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Improvement of slope stability based on integrated geotechnical evaluations and hydrogeological conceptualisation at a lignite open pit

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ABSTRACT

Safe design of surface coal mine slopes must be considered early in the mine planning stage and is required throughout the life of mining operation. The success and efficiency of such an operation depend primarily on the reliability and accuracy of stability assessments based on integrated geotechnical evaluations and hydrogeological assessment. The Işıkdere lignite mine is one of the most recently operated large coal pits in Turkey since late 2009 and its depth will reach up to about 170 m. A few local failures experienced in the current pit and considerations on its maximum depth forced the mine operators to consider the redesign of the final pit wall slopes. The technical objectives of this study are to evaluate the stability of the final pit wall slopes considered in the initial pit project and to investigate and demonstrate the application of possible remedial measures to achieve safe conditions based on integrated geotechnical assessments and hydrogeological conceptualisation. To study the problem, a two-year collaborative program of geotechnical and hydrogeological investigations throughout the current pit and the area in the direction of advance of the pit in accordance with laboratory tests and analyses was commenced by the authors. The analysis results indicate that stability of the final pit slopes is sensitive to multi-planar failures and confined water in the coal seam is also a factor adversely affecting the stability. Problems associated with groundwater at the site were also assessed with the analyses of piezometric level and groundwater inflow. Remedial measures investigated suggest that at some parts of the pit, the initial pit project should be modified by flattening or shifting the final pit wall slopes towards the north or stripping them to a certain elevation.

1. Introduction

Surface coal mining requires excavation of steep slopes in coal measures and coal seam and the development of spoil piles for waste disposal. Steepening the slopes of open pits results in less re-handling with consequent savings in cost. However, safety considerations are of paramount importance, and safety must be effectively integrated with design and economics. The design of the final slopes of an open pit mine is one of the most important aspects in surface mine planning because slope stability calculations are necessary to balance the safety of excavated slopes with the economic viability of the mining operations. Safe design of open pit mine slopes must be considered early in the mine planning stage. The main factors affecting pit slope stability are slope geometry, geo-engineering characteristics of slope forming materials and groundwater pressure. With increasing depth of mining, geotechnical factors have increasing importance in the design and operation of open pit coal mines. In addition, increase in groundwater head is often another critical factor and high groundwater heads and hence high pore water pressures reduce the stability of slopes. For this reason, open pit design based on integrated geotechnical evaluations and hydrogeological assessment thus become important for mine planning.

Turkey has significant lignite reserves which are generally being operated using open pit mining methods by the General Directorate of Turkish Coal Enterprises (TKI) and private companies. Mugla is one of the provinces in Western Turkey, where a number of lignite open pits are being operated, and there are also large coal fields with considerable reserves where mining has not been initiated yet. This province has two main coal basins called Milas and Yatagan. In the Milas basin, the coal is mined in a number of open pits, which are generally located close to each other, to extract lignite for the two thermal power stations located in their close vicinity (Figure 1). The Işıkdere open pit locates next to other old pits in the basin. Excavation of the pit has recently been initiated at the southeast boundary of the coal sector and is progressing towards the northwest, and only a small part of the sector has already been excavated as seen in Fig. 2. Based on the initial mining project, the maximum depth of the pit will reach to about 170 m below the ground surface. The overburden in the pit mainly consists of stratified, clay-bearing and carbonated Tertiary coal measures. The initial design and the boundaries of the pit were based on the classical final slope angles, which are observed in old closed mine sites in Tertiary coal measures at some parts of Turkey, constrained by the presence of a

