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RESEARCH ARTICLE

A TECHNOLOGICAL APPROACH TO REDUCING LABOR AND MATERIAL CONSUMPTION OF CRANE RUNWAY I-BEAMS WITH CORRUGATED WEB

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Abstract. *The growing demand for industrial and logistics infrastructure has intensified the need for efficient and economically viable structural systems, particularly in crane runway applications. Welded I-beams with corrugated webs have emerged as a promising alternative to conventional flat-web designs, offering notable advantages in terms of production efficiency, weight reduction, and structural performance. This study investigates the technological strategies involved in manufacturing such beams, with a focus on minimizing labor intensity and material usage through process optimization. A comparative analysis is conducted between beams with flat and corrugated webs, drawing upon experimental data and practical observations from automated production lines. The research highlights the implementation of rotary corrugation machines, automated welding stations, and mechanized assembly platforms. A key innovation lies in eliminating transverse stiffeners, made possible by the enhanced out-of-plane stability provided by the corrugated profile. This not only reduces the number of fabrication steps but also contributes to overall simplification of the production workflow. The findings indicate that the use of corrugated webs results in a weight reduction of up to 6.9%, depending on the design load, and a decrease in labor intensity by up to 40% when compared to traditional flat-web I-beams. These improvements are achieved without compromising structural integrity or regulatory compliance. In conclusion, the study demonstrates that corrugated web beam technology is a viable solution for modern steel construction. It enhances productivity, lowers manufacturing costs, and supports broader adoption of efficient beam systems in industrial and civil engineering contexts.*

Keywords: *crane runway girders, corrugated web, welded I-beams, production technology, metal structures, automated welding, labor cost reduction.*

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ҒЫЛЫМИ МАҚАЛА

ГОФРЛЕНГЕН ҚАБЫРҒАСЫ БАР ҚОСТАВРЛЫ КРАНАСТЫ АРҚАЛЫҚТАРДЫҢ ЕҢБЕК ЖӘНЕ МАТЕРИАЛ ШЫҒЫНЫН АЗАЙТУҒА БАҒЫТТАЛҒАН ТЕХНОЛОГИЯЛЫҚ ТӘСІЛІ

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Аңдатпа. *Индустриялық және логистикалық инфрақұрылымға деген сұраныстың артуы, әсіресе кран жолдары жүйелерінде, тиімді әрі экономикалық тұрғыдан негізделген көтергіш конструкцияларға деген қажеттілікті күшейтті. Гофрленген қабырғасы бар дәнекерленген қоставрлы кранасты арқалықтар дәстүрлі жазық қабырғалы балкаларға балама ретінде қарастырылады және өндірістік технологияны оңтайландыру, құрылымдық салмақты азайту және беріктікті арттыру тұрғысынан бірқатар артықшылықтарға ие. Осы зерттеуде мұндай арқалықтарды дайындауға арналған технологиялық тәсілдер қарастырылып, еңбек шығындары мен материалдық тұтынуды азайтуға бағытталған үдеріс тиімділігін арттыру жолдары талданады. Жазық және гофрленген қабырғалары бар кранасты арқалықтарға салыстырмалы талдау жүргізілді, ол автоматтандырылған өндірістік желілерден алынған эксперименттік деректер мен бақылауларға негізделген. Зерттеу барысында гофрлеуге арналған ротациялық машиналарды, автоматтандырылған дәнекерлеу жүйелерін және механикаландырылған жинақтау жабдықтарын қолданудың маңыздылығы атап көрсетіледі. Негізгі технологиялық артықшылық — гофрленген қабырғаның жоғары орнықтылығы арқасында көлденең қатаңдық элементтерінен бас тарту мүмкіндігі. Бұл өндірістік процесті едәуір жеңілдетіп, технологиялық операциялар санын қысқартуға ықпал етеді. Зерттеу нәтижелері көрсеткендей, гофрленген қабырғаны қолдану арқасында кранасты арқалықтың салмағы жүктеме түріне қарай 6,9 %-ға дейін, ал еңбек шығыны 40 %-ға дейін төмендейді. Бұл артықшылықтар құрылым сенімділігі мен нормативтік талаптарды сақтай отырып жүзеге асады. Қорытындылай келе, гофрленген қабырғалар технологиясын кранасты арқалықтарда қолдану қазіргі заманғы болат құрылысында өндіріс тиімділігін арттырудың, шығындарды төмендетудің және өнеркәсіптік пен азаматтық инженерияда қолдану аясын кеңейтудің тиімді жолы болып табылады.*

