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Stand tests of a powered roof support after a long time of operation. Case study

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Słowa kluczowe: górnictwo, sekcja obudowy zmechanizowanej, wytrzymałość statyczna, wytrzymałość zmęczeniowa

Abstract:

The process and results of stand tests on the powered support manufactured in 1996 are discussed. The tests were conducted at the KOMAG's accredited testing laboratory, implementing an author's testing program. After completion of the static strength, load bearing capacity and fatigue strength tests, the roof support was inspected and no mechanical damage to the basic components of the tested roof support was found. The recorded permanent deformations of the basic components of the roof support tested in 2020 were compared with the results of tests of the same roof support, conducted in 1996 (prototype tests) and 2009 (tests after modernisation), also at the KOMAG laboratory. Based on the results of tests conducted in 2020, it was shown that the current properties of the roof support meet the normative requirements. Therefore, the customer may decide to continue using them in other longwall panels.

Streszczenie:

Omówiono przebieg i wyniki badań stanowiskowych sekcji obudowy zmechanizowanej wyprodukowanej 1996r. Badania wykonano w akredytowanym laboratorium badawczym ITG KOMAG, realizując autorski program badawczy. Po zakończeniu badań wytrzymałości statycznej, podporności i wytrzymałości zmęczeniowej, przeprowadzono oględziny sekcji i nie stwierdzono uszkodzeń mechanicznych elementów podstawowych badanej sekcji. Zarejestrowane odkształcenia trwałe elementów podstawowych sekcji badanej w 2020 r. porównano z wynikami badań tej samej sekcji, wykonanych w 1996 r. (badania prototypu) oraz 2009 r. (badanie po modernizacji), również w laboratorium ITG KOMAG. Na podstawie wyników badań wykonanych w 2020 r. wykazano, że aktualne właściwości funkcjonalne sekcji spełniają wymagania normatywne. Zleceniodawca może więc podjąć decyzję o dalszym użytkowaniu w kolejnych ścianach.

1. Introduction

The safety requirements [1] applicable in the case of installation of the powered roof support that has been in use for more than 20 years in a newly opened longwall, [2], require the strength tests at an accredited testing laboratory. In the case discussed in this article, the shielding support with a 1.5 m pitch and after over 20 years of operation was tested [3, 4, 5, 6]. Due to the anticipated deterioration of the technical condition of the roof support [7], the mine ordering the tests, suggested the KOMAG Testing Laboratory to develop an additional, extended testing program, carried out in several stages until the powered roof support loses its functional features. The aim of the testing was to collect data on the basis of which the Orderer could make a rational decision to install the roof support in a new longwall panel faces or to scrap it.

The roof support strength tests were an inspiration for a broader presentation of the results of permanent deformation measurements of roof support's basic components and for comparing them with the results of previously performed tests. The analysis was possible because the authors of this

article had not only information on the time and conditions of operation of tested roof supports, but also had the results of previous strength tests:

- the first tests were carried out in 1996 and concerned the roof support prototype,
- others were carried out in 2009 after the roof support was modernized.

All the aforementioned tests were conducted at the KOMAG Testing Laboratory, using the testing procedures and normative requirements in force at that time, while the purpose, scope and results of the tests conducted in 2020 are presented below.

2. Laboratory tests of used powered roof support

2.1. Scope and objectives of testing

The aim of the stand tests carried out in 2020 [8] was to determine the present technical condition of the roof support by loading it until it loses its functionality. The test program was developed on the basis of PN-EN 1804-1 + A1: 2011 Standard [9] and was submitted for approval to the Orderer. The test was divided into several stages, and after completion of the first or each subsequent stage the mine had to decide whether to continue the test or to end it. The first stage assumed static strength tests according to the program presented in Table 1 and fatigue strength tests according to the program presented in Table 2. In the following stages it was expected that the fatigue strength tests would be continued according to the program presented in Table 2, and the static strength tests according to the program presented in Table 3.

