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METHODICAL ASPECTS OF APPLICATION OF VISUAL AIDS WHEN TEACHING THE «KINEMATIC ANALYSIS» MODULE TO ENGINEERING STUDENTS

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In article are considered somemethodical aspects of the practical effectiveness of application of visual aids in «Structural Mechanics» classes at higher education institutions to improve the quality of the professional training for future civil engineers. This paper examines using such visual aids as construction sets whenteaching the «Kinematic Analysis» module to students studying in civil engineering. Construction sets can be considered as visual aids for modeling that can be useful for students and instructors.
Keywords: structural mechanics, engineering education, visual aids, analytical model, construction set.

Introduction. The construction industry in the modern world is undergoing changes driven by the implementation of new design technologies of structures, new complex architectural forms, using new materials, and the urgent need for rapid workforce training to restore destroyed infrastructure. As the result of these changes new requirements for education of future civil engineering specialists are presenting. Structural mechanics is one of fundamental disciplines in training future specialists. Laws of mechanics are often complex for students because to understand them they need to have the preliminary mathematical background and the spatial imagination.Structural mechanics is the science of calculating the strength, the stiffness, and the stability of engineering structures and buildings. It is often difficult for students to understand the physical nature of deformation processes looking only at drawings and theoretical calculationsthat they see and perform on paper or the university board.

The integration of traditionalteaching methods and innovative visual aids into the educational process can help studentsto understand the material more easily and to learn it more effectively. Learning through visual aids is more effective for several reasons. First, approximately 65% of the global population are visual learners – people who interact with visual content to retain information. Second, humans receive about 90% of all information about the world through the visual channel. Third, bright and interesting visualaids help attract and hold attention.

Analysis of recent research and publications. In light of constant global shifts and generational changes in education, there is the continuous search for new pedagogical methods in education, particularly in higher engineering education. Sources [1, 2] state that not all future bachelors possess the well-developed spatial imagination and the spatial reasoning. In [1], the author examines the process of forming the spatial imagination and the spatial reasoning throughout the student's engineering education at the university level. Therefore, the author deems it appropriate to utilize specialized tasks to develop these abilities, to structure such tasks across various disciplines, and to establish new criteria for evaluating the development of the spatial imagination and the spatial reasoning. In [2], the author notes that forming the necessary level of spatial reasoning in students must begin with fundamental disciplines, such as descriptive geometry and engineering graphics, through the use of computer-aided geometric modeling. Also, the author proposes implementing full computerization and informatization of the educational process for future engineering and technical specialists.

Original software tools were developed by the chair of structural mechanics at the Kyiv National University of Construction and Architecture and have been integrated into the educational process for many years. These include: the «ASSISTANT» educational complex [3], which accommodates applied

programs for performing calculation works in structural mechanics,alsofor analyzing planar frame systems for statics, stability, and dynamics; the «CONTROL» software complex [3, 4] is utilized for student knowledges assessment; the «OLYMP» software complex [3] is utilized for holding subject-specific academic olympiads.

In [5], authors describe features of the integrated approach while teaching the structural Mechanics course. Authors emphasize the practical orientation, the integration of theory and practice, and the use of various interactive simulations and specialized software products. The article also argues that the successful mastery of fundamental knowledge and the preparation of students for real-world engineering tasks require, among other things, the implementation of modern auxiliary tools for processing practical material and information technologies during the educational process. In [6], the conditions for the implementation of the tutoring technology in teaching structural mechanics are described, including theinstructor training, the development of methodical strategies for the student support, and the creation of educational and methodical resources that promote the development of future professional competencies.

The purpose of the article. In article are considered somemethodical aspects of the practical effectiveness ofapplication of visual aids in «Structural Mechanics» classes at higher education institutions to improve the quality of the professional training for future civil engineers. This paper examines usingsuch visual aids as construction sets when teaching the «Kinematic Analysis» module to students studying in civil engineering.

