A project-oriented approach to conducting laboratory work for postgraduate students of civil engineering specialty

Assel S. Tulebekova, Atogali A. Jumabayev & Dana G. Bakirova

L.N. Gumilyov Eurasian National University
Astana, Kazakhstan

ABSTRACT: In this article, the authors present a pedagogical approach to organising and conducting practical and laboratory work in the field of construction, with a focus on project-based learning that encompasses various types of research. All studies were carried out in the Department of Civil Engineering and ENU-Laboratory at *L.N. Gumilyov* Eurasian National University, Astana, Kazakhstan. In the first stage, postgraduate students conducted a standard search and literature review using international scientific databases. The second stage carried out the experimental part of the work, focusing on the development of modified bitumen composition. In the subsequent stages technological solutions were developed and evaluated. The originality of the work consisted in developing a technological solution for applying modified bitumen to the real climatic conditions of the regions based on the experimental results. As a result, postgraduate students have acquired a range of skills essential for professional activities. Integrating project-oriented learning in the educational process has facilitated the accumulation of teamwork experience and expanded students' research capabilities.

INTRODUCTION

The purpose of the educational programme for postgraduate students in civil engineering is to prepare professionals with scientific competence in the field of design, construction and their application in research activities. In this regard, the content and scope of the programme of professional modules should be sufficient to form key professional competencies of the students. And, the key role to achieve this goal are practical and laboratory classes. Laboratory works provide students with the opportunity not only to apply theoretical knowledge in practice, but also to develop skills to solve real professional problems [1][2]. Effective assessment in laboratories helps not only to measure students' performance, but also to stimulate their activity, maintain motivation to study and develop critical thinking [3].

Today, standardised laboratory and practical assignments are widely used [4]. Standardised laboratory assignments involve the use of the same tasks or experiments for all students participating in the laboratory work. This type of activity is important for assessing the basic level of knowledge. Project-oriented laboratory assignments, on the other hand, are focused on the development and implementation of projects or research tasks by students. Features of both approaches that were identified by the authors of this article based on the literature review are presented in Table 1 [5][6].

Table 1: Features of standardised and project-oriented approach to conducting assignments.

Indicator	Standardised laboratory assignments	Project-oriented laboratory assignments
Objective	Assessment of basic knowledge and skills	Development of creativity and independence, deep understanding of the material studied
Approach to implementation	Strictly defined techniques and procedures	Flexible methods and approaches to problem-solving
Skills	Basic knowledge of techniques and procedures	Knowledge of techniques and procedures, development of communication, teamwork and research skills
Flexibility	Limited choice of methods and tasks	Highly flexible, encourages independent research and creativity
Complexity	Less complex tasks and experiments	More complex tasks and integration of knowledge from different fields
Deadline	Requires less time for preparation and implementation	Requires a longer time for project planning and implementation
Assessment	Homogeneous analysis	Multi-criteria analysis

Thus, the project-oriented approach allows to reveal the potential of each student and develop therir thinking skills [7]. Complementing their knowledge in postdoctoral training and combining its application in practice through specific projects allows students to properly approach the study of a particular professional field.

In this study, project assignments were integrated into practical classes and laboratory work, where postgraduate students performed standard laboratory experiments and developed projects based on the obtained data and research results. The research topic was the optimisation of bitumen mixture composition, which included studying bitumen's physical and mechanical properties with various additives and then developing a project. All works were carried out in the Department of Civil Engineering and ENU-Laboratory at *L.N. Gumilyov* Eurasian National University, Astana, Kazakhstan.

Many techniques are employed in developing modified bitumen [8]. However, each composition of bitumen has its advantages and disadvantages, so developing an optimal composition suitable and effective for use is one of the professional tasks of engineers [9]. Therefore, understanding the properties of construction materials, their practical application, methods of laboratory testing, and utilising these properties to solve practical construction challenges are important components of students' education.

The experience gained by postgraduate students in experimenting using a project-oriented approach allows them to develop key practical skills, teamwork abilities, analysis and decision-making in construction.

METHODS AND MATERIALS

The purpose of the project for postgraduate students was to develop a recipe for a bituminous mixture with additives aimed to apply in road construction in different climate conditions. The choice of this topic is related to the annual shortage of quality bitumen in the road industry and the necessity to enhance its properties by adding materials that improve its operational characteristics. The students worked on the assignment in subgroups, employing empirical research methods. The total amounted to three groups of five postgraduate students each.