Table 1. Program of the static strength test of the roof support – stage I [own source]

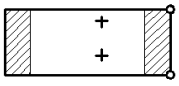
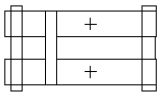
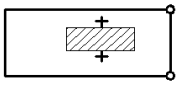
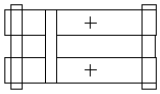
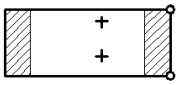
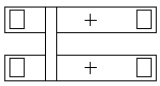
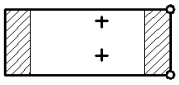
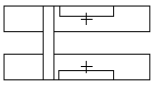
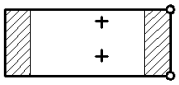
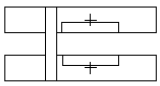
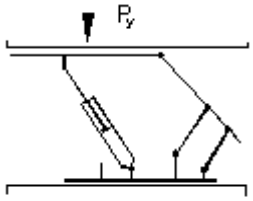
Item	Supporting diagram		Load p/p_n	Height of the roof support set to load, m
	Canopy	Base		
1.			1.2	2.0
2.			1.2	2.0
3.			1.2	2.0
4.			1.2	2.0
5.			1.2	2.0
6.			1.0	1.95÷1.81 1.68÷1.56 1.41÷1.29

Table 2. Program of the fatigue strength test of the roof support – stage I and the next stages [own source]

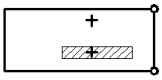
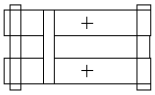
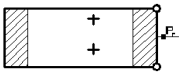
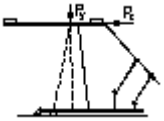
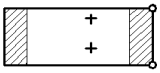
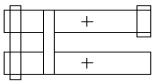
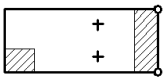
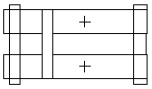
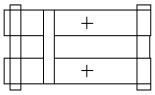
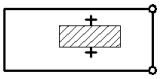
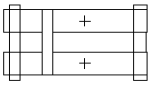
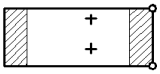
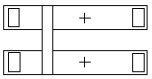
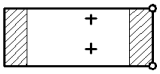
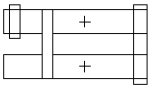
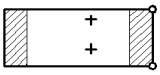
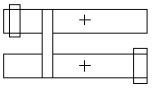
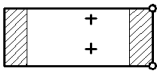
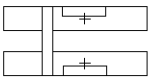
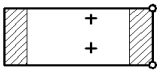
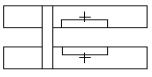
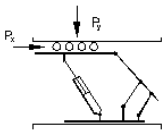
Item	Supporting diagram		Item	Load range p/p_n	Number of cycles	Max. overloads p/p_n
	Canopy	Base				
1.			1.4	0.25÷1.05	2000	1.05
2.			2.0	0.25÷1.05	10000	1.05
3.			2.0	0.25÷1.05	1000	1.05
4.			2.0	0.25÷1.05	2000	1.05
5.			2.0	0.25÷1.05	2000*	1.05
6.			2.0	0.25÷1.05	2000	1.05
7.			2.0	0.25÷1.05	2000	1.05
8.			2.0	0.25÷1.05	1000	1.05
9.			2.0	0.25÷1.05	2000	1.05
10.			2.0	0.25÷1.05	1000	1.05
11.			2.0	0.25÷1.05	1000	1.05

Table 3. Program of the static strength test of the roof support – next stages [own source]

Item	Supporting diagram	Load p/p_n	Height of the roof support set to load, m
1.		1.0	1.95÷1.81
			1.68÷1.56
			1.41÷1.29

2.2. Testing procedure and the results

After the I stage of static and fatigue strength tests, carried out in accordance with the assumed program, an inspection was made and no damage to the basic components of the tested support was found. The functionality of the roof support was maintained. Information on the results of the completed stage of the test was provided to the Orderer (the mine). After analysing the results of the I stage, taking into account the panels and geological and mining conditions of the future longwalls in which the tested roof support are to be operated, the mine decided to end the test at that stage.

Users of the powered support have considered many times the possibility of further use of more than 20-year-old roof supports. In view of the above problem, the authors, after being familiarize with the results of the stand tests from 1996 [10], 2009 [11] and 2020, as well as test programs and load parameters, which resulted from the standards and regulations in force at that time, decided to analyse the elastic and plastic (permanent deformation) deflection of the following basic components: a base, a canopy and a gob shield (Fig.1).

Arrangement of the elastic and plastic deflection measuring points on the roof support tested in 2020 is presented in Fig. 1.