The main part. In Ukrainian schools at the primary level the training using construction sets is introduced. They are used for development of mental abilities, intellect and creative thinking of the younger generation.The New Ukrainian School is based, among other things, on fundamentals of STEM-education (S – Science, T – Technology, E – Engineering, M – Mathematics). The effective tool of STEM- education is using LEGO construction sets [7]. Authors argue that such the practice-oriented approach allows students to achieve the practical implementation of their knowledge with future ability to apply it in real-world scenarios. In [8], educational models of LEGO Education construction sets are described, which can be applied at various stages of physics lessons. The construction set is presented in the manual as the pedagogical system for modeling the real world and as the subject-play environment for teaching children and providing basic physics education.

There is the opportunity to utilize construction sets in higher civil engineering education, particularly within structural mechanics.The learning engineering disciplines with using models assembled from construction sets can improve the development ofthe students' spatial imagination.In the education activity construction sets can help students to understand how various elements are combined in one complex system andinteract with each other.This understanding futurespecialists may need in their professional activities when performing real projects.

Construction sets can assist students in gaining the better understanding methods ofconnecting disks and joints into geometrically stableanalyticalmodel, as well as the exceptions to these methods, in the structural mechanics course, specifically within the «Kinematic Analysis» module. Students typically observe examples of disk and joints connections through 2D-diagrams on paper in the traditional structural mechanics instruction.

Analogous models assembled from construction sets can help the instructor:

- demonstrate these methods using simple examples directly within the classroom;
- explain why the specific number of connecting devices is the minimum requirement for connecting the certain number of disks;
- explain why specific links arrangements cause the system to become instantaneously unstable;
- explain the relationship between real and virtual hinges;
- explain interconnections between disk connection methods when representing certain elements of the analytical model as others [9].

Consider the «dyad» method as the example. Figure 1a illustrates the scheme for this method. According to this method, the simple disk (D_1) can be connected with thesimple joint (J_1) into thegeometrically stable system using two kinematic links (L_1, L_2), provided their axes are not collinear. Figure 1b displays the photograph of the model assembled from the construction set, featuring analogous components (the disk, the joint, and two links). In cases where these two kinematic links

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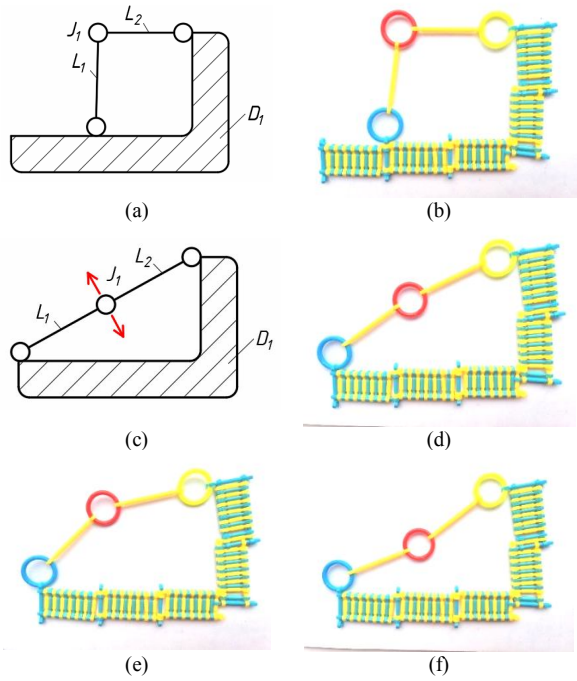

Fig. 1. The illustration of the «dyad» method

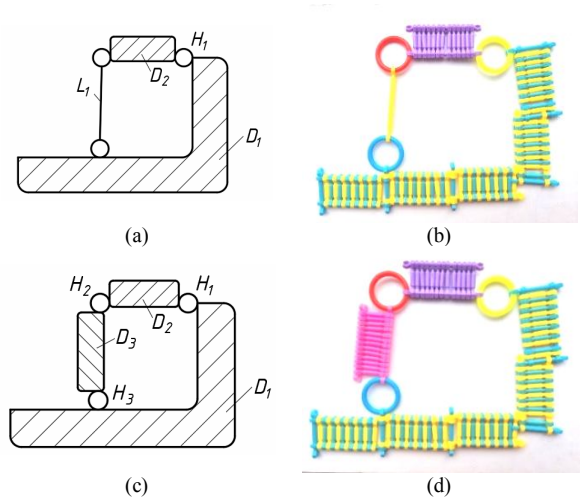

Fig. 2. Illustration of Polonceau andhinged triangle methods

share the common axis – the system becomes instantaneously unstable (Fig. 1c, Fig. 1d), allowing the joint J_1 to displace along the line perpendicular to the axis of links L_1 and L_2 (Fig. 1e, Fig. 1f).