Түйін сөздер: *кранасты арқалықтар, гофрленген қабырға, дәнекерленген қоставр, өндіріс технологиясы, металл конструкциялар, автоматтандырылған дәнекерлеу, еңбек шығынын төмендету.*

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НАУЧНАЯ СТАТЬЯ

ТЕХНОЛОГИЧЕСКИЙ ПОДХОД К СНИЖЕНИЮ ТРУДОЗАТРАТ И МАТЕРИАЛОЁМКОСТИ ДВУТАВРОВЫХ ПОДКРАНОВЫХ БАЛОК С ГОФРИРОВАННОЙ СТЕНКОЙ

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Аннотация. *Рост потребности в индустриальной и логистической инфраструктуре увеличил спрос на эффективные и экономически обоснованные несущие конструкции, особенно в системах крановых конструкций. Сварные двутавровые подкрановые балки с гофрированной стенкой становятся перспективной альтернативой традиционным подкрановым балкам с плоской стенкой, демонстрируя преимущества в технологичности производства, снижении массы и повышении прочности. В настоящем исследовании рассматриваются технологические подходы к изготовлению таких балок с акцентом на сокращение трудозатрат и расхода материалов за счёт оптимизации процессов. Проведён сравнительный анализ подкрановых балок с плоской и гофрированной стенками на основе экспериментальных данных и наблюдений с автоматизированных производственных линий. В работе подчеркивается значение применения ротационных машин для гофрирования, автоматизированной сварки и механизированной сборки. Ключевое технологическое преимущество заключается в отказе от поперечных ребер жёсткости, благодаря повышенной устойчивости гофрированного профиля. Это существенно сокращает количество операций и упрощает производственный процесс. Результаты показывают, что использование гофрированной стенки позволяет уменьшить массу балки до 6,9 % (в зависимости от расчётной нагрузки), а трудоёмкость — до 40 % по сравнению с традиционными балками. Эти преимущества достигаются без ущерба для надёжности конструкции и соответствия нормативам. Таким образом, применение технологии гофрированных стенок в подкрановых балках представляет собой эффективное решение для современного строительства металлоконструкций, повышающее производительность, снижающее затраты и расширяющее возможности применения в промышленной и гражданской инженерии.*

Ключевые слова:. *подкрановые балки, гофрированная стенка, сварные двутавры, технология производства, металлические конструкции, автоматизированная сварка, снижение трудозатрат.*

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу өз қаражаты есебінен жүргізілді.

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Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

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Исследование проведено за счет собственных средств.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

The increasing demand for industrial and civil infrastructure has led to the growing importance of optimizing structural components in steel-framed buildings. Among these, crane runway systems play a critical role in the operation of overhead lifting equipment and must ensure high reliability under variable and cyclic loads. A key factor influencing their performance is the stability of the beam web, particularly in I-section crane runway beams. When subjected to elastic-plastic deformation and potential overloads, the structural integrity of the web determines the overall energy absorption capacity of the system. Therefore, the search for optimal cross-sectional configurations is a crucial research direction in improving the resilience of steel frameworks.

Recent advances have shown that replacing traditional flat webs with corrugated ones can significantly enhance the buckling resistance of the web, even when using thinner steel plates. This structural improvement not only reduces the need for transverse stiffeners but also lowers material consumption and simplifies the manufacturing process. Despite these advantages, normative documents in Kazakhstan and abroad still lack clearly defined methods for the design and calculation of crane runway I-beams with corrugated webs. This creates a gap between practical needs and regulatory support, underlining the necessity of developing new approaches and adapted analytical tools for structural engineers.

Modern structural solutions in the field of light metal structures (LMS) aim to achieve high techno-economic performance by utilizing thin steel sheets and implementing mechanized or fully automated production lines. The comprehensive use of efficient LMS, automated manufacturing, large-block assembly, as well as high-strength steels and lightweight thermal insulation materials for enclosing structures, enables a significant increase in the pace of building and structure construction.

One of the promising directions in the field of load-bearing metal structures is the application of welded I-beams with thin corrugated webs. In Kazakhstan, construction systems such as "Alma-Ata" and "BGS-Kazakhstan" have been developed and applied in practice, including in roof and floor beams, as well as in columns of single-story and multi-story building frameworks. Based on extensive research and design studies, a range of standard profiles and regulatory documents has been developed to support the use of such systems, even in seismic zones. The importance of these developments is evidenced by the inclusion of corrugated-web I-beams in the Eurocode adaptations for Kazakhstan. Between 1981 and 2015, over 250 buildings were constructed using these beams, designed by the "Institute Proektstalkonstruktsiya" (Almaty), with long-term operational success.

