PUMPED-SLURRY BACKFILLING OF ABANDONED COAL MINE WORKINGS FOR SUBSIDENCE CONTROL AT ROCK SPRINGS, WYO.

by

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ABSTRACT

The Bureau of Mines, at the request of local authorities in Rock Springs, Wyo., investigated and conducted through contracts a multistage program of exploratory drilling and pumped-slurry backfilling of 15 areas of potential subsidence in abandoned mine workings underneath that community. Initially, the Bureau in 1969 had recommended a program of gravity blind flushing of some of the inaccessible mine voids, and in 1970 a new technique, the pumped-slurry injection process, was tested for the first time in a site adjacent to the city's area of severe surface subsidence. Success of this initial testing program, and of a large-scale project in Scranton, Pa., led to further large-scale projects, funded by Congress, that resulted in the successful backfilling not only of all 15 target areas of potential subsidence in Rock Springs, but also of several areas in other States. Total cost of the projects in Rock Springs, including the original pumped-slurry test, was $3,243,993. A total of about 923,000 tons of sand was injected hydraulically into mine voids, rendering 178 acres of residential and central-downtown areas of Rock Springs less susceptible to subsidence damage. The pumped-slurry method was proved to be much superior to the gravity blind flushing method in terms of the amount of solids that could be injected underground through a single borehole. However, there are special conditions that make this technique more or less applicable in different areas or underground configurations, as noted in the report's conclusions.

INTRODUCTION

Surface subsidence is often the consequence of underground mining operations. Removal of solid material from beneath the earth's surface produces voids, and once the natural support afforded by this material is taken away, the weight of the overburden is redistributed. If pillars of material that are left unmined or timbers or other artificial support left underground are

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not sufficiently strong to support the overburden, the overlying rock breaks and falls into the voids and/or crushes the pillars. This breakage may proceed upward in overlying material as far as the surface, causing potholes, cracks, or general settling of the ground. The time between the completion of mining operations and the disturbance at the surface may be a matter of days or a period of many years, depending upon a number of factors including the nature of the overlying rocks, depth of the excavation beneath the surface, and the method of mining employed. Subsidence is postponed when correctly spaced and adequate-size pillars are used to provide overburden support or is minimized when voids are backfilled with suitable material for the same purpose.

In the United States, nearly 100,000 underground mines are in existence, of which an estimated 90,000 are closed or abandoned. The total land that has been undermined for the production of coal, metals, and nonmetallic minerals has been estimated to be about 7-1/2 million acres. The exact percentage of the undermined land that has been affected by subsidence is not known. In a recent study of land utilized by the mining industry, the surface area that had subsided or was otherwise disturbed by underground mining from 1930 through 1971 was estimated at 105,000 acres. Of this acreage, 84 percent resulted from mining coal (15).[4]

Most of the land affected by subsidence is removed from centers of population. Adverse effects in these areas consist of crop damage, altered drainage patterns, and reduced land values. The most severe damage, of course, has occurred in urban areas. Millions of dollars in damage has resulted from the differential settling of buildings, pavements, subsurface pipelines, and other facilities, compounding existing problems as the pressure to develop undermined land is increasing in many metropolitan areas in response to accelerating demands for more living space.

For the control of subsidence in built-up areas where the underlying mines have been abandoned, backfilling is believed to provide the most practical means of minimizing damage to the communities. From time to time, studies of subsidence problems have been made for the city of Scranton (7, 11, 23) and for the Commonwealth of Pennsylvania (16-17). All the studies recommended programs of hydraulic backfilling.

The first reported use of hydraulic backfilling of mine workings was in the Anthracite region over 100 years ago. The purpose was to stop the subsidence of a church, and the treatment succeeded (2, pp. 99-100). Hydraulic backfilling was developed during the late 1800's and early 1900's and was used in about one-fourth of the anthracite mines for such purposes as to extinguish mine fires, to arrest the development of progressive pillar failure known as mine squeeze, to permit the reclaiming of pillars, to dispose of unwanted mine refuse, and to protect the surface. The practice of backfilling by the coal industry in the United States decreased after World War I with the decline of the anthracite industry. In domestic bituminous coal mining operations,

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[4] Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

backfilling has never been common practice (4). Applications to metal mining, however, in the United States and elsewhere, have provided solutions to a variety of ground control problems resulting in greater resource recovery, safer working conditions, and reduced mining costs (12).