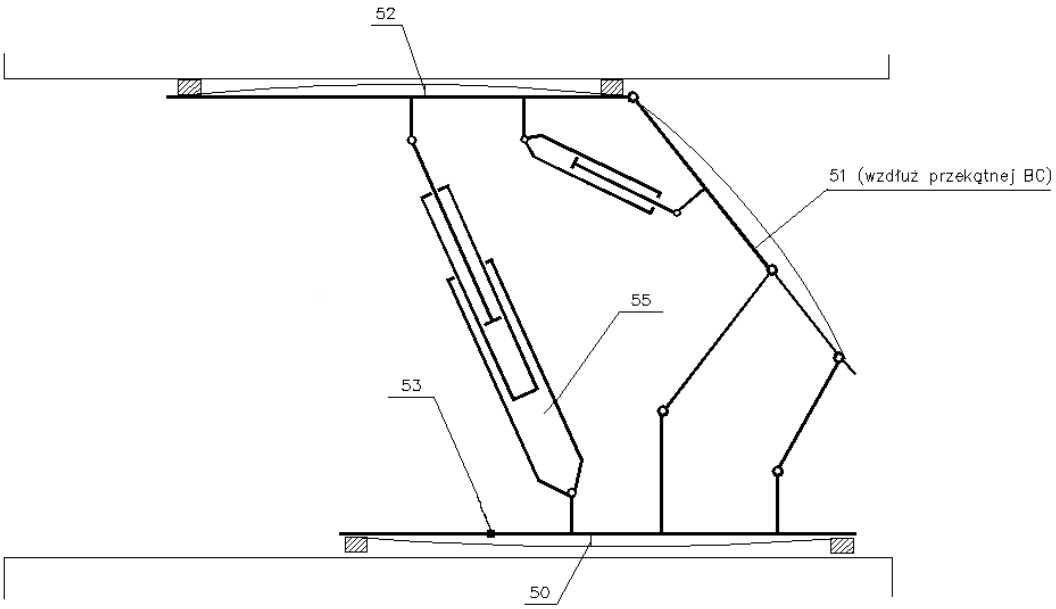


Fig. 1. Arrangement of the elastic and plastic deflection measuring points on the tested roof support [7]

Numbers of the measuring points specify the deflection measurement at the place of their location:

50 – base deflection – longitudinal measurements,
51 – gob shield deflection,
52 – canopy deflection,
53 – base deflection – transverse measurements (in a plane perpendicular to the object plane).

Maximum elastic deflection of the powered roof support components is presented in Table 4.

Table 4. Maximum elastic deflection of the powered roof support components in mm [own source]

Point No.	Ratio p/p_n	Supporting method according to Table 1				
		1	2	3	4	5
		Roof support height, m				
		2.00	2.00	2.00	2.00	2.00
50	1.00	-3.3	-2.7	-2.3	---	---
	1.05	-3.4	-2.9	-2.3	---	---
	1.20	-3.3	-3.2	-2.8	---	---
51	1.00	0.5	0.7	1.3	0.0	0.5
	1.05	0.7	0.9	1.3	0.6	0.5
	1.20	0.9	1.0	2.0	0.8	0.8
52	1.00	-14.7	-1.7	-15.1	-12.1	-13.0
	1.05	-15.3	-1.8	-15.5	-12.8	-13.3
	1.20	-17.9	-2.0	-18.0	-15.4	-15.9
53	1.00	---	---	---	-0.8	0.7
	1.05	---	---	---	-0.8	0.7
	1.20	---	---	---	-1.0	0.9

The measurements results of permanent deformations of the canopy (Fig. 2) and the gob shield (Fig. 3) are presented in Table 5 and Table 6, respectively. Measurement of permanent deformation was taken by the method developed at KOMAG Testing Laboratory using the instruments for flatness measurements being at KOMAG disposal [12]. Measurements uncertainty was estimated for the confidence level of 95% and is U = 0.4 mm. Measurements of flatness were made just after the roof support delivery and after the tests were completed. Points A and B are the supporting points of the measuring bar. The measuring points are 500 mm apart from each other, starting from the reference point A which is 100 mm from the edge of the tested part. The permanent deformation of the tested part is a difference between the measurements before and after the strength tests, at subsequent measuring points. The sign "+" means that the part is bent upwards, the sign "-" means that the part is bent downwards in relation to the measuring bar.