The purpose of this study is to conduct a comprehensive analysis of the performance of welded I-section crane runway beams with corrugated webs under overhead crane loading, and to develop engineering-based methods for calculating their behavior, including optimization of the corrugation geometry (length, pitch, and depth).

2 LITERATURE REVIEW

A corrugated beam is a beam with flanges made of metal of various cross-sections and a transversely corrugated (bent) web. The corrugated webs of beams can have triangular, sinusoidal, trapezoidal, rectangular, and other profiles **(Misiek, 2021).** The flanges of such beams are made of rolled steel, shaped profiles, electric-welded pipes, or reinforced concrete elements. Beams with corrugated webs are widely used in many countries.

In recent years, crane runway girders have received increased attention due to the growing construction of industrial buildings. Their reliability, strength, and efficiency contribute to improving production and logistics processes, as well as ensuring safety when handling heavy loads. A crane runway girder is a load-bearing structure that supports the loads from the wheels of an overhead crane moving within a workshop. Additionally, as structural elements of the frame, crane girders help decouple columns from the frame plane, transfer longitudinal forces from braking and wind loads to vertical connections between columns, and mitigate the impact of seismic and other external factors, thereby improving the coordinated performance of the entire structure.

Several design solutions for crane runway girders with corrugated webs have been proposed in the literature **(Wei, 2015)**. The effectiveness of corrugated webs in welded I-beams has been studied from various perspectives, including load-bearing capacity, strength **(Hlal, 2024)**, stability, and durability **(Yuan, 2024).** Methods for reinforcing crane girders**(Sebastiao, 2023)**, stress-strain behavior (SSB), and their response to various impacts have also been analyzed **(Kettler, 2023).** The application of corrugated webs in box-section crane girders has been studied in **(Wei, 2015).**

In certain industrial building conditions, the use of crane runway girders with corrugated webs becomes necessary, as these significantly influence their strength and stability. Steel savings of up to 20% can be achieved through the use of thinner web plates compared to flat web girders, eliminating the need for stiffeners due to improved stability achieved by the corrugation folds, whose peaks extend beyond the web plane. However, apart from studies by **(Wei, 2015)** and **(Bryantsev & Okanov, 2024),** further research on girders with corrugated diaphragms and triangular web profiles remains limited **(Bradford, 2002).**

This study focuses on the analysis of the strength characteristics and optimization of corrugated web parameters in crane runway girders**(Bryantsev, 2019)**, aiming to improve calculation methodologies and expand their application in construction **(Bryantsev, 2019).**

3 MATERIALS AND METHODS

The manufacturing process of crane runway girders includes the stages of preparation, assembly, and welding of structural elements. The technological operations differ depending on the type of girder web: flat or corrugated.

3.1. Manufacturing of a girder with a flat web

At the initial stage, the girder body, which includes the web and two flanges, is assembled in the fabrication area. After positioning the elements, they are fixed in place to prevent deformation. The girder body is then transferred to the welding section, where the web is welded to the flanges.

After completing this operation, the semi-finished product is returned to the assembly area for the installation of stiffeners, which are necessary to increase the load-bearing capacity of the structure. The stiffeners are installed with precise adherence to design dimensions and geometry **(Bryantsev, 2024)**. The girder is then sent back to the welding section for the final welding of the stiffeners. This additional stage of assembly and welding increases the overall manufacturing time of the structure.

3.2. Manufacturing of a girder with a corrugated web

The manufacturing technology of a girder with a corrugated web has significant differences. After fabricating the main body, which consists of the corrugated web and two flanges, welding is performed as the first stage**(Bryantsev, 2020)**.. Due to the structural advantages of the corrugated web, which provides stability and rigidity without the need for stiffeners, additional assembly and welding stages are not required. Once the end elements are welded, the structure is considered complete.