With the physical model in hands, the instructor can demonstrate the process of connecting elements into the enlarged disk and visually illustrate potential displacements within the instantaneously unstable system (Fig. 1e, Fig. 1f). This provides the clear rationale for why such schemes are inadmissible in real-world structures. Besides, using these visual aids, the instructor can show how change of the placement of one connecting device can transform the instantaneously unstable system (Fig. 1d) into a geometrically stable one (Fig. 1b).

When representing one or two kinematic links as disks, the «dyad» method may transform into the Polonceau method (Fig. 2a, Fig. 2b) or the hinged triangle method (Fig. 2c, Fig. 2d), respectively. By using elements of the construction set, the instructor can perform the appropriate replacement, visually demonstrating to students the relationships between methods of connecting disks and joints.

To demonstrate the Shukhov method of the disk's connection (Fig. 2a), the model composed of two disks and three kinematic links can be utilized (Fig. 2b). This example illustrates that two kinematic links are insufficient to form the geometrically stable system, becausethe system becomes instantaneously unstable, allowing for potential point displacements (Fig. 2c). The scheme in the Figure 2c also helps to explain the concept of thevirtual hinge located at the intersection of axes of two kinematic links. Much like the real hinge (Fig. 2d), it permits angular displacements of disks relative to each other.

One of exception tothe Shukhov's method, where all three kinematic links are parallel to each other, is illustrated in Figure 2e. In such the system, point displacements can occur, therefore it is instantaneously unstable. These deformations can be demonstrated to students (Fig. 2f, Fig. 2g) to explain the necessary modifications to the analytical model – such as altering the axis of one of the kinematic links (Fig. 2b)– to ensure it becomes geometricaly stable.

Construction setscan help students in independently assembling enlarged disks from components of analytical models during practical sessions (Fig. 4). Such skills to build complex schemes from small parts will additionally contribute to the development of professional skills of future civil engineers.

