THE DECREASE OF THE MECHANICAL STRESSES AND THE REDUCTION OF THE DISTORTIONS OCCURED IN THE FLEXIBLE JOINTS OF THE GLIDING STEEL TIMBERING

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ABSTRACT

Given the shortcomings discovered in practice for the proper functioning of the gliding steel timbering used in horizontal mine works, this study tells into consideration theoretical and practical facts in order to determine the causes of these deficiencies and suggests solutions for the improvement of performances.

INTRODUCTION

In order to ensure the best conditions of execution and subsequent stability for the small bent or horizontal excavation galleries or for those with a small angle of inclination, irrespective of their purposes (mine exploration works; hydro technical works; subway read or railway tunnels, etc.) sliding steel mine timbering is used almost exclusively. This can be temporarily used when its mode of operation is under alternating loads, case in which they subsequently require the assembling of the rigid timbering, or it can be constantly used when it works under given loads.

A sliding steel timbering is made up of chute type heavy sections similar to SG (18,23,…,29) sections, manufactured in the past in our country, or heavy sections brought from import such as K 21, K 24,TH 21, TH 29 from Czech Republic or THN section imported from Bulgaria, interweaved at the extremities by overlapping and tightened with screws through pieces called bridles.

Bridles are conceived so as to allow the gliding between them at some stress values which act on the heavy sections, narrowing in this way the radius of the mine work but maintaining the lifting power at an approximate constant value.

All the above mentioned heavy sections are manufactured from the same type of steel 31 Mn 4 DIN 21544 trade marks which has the following mechanical characteristics:

Rc = 350 N/mm^2 , the ultimate tensile strength
Rm = 550 N/mm^2 , and the breaking extension t_5 =18%;

A study from 2013 certifies the fact that the SG 23 heavy section (the most used profile at the mines from Jiu Valley region) is similar with THN 21 heavy section manufactured in Bulgaria and with TH 21 made in the Czech Republic.

All the heavy sections from our country and those imported are assembled in sliding support sets with the help of some bridles produced in our country similarly made after OL3-7-2K steel bridles.

The operation of sliding steel timbering is a dynamic and throbbing phenomenon; the heavy sections and the bridles which tighten them are moving because of the frictional force.

As a result, the position of the bridles changes during sliding modifying the mechanic parameters of the mine timbering as well.

This system has been widely and satisfactorily used in the mines from Jiu Valley region at a moderate mine pressure with total distortions of the rocks of 100-150 mm.

Severe problems appear when the mine pressure increases, the distortions exceed these values and some phenomena which compromise the normal operation of the timbering appear in the joint systems.

The shape of SG 18, SG 23 and of those sections brought from the import implies jointing over the mating surfaces obtained between flanks, resulting free spaces of 3 and 5 mm between flanges which favors the emergence of the heavy sections structural change and the intermission of the sections through splitting (extension) of the underneath section (the iron prop) and the compression of the upper section (the bar). This produces the stress relieving of the bridles resulting in this way their uncontrolled gliding and the blockage of the sections alongside the transformation of the system into a rigid timbering type.

Numerous bridles present a contortion effect by exceeding the contact pressures> between the lower clamp made from strip steel and the lower section or between the round bridle and the upper section together with the tension release of the bridles and the blocking obstruction.

Frequently enough permanent elongations of the round bridle, even its rupture because of the stretch or the rupture of the thread of the screw nuts appear and the bridles stop functioning.

Given the shortcomings discovered in practice, this study examines all the phenomena that occur and gives practical usability conclusions in order to fix all the problems.

The calculation of the forces of reaction in the bridles during the mine timbering operation

In order to study sliding timbering, the following situation of a circular mine work propped up by a fastening ring mode up of 4 segments partially stacked at their heads and tighten with two bridles should be taken into consideration.

This fastening ring is pressed by the mine pressure represented by two loads uniformly distributed (fig.1).

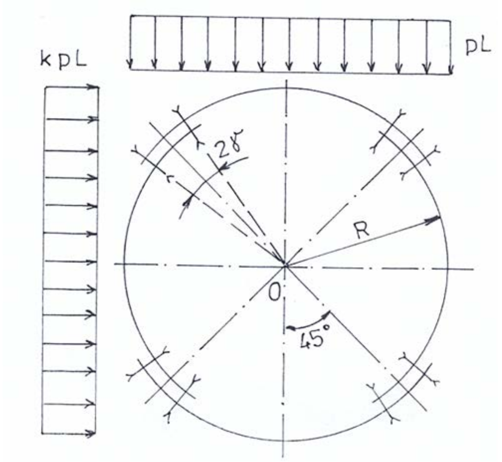

Fig.1.