Thus, the manufacturing process of a girder with a corrugated web is characterized by lower labor intensity, resulting from the reduction of technological operations and fewer material transfers between workstations. This ensures time and resource savings in production **(Shuryn, 2020).**

A flat steel sheet is fed between two toothed rollers that rotate toward each other **(Figure 1)**. A set of removable plates (teeth) of various sizes allows for adjusting the corrugation parameters. The experimental version of this machine confirmed the correctness of the selected corrugation method. When operated by a single worker, the machine was capable of corrugating sheets up to 1,600 mm in width and 8.0 mm in thickness at a speed of 10 to 12 m/min, which is three to four times faster than forming corrugations using press equipment **(Ibrahim, 2006).**

One of the advantages of this corrugation method is that the sheet maintains a constant cross-section along its entire length, whereas press-based corrugation may lead to local thinning of the sheet and significant changes in the steel's properties. Thanks to its compact dimensions, the machine was easily integrated into the main production line for girder fabrication. Additionally, the flexible technology developed on its basis fully addressed the issue of corrugated web production **(Figure 2)** and allowed for an annual production capacity increase of welded I-beams under the "Alma-Ata" system from 10,000 to 12,000 tons, equivalent to the fabrication of 600,000 to 800,000 m² of roofing and flooring elements **(Kettler, 2021).**

The **Figure 1** illustrates the process of forming corrugations in a steel sheet using a rotary machine. The steel sheet passes between two rotating rollers, which are equipped with removable plates designed to shape the material into a corrugated profile. The upper and lower rollers rotate in opposite directions, gradually bending the sheet as it moves through the machine. The spacing between the rollers is adjustable, allowing for control over the depth and shape of the corrugations. This method ensures uniform deformation of the sheet while maintaining a consistent cross-section along its entire length, making it an efficient technique for manufacturing corrugated structural elements **(Kudryavtsev, 2021)**.

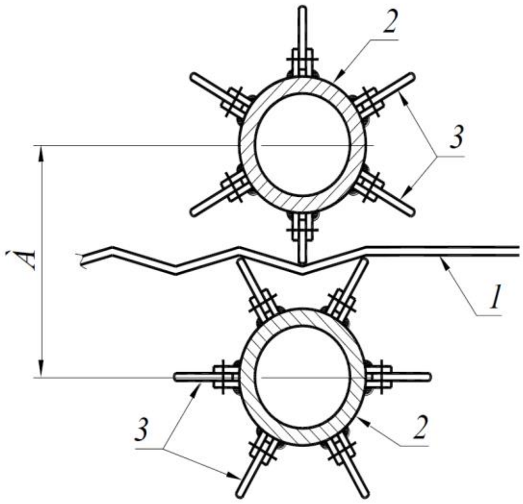

Figure 1 – Schematic diagram of steel sheet corrugation on a rotary machine.

Figure 2 – Corrugated webs in the assembly shop.

The comparative analysis of the manufacturing processes for flat-web and corrugated-web crane runway beams reveals a clear advantage in favor of the latter. The use of corrugated webs eliminates the need for transverse stiffeners, thereby reducing the number of fabrication steps and significantly lowering labor intensity. The integration of rotary corrugation machines into production lines further enhances efficiency by enabling faster, uniform, and more stable web formation without compromising steel properties. This streamlined approach results in time and cost savings, increases production capacity, and supports the widespread implementation of corrugated web technology in the fabrication of high-performance steel beams.

4 RESULTS AND DISCUSSION

The evaluation of cost-effectiveness and manufacturing efficiency plays a crucial role in assessing the practical advantages of using corrugated web I-beams in crane runway systems. To quantify these benefits, a detailed comparison was conducted between beams with flat and corrugated webs under various load conditions. The analysis includes structural weight distribution, material utilization, and labor intensity across key production stages. Graphical data and tabular results were used to illustrate the reductions in weight and complexity associated with the corrugated web configuration. This section presents the findings of the comparative study, supported by numerical and experimental observations, and highlights the economic and technological advantages that support the broader adoption of corrugated web technology in beam fabrication.

4.1. On Cost-Effectiveness

The factory cost of the structure consists of the cost of raw materials and manufacturing expenses.

