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STRUCTURAL MECHANICS IN THE USSR FOR 50 YEARS ACHIEVEMENTS AND PROSPECTS

by

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ABSTRACT

A synthesis of the structural mechanics of rod systems and the theory of elasticity is underway. The problems closest to structural mechanics are those involving the theory of plates, shells and three-dimensional systems formed from plates and shells. The development of the theory of these structures in associated with the ~~accomplishments of the Soviet school~~ of elasticity theory and is based on the accomplishments of modern mathematics. In the USSR a number of outstanding accomplishments have been made in the theory of the bending of thin plates, the greatest accomplishment involving methods of computing plates within the framework of the technical theory of bending. Related methods of solving the biharmonic equation are by nature close to those which the Soviet school of elasticity theory so successfully solved in the study of the two-dimensional problem. The theory of shells, which enjoyed a number of outstanding accomplishments, is one of those areas which attract the attention of a great number of scholars. In the USSR the linear static theory of shells achieved a considerable degree of accomplishment. At the present time calculations of the effect of dynamic loads have widely come into the practical work of planning organizations, and in the USSR a number of standard works in this area have been produced. It should be noticed, however, that although the USSR has developed an experimental base for structural mechanics and a broader output of test instruments, a definite lag still exists in this area, and

overcoming it will be one of the most important practical problems.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

Structural mechanics on the Great October anniversary

The efforts of Soviet scientists are concentrated on developing prospective, leading theoretical specializations and branches of science, and increasing the results and practical effectiveness of investigations. The Party works persistently to ensure that the results of scientific investigations were realized quickly in production. The further improvement of the organization of science, its planning, advancement, and the support of young, capable scientists, creative scientific research and scientific discussions are the necessary conditions of an accelerated development of science.

From the Theses of Central Committee of the Communist Party of the Soviet Union, "50 Years of the Great October Socialist Revolution."

Soviet scientists, preparing for this significant anniversary, are summing up the results and will outline the prospects of scientific investigations and their realization in practice.

In this edition let us continue the publication of surveys of the greatest achievements of Soviet scientists and design engineers in the field of structural mechanics and the design of structures.

STRUCTURAL MECHANICS IN THE USSR FOR 50 YEARS ACHIEVEMENTS AND PROSPECTS

The basic features of the development of structural mechanics in the USSR are difficult to characterize within the bounds of a small article. Essentially, all of the main achievements in this field pertain to the Soviet period. If in the first years of Soviet power only individual scientists were occupied with structural mechanics then at present the front of structural mechanics has reached very impressive dimensions. Now in this field there are thousands of scientists, teachers, and research engineers. Structural mechanics at its forums – conferences, symposia, seminars, congresses – assemble many hundreds of participants. It is interesting to note that the development of structural mechanics has caused its differentiation,

the wide development of the different traditional divisions and the appearance of new ones. And such comparatively local questions as the theory of shells, the theory of stability, and the separate divisions of the dynamics of constructions are the subject of special conferences which are broad and representative. A number of journals have come into being; a great place in the publication of works in the field of structural mechanics, besides the specialized journal "Structural mechanics and the design of constructions," is allotted to such publications as "Bulletin of Higher Educational Institutions" (series "Construction and Architecture"), "Solid Mechanics,"" "Applied Mechanics"; separate questions of structural mechanics are also expounded in the journals "Concrete and Reinforced Concrete," "Bases and Foundations," "Hydrotechnical Construction," and others. Also issued are the traditional yearly collections "Research on the Theory of Constructions," and "The Design of Space Constructions." Furthermore, scientific research institutes and higher educational institutions – TsNIISK – Central Scientific Research Institute of Structural Parts, MISI – Moscow Construction Engineering Institute im V. V. Kuybyshev, MIIT – Moscow Institute of Railroad Transportation Engineers, LIIZhT – Leningrad Institute of Railroad Transportation Engineers im Academician V. N. Obraztsov, and many others – will issue numerous collections of transactions. Also, monographic, informational and educational literature will be widely issued.