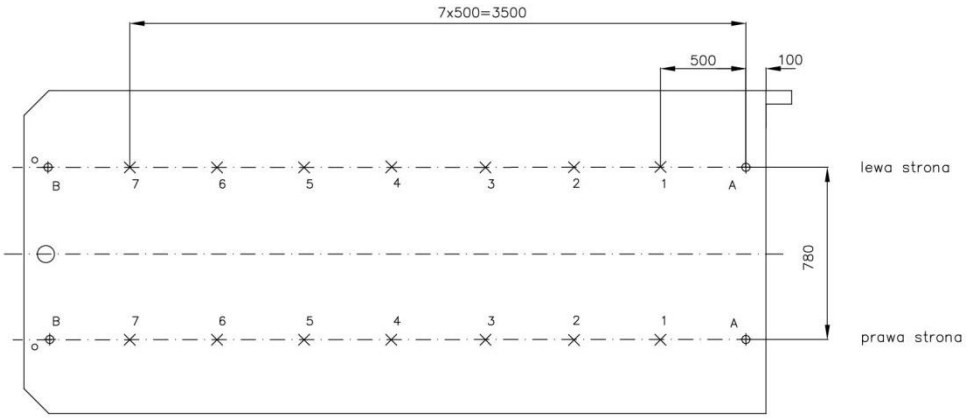


Fig. 2. Arrangement of the measuring points on the canopy: A and B – points of supporting the measuring bar; 1 ÷ 7 measuring point located at left and right side of the canopy [7]

Table 5. The results of measurements of the canopy permanent deformations [own source]

Distance from the edge of the part, mm	Point No.	Measurements results, mm				Permanent deformations, mm	
		Left side of the canopy		Right side of the canopy		Left side of the canopy	Right side of the canopy
		Before testing	After testing	Before testing	After testing		
600	1	+1.6	+1.6	-0.1	+0.1	0	+0.2
1100	2	+1.0	+1.2	-1.0	-0.7	+0.2	+0.3
1600	3	-0.7	-0.3	-2.1	-1.7	+0.4	+0.4
2100	4	-5.1	-4.8	-2.4	-2.0	+0.3	+0.4
2600	5	-9.9	-9.1	-7.6	-7.3	+0.8	+0.3
3100	6	-1.5	-1.0	+1.1	+1.4	+0.5	+0.3
3600	7	+5.1	+5.8	+4.7	+4.9	+0.7	+0.2

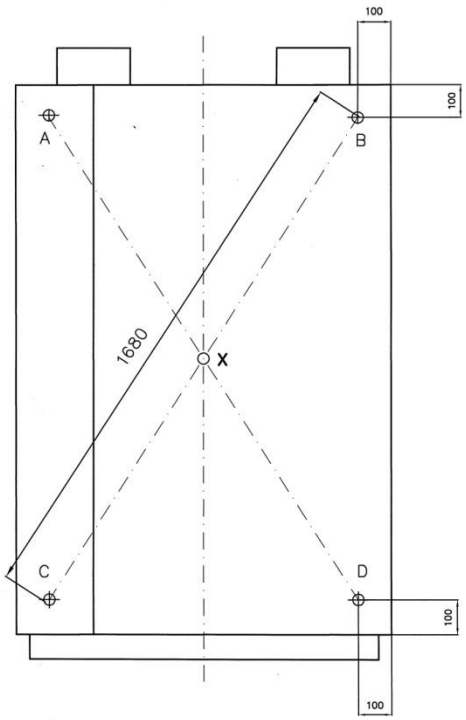


Fig. 3. Arrangement of the measuring points on the gob shield:
A, B, C, D - supporting points of the measuring bar; x - measuring point on the shield [7]

Table 6. Results of measurements of permanent deformation of the gob shield [own source]

Point No.	Measurement results, mm		Permanent deformations, mm
	Before testing	After testing	
X_{AD}	+9.6	+9.8	+0.2
X_{BC}	+1.0	+10.5	+9.5

3. Laboratory tests of the powered roof support prototype in 1996

The stand tests were conducted according to the requirements of the Ministry of Industry and Trade Guidelines, being in force then, to verify the design assumptions [13] in the field of kinematics, fatigue and static strength requirements of the PN-G-50041 1994 standard [14]. The prototype tests were necessary to get approval for the powered roof support from the State Mining Authority to be used in mine underground.

The elastic deflection of the powered roof support tested in 1996 is presented in Table 7.