Calculation of the total weight of all crane runway girders for a 10-ton load

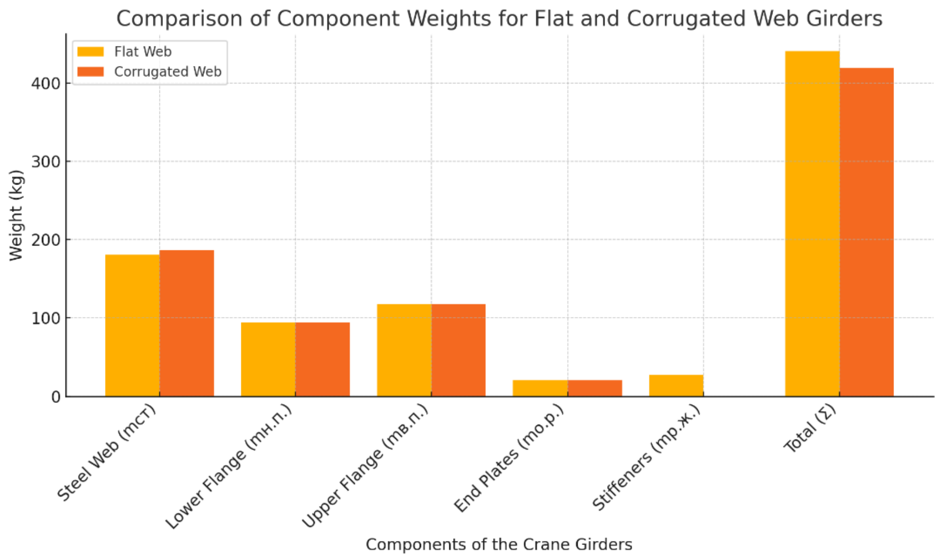

Figure 3 – Comparison of Component Weights for Flat and Corrugated Web Crane Girders (10t Load).

The **Figure 3** illustrates the weight distribution of different components in crane runway girders with flat and corrugated webs. The comparison highlights that the total weight of the girder with a corrugated web is 4.9% lower than that of the girder with a flat web. This reduction is primarily achieved by eliminating the need for stiffeners while maintaining structural integrity. The use of a corrugated web allows for weight savings, leading to more efficient material utilization and reduced production costs.

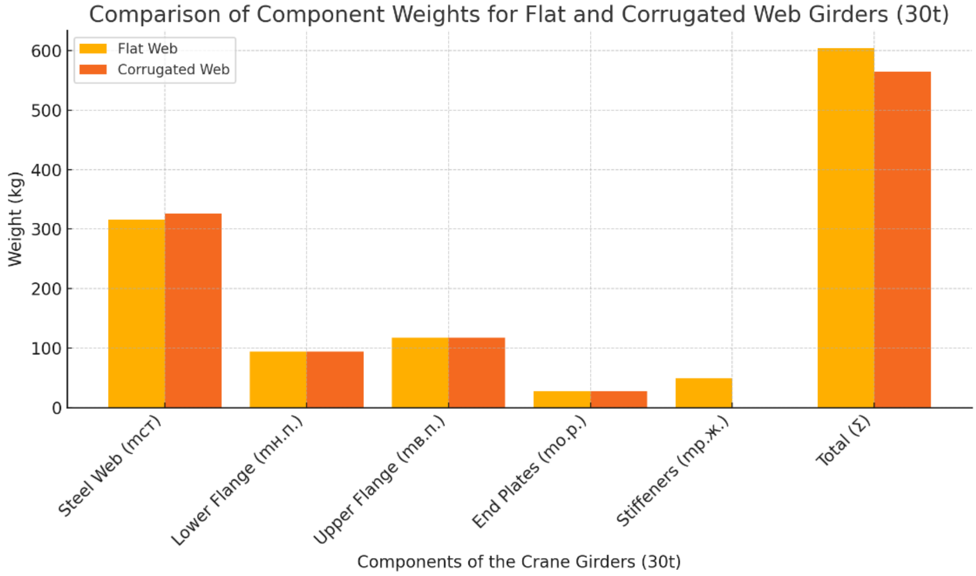

Figure 4 – Comparison of Component Weights for Flat and Corrugated Web Crane Girders (30t Load).

The **Figure 4** compares the weight distribution of different components in crane runway girders with flat and corrugated webs for a 30-ton load. The results show that the total weight of the girder with a corrugated web is 6.5% lower than that of the flat web girder. This reduction is achieved by eliminating stiffeners while maintaining structural stability, leading to improved material efficiency and reduced manufacturing costs.

