Marek Rotkegel
dr inż.
Główny Instytut Górnictwa
Zakład Technologii Eksploatacji i Obudów Górniczych
mrotkegel@gig.katowice.pl

Łukasz Szot
mgr inż.
Główny Instytut Górnictwa
Zakład Technologii Eksploatacji i Obudów Górniczych
lszot@gig.katowice.pl

Michał Kapała
mgr inż.
Jastrzębska Spółka Węglowa S.A.
Biuro Produkcji, Zespół Górniczy
mkapala@jsw.pl

Marek Dras
mgr inż.
Jastrzębska Spółka Węglowa S.A.
KWK Budryk
mdras@budryk.jsw.pl

DOI: 10.35117/A_ENG_17_05_04

New construction of rail for underground suspended monorails as an example of typification for deep mining transport in the mines of JSW SA

Abstract: The article describes the course of design work, leading to the implementation of a new construction of suspended rails rails for the needs of mines belonging to the Jastrzębska Coal Company. The aim of the works, which was one of the stages of the typification of mining excavation equipment within JSW SA, was to improve the material management within the Company, reduce the production costs of rails, improve their anti-corrosion properties and extend the service life of the track. The design of the new construction was also characterized by easy construction, high straightness of the rail and also the possibility of easy adaptation to the increased speed of transport by suspended rail. The overriding objective of all activities is to reduce the cost of extraction. The design work was carried out using a feedback loop, taking into account the necessary corrections in the subsequent stages, resulting from the results of the strength calculations, laboratory tests and comments of the representatives of JSW SA. The final part of the work was the production of a prototype batch of rails, with the load capacity in accordance with the provisions of the applicable regulations, as well as the usable properties corresponding to the needs of mines JSW SA. JSW SA rails, according to the GIG documentation, are available in several variants: straight rails, curved rails, concave or convex rails and transition rails. The JSW rail system is a complement to the JSW rail system, including suspension, pull-outs, turnouts, locks, and track stops from third-party systems that comply with the JSW system's compatibility and compatibility criteria.

Keywords: Mining; Transport; Queue suspended; Rail

Introduction

According to the literature [7], the typification of a construction consists in reducing the number of equivalent parts, subassemblies, structural nodes, as well as finished articles to a minimum number, sufficient under given conditions to ensure correct operation of the technical process or function of the structure..

Typification, by reducing the variety of available structural solutions, brings a number of benefits. First of all, shorten design time, reduce production costs, purchase, storage and servicing, and improve the quality of the final product [7].