The development of structural mechanics is closely connected with the activity of numerous scientific establishments. During the years of Soviet power a network of scientific research institutes has been created in the field of structural constructions, for which structural mechanics is the theoretical base and field of scientific activity. These include: the TsNIISK – Central Scientific Research Institute of Structural Parts im V. A. Kucherenko, the NIIZhB – Scientific Research Institute of Concrete and Reinforced Concrete, the Institute of Bases, Foundations, and Underground Constructions in Moscow, the Institute of Mechanics of the Academy of Sciences of the Ukrainian SSR and the NIISK – Scientific Research Institute of Structural Parts in Kiev, the VNIIG – All-Union Scientific Research Institute of Hydraulic Engineering im B. Ye. Vedeneyev in Leningrad

and scientific institutes in Georgia, Uzbekistan and different design-research institutes. A great role in the development of structural mechanics is played by the scientific institutes of the academies of sciences of the Union's replublics, the scientific institutes which work in the field of transportation, and many others. Finally, we should mention the faculties of the "Structural mechanics and strength of materials" of higher educational institutions, and first of all the corresponding faculties of the structural higher educational institutions. The development of structural mechanics also finds reflection in numerous doctoral and master's dissertations.

In the Theses of Central Committee of the Communist Party of the Soviet Union, "50 Years of the Great October Socialist Revolution," it states: "Our people are rightfully proud of the fact that the world's first socialist state has produced outstanding scientists who have made great contributions in the scientific and technical progress of mankind and who garner the glory of domestic and world science."

Among those scientists who have played an outstanding role in the development of structural mechanics for the 50 years of Soviet power, one should first name the great Russian mechanical engineer N. Ye. Zhukovskiy, academicians B. G. Galerkin, A. N. Dinnik, A. N. Krylov, L. S. Leybenzon, N. I. Muskhelishvili, professors P. F. Papkovich, N. M. Belyayev, N. S. Streletskiy, M. M. Filonenko-Borodich, A. A. Gvozdev, V. A. Vlasov and the many other authors of great ideas and valuable methods whose talent assisted the progress of structural mechanics.

The growth of structural mechanics has been accompanied by an expansion of its subjects and by a deeper and more precise penetration into the essence of the problems examined. Indisputably, the basic source of the expansion of subjects is the gigantic growth of Soviet industry and the vast span of construction. It is impossible to imagine the planning of contemporary constructions without the methods design which are based on the achievements of structural mechanics.

Structural mechanics began its life as "graphic statics" and "statics of constructions," which, first of all, was concerned with the problems of designing rod systems in an elastic region. Having mastered this region, in which the designs of trusses and statically indeterminate frame systems were basic, structural mechanics began more deeply and comprehensively to be involved with rod systems: space framework and frames, guy systems, the stability and vibration of rod systems and beams and frames on an elastic basis. All of these constructions are studies, to a great degree, with the help of methods examined in the problems of statics of flat frame systems. The structural mechanics of rod systems is being developed further - elastic-plastic problems, the calculation of geometric nonlinearity and the design of thin-walled rods; all of the more complex problems of dynamics - the calculation of the action of impulsive loads, studying the striking phenomena, and many others are being examined. Its methods are being enriched, and it is involved with problems not only in a deterministic, but also in a statistical setting; it uses the rich apparatus of contemporary analysis and makes use of computer technology. Its contents is being expanded due to the more exact and detailed description of construction work by the design diagram. We have in mind, for example, the design of frame-type buildings, in which the compliance of subassemblies of frame elements is considered, the spatial character of work of the construction, the interconnection of linear and two-dimensional elements: rods and plates, rods and shells. Of great interest is the further refinement of design diagrams of different constructions with the aid of full-scale experiments and as a result of the use of modeling; this, indisputably, will enrich even more not only the contents of the structural mechanics of rod systems. There is no need to repeat that the development of this region leads to problems, where in the composition of the basic system we find a combination of plates, shells, and rods.

A synthesis of the structural mechanics of rod systems and the theory of elasticity is occuring. The closest to structural mechanics are the problems of the theory of plates, shells, and space systems which are formed from shells and plates. The development of the theory of these constructions is connected with the use of

achievements of contemporary mathematics. At the same time, the theory of the design of plates and shells assimilates and widely uses specific methods of structural mechanics in which the static interpretation of mathematical operations makes computations for the engineer clear from the mechanical point of view. Thereby structural mechanics suggests routes to the mathematicians which facilitate the solution of problems posed by it.