Table 7. Maximum elastic deflection of the powered roof support components in mm [own source]

Point No.	Ratio p/p_n	Supporting method according to Table 1	
		1	2
		Left side	Right side
		Roof support height, m	
		2.10	2.10
50	1.00	-2.9	-3.0
	1.25	-3.7	---
51	1.00	0.8	0.3
	1.25	1.3	---
52	1.00	-15.9	-16.2
	1.25	-20.2	---
53	Not measured		

Arrangement of the measuring points from Table 7 is shown in Fig.1.

The results of measurements of permanent deformations of the canopy (Fig. 2) and the gob shield (Fig. 3) are presented in Table 8 and Table 9, respectively.

Table 8. Permanent deformations of the canopy [own source]

Distance from the edge of the part, mm	Point No.	Measurements results, mm				Permanent deformations, mm	
		Left side of the canopy		Right side of the canopy		Left side of the canopy	Right side of the canopy
		Before testing	After testing	Before testing	After testing		
600	1	+3.5	+4.2	+2.8	+4.5	0.7	+1.7
1100	2	+7.2	+9.1	+4.9	+8.2	+1.9	+3.3
1600	3	+10.0	+12.5	+8.3	+11.8	+2.5	+3.5
2100	4	+13.2	+16.0	+11.9	+15.5	+2.8	+3.6
2600	5	+12.9	+15.7	+11.7	+14.8	+2.8	+3.1
3100	6	+9.5	+9.6	+96	+11.5	+2.3	+1.9
3600	7	+3.5	+3.2	+3.2	+3.8	+1.0	+0.6

Table 9. Permanent deformations of the gob shield [own source]

Point No.	Measurements results, mm		Permanent deformations, mm
	Before testing	After testing	
X_{AD}	+11.5	+11.4	-0.1
X_{BC}	+12.4	+12.6	+0.2

4. Laboratory tests of the modernised powered roof support

The powered roof support tested and approved for operation in 1996, had been used for 13 years. After this period of operation, the user decided to have it modernized. The stand tests on the modernised powered roof support, conducted in 2009, was to verify the design assumptions of the roof support after the modernisation (the canopy was modernised by extending it by 300 mm). The tests were conducted in accordance with the requirements of the PN-EN 1804-1:2004 standard, which was introduced after Poland joined the European Union in 2004 [15, 16].

Elastic deflection of the powered roof support tested in 2009 is shown in Table 10.

Table 10. Maximum elastic deflection of the roof support components in mm [own source]

Point No.	Ratio p/p_n	Supporting method according to Table1				
		1	2	3	4	5
		Roof support height, m				
		2.00	2.00	2.00	2.00	2.00
50	1.00	-2.1	-2.1	-2.0	---	---
	1.05	-2.2	-2.1	-2.1	---	---
	1.20	-2.5	-2,5	-2.4	---	---
51	1.00	0.6	0.7	0,6	0.9	0.6
	1.05	0.6	0.6	0,7	1.0	0.5
	1.20	0.8	0.8	0,8	1.2	0.6
52	1.00	-16.7	---	-17.0	-16.2	-15.9
	1.05	-17.7	----	-18.1	-16.7	-16.8
	1.20	-20.4	----	-20.9	-19.8	-19.3
53	1.00	---	---	---	-1.1	1.2
	1.05	---	---	---	-1.1	1.6
	1.20	---	---	---	-1.2	1.4

Arrangement of the measuring points from Table 10 is shown in Fig.1.

The results of measurements of permanent deformations of the canopy (Fig. 2) and the gob shield (Fig. 3) are presented in Table 11 and Table 12, respectively.

Table 11. The results of measurements of the canopy permanent deformations [own source]

Distance from the edge of the part, mm	Point No.	Measurement results, mm				Permanent deformations, mm	
		Left side of the canopy		Right side of the canopy		Left side of the canopy	Right side of the canopy
		Before testing	After testing	Before testing	After testing		
600	1	+5.1	+5.1	+3.2	+3.6	0.0	+0.4
1100	2	+11.5	+11.8	+7.9	+9.0	+0.3	+1.1
1600	3	+17.6	+18.6	+16.2	+17.4	+1.0	+1.2
2100	4	+22.7	+23.9	+23.0	+23.9	+1.2	+0.9
2600	5	+24.6	+26.0	+22.9	+23.8	+1.4	+0.9
3100	6	+19.7	+21.4	+18.1	+18.7	+1.7	+0.6
3600	7	+12.8	+14.3	+12.2	+12.5	+1.5	+0.3

Table 12. The results of measurements of the gob shield permanent deformations [own source]

Point No.	Measurement results, mm		Permanent deformations, mm
	Before testing	After testing	
X_{AD}	+10.0	+10.0	0.0
X_{BC}	+9.9	+9.9	0.0

5. Comparison of permanent deformations

In order to analyse elastic and plastic deflection (permanent deformations), the results, included in tables 5, 6, 8, 9, 11 and 12, were presented as graphs of the permanent deformations in a function of distance from the edge of the tested canopy part (Fig.4, and 5), as well as the permanent deformation of the gob shield (Fig. 6 and 7).