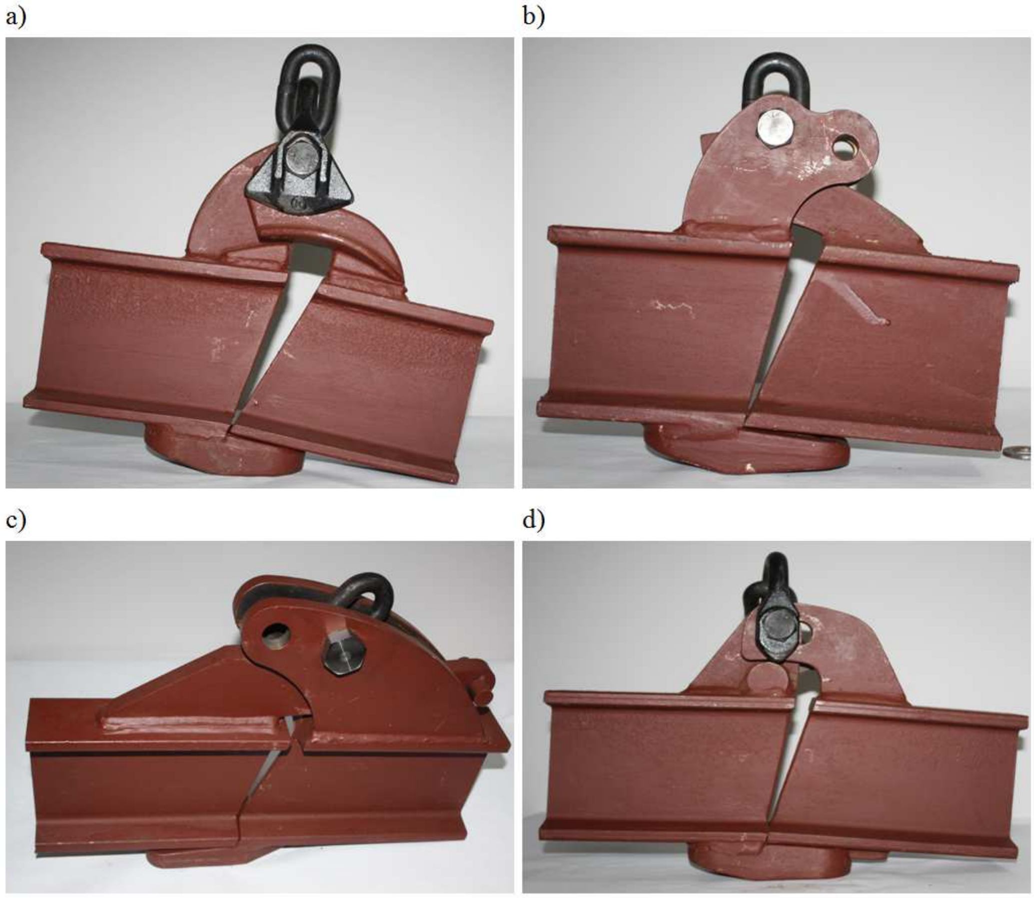
Since 2011 the JSW, efforts are aimed at typing steel housing roadway excavation and its accessories. In cooperation with the Main Mining Institute, the following projects were developed: the series of doors of ŁProJ and ŁPrPJ enclosures, SDJ type two-bar stirrups, JSW type inter-door strut and JSW support feet. In addition, two series of doors were created, dedicated to the needs of mines "Zofiówka" (ŁPZof) and "Borynia" (ŁPCBor). The last stage of the typewriting in JSW was the design of rails for suspended rails with the connector of a new construction. These measures aimed at reducing the variety of construction solutions used in mines belonging to the Jastrzębska Coal Company.

The guidelines for the design of new construction rails included reducing their production costs, improving corrosion resistance and extending the life of the track. The railroads were also designed to have uncomplicated development, a high traverse of the track and easy adaptation to the increased speed of rail transport. However, the most important assumption was to eliminate incompatible rails solutions from different manufacturers.

At present, several types of rails are used in the JSW SA mines, differing mainly in the construction of joints. Such a multitude of solutions causes considerable difficulties in logistics and the servicing and maintenance of the technical condition of the railways. This also necessitates the use of a significant number of transitions between each of the rail systems. The implementation of a new, uniform mine for the mines of the Company is an important stage of the process of mining equipment excavation within JSW SA. The main goal of such activities is to reduce the cost of extraction.

Previously used rail couplings in suspended rails

In JSW SA mines, several different types of rail joints have been used to track underground traffic (depending on the track manufacturer). They differ mainly from the construction of the upper joint, but also the geometric form of forgings, as well as the way of joining the rail with the slings. The rigidity, especially transverse, of tracks constructed from rails of individual constructions, as well as their mass, are also different. All of these parameters directly affect the maximum permissible loads of the joints along the track and across the track axes, which in turn makes it possible to use a particular type of rails under specific conditions. Photo 1a ÷ d shows examples of joints used for the construction of mines in JSW SA.



