

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD)
in specialty 6D073000 – Production of Building Materials,
Products and Structures

by Yessirkepova Aiyem Bakytbekovna

«Development of the technology of reinforced concrete products manufacture, using welded reinforcement from metal waste»

The relevance of the study. The results of the studies conducted under the conditions of construction enterprises of the Republic of Kazakhstan showed that there is a large consumption of reinforcing bars to waste, which exceeds the norms defined by GOST and is about 2%. The consumption of a reinforcing bar in this ratio results in an increase in the prime cost of production of reinforced concrete products, which plays an important role under the current conditions of the construction industry of the Republic of Kazakhstan. It is also known that concrete with the addition of man-made waste has greater strength, density, and water resistance, as well as lower thermal conductivity, resistance to certain types of corrosion. In this regard, the study of the possibility of using man-made waste (fly ash) in the production of reinforced concrete products, the frames of which are made from non-ferrous reinforcing waste is of great scientific and practical importance for the construction industry of the Republic of Kazakhstan. In this regard, research work aimed at developing a technology for the waste-free use of waste reinforcing bars and concrete mix with the addition of man-made waste (fly ash) in the production of reinforced concrete products is relevant.

The objective of the dissertation work is to increase the efficiency of the production of reinforced concrete products by using rods made of unmeasurable waste of reinforcing bars and concrete mix with the addition of fly ash.

To achieve this objective, the following scientific tasks were elaborated and solved:

1. Research and analysis of the design, manufacturing technology of reinforced concrete products and the consumption of reinforcing steel bars in the conditions of domestic and foreign construction enterprises.
2. Study of welding methods for joining reinforcing bars and developing the design of a special device for welding non-dimensional reinforcing bars.
3. Conducting experimental studies of the welded method of joining non-dimensional reinforcing bars, the strength of the concrete mixture with the addition of fly ash.
4. Analysis and selection of reinforced concrete products for the use of a frame structure from non-dimensional reinforcing waste, a concrete mixture with the addition of man-made waste (fly ash) and the manufacture of prototypes.
5. Carrying out testing of prototypes of reinforced concrete products in the conditions of certified testing centers.

6. Calculation of the economic efficiency of technology, development of practical recommendations and implementation of the results of work in production.

The object of the study: Technologies for the manufacture of reinforced concrete, in particular, bar lintels.

The subject of the study: Patterns of the effect of the physical and mechanical characteristics of welded reinforcing bars on the quality performance characteristics of reinforced concrete products.

The methodology of the study. The methodology of the study is based on the position of such sciences as reinforced concrete production technology, welding technologies and equipment, and the theory of welding processes. Experimental studies on resistance welding were carried out on the MSR-25 resistance welding machine of the laboratory base of the Kazakhstan Institute of Welding at Karaganda Technical University (KTU). Experimental studies on friction welding were carried out on a special device for friction welding, mounted on a lathe under the conditions of the laboratory base of the department of “Technological equipment, mechanical engineering and standardization” at KTU. Reinforcing bars joined by flash butt welding passed the tensile test using the electromechanical testing machine INSTRON 5980 in the laboratory of the Engineering profile at KTU. The samples of reinforcing bars joined by friction welding passed the tensile test at the testing center of JSC “National Center for Expertise and Certification” (Karaganda, Kazakhstan). To test samples of welded reinforcing bars for static tension with the determination of the ultimate strength depending on the loads, the Solidworks computer program was used. Study of the deflection of a beam lintel with a special frame of unmeasured reinforcing sections under various loads was carried out using the ABAQUS CAE program. Samples of bar lintels were manufactured under the conditions of Karagandastroykonstruktsiya LLP. To use a concrete mixture with the addition of industrial waste and welded reinforcing bars from unmeasured pieces of reinforcing bars in the production of bar lintels, they were tested for strength in accordance with GOST 10180-2012. Testing of samples-cubes made with different contents of industrial waste was carried out in the laboratory of NORD Prom NS LLP (Temirtau, Kazakhstan).

Scientific novelty are as follows:

1. A technology was developed for the production of reinforced concrete products, in particular, bar lintels, which includes: special concrete mixture with the addition of industrial waste; a special structure of the spatial frame, made of unmeasured reinforcing sections; a special structure of the bar lintel.

2. It was established that the addition of 10% industrial waste can reduce cement consumption by 10% and increase the strength of the product by 20%.

3. A mathematical dependence is proposed for assessing the strength of concrete.

4. A method was developed for joining unmeasured reinforcing sections by friction welding and the structure of a special device for its implementation.

5. It has been established that reinforcing bars made of unmeasured pieces of reinforcing bars having 2-3 welds withstand flexure $<45^{\circ}$ and a load of 25000 ÷ 40000 N.

6. Performed for the first time: simulation of the process of testing samples of welded reinforcing bars for static tension with the determination of the tensile strength depending on the loads using the Solidworks computer program; study of the deflection of a beam lintel with a special frame of unmeasured reinforcing sections under various loads using the ABAQUS CAE computer program.

The main scientific provisions submitted for defense:

1. Technology for the production of reinforced concrete products, in particular, bar lintels, which include a new composition of the concrete mixture with the addition of industrial waste (fly ash), the structure of a spatial frame and a bar lintel made of unmeasured reinforcing sections.

2. Mathematical dependence for assessing the strength of concrete.

3. The method of joining unmeasured reinforcing sections by friction welding and the structure of a special device for its implementation.

4. Results of experimental tests of joining unmeasured reinforcing sections by friction welding and flash butt welding.

5. Results of laboratory and industrial testing of the strength of welded joints and the structure of bar lintel.

6. Methods for modeling and studying the strength of welded reinforcing bars and the structure of a bar lintel using Solidworks and ABAQUS CAE computer programs.