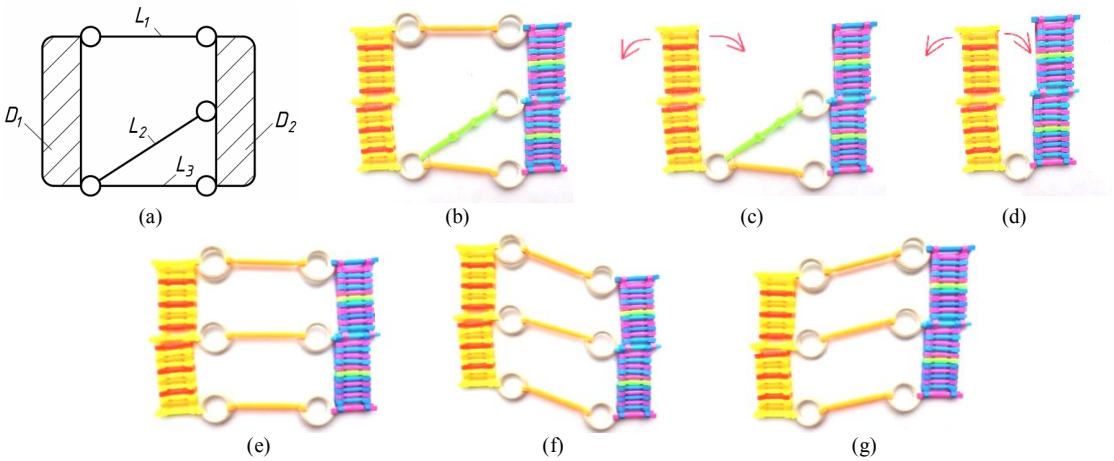

Fig. 3. The illustration of the Shukhov method

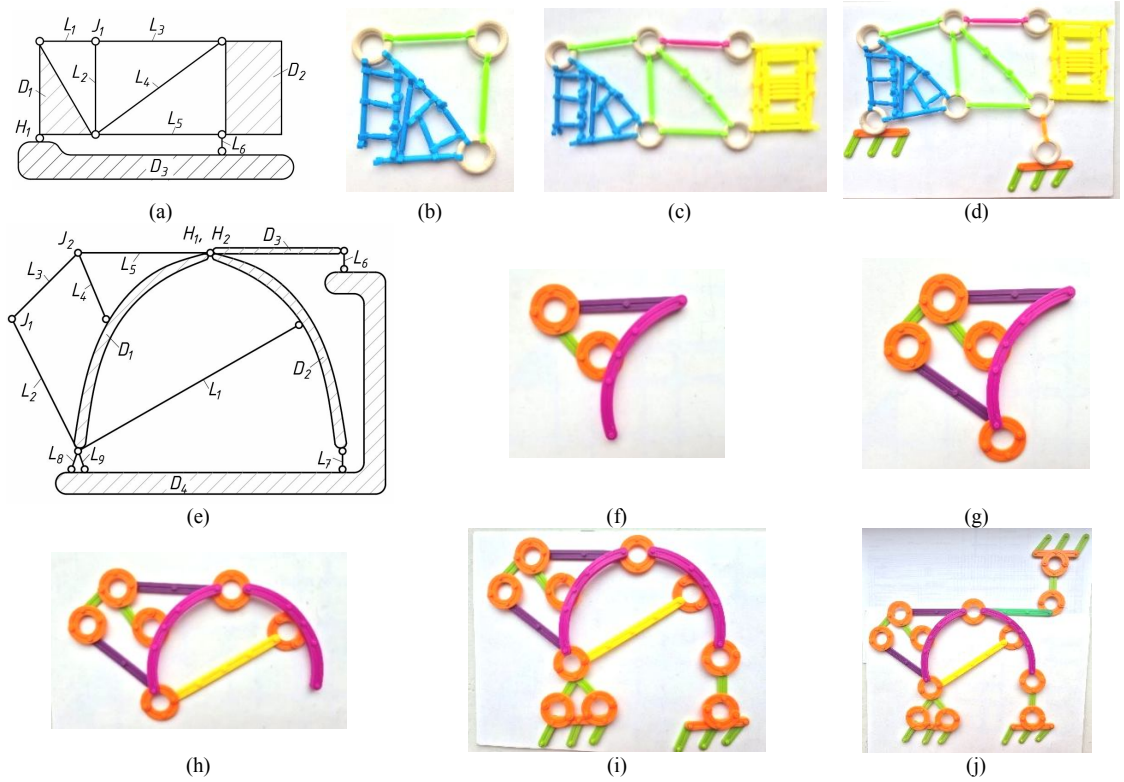

Fig. 4. Examples of the qualitative stage of kinematic analysis using construction sets

Conclusion. Construction sets during learning the kinematic analysis within the structural mechanics can be considered as visual aids for modeling that can be useful for students and instructors. Their application into the educational process can: improve the student' spatial imagination; facilitate students understand how various connecting devices work in theanalytical model; facilitate students understand methods ofconnecting discs and joints and their interconnections among themselves; transform schemesfrom paper drawings into visual models; promotethe understanding principles of combining various elements into the complex construction structure.

Application of AI: the AI tool «Google Gemini» was used to translate the article into English.

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Кара І.Д., Андрієвський В.П.