The principal development of hydraulic backfilling in coal mining took place in Europe in the early 1900's, where the practice had spread from the Anthracite region of the United States. Most European coalfields differ from those in the United States in that the coalbeds are much deeper, the concentration of coal within a vertical section is much greater, and longwall mining methods predominate, whereas room-and-pillar mining is the most common method in the United States (18, p. 35). Many European coal mines underlie highly developed industrial areas or commercial waterways that require protection. The purposes of backfilling are to contribute to roof control under ground pressures and to permit as nearly complete recovery of the coal as possible as well as to support the surface. Hydraulic backfilling remains a part of mining operations in some European coalfields where thick beds of coal are being removed from beneath densely populated areas such as in France and Poland.

The Bureau of Mines' interest in hydraulic backfilling is as old as the Bureau itself. The First Annual Report of the Director (8, pp. 42-43) describes an ongoing study of mine filling (hydraulic backfilling) to make the mines a safer place in which to work and to reduce settlement of the surface. The report resulting from that study covered the history, applications, methods, and costs of hydraulic backfilling (6). Other early Bureau publications reported on sources of backfill materials and applications of hydraulic backfilling to various mining problems. At the end of World War II, the Bureau looked into the backfilling problem as it related both to the conservation of anthracite and to the prevention of subsidence in order to determine what role the Federal Government might play (1). A comprehensive engineering study of the backfilling problem in the Anthracite region by the Federal Government was recommended; the work was to be done in cooperation with the Commonwealth of Pennsylvania, and with the anthracite industry, should the study lead to action.

The current participation by the Bureau of Mines in subsidence-control projects in areas of abandoned mines is provided for by two pieces of legislation that authorize Federal-State cooperation. Public Law 87-818, an amendment in 1962 to the 1955 Anthracite Mine Drainage Act (Public Law 84-162), authorized the Secretary of the Interior to participate equally with the Commonwealth of Pennsylvania in the filling of voids in abandoned anthracite mines, in those instances where such work is in the interest of the public health or safety. Under this provision, four subsidence-control projects were completed between 1962 and 1965. The Appalachian Regional Development Act of 1965 (Public Law 89-4) and its amendments of 1967 (Public Law 90-103) included authorization to fill voids in abandoned coal mines within the Appalachian region. Costs under the Appalachian Act are shared 75 percent by the Federal Government and 25 percent by the cooperating State. By the end of 1978, fifteen subsidence control projects had been completed under the Appalachian program and additional projects were in progress in the Anthracite region of

Pennsylvania. Under the same program one project in Maryland and one in West Virginia have also been completed.

Under the authority assigned to the Bureau of Mines by the Organic Act (May 16, 1910) and its succeeding amendments and pursuant to regulations (30 U.S. Code 1-11), the Bureau conducts scientific and technologic investigations concerning mining and its related problems. By the end of 1978, twenty-one subsidence-control demonstration projects had been conducted under this authority, including the Rock Springs, Wyo., projects and the demonstrations in Pennsylvania, Maryland, West Virginia, and Illinois.

In demonstration projects conducted under the Organic Act, the Bureau is the primary signatory to any contract that is entered into. Aside from any agreements with contractors, the Bureau enters into cooperative agreements with State or local authorities. Through these agreements the State or local government, referred to as the "cooperator," grants the Bureau and its contractors the right to enter onto public streets and land in order to carry out the proposed project work.

A Draft Environmental Impact Statement, DES 75-37, on "Surface Subsidence Control in Mining Regions," was used (prior to its final approval in November 1976) as a guide in conducting the subsidence control projects in Rock Springs, Wyo. (21).