1. Joints of suspended rail rails used in JSW SA mines; a) joint type KSP-32 (Stalpol), b) type S-100, c) ZD24D (Transl - Czech), d) P-130 (Pioma)

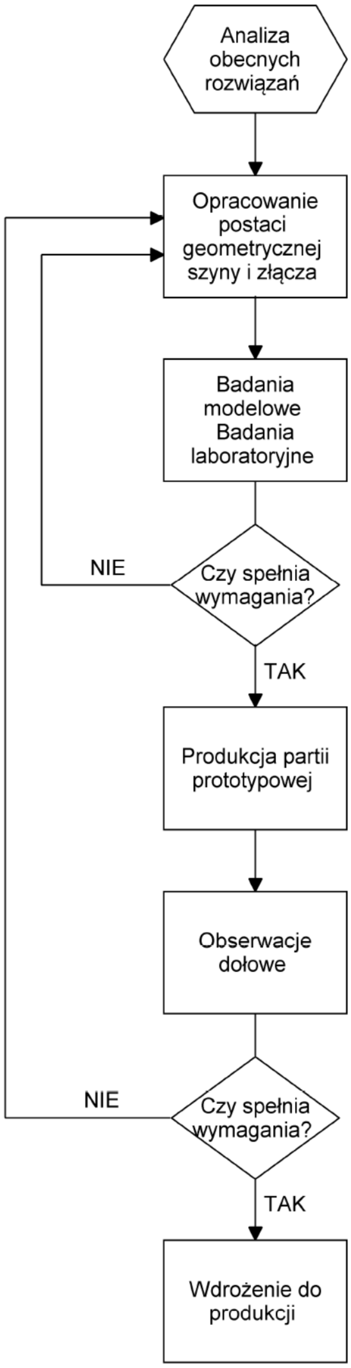
Design work on new connector design

The design work on the new construction of the rails for suspended rails was started after a careful analysis of the current situation and after numerous consultations with representatives of JSW SA. In the design process, the following assumptions were defined by the Principal:

1. the rail will be made of I155 hot-rolled double-taper or equiponderant, in accordance with PN-H-93441-10: 1994 standard,
2. the permissible load on the joints in the direction of suspension shall not be less than 80 kN,
3. the permissible load on the joints along the track shall not be less than 120 kN,
4. the articulated joint will allow the vertical line to be swept up to ± 6 ° and ± 0,5 ° in the horizontal plane. Connections between the running rails will be made by means of connectors attached to the end of the rail securing the connection before disconnection. The complete joint will contain a protective element against disconnection, also used to attach sling or lashing components,
5. the upper part of the coupling bus line will be the two elements made of a flat bar with holes for the bolt, welded to the upper flange beam,
6. the rails will be equipped (optionally) with an additional handle, enabling the installation of stabilizing braces, latches and other accessories,
7. 15 ° and 7.5 ° curved rails for changing the horizontal direction of the carriageway horizontally will be terminated on both sides with a flange connection ensuring a rigid

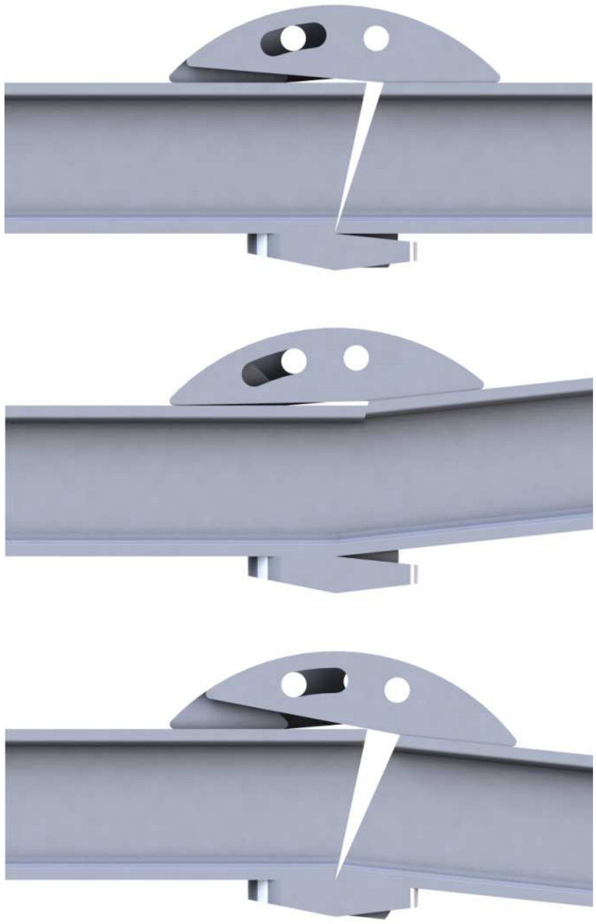
connection of these rails to the route of the queue. The length of the rail will be 1,0÷1,1 m. The minimum bending radius of the rails will be 4.0 m
8. arched, concave and convex rails will be equipped with a connector with the structure of the upper part as in point 5 above.

