ABSTRACT

for the PhD dissertation in the educational program
8D07321 “Construction” by Dias Almatovich Okanov
Title: «Experimental–theoretical study of crane runway
I-girders with triangular-profile corrugated
webs for general-purpose bridge cranes»

In contemporary construction practice, a key task for design engineers is to identify structural solutions that simultaneously ensure the reliability, strength, and economy of steelwork. These three attributes determine the competitiveness of solutions used in industrial and civil construction. The tightening of requirements for load-bearing systems is driven not only by increasing loads and longer spans but also by the need to reduce steel consumption and fabrication labor. In this context, advancing analysis and design methods that meet safety and durability requirements is a priority of modern structural engineering science and practice.

Particular attention has recently shifted to crane runway systems in industrial buildings: crane runway girders are subjected not only to static actions but also to dynamic, cyclic, and impact effects from bridge cranes, which imposes elevated demands on strength, stability, and stiffness. In design and construction practice, there is a growing need for solutions that reduce the mass of crane girders while improving their service performance. One promising path is replacing flat webs in I-girders with corrugated webs.

Using a corrugated web within an I-girder makes it possible to reduce member weight and fabrication effort without sacrificing strength and stability. The corrugation shape improves resistance to local buckling and leads to a more uniform stress distribution. However, despite the evident advantages, issues related to the stability of corrugated-web girders, evaluation of critical stresses, and the in-service behavior of the web remain insufficiently studied—especially for triangular corrugations intended for general-purpose crane runways.

Research relevance. The relevance of this study is dictated by the need for a comprehensive investigation of welded crane runway girders with corrugated webs under bridge-crane actions. In modern industrial construction, selecting a rational web form for the crane girder is crucial for improving the reliability of steel structures. This is especially important in seismic regions and under multiple cyclic actions. The stability of the web in the elastoplastic stage directly affects the ability of the structure to absorb external actions without failure or loss of load-carrying capacity.

Replacing flat webs with corrugated ones can markedly increase stability and performance at smaller web thicknesses, ultimately reducing steel consumption and fabrication cost. At the same time, this approach demands the development of new engineering design and analysis methods. Current codes of the Republic of Kazakhstan and international standards provide no explicit provisions for the design and analysis of crane runway girders with triangular corrugations. This creates a need for scientific substantiation and adaptation of approaches that reflect real service conditions and the web geometry.

Accordingly, the development and implementation of methods that enable rational design of crane girders with corrugated webs is a task of considerable scientific and practical importance. Research in this area supports the evolution of the normative base, the deployment of resource-saving technologies, and the improvement of reliability in industrial buildings.

Scope of the study. The dissertation is limited to the experimental–theoretical investigation of crane runway girders with triangular corrugations for general-purpose cranes, emphasizing rational geometric parameters of the corrugation and a stability-oriented design method. It does not cover the full spectrum of structural solutions and service environments.

Object of the study: industrial buildings equipped with crane runways.

Subject of the study: the influence of corrugation geometry (pitch, length, depth, thickness; triangular profile) on deformability, stability, and load-carrying capacity of the girders.

Goal. To perform an experimental–theoretical study of welded I-section crane runway girders with triangular corrugated webs for general-purpose cranes and to develop engineering methods for analysis and for selecting rational corrugation parameters.

Research tasks

- Analyze the application domain of crane girders with various corrugation shapes.
- Develop a calculation methodology for girders with corrugated webs (including load eccentricity).
- Investigate the behavior of welded girders while varying corrugation geometry.
- Substantiate the efficiency of triangular corrugations by strength, stiffness, and stability criteria.
- Identify optimal corrugation parameters via numerical modelling.
- Conduct laboratory tests on models with flat and corrugated webs (scale 1:3).
- Assess the effect of replacing the flat web with a corrugated one on structural efficiency.
-Perform a techno-economic evaluation of the solution.

Methods and validity. The study combines: analytical evaluations of sectional inertia and stability (including a modified Hicks method with load eccentricity), numerical modelling (LIRA-SAPR 2024, SCAD TONUS) with mesh-convergence analysis, and laboratory testing of 1:3 scale models. Comparison of computed and experimental data confirms model adequacy: deflection discrepancies in the elastic stage are about 2.9–10% (up to 15% in adverse cases), with verified repeatability. Normative approaches (SP/EN/AISC by analogy) and literature benchmarking were used.

Scientific novelty

1. Establishment of an effective parameter range for triangular corrugations in 6–10 mm webs.

2. Clarification of cross-section classification under Eurocode for crane-induced effects.

3. A modified engineering web-stability method (after Hicks) with explicit eccentricity effects.

4. Quantitative assessment of corrugation length/depth/pitch influence on the stress–strain state (SSS) and critical stresses.

5. Integration of test results into parametric calibration of FE models.

Brief state-of-the-art review. Corrugated webs primarily carry shear, increase torsional stiffness, and allow reductions in web thickness and weight while maintaining reliability. International and domestic studies confirm good fatigue performance under cyclic actions; however, there are no direct code methods for crane runway girders with triangular corrugations. Practice relies on adapted approaches (equivalent rigidities, truss analogies, and FE models with local wheel-load zones), underscoring the need for a unified engineering methodology.