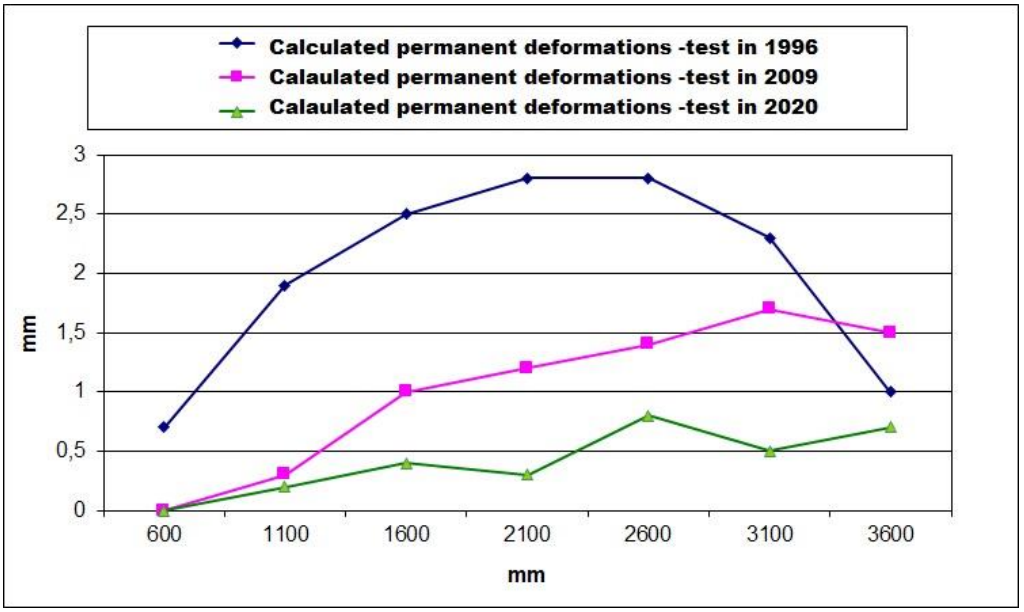


Fig. 4. Graph of the maximum permanent deformation of the left side of canopy (own source)

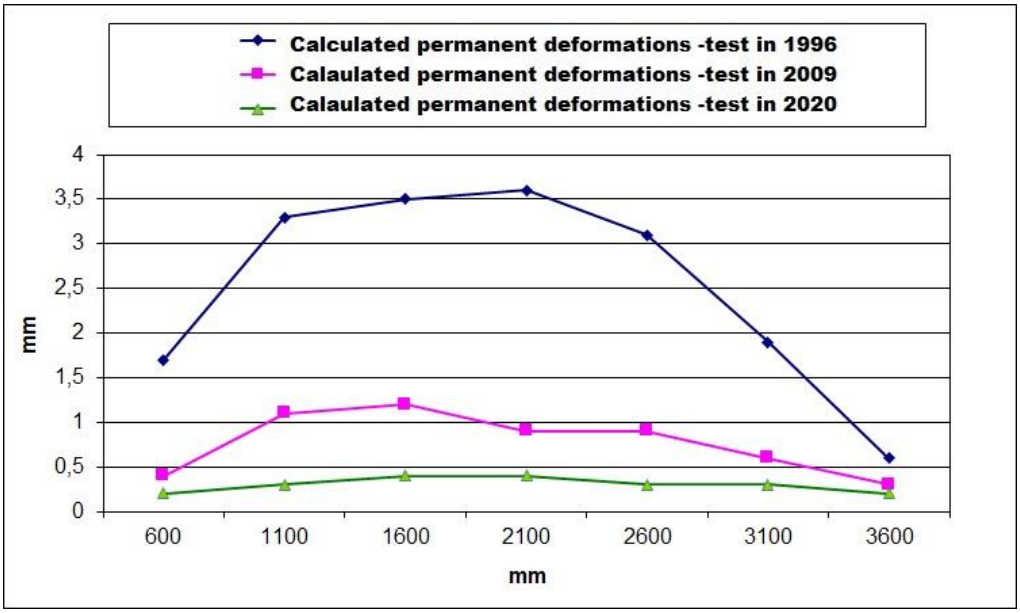


Fig. 5. Maximum permanent deformation of the right side of the canopy (own source)

