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Void fill techniques for stabilizing roof conditions during longwall recovery

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ABSTRACT

It has been proven that longwall faces can be moved safely and efficiently. However, abutment pressures and poor ground control conditions can halt operations and be hazardous to coal miners. Recently at a mine in Southwestern Pennsylvania, roof material collapsed above shields that created two large voids and caused major challenges for shield recovery. A unique, engineering solution was developed that utilized a modified concrete material to fill the voids, creating stability in the affected area. The many phases of this project included the construction phase, void pumping, cutting out, and bolting of the concrete material. This project eliminated the hazards associated with bolting the recovery face and removing shields in adverse conditions, making it possible for the mine operator to safely complete the longwall move.

1. Introduction

Frequently in the mining process, especially during the recovery phase, voids above the longwall supports have occurred. These voids are simply roof cavities caused by falling rock strata above the longwall face. Most often, this condition slows down or halts mining operations and creates hazardous work conditions for coal miners. Numerous methods of supporting void areas on longwall faces have been attempted and utilized throughout the mining industry since the advent of the longwall mining system. These methods have utilized many different materials and processes and have included the installation of steel or wooden beams, crib blocks, and various types of roof bolts. However, these methods can be dangerous due to exposure of personnel to the mine voids, falling roof material, and the necessity to handle large amounts of heavy support materials.

Studies have focused on the roof falling at home and abroad from different aspects [1–3]. This paper describes a unique case study in Southwestern Pennsylvania where longwall recovery methods, through two void fills, were successfully completed, eliminating exposure of coal miners to the rock voids above. At the start of this endeavor, normal recovery operations were halted, and hazardous conditions became a concern when the voids were encountered. However, in the interest of safety, the decision was made to try a unique method to completely fill the void from the bottom of the coal seam to the top of the void with a cementitious material and then mine through it. This is in contrast to traditional methods where beams and support materials are used to stabilize the area above and in front of the mine shields, which can expose miners to the void above.

1.1. Geology and void characteristics

The Pittsburgh coal seam in this area averages 1.75 m thick, as shown in Table 1. The immediate roof consists of relatively unstable strata made up of layers of shale and coal, totaling 2 m thick. The main roof above consists of a 2.1 m layer of gray sandstone, 1.7 m of dark gray shale, and above that lies 3 m of sandy shale. The first void was located in between #60 shield and #80 shield on the face, measuring approximately 23 m in length. The height to the top of the void from the bottom of the coal seam measured 6.4 m. The total volume of this void was calculated to be 367 m^3. The second void was located from #20 shield to #30 shield on the face, measuring approximately 9 m in length. The total volume of this void was calculated to be 153 m^3, with a maximum height of 5.2 m from the bottom of the coal seam to the top of the void.

2. Methodology

The two voids were encountered while making the pushover pass to widen the longwall face to make it easier to pull the

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Table 1
Stratigraphic column (m).

Max. cover	Main roof			Immediate roof—layers of shale and coal	Coalbed—Pittsburgh coal bed	Bottom—gray shale and limestone
	Sandy shale	Dark gray shale	Massive gray sandstone			
366	3	1.7	2.1	2	1.75	3

equipment off the face. The longwall move was started as usual, with the removal of the tailgate and headgate drives. The shearer was kept on the face, in between the two voids, positioned so that it was capable of cutting out both voids. The area between the shield tips and the face were bolted on 1.5 m centers utilizing a face conveyor mounted bolter, except at the locations of the voids. All equipment, including the face conveyor and shields, were removed from the tailgate to midface, approximately 61 m away from void #2. When this void was encountered, it was evident that the shields could not be pulled from this area without risk to the safety of the miners. The void created an area that could not be bolted within 1.5 m of the face without creating hazardous exposure to miners. Various methods of addressing the void were considered before deeming it necessary to fill the void with a cementitious material. The stages of this operation included the construction phase, the void fill phase, and finally the cutting out and bolting of the newly established face. The construction phase included building both omega block molds to encapsulate the fill material and foaming in between the blocks to yield extra strength and discourage leakage. Each omega block used was 61 cm long, 41 cm wide and 30 cm deep. The gaps between the shields also were thoroughly sealed using a two-part polymer. Finally, the PVC monitoring system was installed, which was used to monitor the height of the fill while pumping. The total time for this construction phase was 12 h. The next stage of the process was the pumping of the cementitious material. The pump and slickline was established from the pump location to void #2, which was a distance of 201 m. Voids #1 and #2 were pumped in five shifts and two-and-a-half shifts, respectively. The cutting and bolting phase of the project was the last phase of the void fill. It took three shifts (one day) to cutout and bolt void #1, and two shifts (16 h) for void #2. The total timeframe from beginning to build the frame to finishing the cut-out of the material was four-and-a-half days, as shown in Fig. 1. Due to the mine equipment utilization, the recovery of this longwall was not time sensitive.