The following annotations are made: R= is the radius of the transverse section of the mine work; L= is the timbering field (the distance between two successive timbering rings); 2γ= the central angle for the area where the sections overlap, an area which is delimited by the position of the two bridles; the central angle varies during the gliding of the timbering; p= the vertical component of the mine pressure; px = the horizontal component of the mine pressure;

Considering that px=kp where k coefficient takes the following values: k=0 the pressure of the rocks will only push vertically, k=0,5 the horizontal pressure is half the vertical pressure, k=1 the pressure of the rocks will equally act vertically as well as horizontally, k=1,5 the horizontal pressure will be once and a half bigger than the vertical pressure and k=2 the horizontal pressure is two times bigger than the vertical one. Generally, k>1 in areas with difficult geological mine conditions.

If we consider the timbering as an uninterrupted rigid ring with the symmetry of a circle we will take into consideration only a quarter of the work 6-0-3, which is statically indeterminate.

An imaginary section has a variable a central angle is drawn. The indetermination is lifted and calculating all the operations the stress from the steel timbering section is determined

axial load:

$$N = -pLR + (1-k)pLR\,sin^2\theta$$

shearing force:

$$T = (1-k)\,pLR\;sin\theta\;cos\theta$$

moment of flexure:

$$M = -\frac{1-k}{4}pLR^2(1-2sin^2\theta)$$

The steel timbering is actually mode up of 4 circle segments which are jointed together through four bridle systems.

The remark to be mode is that the upper segment of the ring is leaning on the other 2 lateral segments so that it seems like a curved bar on 4 points of support due to the binding forces which appear in the bridles.

The same happens to a lateral segment clung through 4 bridles on the superior the inferior segment.

Being under moments of flexure, the 2 segments which, at first, have contact on all the covering surface, tend to get to a two points contact because the bridle from the outside will be stressed to stretch and the bridle from the inside the superior section leaning in this way on the base of the lateral section.

As a consequence of all the counteracting forces which act on the bridles, the segments of the ring are differently stressed.

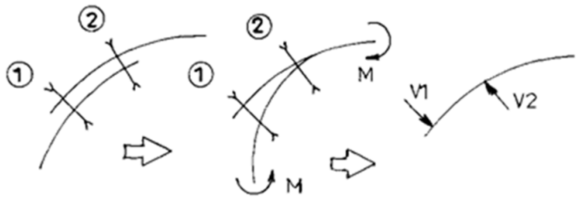

Fig.2

Even though each segment looks like a curved bar on four piles, the problem involves only 2 unknown, V1 and V2 reciprocal forces as a result of geometrical and physical symmetry of the ring.

To determine the values of the forces, the upper segment and the lateral one from the left pressed by the rock pressure and the interchangeable forces (figure 3) should be taken into consideration.

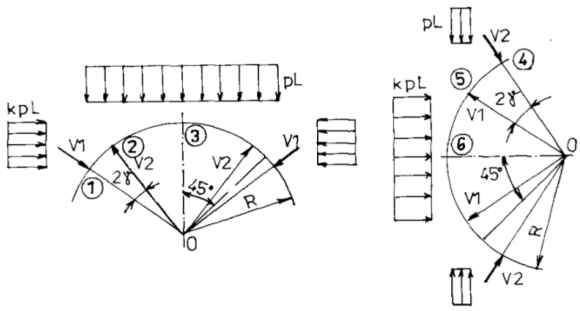

Fig.3

The condition for vertical projections $\sum F_y = 0$ for all the forces which press the upper segment is

$$2V_1 \cos(45^0 + \gamma) - 2V_2 \cos(45^0 - \gamma) + pL \cdot 2R \sin(45^0 + \gamma) = 0 \quad (2)$$

The condition for horizontal projections $\sum F_x = 0$ is:

$$2V_1 \cos(45^0 - \gamma) - 2V_2 \cos(45^0 + \gamma) - qL \cdot 2R \sin(45^0 - \gamma) = 0 \quad (3)$$

Solving this system of equation allows us to discover the values of the forces:

$$V_1 = pLR\frac{1}{2}\cdot\frac{\cos 2\gamma + k\cdot \cos 2\gamma}{\sin 2\gamma}$$

$$V_2 = pLR\frac{1}{2}\cdot\frac{(1+\sin 2\gamma) + k(1-\sin 2\gamma)}{\sin 2\gamma} \quad (4)$$

It can be noticed that for some determined values for p, L and R, the values of the reacting forces depend on the overlap angle 2γ and the k pressure ratio.

Chart number 1 shows the values for the V1 and V2 notions (divided to pLR product) depending on the different values of the 2γ and k parameters.