Purpose and Scope of Report

This report reviews the investigation by the Bureau of Mines to determine the cause and magnitude of the subsidence problem at Rock Springs, Wyo. It discusses methods of backfilling mine voids that are used to minimize the effects of subsidence. Four subsidence control demonstration projects at Rock Springs are discussed in detail, and an assessment is made of the effectiveness of the work performed.

Acknowledgments

The contributions of many individuals to this report, and to the demonstration projects on which it is based, are gratefully acknowledged. Paul L. Russell, former Research Director of the Bureau's Denver Research Center, was responsible for Bureau of Mines activities at the demonstration projects in Rock Springs. Neil Morck, District Manager for the U.S. Bureau of Land Management at Rock Springs, provided leases for two of the borrow pits and stipulations governing their use. Robert Oster, District Engineer for the Union Pacific Railroad, provided leases for use of the railroad's right of way.

Officials of the city of Rock Springs, including Paul Wataha, Mayor, Wayne Johnson, City Engineer, and Hyram Fedji, Director of Planning, Engineering and Development, provided excellent cooperation in the performance of the work on city streets. Valuable information to the drillers on the location of utilities under streets was obtained from Mountain States Telephone and Telegraph companies and the Mountain Fuel Supply Co. Data on surface altitudes

from several bench marks in the three large-scale project areas were made available to the Bureau as needed by the firm of Johnson-Fermelia & Crank, Inc.

Injection operations at the first test of the pumped-slurry process and at the first large-scale demonstration, both at Rock Springs, were performed by the Dow Chemical Co., Dowell Division, of Tulsa, Okla. A concept that sand slurry could be transported in pipelines directly from the borrow pit to the injection boreholes, a distance of over 2 miles, demonstrated additional flexibility in the use of the pumped-slurry process. Dowell Division personnel who contributed to the success of these nonroutine operations were John D. Stewart, Milton E. Heslep, Robert Hurst, L. D. Boughton, and George Laflin; and also A. J. Meyers on the use of sonar caliper surveys.

Engineers of the WHAN Co. and of the Bober Co., contractors for the second and third large-scale projects, contributed to improving the overall operations through more efficient use of the automated controls of the slurry mixture. In this way, delivery of a more uniform mixture to the injection boreholes was gradually accomplished with a considerable saving in the use of power. As the work progressed they relocated the equipment within the confines of the plant site and altered the use of the equipment from time to time to improve performance and eliminate as much noise and dust as possible.

Charles S. Kuebler, Chief of the Bureau's Environmental Affairs Field Office at Wilkes-Barre, Pa., where similar type projects were being conducted, and E. J. Carlson, engineer, Hydraulics Branch, U.S. Bureau of Reclamation, Denver, Colo., in charge of the model studies, provided valuable insight into the operation of the pumped-slurry method and the behavior of the slurry.

Much of the description of the nature of mine subsidence, its history, and various methods of control, including discussions of the pumped-slurry technique that appear in this report, is attributed to Alice S. Allen and Ralph H. Whaite, authors of Bureau of Mines Information Circular 8667 (22).

BACKGROUND

Development of Rock Springs, Wyo., as a mining community began in the 1860's with the westward extension of the Union Pacific Railroad through southern Wyoming. The railroad's demand for coal persisted well into the 20th century, leaving about 900 acres of Rock Springs undermined. Extraction of coal by the room and pillar method under most of the city had reached an advanced stage, and according to available mine maps it appeared that many of the remaining pillars were too small to support the overburden indefinitely. Under other areas some of the pillars had been removed. Reports of surface subsidence in various parts of the city became noteworthy in the late 1960's. Damage to houses, commercial buildings, streets, gas mains, waterlines, and sewers was considerable.

Subsidence Problems

The city of Rock Springs (fig. 1) is located in Sweetwater County in southwestern Wyoming on U.S. Highway 30, Interstate 80, and the Union Pacific