The theory of bending of plates in the USSR has a number of great achievements. A greater degree of completeness has been attained by methods of the design of plates in posing the technical theory of bending. Methods connected with this problem of solving a biharmonic equation are naturally, in many respects, close to those which were so successfully developed by the Soviet school on the theory of elasticity in the study of a two-dimensional problem. Great progress has been noted in the development of different approximation methods of the solution of problems of the theory of plates. Serious attention is being attracted by works in which the theory of bending of plates, and primarily, the theory of thick plates is definitized. Occupying an intermediate position between these two theories, a scheme which is close to the model by Reissner has been deeply and creatively studied by Soviet scientists. Successful research is being conducted on the design of multilayer plates; work on the bending theory of plates, taking into account geometric and physical nonlinearity, has been advanced. The problems in this field are very great and diversified. The contemporary technology of construction production advances various plates and panels as basic structural elements. A variety of geometric profiles, reinforcements by ribs, coupling conditions, forms of loads – all of these cause the posing of important problems, and it will be correct to think that in the very near future the structural mechanics of plates, laminar and laminar-rod systems will be one of the practically most significant divisions. It is indisputable that great attention will be allotted to the refinement of the plate model; it is doubtful whether it is possible in the future to connect rigidly the theory of technical bending of plates with biharmonic equations – we must depart from this in problems where the phenomena are considered of the formation of cracks, and the plate

becomes nonuniform and anisotropic; important problems appear also in connection with the introduction of multilayer plates, and especially with the necessity for calculating large openings which are commensurate with the basic dimensions of the plates.

The theory of shells, enjoying a number of the greatest achievements, is one of those regions which attracts the attention of many scientists. The linear static theory of shells in the USSR has attained a great degree of completeness; one can expect a further simplification of the methods of calculating and developing the methods of approximation which are accessible to the engineer. At present there are interesting investigations in the field of dynamics and stability of shells; in this connection it is appropriate to mention the nonlinear problems of the theory of shells. From the practical point of view works are very important in which the design diagram of shells and coverings is definitized and the corresponding problems of their calculation are examined. Here of great importance is the study of the influence of cracks on the work of shells, the correct calculation of the connection of a shell with diaphragms and board elements, the calculation of the influence of dynamic impacts of cranes, and others.

The wider application of thin-walled constructions of the tower type poses a number of new engineering problems concerning the design of rotation shells having cuts, strengthened ribs, etc., and taking, as a rule, different nonaxisymmetric loads, both defined and random. These problems are connected with the design of tower constructions for wind and seismic influences.

Speaking of shell coverings, one should also mention the other constructive forms - the so-called structures, and, to an even greater measure, suspended systems. In this field there are interesting theoretical works and new constructive solutions. There is every reason to believe that the theory of the design of suspended systems will be widely developed and will occupy an important place in structural mechanics. In general, nonlinear problems in the theory of shells, plates, suspended systems, rod systems and in other divisions of structural mechanics already occupy a very great

place, and the importance of these problems is ever increasing.

In the structural mechanics of different constructions, great attention is being allotted to the study of stability problems. This field has also attracted the attention of wide circles of scientists. Here complication of the problems related to the Euler setting is characteristic, in connection with the consideration of more complex design diagrams. A great role in the solution of problems appearing here about the determination of eigenvalue is played by the application of digital computers. However, no less important and interesting are those trends which embrace an account of the phenomena which are connected with physical and geometric nonlinearity, the statistical approach to the calculation of initial imperfections, the variability of mechanical characteristics of systems, the random character of loads and the division of new classes of problems, for example, such as nonconservative problems of the theory of stability.

The dynamics of constructions has presently become one of the significant divisions of structural mechanics. It has used achievements in the field of statics of constructions and general methods of the theory of vibrations, which have been developed in works on the study of oscillations in different fields of technology. The dynamics of constructions has significant achievements in the field of designing structures for the action of periodic and impulsive loads; the question of random loads, mobile loads etc., has been examined in detail. An important cycle of works in the field of study of the dynamic properties of construction materials, and especially damping, has been conducted. Various and effective methods have been developed to combat vibrations; thus, great attention is being allotted to vibration isolation, which is widely used in construction, and to long-term, but as yet not widely used vibration dampers.

At present, calculations for the influence of dynamic loads have widely entered into the work practice of design organizations, and in the USSR a series of normative documents in this field has been developed. The apparatus of dynamics of structures is widely used

not only during the calculation of structures to the influence of loads induced by the work of machines, but also when calculating the influence of natural factors such as wind, and, which is by no means less important, seismics. The earthquake resistancy of structures at present is ensured by a complex of calculation rules and constructive measures; their development and checking their correctness are also a field of study of structural mechanics in the broad sense of this word.

At present, before the dynamics of structures there are many serious and responsible problems. It is necessary more deeply, from an engineering standpoint, to solve wave problems which are connected with the propagation of vibrations, to develop methods of solving nonlinear problems and statistical methods. A more precise definition of design diagrams of structures for problems of dynamic calculation is very important as well as the further development of the theory of methods of combatting vibrations. In practical calculations it is often necessary to solve important problems of hydro- and aeroelasticity, for example, when calculating flexible structures for wind action, flexible designs, hydrotechnical and naval structures.