The project tasks consisted of:

1. Analysis of status and best practices, regulatory, technical and literature sources on the investigation subject.
2. Planning and conducting laboratory experiments.
3. Development of technical solutions.
4. Development economic rationale.
5. Preparing project presentations and presenting all stages of work and research results.

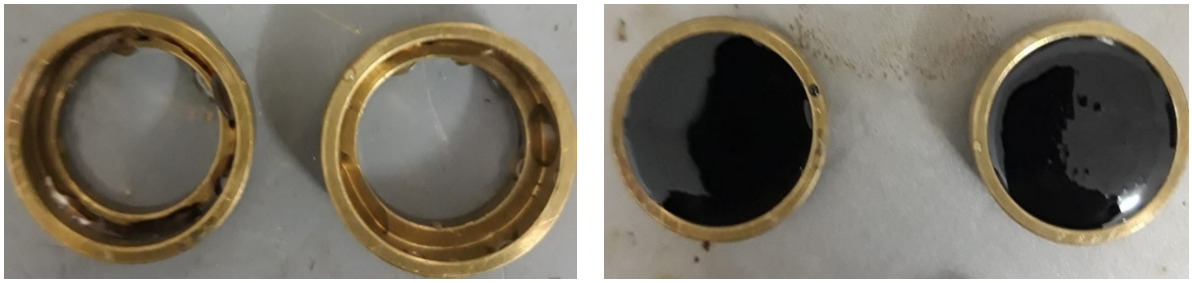
The first stage included an in-depth analysis of various sources of data, and a study of regulatory documents governing the research area, which is important for the development of technically sound solutions.

In the second stage the aim was to plan the methodology, conduct the experiment and process the results. The road bitumen, and additives: polyethylene (additive 1), shredded plastic (additive 2) and adhesion additive in the form of powder (additive 3) were used in the investigation. To study the properties of bitumen with the use of various additives was tested on a ductilometer and a *ring and ball* device.

The *ring and ball* device is used to determine the softening point of bitumen. This parameter reflects the heat resistance of bitumen and its ability to become viscous while reducing the adhesion ability of the material. The softening point also determines the point at which the bitumen becomes elastic, which is important for assessing its suitability in different climatic conditions during operation [10]. The ductilometer test determines the tensile strength of bitumen, and its ability to deform without breaking at low temperatures [11]. This indicator is critical to assess the behaviour of bitumen in cold climates, where it can be subjected to significant mechanical stresses and deformations. The spread-ability of bitumen determines its ability to retain integrity and elasticity even at low temperatures, which is a key factor in the selection of material for road surfaces and other engineering structures [12].

Initially, bitumen tests were carried out in *pure* form without additives on the device to establish the softening point of bitumen and for the ductility. Different ratios of bitumen additives were used in the test to achieve the optimum effect. The methodology of the laboratory experiments consisted of:

1. Bitumen was preheated on a hotplate to its melting point.
2. The moulds from the instruments were pre-lubricated with an ointment consisting of a 1:2 mixture of glycerine and talc to effectively remove bitumen residue after the test was completed.
3. Bitumen was poured into special moulds to the value according to the requirements of the standard.
4. Bitumen was mixed with the additive.
6. The container with bitumen was heated to the melting point of the additive to achieve a homogeneous mixture.
5. Bitumen with additives was poured into the moulds of devices for testing (Figure 1 and Figure 2).
7. The moulds were kept in the open air and water according to the approved requirements for testing.
8. Experimenting according to standard requirements [13][14] (Figure 3).



a) b)

Figure 1: Moulds for the *ring and ball* experiment: a) before bitumen filling; and b) after bitumen filling.

a) b)

Figure 2: Moulds for the ductilometer experiment: a) before bitumen filling; and b) after bitumen filling.

When tested on the *ring and ball* apparatus, balls placed in the centre of special round moulds were squeezed through the bitumen due to the increase in the temperature of the water in the apparatus, and also due to the gradual softening of the bitumen. When testing on the bitumen ductilometer, the end of the test was the affixing of the thread break in the tension.

a) b)

Figure 3: Testing process: a) *ring and ball*; and b) ductilometer.

The third stage of the project for postgraduate students was the development of the final solution, the recipe for the modified bitumen mix. The final stage was the estimation of costs and revenues, and risk assessment.