The adopted block diagram of the design and implementation process is shown in Figure 2.



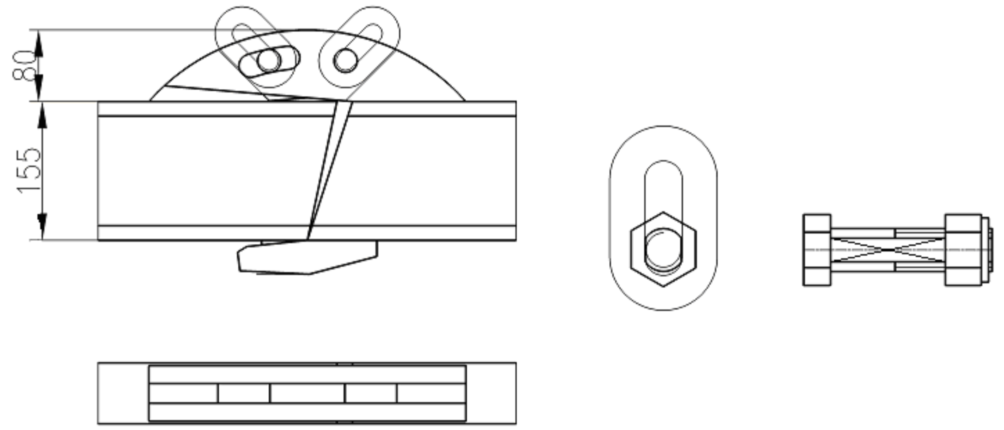
2. Block diagram of the design and implementation process

In order to determine the geometrical parameters of the connector, enabling the fulfillment of the adopted design assumptions, a kinematic analysis of the joined elements - the ends of the rails - was carried out. This allowed determining the required shapes and dimensions of the elements constituting the joint. Figure 3 shows the characteristic arrangements of the connector elements.



3. Kinematic analysis of the joint - vertical inclination ±6°

20 mm thick and welded to the upper shelves of the I155 section - one for each part of the joint. Between the connectors there is left space in which the link chain link is fastened, as well as steel guides similar in shape to the triangle, ensuring adequate stiffness of the joint and acting as a limiter of chain link inclination. The bottom connector is two cooperating forgings. Both the upper and lower joints, thanks to their kinematics, meet the guidelines for vertical and horizontal joint inflection. The fasteners proposed to screw the joint are M24 special bolts with undercut for insertion into the 18x64 chain link, together with self-locking nuts. The general view of the connector according to the concept is shown in Figure 4.



4. Diagram of the joint according to the concept

New structural solution for suspended rail joints

As a result of the conducted analyzes, as well as consultations with representatives of JSW SA, for further construction works a concept for the joints of suspended overhead rails was selected, slightly modified in a way that would enable to meet the requirements of movement and strength.

Before starting the appropriate design stage, a strength analysis of the basic connector elements was performed.