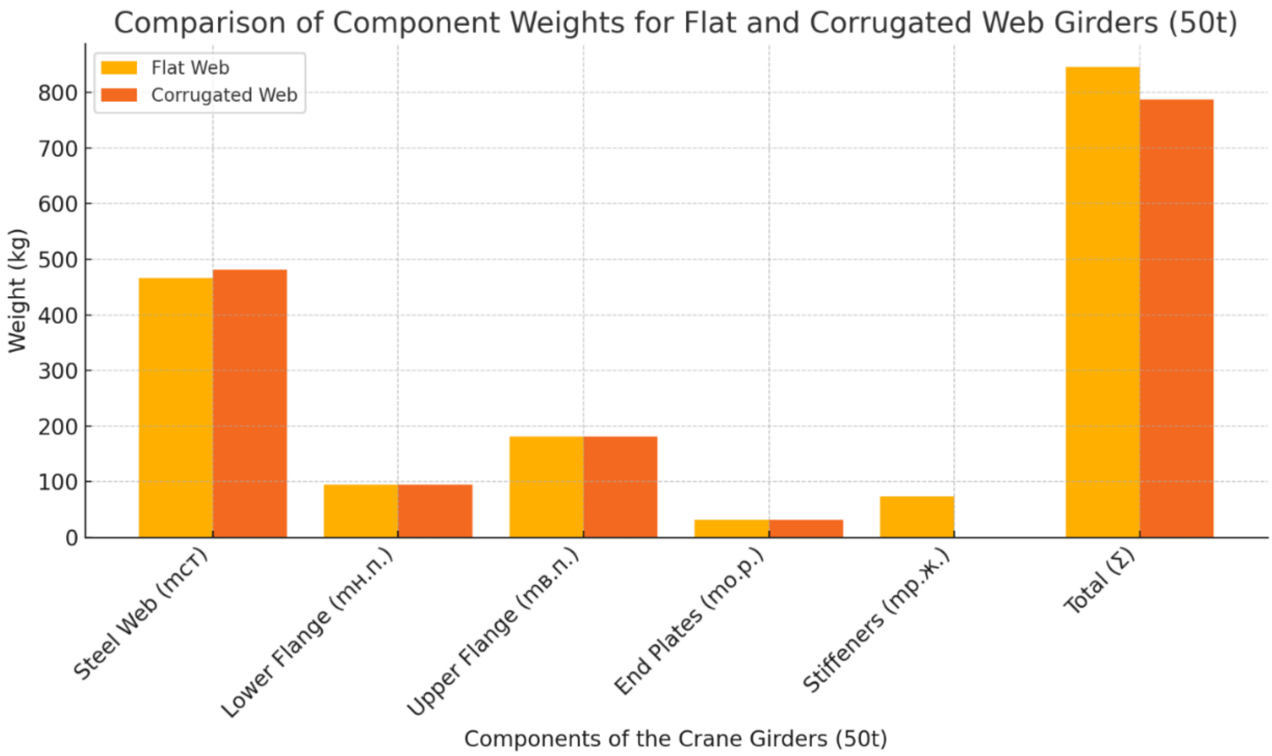

Figure 5 – Comparison of Component Weights for Flat and Corrugated Web Crane Girders (50t Load).

The **Figure 5** compares the weight distribution of different components in 50-ton crane runway girders with flat and corrugated webs. The results demonstrate that the total weight of the girder with a corrugated web is 6.9% lower than that of the flat web girder. This weight reduction is primarily achieved by eliminating stiffeners while maintaining the necessary structural integrity. The use of a corrugated web improves material efficiency, reduces production costs, and simplifies the manufacturing process.

4.2. Labor Intensity

Since 1989, second-generation rotary-type machines have been installed in the republic's manufacturing facilities, capable of corrugating sheets up to 1950 mm in width and 12.0 mm in thickness at a processing speed of 8 to 10 m/min **(Figure 6)**. The labor intensity of fabricating girders with corrugated webs accounts for 83% of that required for manufacturing thin-walled girders without stiffeners and 60% to 74% of that for thin-walled girders with stiffeners. This reduction in labor intensity is attributed to:

- Standardization of corrugation parameters and flange cross-sections, optimizing the manufacturing process;
- Minimization of the number of assembly components, reducing material handling and assembly complexity;
- Extensive use of single-sided flange welds, which simplifies the welding process and enhances efficiency;
- Elimination of transverse stiffeners, reducing the need for additional manufacturing steps;
- High productivity of advanced corrugation equipment, allowing for increased output with reduced processing time;
- Implementation of automated assembly of welded I-sections on mechanized stands with hydraulic fixation of section components (web and flanges), followed by integration into a unified girder element **(Figure 7)**. Alternatively, inventory stands at production facilities can be utilized, depending on the production volume and the availability of specialized equipment;
- Mechanization and automation of the flange welding process, improving efficiency and reducing manual labor.

The adoption of these technological advancements has resulted in a significant decrease in production time and labor costs, enhancing the overall efficiency of manufacturing girders with corrugated webs.