The calculations were limited to the $2\gamma = 3^0$ value, an adequate value for the situation in which the overlapping is so small that the two bridles are stick together so that 2γ cannot increase anymore

Table 1

$2\gamma^0$	$-V_1 : pLR$					$-V_2 : pLR$				
	K					k				
	0	0,5	1	1,5	2	0	0,5	1	1,5	2
3^0	9,610	14,400	19,160	24,95	29,94	10,010	14,670	19,250	24,75	29,5
6^0	4,780	7,180	9,550	11,9	14,33	5,310	7,470	9,620	11,76	13,92
10^0	2,840	4,270	5,700	7,1	8,53	3,390	4,590	5,780	6,97	8,17
15^0	1,860	2,790	3,730	4,67	5,61	2,430	3,140	3,860	4,59	5,3
20^0	1,370	2,060	2,740	3,43	4,11	1,960	2,440	2,930	3,40	3,88
30^0	0,866	1,300	1,730	2,165	2,59	1,500	1,500	2,000	2,25	2,5
45^0	0,500	0,750	1,000	1,87	2,28	1,210	1,310	1,415	1,72	2,07

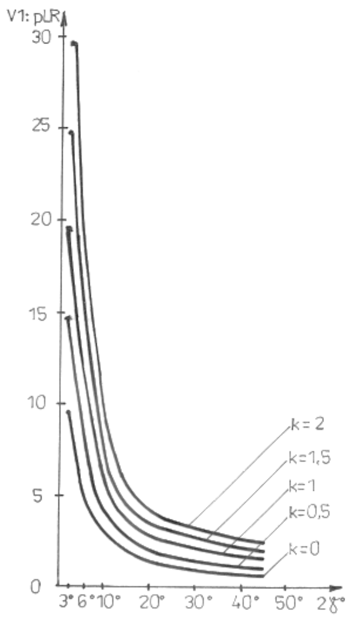

Fig.4

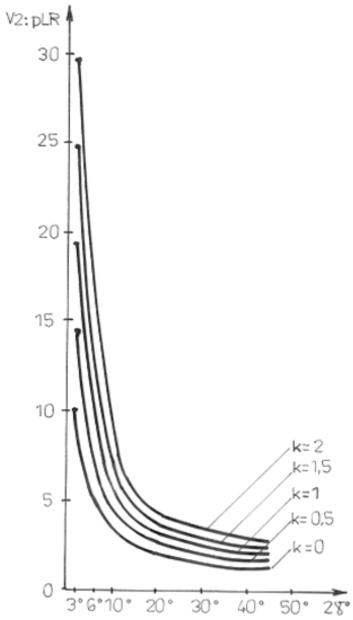

Fig.5

The main stress of the timbering structure is given by the action of the moments of flexure. That is why, these shall be calculated for the most stressed sections of the ring.

$$M_1 = 0 \tag{5}$$

$$M_2 = -V_1 \cdot R \sin 2\gamma - pL \cdot \frac{[R \sin(45^0+\gamma) - R \sin(45^0-\gamma)]^2}{2} - kP_y L \cdot \frac{[R\cos(45^0-\gamma) - R\cos(45^0+\gamma)]^2}{2} \tag{6}$$

$$M_3 = -V_1 \cdot R \sin(45^0+\gamma) + V_2 R \sin(45^0-\gamma) - pL \cdot \frac{[R \sin(45^0+\gamma)]^2}{2} - kP_y L \cdot \frac{[R - R\cos(45^0+\gamma)]^2}{2} \tag{7}$$

And the calculation for the lateral segment is also done:

$$M_4 = 0 \tag{8}$$

$$M_5 = -V_2 \cdot R \sin 2\gamma \tag{9}$$

$$M_6 = -V_2 \cdot R \sin(45^0+\gamma) + V_1 R \sin(45^0-\gamma) - pL \cdot \frac{[R - R\cos(45^0-\gamma)]^2}{2} - kP_y L \cdot \frac{[R \sin(45^0-\gamma)]^2}{2} \tag{10}$$