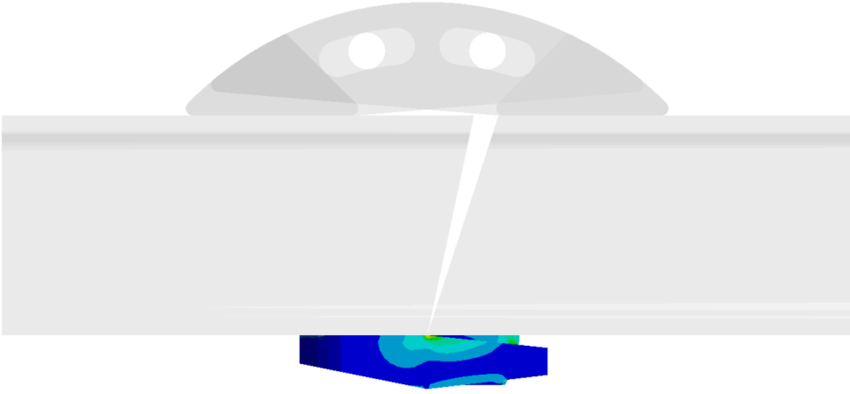
Model strength tests were performed numerically using the finite element method (FEM) [4,5]. From the user's point of view, modeling in modern FEM systems is limited to introducing the geometry of the whole system under examination and determining the parameters of its individual parts, such as material properties, cross-sectional parameters, and in the case of non-linear analysis, material curves. The geometry of the system can be given by creating it or by importing a ready-made CAD program. Burdensome discretization, especially in the case of complex models, is often done in an automatic or semi-automatic manner, under the user's control. After entering the above data, it is necessary to determine the way of loading and supporting the model. As a result of calculations, the values of internal forces automatically converted to reduced stresses are obtained.

Computer programs operating on the basis of the MES algorithm, in addition to displacements and internal forces, automatically calculate the stresses reduced according to the Huber-Mises-Hencky hypothesis, according to the general dependence [2,3]:

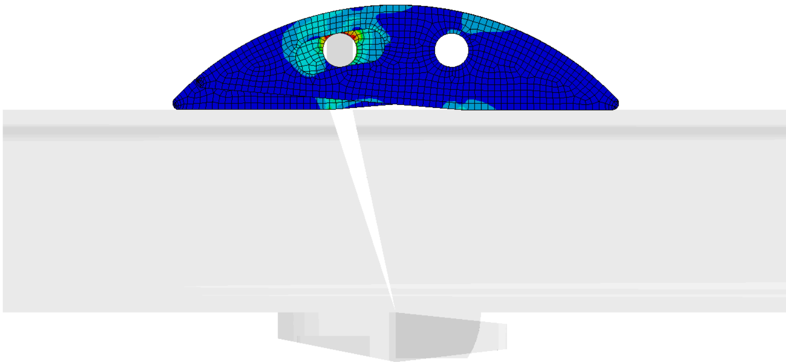
$$\sigma_{red} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3 \cdot \left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)} \qquad (1)$$

Comparing the obtained values of the maximum reduced stresses with the limit values for a given material, you can get the answer to the question about the correctness of the designed structure in a simple, inexpensive, non-destructive way (even before the production is started).

In the first stage, models were built that reflect both the geometry of the tested elements as well as their material parameters. The upper and lower joint elements subjected to the tests were subjected to tensile loads, axially and transversely to the axis of the queue's track. Figures 5 and 6 show examples of colored maps of reduced stresses.