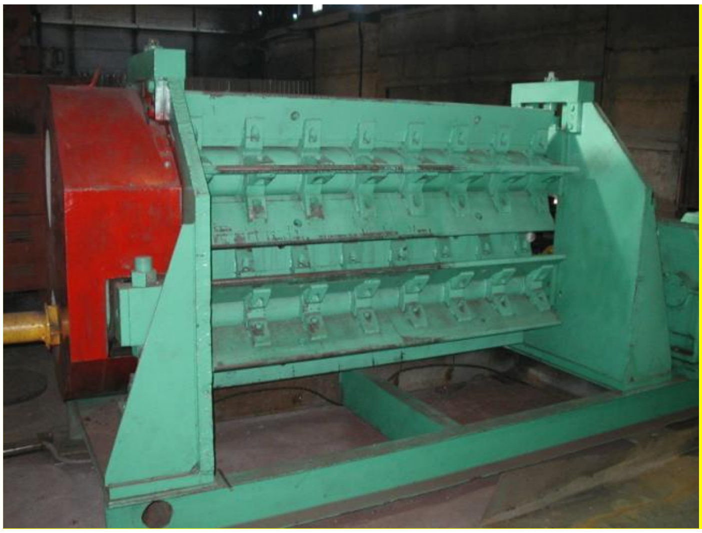

Figure 6 – Rotary Machine for Continuous Corrugation of Steel Sheets.

The machine is designed for the continuous corrugation of steel sheets with a maximum width of 1950 mm and a maximum thickness of 12.0 mm.

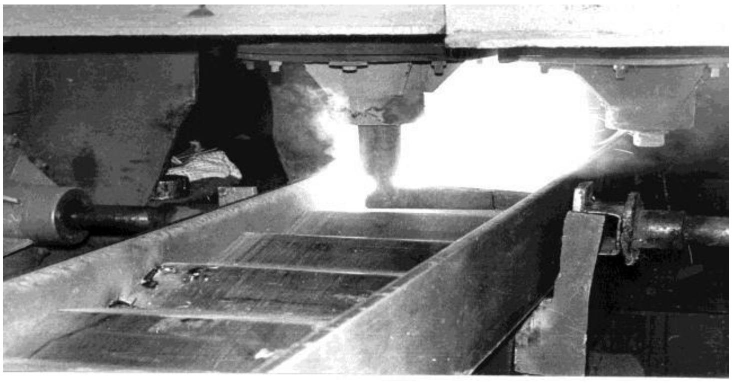

Figure 7 – Assembly of Welded I-Beams with Corrugated Webs in Mechanized Production Areas.

To address these challenges, relevant developments have been carried out to improve the technological processes for manufacturing welded I-beams with corrugated webs. In particular, a specialized device has been designed for the production of girders with corrugated webs, with a projected capacity of up to 10,000 tons of metal structures per year. Given its compact dimensions, this equipment can be integrated into one of the modular buildings of the "Alma-Ata" type, ensuring efficient and scalable production.

Figure 8 – Universal Steel Coils for I-Beam Webs.

Relevant efforts have also been undertaken to implement automated submerged arc welding (SAW) for the flange joints of BGS beams, utilizing a serial welding machine with adjustable wire feed speed, ADF-1202 **(Figure 8)**.

Subsequently, similar work was carried out to automate the welding of flange plates in a carbon dioxide environment and in a mixed gas environment with argon **(Figure 9)**.

The welding quality in both methods complies with the requirements of regulatory documents.

Since the web thickness typically ranges from 3.0 mm to 5.0 mm, the flange welds are usually performed from one side. However, when welding thicker webs, double-sided welding is applied, with the beam positioned optimally for the welding process. The fillet weld sizes are either made equal or welded with unequal fillets to meet the regulatory requirements for fillet dimensions depending on the thickness of the welded components.

After attaching various fastening elements to the beam using semi-automatic or manual welding, the structure undergoes anti-corrosion treatment in a specialized sandblasting chamber. Subsequently, the metal structure is primed once and dried in a drying chamber. **Figure 10** presents a welded I-beam of the "BGS-Kazakhstan" system, fully treated with anti-corrosion protection and ready for delivery to the customer.

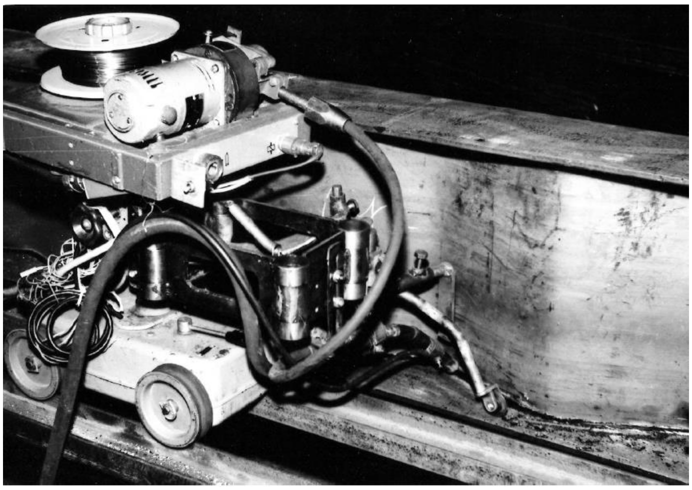

Figure 9 – 1985. Serial Welding Tractor with a Device for Welding Flanges of Beams with Corrugated Webs.