The reliability of the obtained results is confirmed by: the correctness of the problem statement, the adequacy of theoretical and experimental studies; satisfactory convergence of the results of planning and experimental studies and tests; patents of the Republic of Kazakhstan for utility models; implementation of research results into production; approbation of the research results at national and international conferences, as well as publication in domestic and foreign high-ranking publications; approbation of the obtained scientific results at scientific seminars of domestic and foreign universities and at technical meetings of domestic construction industries.

The dissertation work was prepared as part of the implementation of the state housing construction program “Nurly Zher” adopted in 2016 and the state program of housing and communal construction “Nurly Zher” for 2020-2025.

The results of the dissertation were introduced into the production of Karagandastroykonstruktsiya LLP, as well as into the educational process of KTU in the preparation of the specialties “Production of building products, materials and structures” and “Construction”.

Approbation of work. The main provisions of the doctoral dissertation were reported and discussed at: international scientific and practical conferences, at scientific seminars of domestic and foreign universities, at technical meetings of construction enterprises.

The author's personal contribution is in setting goals and developing research methods; conducting a review of scientific and technical literature and

patent search on the topic of the dissertation; development and manufacture of a special device for friction welding; organization and conduct of experimental studies, pilot tests; approbation of the results of work at scientific seminars of domestic and foreign universities, at technical seminars of domestic construction industries, as well as at international scientific and practical seminars.

Publications. Based on the results of the doctoral dissertation, 18 papers were published in Russian, Kazakh and English, including: 3 articles in an international scientific publication, according to the Web of Science database or included in the Scopus database, 4 articles in publications recommended by the Committee for Quality Assurance in the field education and science of the Republic of Kazakhstan. The reports of the presented work were considered at 5 international conferences, including 1 at a foreign international conference. Received 4 patents of the Republic of Kazakhstan for a utility model and 2 certificates of state registration of rights to an object of copyright.

CONCLUSION

When performing the dissertation work, it was revealed that the domestic industry of building materials (in particular, reinforcing bars) is currently able to satisfy only part of the needs of the construction complex of the Republic of Kazakhstan, and as a result, imported products occupy a significant share of the market. This current situation negatively affects the prime cost of production of construction products. It was also revealed that there is a large consumption of reinforcement to waste, which exceeds the norms defined by GOST and is about 2%. Consumption of reinforcing bar in this ratio leads to an increase in the prime cost of production of reinforced concrete products, which plays an important role in the current condition of the construction industry of the Republic of Kazakhstan. Based on this, the scientific study of the dissertation work was aimed at improving the efficiency of the technology for the production of reinforced concrete products through the use of rods made of unmeasured waste of reinforcing bars and industrial waste (fly ash). To solve this problem, a comprehensive research work was carried out and the following results were obtained:

1. The structures of reinforced concrete products and their production technologies, as well as the consumption of reinforcing steel bars, were studied. As a result, the subject of research was determined – the technology of production of bar lintels.

2. To join unmeasured segments of reinforcing bars, the methods of butt resistance welding and friction welding were selected and studied. To implement the friction welding method, a special device based on a lathe was developed and manufactured (RK Patent No. 4676).

3. Strength tests (tensile and bending) of welded joints were carried out under laboratory conditions and under conditions of special certified centers. As a result of the test, it was found that:

- rods connected from several rebar wastes by flash butt welding, having 2-3 joints each, withstand a tensile load in the range of 25000 - 40000 H and in bending $\geq 45^{\circ}$;

- the mechanical properties of the welded joint obtained by friction welding are higher than the mechanical properties of the base metal of the reinforcing bar and meet the requirements established by GOST 34028-2016. The rupture of the reinforcement occurred not in the weld, but in the base metal. Reinforcing bars during bending withstood flexure $\geq 45^{\circ}$.

4. Using the Solidworks program, the simulation of the static tensile test process was performed with the determination of the tensile strength of reinforcement with a welded seam depending on the loads.

The test results are also confirmed by calculation, while the strength conditions of butt welded joints are fulfilled in accordance with regulatory documents.

5. A special composition of the concrete mixture with the addition of industrial waste was developed (RK Patent No. 6277). As a result of the test, it was found that the addition of 10% industrial waste can reduce cement consumption by 10% and increase the strength of the product by 20%.

6. A mathematical relationship is proposed for assessing the strength of concrete:

$$R_{\text{сж}}(x,y,z) = 37.586164601763 \cdot x + 31.689571020189 \cdot y + 16.828267035537 \cdot z.$$

7. A special structure of a spatial frame for bar lintels was developed (RK Patent No. 6375).

8. The design of the bar lintel was developed (Patent No. 6360). Prototypes of bar lintels were made under the conditions of the reinforced concrete plant of Karagandastroykonstruktsiya LLP. The results of testing a prototype bar lintel 3PB 13-37 carried out in the laboratory of the test center of GIO TRADE LLP, as well as the results of a study performed using the ABAQUS CAE program, showed that the proposed technology for the production of reinforced concrete products using welded reinforcement from metal waste and concrete mix with the addition of industrial waste allows to obtain reinforced concrete products, in particular bar lintels, in accordance with the regulatory data required for bar lintels. The deflection value at a maximum load of 50 kN is 1.48 mm, which does not exceed the standard allowable value of 2.2 mm.

9. Methods have been developed for determining the deflection of a bar lintel with a special frame of unmeasured reinforcing sections (Certificate No. 25063) and modeling the process of tensile testing of reinforcement with a welded seam under various loads (Certificate No. 25062).

10. Recommendations for production were developed. The developed technology for the production of bar lintels was introduced into the production of Karagandastroykonstruktsiya LLP (Karaganda, Kazakhstan). The expected annual economic effect is 18%.