5. Results of the bottom joint strength analysis

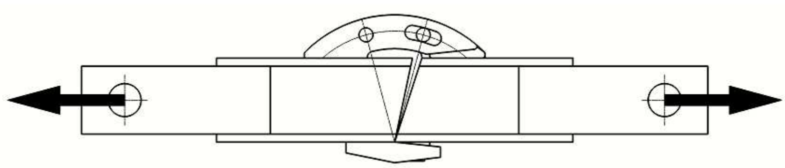


6. Results of the upper joint strength analysis

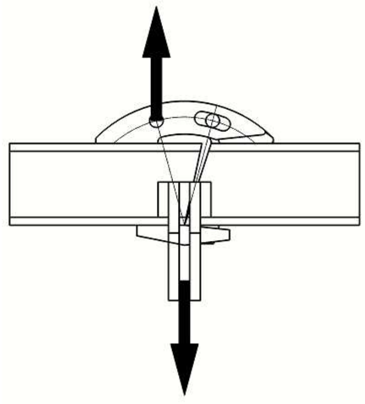
On the basis of the obtained positive results of model tests, a decision was made to manufacture a test batch of rails intended for bench tests. In addition, due to the place of stress concentration, it was decided to increase the transverse dimensions of key supporting joints, as well as to tighten the standards for their performance and quality control.

Workplace tests

On the basis of the drawing documentation improved after the numerical calculations, a test batch of the JSW type suspended rail rails was made. The samples were prepared to determine the strength of the joint, and thus enable determination of the maximum permissible joint load along the longitudinal axis of the carriageway, taking into account the corresponding safety coefficients. The tests were carried out in several stages to enable applying appropriate changes to the joint structure, resulting from the need to increase the load capacity or change the behavior of the joint under load. The testing scheme is shown in Figures 7 and 8.



7. The method of loading the joint in the longitudinal tensile test



8. Method of loading the joint in the transverse strength test

Examples of samples after testing are shown in photographs 9 ÷ 11. A summary of results together with comments on the type of test and the sample version are given in Table 1.

9. Sample after study

10. Sample after study

11. Sample after study

Tab.1. The results of joints laboratory test for suspended rails JSW type

Sample number	The way of charging	Pc [kN]	Comments	
1	Axially	317,8	Version I – screw 8.8	Research during project work (GIG)
2	Crosswise	204,9		
3	Crosswise	174,1		
4	Crosswise	233,8	Version II - shekel	
5	Crosswise	269,0		
6	Axially	312,9		
7	Axially	519,1	Version III (improved version I) - screw 10.9	
8	Crosswise	280,5		
9	Crosswise	275,9		
10	Axially	441,0		
11	Axially	452,1		
12	Axially	460,6		
13	Axially	436,6		
14	Axially	650,5	Final version	Attestation tests (KOMAG)
15	Axially	589,6		
16	Axially	653,7		
17	Axially	675,4		
18	Axially	681,6		
19	Axially	725,4		
20	Crosswise	370,8		
21	Crosswise	374,8		
22	Crosswise	349,3		
23	Crosswise	370,1		
24	Crosswise	369,1		
25	Crosswise	344,7		

Summary and conclusions

The results of workplace tests, as well as further opinions of JSW SA representatives, were taken into account at the final design stage, which resulted in a set of drawing documentation. The drawing documentation is supplemented with the technical conditions of execution and acceptance as well as the technical and operational documentation.JSW suspended rail rails, according to the documentation as above, exist in the following variations:

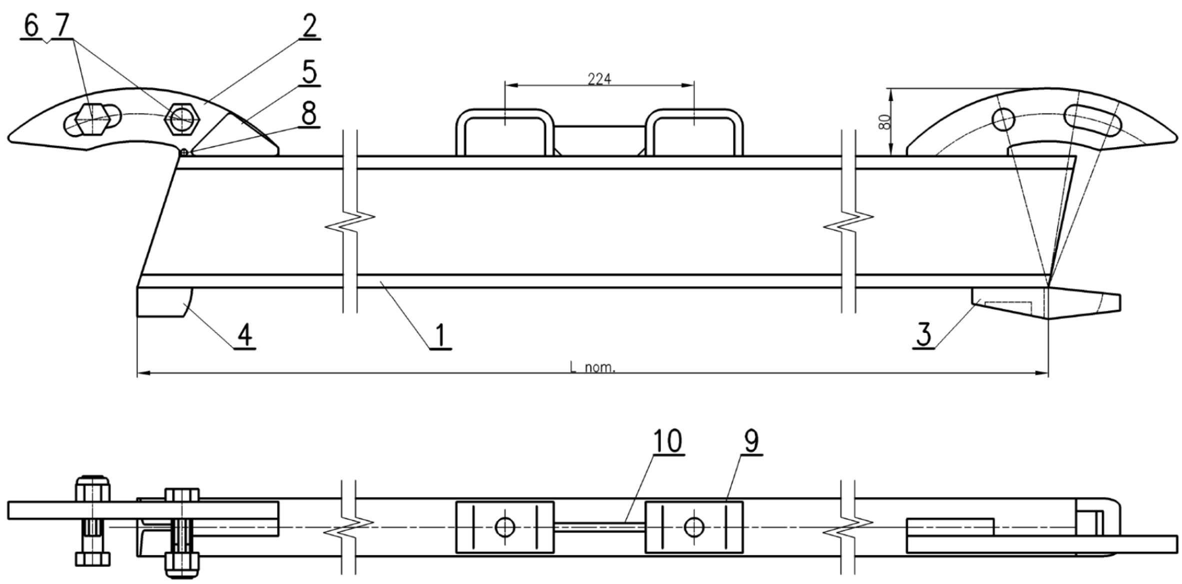
- straight rails,
- corner rails,
- concave or convex rails,
- transition rails.

The track system based on JSW rails can be supplemented with slings, stays, turnouts, interlocks and track terminations from other manufacturers' systems, meeting the admittance and compatibility with the JSW type system.

The JSW type rail in the basic, simple version (Fig. 12) consists of:

- straight section I155 according to PN-H-93441-10 (item 1),
- two identical elements made of 20 mm thick flat sheet (item 2), which, after connecting successive rails, constitute the upper part of the runway lock and at the same time a track sling, as well as a transport holder in manual transport,
- two different, cooperating forgings (items 3 and 4), which, after joining successive rails, form the bottom part of the runway lock,
- two identical spacers (item 5) made of sheet metal with a thickness of 20 mm,
- two sets of special bolt M24 with a self-locking nut (items 6 and 7), intended for joining and stabilizing subsequent rails in the track, as well as slings of the 18x64 mining chain,
- protection against pulling the joint vertically, made of a Ø8 rod (item 8),
- • holder for additional accessories with strengthening plate (items 9 and 10).

JSW suspended rail rails are produced in lengths from 1000 mm to 2250 mm, depending on the requirements of the customer.



12. Straight rail JSW type

As part of the design work, suspended rail rails with a new type of joint with high load capacity were designed. In the case of a properly made joint, the permissible transverse load is 70 kN, and if two load carriers are used, it is 80 kN. The permissible longitudinal loading is 120 kN.

Source materials

[1] Chmielewski T., Nowak H. Mechanika budowli. Metoda przemieszczeń. Metoda Crossa. Metoda elementów skończonych. Wydawnictwa Naukowo-Techniczne. 1996.
[2] Cook R.D. i inni. Concepts and applications of finite element analysis. John Wiley & Sons, Inc., 2002.
[3] Dyląg Z. i inni. Wytrzymałość materiałów. Wydawnictwa Naukowo-Techniczne, 1996.
[4] Rakowski G., Kacprzyk Z. Metoda elementów skończonych w mechanice konstrukcji. Oficyna wydawnicza Politechniki Warszawskiej, 1996.
[5] Rusiński E. Metoda elementów skończonych. System COSMOS/M. Wydawnictwa Komunikacji i Łączności, 1994.
[6] Szuścik W., Kuczyński J. Wytrzymałość materiałów (Mechanika modelu ciała odkształcalnego i ciała rzeczywistego). Część I. Wydawnictwa Politechniki Śląskiej, 1998.
[7] Wrotny L.T. Projektowanie obrabiarek. Zagadnienia ogólne i przykłady obliczeń. Wydawnictwa Naukowo-Techniczne. 1986.