the prestress can be effectively used when designing new car constructions as well as at diverse improvement of already existing ones [1-4].

In the structures of rolling equipment and freight wagons in particular, it is practical to introduce prestressed blocks and elements. At that, it is possible to effectively implement the mentioned issues only on the basis of scientific evidence on the structure and parameters for the engineering solutions.

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