RESULTS AND DISCUSSIONS

Effectiveness of Using Additives to Bitumen

Selection of bituminous binders and modifying additives should be carried out based on their physical and mechanical properties, as well as determining the ratio of the components used, considering the composition that would result in the optimal structure of the mixture. The positive effect from the use of such additives is achieved, as the research has shown, only at their optimal concentration, which is specified in each specific case considering the grade of bitumen used, and the nature and properties of the materials used.

The softening point of bitumen is the arithmetic mean of two parallel determinations. Processed results after bitumen modification are presented in Figure 4.

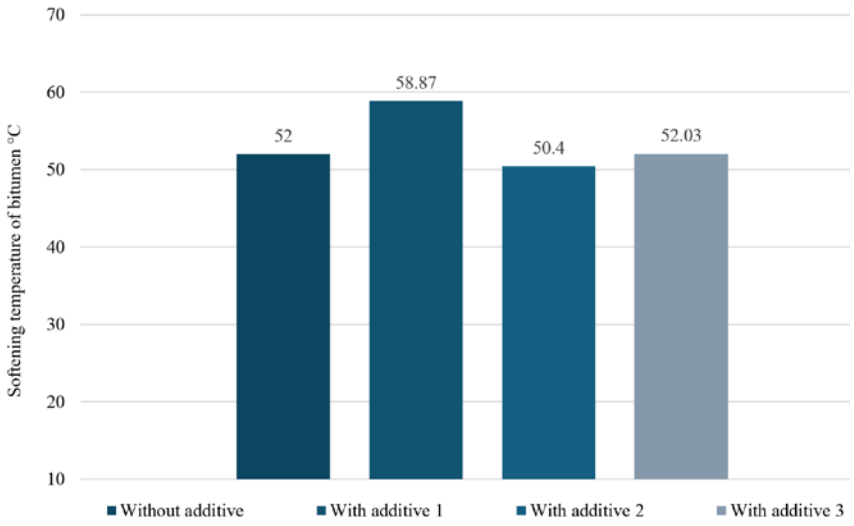


Figure 4: Results of the *ring and ball* experiment.

Bitumen with a high softening point (additive 1) is more stable at high ambient temperatures. This means, it is less susceptible to deformation or changes in its properties in hot climates. Bitumen with additive 2 showed the highest tensile strength index among all the modified mixtures studied. The bitumen with another additive showed results within the normal range. Thus, each modified bitumen is suitable for use in certain climatic conditions and must be selected in a specific way.

Evaluation Results

Each stage of the project is characterised by the acquisition of skills and abilities of postgraduate students, the main ones of which are presented in Table 2. At each stage of task implementation, students demonstrated their ability to solve the task at hand; owing to the team approach, it was possible to compensate for the lack of knowledge and skills of individual participants.

Table 2: Competencies acquired through a project-oriented approach.

Stage of project	Competencies	Description of the developed competencies
1	Project management	Ability to create a detailed project plan, including the definition of goals, objectives, resources and deadlines.
	Organisation	Ability to work in a team, allocate responsibilities, and allocate the time necessary to achieve project goals.
	Communication skills	Ability to work with students considering their views and making a team decision.
	Research skills	Ability to identify key trends, problems and solutions in the field of the topic.
	Analytical skills	Ability to systematise data and conduct critical evaluation of information.
	Technical knowledge	Understanding of technologies, methods and techniques for conducting laboratory tests.
	Knowledge of normative regulations	Knowledge of the requirements of regulatory and technical documents in the researched area.
2	Planning the experiment	Ability to develop a detailed experimental plan, including the choice of methods.
	Working with equipment	Practical skills for conducting laboratory tests using equipment.
	Critical thinking	Ability to combine and integrate different ideas, data or viewpoints to create a new solution.
3	Engineering design	Ability to create an engineering solution and justify its application in the construction field under study.
4	Financial analysis	Formulated skills for conducting cost calculations of a new construction product and performing comparative analyses with traditional types.
	Risk assessment	Conducting financial risk assessment when using a new construction product.
5	Presentation skills	Ability to present project results, including competence in presenting information clearly and effectively using visual materials.

The approach also allowed for identifying the need for each student to study or develop specific skills.