In the solution of the problems of dynamics of structures, a great role is played by experimental methods. Their development is connected with the execution of full scale and model experiments. It is necessary in all possible ways to develop work in the field of photoelasticity, photocreep and other similar methods; worthy of great attention is the further development of the theory and practice of tensometry, the use of methods based on the excitation of ultrasonic oscillations, the method of moire coverings, i.e., we should more fully use the achievements of contemporary physics and electronics technology. It is necessary to note the presence in the USSR of a well-developed experimental basis of structural mechanics and the expansion of the output of measuring equipment. However, there is still a certain lag, and overcoming it is one of the most important practical problems.

Those experimental methods listed above cannot be separately

examined or examined apart from theoretical research. The complex of these methods and the general theory of their application are the object of an old (but enriched by new contents) division of structural mechanics – structural testing – which is especially important and prospective.

The apparatus of structural mechanics also leans on the application of electrical simulating machines and analog computers. But a more important role is played by the application of digital computers. Achievements in the field of computer technology and mathematics can, in the necessary manner, influence the progress of structural mechanics only with such a modification of its apparatus which originates from the capabilities of computer technology. At the same time it is impossible to contrast the numerical and analytical methods. Obviously, an increase of the general mathematical level of investigations in the field of structural mechanics is a necessary and lawful process.

The development of structural mechanics is impossible without considering the properties of construction materials, an analysis of the specific character of manufacture of structural elements, their installation and their conditions of use. Therefore it is very difficult to draw the line between structural mechanics in the narrower sense of the word and the design theory of engineering structures.

Theories of the design of reinforced concrete, metallic and wooden structures are all divisions of engineering science concerning designs which are most intimately connected with structural mechanics. Here it is desirable to strengthen the enrichment process of structural mechanics by concrete problems from these fields and to accelerate the introduction of contemporary methods of mechanics into the design theory of engineering constructions. This especially concerns such questions as maximum state calculation, application of the theory of creep and the theory of plasticity. Very essential are those investigations which pertain to the formation of a stressed state in the manufacturing process of structures. Here questions pertain to initial stresses in elements of reinforced

concrete structures, to the fields of temperatures and stresses appearing in the process of welding and to stresses which appear in the process of fluing elements of wooden structures.

The problems of strength of prestressed reinforced concrete and metallic structures are very important. The number of comparatively undeveloped divisions of the theory of engineering designs includes questions of the determination of local stresses.

A frontier area of structural mechanics is a series of divisions of the mechanics of grounds. Development of the calculation theory of structures on an elastic basis is one of the significant achievements of the Soviet school of structural mechanics. In this field there are still many unsolved problems. They pertain, in the first place, to the selection of elastic basis models. The answer to this question requires serious experimental investigations and theoretical developments, and it is necessary to connect the selection of nuclei of the model of elastic basis with the character of the estimated ground model. Together with this, of great interest is the further refinement of design models of structures on an elastic basis and the development of the theory of their calculation to the action of various loads. It is very important to approach more closely the problem of designing the system basis-foundation-construction.

Another frontier area is structural physics. Theory on the service-life of structural designs must still be created. But even now a cycle of works has been conducted in this field. In this connection very important are works on thermoelasticity, thermoplasticity, etc. Along with this and for the solution to these problems, the attention of structural mechanics specialists should be turned to the study of temperature fields and humidity distribution. Structural mechanics cannot be limited to checking structures for strength and stability, but it should affect the selection of the most economic and effective design diagrams of structures and the determination of optimum parameters of structures. This field is comparatively undeveloped, although one of its divisions – structures of the lowest weight – has been the topic of many important

and interesting works.

As we see, the future of structural mechanics consists not only of deepening and expanding the divisions which exist at present, but also in creating new divisions, which have as yet not enjoyed proper development. Indisputably, the future of structural mechanics is intimately connected with the achievements of mathematics and physics including structural physics. It requires even more active contacts with the theory of engineering designs and will, to a great degree, lean on experimental methods. The range of questions which structural mechanics occupies has widened considerably, but it does not have to become a conglomerate of separate disciplines. Close contacts between its divisions, the generality of methods and established goals must serve the further development of structural mechanics, which, although different according to the character of its separate divisions, is but a single science.

Structural mechanics in the USSR meets its 50th anniversary with great successes on the threshold of new and grandiose problems.

B. G. Korenev and I. M. Rabinovich.