SUMMARY

Pumpable roof supports are increasingly used in underground mines to prevent ground falls because of their advantages in terms of installation, particularly in difficult to access areas. A major constituent of pumpable supports is the cementitious material. In current practice, the mainly used pumpable support cementitious material is Portland cement/fly ash (PC/FA) based grout. However, the PC/FA based pumpable supports have limitations, including (1) when exposed to the air, the PC/FA based cementitious material severely deteriorates, rendering the support much weaker and adversely affecting the overall safety, and (2) the peak and residual bearing capacities and the displacement required to reach the peak bearing capacity are all too small. To ensure good performance of the PC/FA based pumpable supports, it is critically important to minimize or alleviate those problems.

In the proof-of-concept project AFC 518-24 completed in 2019, we successfully developed a new hybrid geopolymer/biopolymer (GP/BP) cementitious material for pumpable roof supports. The hybrid GP/BP cement material is stable and does not degrade when exposed to air. Also, the hybrid GP/BP based pumpable supports have much higher peak and residual bearing capacities than the PC/FA based pumpable supports. These advantages have been successfully demonstrated and validated in the full-scale tests just completed at the NIOSH Mine Roof Simulator (MRS) Laboratory under the follow-up project AFC518SP-94. However, like the PC/FA based pumpable supports, the hybrid GP/BP based pumpable supports are still too stiff (i.e., the displacement required to reach the peak bearing capacity is still too small).

Therefore, the overall goal of this project is to further enhance the hybrid GP/BP based pumpable support by increasing its ductility (i.e., increasing the displacement required to reach its peak bearing capacity) while maintaining the high peak and residual bearing capacities. This will be achieved by innovatively increasing the compressibility of the top portion of the hybrid GP/BP cementitious material in the crib bag. To do that, extremely light, highly compressible, micron sized beads will be incorporated in one of the two pumpable streams; after the two streams are mixed and pumped into the crib bag, the beads, due to buoyancy, will move to the top of the grout within the crib bag; and after the crib bag is fully grouted, the beads will be within the top portion of the grout in the crib bag. In this way, after curing, the hybrid GP/BP cementitious material in the crib bag will consist of two portions: (1) the top portion containing beads and being highly compressible, and (2) the bottom portion containing no or very few beads and being strong as the original hybrid GP/BP cement material. By innovatively producing the two unique portions in a crib bag, the pumpable support will be not only strong with high peak and residual bearing capacities but also ductile with a large displacement required to reach the peak bearing capacity, achieving the ideal performance for a pumpable support.

To achieve the overall goal, this research will pursue the following specific aims:

(1) Systematic laboratory experimental studies: The laboratory experimental studies will develop the method for effectively incorporating the right type and amount of extremely

light, highly compressible, micron sized beads into the hybrid GP/BP based grout to form pumpable supports consisting of the top ductile portion and the bottom strong portion. The studies will include identification of appropriate types of beads, characterization of identified beads, study of the effect of incorporated beads on the behavior of the hybrid GP/BP cementitious material, and evaluation of the performance of small size bagged specimens consisting of the top ductile portion and the bottom strong portion.

(2) Demonstration and validation: Full-size pumpable supports will be produced and tested to demonstrate and validate the method developed from the laboratory experimental studies. Specifically, we will work with Minova to produce 8 full-size (0.61 m diameter and 1.83 m height) pumpable supports using commercial crib bags and pumping systems under field-like conditions. The 8 supports will be produced with 4 different types of mixes for the hybrid GP/BP cementitious material to investigate the effect of type and amount of beads. During the production, the pumpability and setting time will be monitored and checked and 0.15 m diameter and 0.30 m height un-bagged specimens will be produced for evaluating the physical and mechanical properties of the hybrid GP/BP cementitious material containing beads. After 28 days' curing, ultrasonic tests will be conducted to measure the wave velocity (or elastic modulus) of the pumpable supports at different depths so that the thicknesses of the soft top portion and the strong bottom portion are determined. Then, the pumpable supports will be transported to the NIOSH Mine Roof Simulator (MRS) Laboratory for testing. The test will follow the MRS testing protocols and small samples will be taken from the tested pumpable supports for later microscale study.

(3) Analysis of data, preparation of plan for further prototype development, and production of final report: The data from the laboratory experimental studies and the production/test of full-size pumpable supports will be analyzed regarding pumpability, workability, physical/mechanical properties and thus applicability of the hybrid GP/BP cementitious material containing beads in practice for producing pumpable roof supports. Then, a plan for further prototype development will be prepared, aiming to make the hybrid GP/BP cementitious material containing beads completely ready for application in practice to produce high-performance pumpable roof supports. Finally, a final report will be produced to summarize the work performed and the results obtained.