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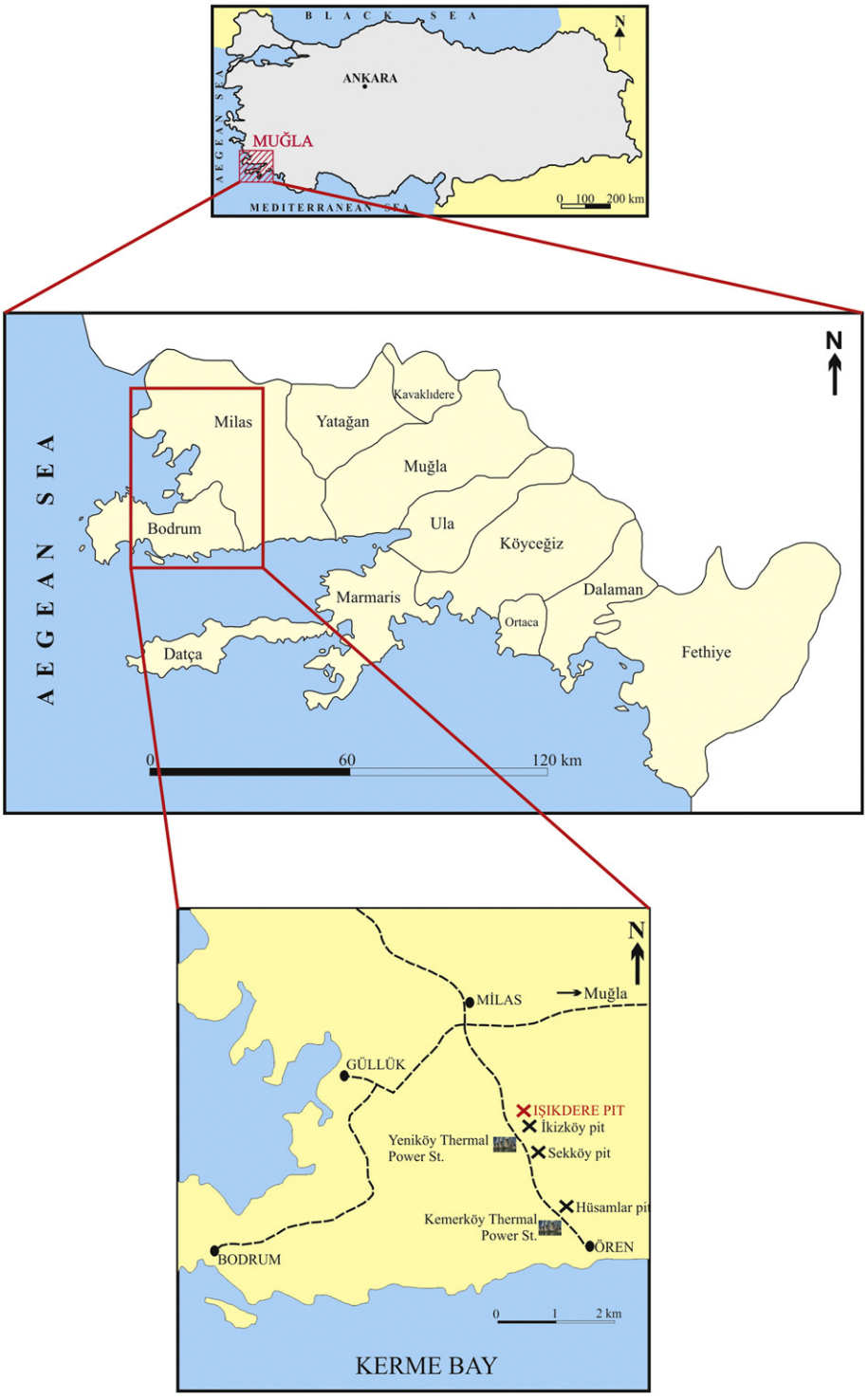

Fig. 1. Location map showing the Işıkdere open pit, other pits and the thermal power stations in the Milas lignite basin.

road and some antique tombs and a stream located south, north and west of the pit, respectively (Figure 2a, b). A few local failures, affected some benches of the northern pit wall slope and those in the direction of advance, and consideration of the desired maximum depth of the pit forced the mine operators to consider the redesign of the final pit wall slopes.

The main objectives of this study are to determine the overall final pit wall slope angles of the Işıkdere lignite pit, which will provide safe condition during the working life of the mine based on the values of safety factor suggested for open pit mining practice; to delineate the optimum pit limits throughout the site, and to investigate and compare possible remedial and control measures for necessary modifications to the initial pit project based on integrated geotechnical assessments and hydrogeological conditions. To study the problem, a two-year collaborative program of geotechnical and hydrogeological investigations was commenced by the authors throughout the current pit and the area in the direction of advance of the pit (Figure 2a). Structural mapping both in the current pit and its vicinity, borings, sampling, geomechanical