3. Construction phase

In order to fill the void above the shields, a mold had to be created to contain the pumpable material. The two voids were filled using the same procedure. Omega block walls were built from the face edge of the pan line up to the shield canopies along the face. Perpendicular walls were then built on both sides of the void, thus tying the wall into the face and up to the roof between the shields and the face. These walls were built 3.7 m beyond the ends of each void, thus creating a void fill area that was 7.4 m wider than the actual void itself. The footing on these walls was laid horizontally, with the remaining blocks laid in the vertical position. After the walls were constructed, the walls were sealed using a two-part polymer. The gaps in between the shields were also foamed to seal this area, which prohibited any void fill material from seeping out of the void. By building the structure in this fashion, it eliminated the need for any worker to get directly under the void. A more traditional method of beaming and using plywood or planks between the beams subjects workers to hazardous roof conditions under the void. During the entire construction phase, workers remained underneath the shields, and, while building the sides of the structure, the roof was fully bolted and remained in good condition. Fig. 2 shows the potential hazardous "Red zone" in relation to where the miners were working while constructing the mold. In a more traditional method of supporting the void, miners would have been exposed to this potentially hazardous area.

4. Void fill

The cementitious grout chosen to fill the voids was Minova Tekseal® LD [1]. This is a low-density foam that has a specific gravity of 0.6–0.8 and weighs 712 kg/m^3. The material is non-toxic, non-combustible, and yields a compressive strength of 28.1 kg/cm^2 [1]. Fifteen gallons of water combined with 45 kg of Tekseal were used in the mixture. Each pallet contained 48 bags that were 20 kg each. The pump unit was set up 201 m from the point of the first and furthest void fill. Slickline was established from the pump to the void. A total of 130 pallets of mix were used in total on both voids. This equates to 127 metric tons of dry mix. PVC pipes were inserted into the wall and extended to the top of the void (Fig. 3). These pipes were used to monitor when the material filled the top of the void. At each pumping location, there were two PVC pipes extended to the top of the void. The one used for pumping was offset approximately 15 cm lower than the adjacent pipe.

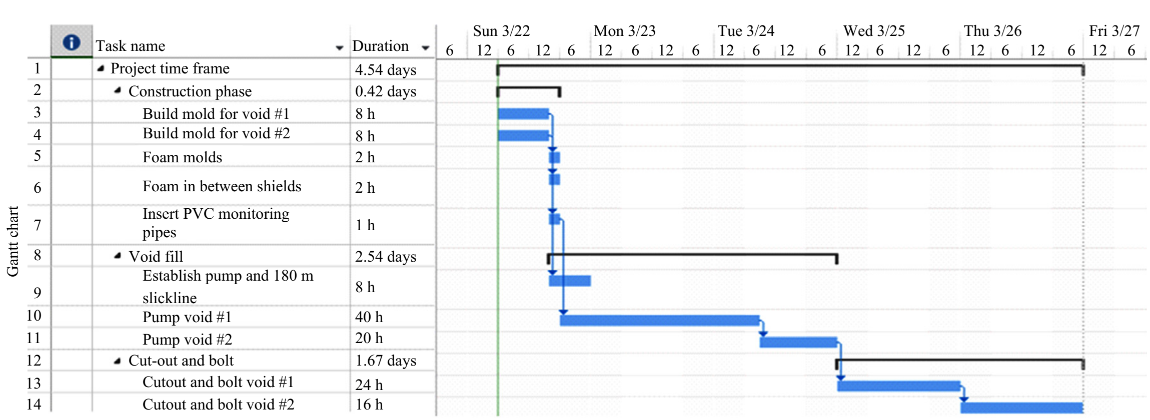

Fig. 1. Project timeline.