Adopted analytical framework. A simply supported girder of about 6 m span under concentrated crane actions (12.5–50 t) is considered, with a 15 mm load eccentricity relative to the axis to emulate realistic crane misalignment. Girders with flat webs and with triangular corrugations are compared while varying corrugation length/depth/pitch and web thickness (6–10 mm). In the laboratory, a 1:3 geometric and physical similarity was observed (loads ≈ 1/9, deflections ≈ 1/3, with moduli and stresses preserved).

Main results

1. Deformability. Compared with a flat web, a corrugated web yields slightly larger mid-span deflections under identical conditions—because the web contributes less to normal stress resistance—yet deflections remain within allowable limits.

2. Stability. A triangular corrugation significantly increases web stability (especially near concentrated wheel loads). By the modified Hicks method, a load eccentricity up to 2–3% of web height reduces the critical load by only ~2–3%, indicating a reserve of stability.

3. Sensitivity to eccentricity. Flat-web girders are more sensitive to flexural–torsional effects; corrugated-web girders display more uniform stress fields and lower shear stresses.

4. Corrugation parameters. A rational range is identified: ≈ 80 mm depth and ≈ 480 mm panel length provide the most favorable balance of stiffness, stability, and mass. Increasing length to 640 mm noticeably reduces stability (by ~35–40% in terms of critical stresses).

5. Laboratory tests (1:3). Load–deflection curves are linear in the elastic stage, with a transition to nonlinearity at ~0.75–0.9 F_p; dominant limit states include buckling of the flanges/web. Residual deflections after unloading are small. FE–test deflection discrepancies at central loading are ~2.9–10%; under eccentric loading they are larger (up to ~28%) due to unmodelled technological and contact effects.

6. Mass, labor, cost. Replacing a flat web with a corrugated one reduces mass by ~4–7%, welding operations by up to ~30%, and total cost by ~15–20% (series-dependent).

7. Mesh independence. FE mesh-convergence is confirmed (optimal element size ~5×5 mm), ensuring stable numerical results for parametric studies.

Propositions submitted for defense

1. A triangular corrugation increases the stability and load-carrying capacity of crane runway girders while reducing mass and fabrication effort.

2. Corrugation geometry (length, depth, pitch) governs stress distribution, torsional resistance, and overall deformability; parameter selection must be carried out parametrically.

3. The modified Hicks-based web-stability method with eccentricity delivers a reliable engineering estimate of critical actions.

4. Laboratory tests confirm the adequacy of the numerical model and support the recommendation of a 480×80 mm corrugation as a rational solution.

5. Using triangular corrugations enables mass reductions up to ~6.9% without degrading—and in some cases improving—stiffness and strength relative to flat-web girders.

Practical significance. The proposed guidelines for selecting corrugation parameters and the modified web-stability method are suitable for engineering practice in crane runway and industrial building design. The derived relationships enable rapid preliminary web-geometry selection, account for load eccentricity, and reduce steel consumption and fabrication effort without compromising required performance.

The findings have been implemented in design practice (LLP “RAS Group Project”) and in the curriculum of the “Design and Analysis of Buildings and Structures” program (2025).

Structure of the dissertation. The dissertation comprises an introduction, five chapters, conclusions, and appendices (149 pages, 30 tables, 65 figures, 161 references, and 12 appendices). In brief:

Chapter 1: literature and practice review; comparison of corrugation types; historical and normative context; behavior of floor and crane runway girders.

Chapter 2: calculation premises; synthesis of theoretical and experimental data for crane girders with corrugated webs; deformability and stability issues; normative gaps.

Chapter 3: theoretical studies of corrugation geometry influence on SSS, stiffness, and stability; parametric analysis.

Chapter 4: mathematical modelling (LIRA-SAPR, SCAD TONUS), calibration, mesh convergence, eccentricity effects, determination of rational parameters.

Chapter 5: laboratory tests (1:3), test plan and methods, “theory–FE–experiment” comparison, refined recommendations.

Overall conclusions

1. Crane runway girders with triangular corrugations exhibit higher stability and fatigue resource under cyclic actions while remaining technological and economical.

2. For the studied parameter range, a 480×80 mm corrugation is most rational; increasing panel length to 640 mm reduces critical stresses by 35–40%.

3. Mass reductions of 4–7%, welding reductions up to ~30%, and cost reductions of ~15–20% confirm the techno-economic viability.

4. The normative base requires development: adaptation of the stability methodology (incl. Hicks) and explicit consideration of fatigue, seismic, and technological factors for crane runway I-girders with corrugated webs.

Future work

— Expand the experimental database (including full-scale specimens, variable corrugation along length/height).

— Develop simplified engineering algorithms and incorporate them into national standards of Kazakhstan, harmonised with EN/AISC.

— Account for fatigue, high-temperature and seismic effects, residual/welding stresses.

— Explore composite and energy-dissipative solutions to enhance durability and reduce vibrations.