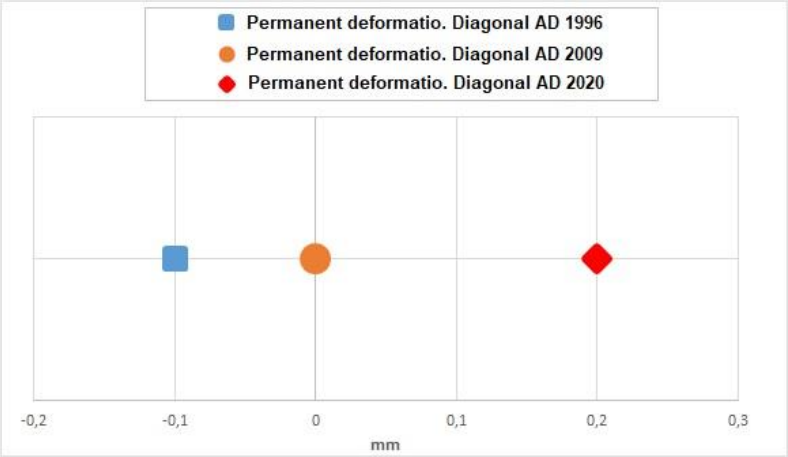


Fig. 6. Maximum permanent deformation of the gob shield – roof support diagonal AD (own source)

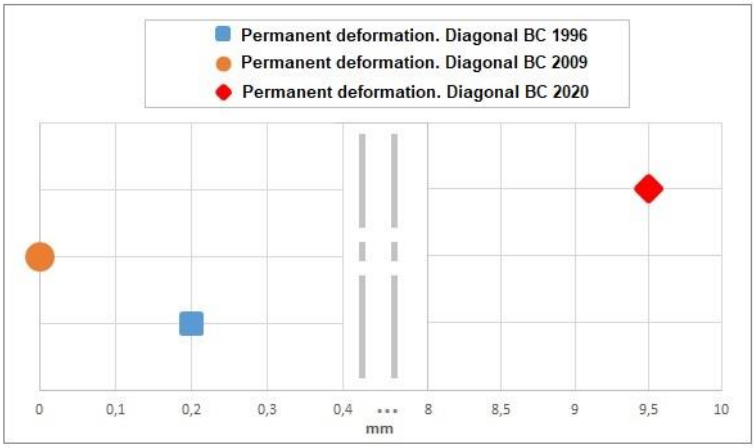


Fig. 7. Maximum permanent deformation of the gob shield – roof support diagonal BC (own source)

Comparing the deformations presented in Fig. 4 and 5, it has been found that the highest permanent deformation was in the canopy tested in 1996, and the lowest in the canopy tested in 2020. These may,, result from the fact that in 1996 laboratory tests were conducted with greater overload required by the regulations (standards) being in force at that time.

On the other hand, when comparing the deformations presented in Fig. 6 and 7, it is noted that the highest permanent deformation of the gob shield, both in the diagonal AD and BC, was recorded during the tests in 2020. Larger permanent deformations of the gob shield can be explained by a significant number of fatigue load cycles (approximately 36,000 cycles) applied to the powered roof support over the entire 24-year of service life.

6. Summary

After completion of the stand tests of an over 20 years old powered roof support, no loss of functionality was found after 26,000 cycles of fatigue load and static strength tests according to the programs presented in Tables 1 and 2. The results of the tests conducted in 2020 may be the basis for the user's decision on the installation of the remaining powered roof supports of the same type as the tested roof supports in the next longwall panels. It was proved that long-term operation did not significantly weakened the structure of the powered roof support. This roof support meets all the requirements included in the PN-EN 1804-1+A1:2011 standard in terms of static and fatigue strength put for new designs.

Comparing the recorded permanent deformations of the roof support's basic components tested in 2020, with the test results of the same roof support from 1996 (prototype testing) and 2009 (testing after modernization), larger deformations of the roof support tested in 2020 are found. Despite the larger deformations, the roof support has not lost its functionality, proved by tests and visual inspections on the test stand.

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