Figure 10 – Positioning of a Welded I-Beam Profile with a Corrugated Web on a Rotator for Welding Flange Joints with Unequal Fillets.

The table 1 provides a comparative analysis of labor intensity for different beam types, including corrugated web beams, beams without stiffeners, and beams with stiffeners. The data illustrate that beams with corrugated webs require the least labor effort across all manufacturing stages, making them the most efficient option in terms of production complexity and cost.

Table 1
Labor Intensity of Structure Manufacturing

Operation	**Beam with Corrugated Web**		**Beam without Stiffeners**		**Beam with Stiffeners**	
	Units of Measurement	%	Units of Measurement	%	Units of Measurement	%
Preparation and Transportation	7,5	100	8,1	108	7,9	104
Processing and Component Fabrication	6,2	100	6,8	110	8,5	137
Assembly	3,5	100	3,5	100	4,4	126
Welding	3,2	100	5,9	184	7,9	247
Finishing, Painting, and Loading	6,0	100	7,3	122	6,9	115
Total	26,4	100	31,6	120	35,5	134

Among the key differences, welding stands out as the most labor-intensive stage, particularly for beams with stiffeners, where additional reinforcement significantly increases workload. Processing and fabrication also demand considerably more effort for beams with stiffeners due to the complexity of additional structural elements. While preparation, transportation, and assembly efforts remain relatively similar across all beam types, the finishing and painting process requires slightly more effort for beams without stiffeners.

Overall, corrugated web beams demonstrate the lowest total labor intensity, reducing welding and processing complexity. This suggests that using corrugated web beams can enhance manufacturing efficiency by streamlining production while maintaining structural integrity.

5 CONCLUSIONS

Based on the conducted research, the following specific conclusions are drawn in accordance with the stated objectives:

1. Corrugated web I-beams have demonstrated considerable potential for use in crane runway systems, particularly those subjected to dynamic and cyclic loading. The triangular corrugation profile enhances the out-of-plane stability of the web, thereby significantly increasing the beam's resistance to local and global buckling. This structural improvement makes it possible to eliminate the need for transverse stiffeners, which are typically used in flat-web beams to prevent buckling. As a result, the overall beam geometry becomes more efficient, lighter, and simpler to fabricate, without compromising structural safety or service performance.
2. The comparative weight analysis of flat versus corrugated web beams under various crane load scenarios (10t, 30t, 50t) showed a consistent and measurable reduction in the total weight of the structure – ranging from 4.9% to 6.9%. This weight reduction is directly attributed to the elimination of stiffeners and the optimized load distribution across the corrugated web. Lower beam weight contributes not only to material savings but also to easier transportation, reduced installation efforts, and potential savings in foundation costs due to lighter loads.
3. The production of beams with corrugated webs requires significantly less labor compared to beams with flat webs and stiffeners. This is due to the reduction in the number of assembly components, fewer welding seams, and minimal repositioning between technological stations. The analysis revealed that labor intensity can be reduced by approximately 20%–40%, depending on the specific design and beam configuration. This makes the use of corrugated webs a highly practical solution in terms of production efficiency and industrial scalability.
4. The introduction of second-generation rotary corrugation machines and mechanized welding stands into beam production lines has led to substantial improvements in output quality and consistency. These systems allow for the continuous, high-speed formation of corrugations in steel sheets while preserving uniform thickness and material properties. When combined with automated welding technologies, the result is a streamlined manufacturing process that reduces fabrication time, minimizes human error, and enhances structural integrity.
5. The study strongly supports the application of triangular corrugation profiles with standardized geometric parameters – specifically in terms of corrugation pitch, depth, and wall thickness. Through numerical modeling and experimental validation, these parameters were found to significantly influence the stiffness, load-bearing capacity, and deformation characteristics of the beam. The research also highlights the importance of considering web eccentricity and localized stress concentrations in design, recommending their inclusion in future engineering calculation methodologies and national code provisions.

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