МЕТОДИЧНІ АСПЕКТИ ВИКОРИСТАННЯ НАОЧНИХ МАТЕРІАЛІВ ПІД ЧАС ВИКЛАДАННЯ МОДУЛЯ «КІНЕМАТИЧНИЙ АНАЛІЗ» ДЛЯ СТУДЕНТІВ БУДІВЕЛЬНИХ СПЕЦІАЛЬНОСТЕЙ

Будівельна механіка є однією з фундаментальних дисциплін при підготовці майбутніх фахівців. Закони механіки для здобувачів часто є складними, оскільки для їх розуміння потрібно мати попередню математичну підготовку і просторову уяву. Студентам часто складно зрозуміти фізичний зміст процесів деформації, дивлячись на лише рисунки та теоретичні розрахунки, які вони бачать і виконують на папері чи університетській дошці. Інтеграція традиційних методів навчання та інноваційних наочних матеріалів у навчальний процес може допомогти здобувачам легше сприймати і ефективніше засвоювати матеріал. В цій статті описуються деякі методичні аспекти практичної ефективності застосування таких наочних матеріалів як конструктори на заняттях з будівельної механіки при проходженні модуля «Кінематичний аналіз» здобувачами будівельних спеціальностей. Конструктори можна розглядати як наочні матеріали для моделювання, які можуть бути корисними здобувачам і викладачам. Складені з конструкторів схеми можуть допомогти викладачу: пояснити способи об'єднання дисків на простих прикладах безпосередньо в аудиторії; пояснити, чому для об'єднання певної кількості дисків мінімально необхідною є визначена кількість з'єднувальних пристроїв; пояснити, чому при певному розташуванні в'язей система перетворюється на миттєво змінювану; пояснити зв'язок між дійсними і уявними шарнірами; пояснити зв'язки між способами об'єднання дисків при представленні одних елементів розрахункових схем як інші. Вивчення кінематичного аналізу в будівельній механіці із застосуванням конструкторів може допомагати здобувачам: розвивати просторову уяву;допомагати здобувачам зрозуміти основи роботи різних з'єднувальних пристроїв в розрахунковій схемі; допомагати здобувачам зрозуміти способи об'єднання дисків і вузлів, їх зв'язки між собою; перетворювати схеми з паперових рисунків на візуальні моделі; сприяти розумінню принципів об'єднання різних конструкцій в одну складну будівельну споруду.

Ключові слова: будівельна механіка, будівельна освіта, наочні матеріали, розрахункова схема, конструктор.

Kara I.D., Andriievskyi V.P.

METHODICAL ASPECTS OF APPLICATION OF VISUAL AIDS WHEN TEACHING THE «KINEMATIC ANALYSIS» MODULE TO ENGINEERING STUDENTS

Structural mechanics is one of fundamental disciplines in training future specialists. Laws of mechanics are often complex for students because to understand them they need to have the preliminary mathematical background and the spatial imagination. It is often difficult for students to understand the physical nature of deformation processes looking only at drawings and theoretical calculations that they see and perform on paper or the university board. The integration of traditional teaching methods and innovative visual aids into the educational process can help students to understand the material more easily and to learn it more effectively. This paper examines some methodical aspects of the practical effectiveness of application of such visual aids as construction sets in «Structural Mechanics» classes at higher education institutionswhen teaching the «Kinematic Analysis» module to students studying in civil engineering. Construction sets can be considered as visual aids for modeling that

can be useful students and instructors. Models assembled from construction sets can help the instructor:demonstrate methods of connecting disks using simple examples directly within the classroom; explain why the specific number of connecting devices is the minimum requirement for connecting the certain number of disks; explain why specific links arrangements cause the system to become instantaneously unstable; explain the relationship between real and virtual hinges; explain interconnections between disk connection methods when representing certain elements of the analytical model as others. Learning the kinematic analysis within the structural mechanics with application of construction sets can help students: to improve the spatial imagination; to understand how various connecting devices work in the analytical model; to understand methods of connecting discs and joints and their interconnections among themselves; to transform schemes from paper drawings into visual models; to promote the understanding principles of combining various elements into the complex construction structure.

Keywords: structural mechanics, engineering education, visual aids, analytical model, construction set.

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Кара І.Д., Андрієвський В.П. **Методичні аспекти використання наочних матеріалів під час викладання модуля «Кінематичний аналіз» для студентів будівельних спеціальностей** // Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2026. – Вип. 116. – С. 360-365.
Розглядаються деякі методичні аспекти практичної ефективності застосування таких наочних матеріалів як конструктори на заняттях з будівельної механіки при проходженні модуля «Кінематичний аналіз» здобувачами будівельних спеціальностей.
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Fig. 4. Ref. 9.

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