Tabl 2

$2\gamma^0$	$-M_2 : pLR^2$					$-M_3 : pLR^2$				
	K					k				
	0	0,5	1	1,5	2	0	0,5	1	1,5	2
3^0	0,500	0,750	1,000	1,25	1,5	0,263	0,632	1,000	1,368	1,737
6^0	0,500	0,750	1,000	1,25	1,5	0,276	0,638	1,000	1,36	1,725
10^0	0,500	0,750	1,000	1,25	1,5	0,294	0,647	1,000	1,35	1,708
15^0	0,500	0,750	1,000	1,25	1,5	0,315	0,658	1,000	1,342	1,685
20^0	0,500	0,750	1,000	1,25	1,5	0,336	0,657	1,000	1,254	1,66
30^0	0,500	0,750	1,000	1,25	1,5	0,375	0,688	1,000	1,06	1,37
45^0	0,500	0,750	1,000	1,25	1,5	0,426	0,713	1,00	0,87	1,14
$2\gamma^0$	$-M_5 : pLR^2$					$-M_6 : pLR^2$				
	K					k				
	0	0,5	1	1,5	2	0	0,5	1	1,5	2
3^0	0,526	0,763	1,000	1,237	1,47	0,763	0,881	1,000	1,11	1,237
6^0	0,552	0,776	1,000	1,24	1,44	0,776	0,888	1,000	1,104	1,22
10^0	0,586	0,793	1,000	1,20	1,41	0,793	0,896	1,000	1,10	1,206
15^0	0,629	0,814	1,000	1,18	1,37	0,815	0,907	1,000	1,09	1,18
20^0	0,671	0,835	1,000	1,16	1,35	0,835	0,918	1,000	1,08	1,16
30^0	0,750	0,875	1,000	1,12	1,25	0,875	0,937	1,000	1,06	1,12
45^0	0,853	0,926	1,00	0.98	1,14	0,928	0,963	1,00	0,84	0,98

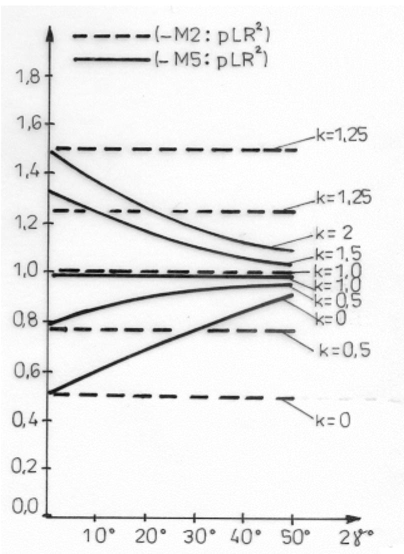

Fig.6

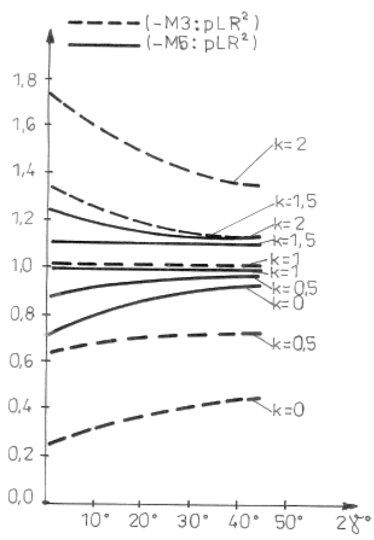

Fig.7.

After all the replacements and calculations are done, the following final formulae for the moments of flexure are obtained:

$$M_2 = -pLR^2\frac{1+k}{2} \quad (11)$$

$$M_3 = -pLR^2\frac{1}{4}[(1+\sin 2\gamma) + k(3-\sin 2\gamma)] \quad (12)$$

$$M_5 = -pLR^2\frac{1}{2}[(1+\sin 2\gamma) + k(1-\sin 2\gamma)] \quad (13)$$

$$M_6 = -pLR^2\frac{1}{4}[(3+\sin 2\gamma) + k(1-\sin 2\gamma)] \quad (14)$$

Conclusions

In figure 3 because the clamp of the bridle 1 is stressed to stretch and the gliding movement is a pulsatory one, a new stress appears. This stress produces the sliding of the bridle 1 towards the bridle 2, shrinking in this way, during the gliding of the sections the distance between the bridles and also the central angle 2γ

For the assembling of the timbering, an angular distance which for a support with the R of 150 cm corresponds to a 40 cm linear distance between bridles.

During the gliding produced of the sliding of the bridles 28= (10-3) the V1 and V2 reacting forces present huge values which stop the steel timbering from functioning.

The technical solutions which maintain the initial distance between the bridles during the gliding of the timbering or which increase this distance because the bridles are clung to the extremities of the sections assure low values for the reacting forces in the bridles and a proper functioning of the steel timbering.

The moments of flexure have low variations depending on the 28 angle and a maximum of 50% variations when the k coefficient increases from 1 to 2 which happens when the lateral mine pressure is twice the vertical mine pressure.

If the mine pressure which act on the contour of the steel timbering has asymmetrical concentrations of forces which produce sizeable moments of flexure in the joint surface, the stress from the bridles is removed, permanent distortions appear and the steel timbering stops functioning.

From the whole gliding steel timbering the most vulnerable parts are the joint surfaces of the bridles because the mechanical and functional characteristics of the bridles influence the performance of the steel timbering.

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