When assessing the fulfilment of the project assignment, a systematic approach was applied, including a comprehensive and structured approach to assessment, which considered not only the final results of the student's work, but also the process of their achievement. Grades were expressed in points from 0 to 100 for each criterion and the mean value was derived. The five tasks were evaluated according to the criteria:

Task 1: Extensiveness of analysis, quality of sources, critical evaluation.
Task 2: Planning the experiment, applying research methods, technical execution, analysis of results.
Task 3: Technical depth, innovativeness, functionality, applicability.
Task 4: Economic feasibility, risk assessment.
Task 5: Structure and content of the presentation, quality of the presentation materials.

Additional evaluation: organisation teamwork and communication skills.

The results of the obtained score are presented in Figure 5. In general, postgraduate students coped well with the tasks, the average score for the first subgroup was 97, and for the second and third subgroups 93 and 89 respectively.

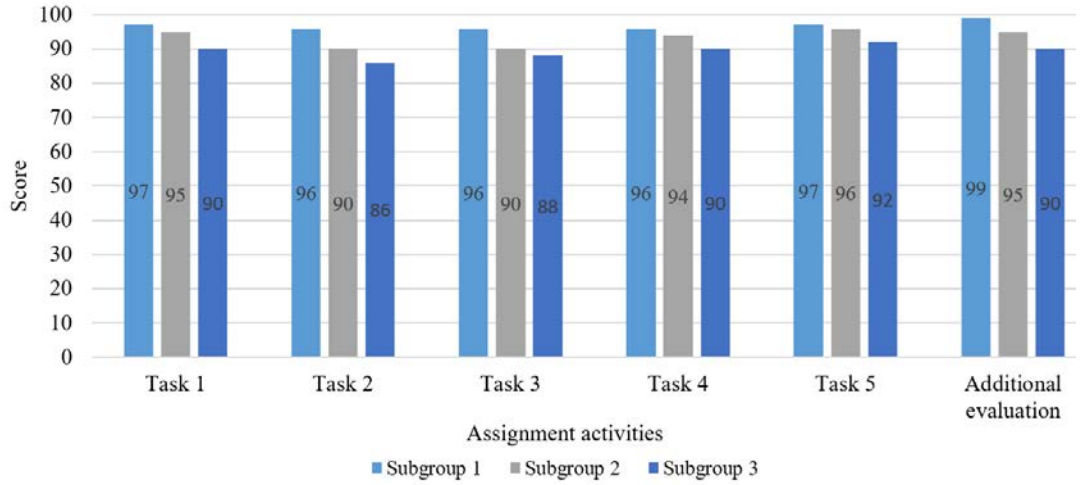


Figure 5: Evaluation of assignments.

CONCLUSIONS

The project-oriented approach to conducting laboratory work contributes to the development of professional skills in postgraduate students. In standardised laboratory work, only competencies from stage 2 shown in Table 2 are formed, whereas in the project-oriented approach, students have an opportunity to demonstrate their full potential. The experiment requires knowledge of the law of thermodynamics governing changes in the state of bitumen when various additives are added, laws of mechanics of materials describing changes in the mechanical properties of bitumen, and methods of improving the quality of bitumen. The acquired knowledge and skills in understanding bitumen modification processes can form the basis for further research and innovation in the field of construction materials whether in developing new types of additives or improving existing technologies.

The analysis showed that postgraduate students coped well with aim of project assignments, but students of the third subgroup had more difficulties in the second and third stages. These indicators are related to the lack of experience in conducting laboratory tests of construction materials and difficulties in analysing the obtained experimental results and their correct interpretation. They received support from the lecturer. For this reason, each subgroup received detailed comments on the work done and the results obtained, as well as recommendations for improvement. This helped students to understand their mistakes, deepen their understanding of the material and develop self-analysis skills.

The presented study demonstrated the experience of conducting practical and laboratory classes for postgraduate students using the project-oriented approach. It highlighted the main advantages of this approach, its impact on the development of the students' professional skills, its significance for professional activity and scientific research, as well as its potential for innovation in the construction industry. Additionally, the evaluation results contribute to the analysis and improvement of educational programmes and the formulation of strategies for further development.

An important stage is to get feedback from postgraduate students, so at the end of the work the students took an anonymous on-line survey on the applied project-oriented approach. Postgraduate students could evaluate their satisfaction with the knowledge and skills acquired, the organisation of the classes, and the technical equipment of the laboratory on a scale from zero to five. The average grade from the students was excellent. The implementation of the project-oriented approach will continue to be introduced in the study of specific professional disciplines.

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