Available online at www.sciencedirect.com
ScienceDirect
Journal of Terramechanics 45 (2008) 51–62
Journal of Terramechanics
www.elsevier.com/locate/jterra

Specific energy based rippability classification system for coal measure rock

H. Basarir [a,*], C. Karpuz [b], L. Tutluoglu [b]

[a] Department of Mining Engineering, Inonu University, 44280 Malatya, Turkey
[b] Department of Mining Engineering, Middle East Technical University, 06531 Ankara, Turkey

Received 6 March 2008; received in revised form 13 June 2008; accepted 17 July 2008

Abstract

Specific energy is simply defined as the work done per unit volume of rock excavated. Specific energy is an important performance parameter as it relates cutting force to the amount of rock excavated. In this paper the development of a new rippability classification system for coal measure rock based on specific energy is presented. Extensive field and laboratory studies were conducted at six different lignite open pit mines and rock mechanics laboratory. Since both ground and machine properties are incorporated, the rippability classes of rocks and the approximate hourly ripper productions of different dozer types can be assessed by using the developed system.

Keywords: Rock rippability; Rippability classification system; Specific energy; Equipment selection

1. Introduction

The environmental problems arising from ground vibration and air blast have been faced and discussed frequently in various industries such as mining and civil engineering work where explosives are used. To reduce the environmental problems arising due to blasting ripping can be used. That is why, the development of a new rippability classification system including up to date equipment information is very important. When the physical limit of ripping is reached and the cost of ripping becomes expensive, blasting or other ground preparation methods can be considered as necessary [1].

Lots of rippability classification systems have been developed to determine the rippabilities of rocks. These systems are mainly divided into two groups as direct and indirect systems. In direct rippability classification systems, direct ripping runs are conducted if the dozer is available in field. Rock mass and material properties are used to estimate the rippability in indirect rippability classification systems [1]. Indirect rippability classification systems can be divided into three subgroups as seismic velocity based methods, graphical methods, and grading methods. Seismic velocity based methods use seismic P-wave velocity to estimate the rippability classes of rocks [2–6]. Graphical methods [7–9] consider discontinuity spacing and strength values for assessing rippabilities of rocks.

In grading methods, different rock mass and material properties are graded separately. The sum or the product of the relative weighted parameters determines the rippability class of rock. These methods are mainly based on the rock mass classification systems. The former of these methods is Weaver's [10] method; parameters and grades were similar to those used in rock mass rating (RMR) rock mass classification system [11] apart from the groundwater conditions. Many researchers have investigated these methods and have proposed different rippability classification methods [12–23].

Some common deficiencies are observed in existing systems: the lack of the awareness of previous case studies, difficulties in determining input parameters and qualitative results of the systems. Therefore, a new classification sys-

* Corresponding author. Tel.: +90 422 3410010/4748; fax: +90 422 3410046.
E-mail address: hbasarir@inonu.edu.tr (H. Basarir).

0022-4898/$34.00 © 2008 ISTVS. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.jterra.2008.07.002

tem should use quantitative and easily obtainable input parameters; also it should give quantitative results that do not lead to any bias. The existing classification systems may need to be extended or recalibrated by taking into account the progress in dozer-manufacturing techniques. Both rock and equipment properties affect the rippability of rocks, and a reliable classification system should consider both machine and rock properties together.

Specific energy is the widely used parameter to assess the performance of surface excavation machines [24–26]. Fowell and Pycroft [27] used specific energy to determine the cuttability of road header. McFeat-Smith [28] established a good relationship between specific energy and other rock properties.

In the developed system here, specific energy is used as a unique parameter to assess the rippability of rock. In this respect the developed system can be regarded as an indirect rippability classification system.

2. Research areas

Field studies have been carried out in two different lignite open pit mines in Turkey. The first mine belongs to GLI (Western Lignite Mines) division (located in Tuncbilek district of Kutahya Province in western Turkey) of Turkish Coal Enterprises. Four different panels of GLI namely, 34 Makina, Omerler, 18 PH, and Kuspinar have been investigated. The second mine, Demir Export's Sivas Kangal (SKL) lignite mine located in Kangal district of Sivas province on the east belongs to a private mining company. In this mine, two different panels were utilized namely, 305 and 310 panels. The locations of mines are given in Fig. 1.

3. Geology

3.1. Tuncbilek

Tuncbilek coal basin comprises two series of Neocene sediments. The lower one is called the Tuncbilek series and is in discordantly on an ophiolitic basement. The coal seam is in these series. The upper one is called the Domanic series and these younger series lie on the Tuncbilek series with slight discordance [1].

After the Upper Cretaceous, the region was exposed to terrestrial environment and subjected to erosion. During the lower Miocene, sedimentation began in the newly evolved soft-water lakes. Deepening of these lakes has given birth to quick-sands and the growth of high forests leading to the formation of coal.

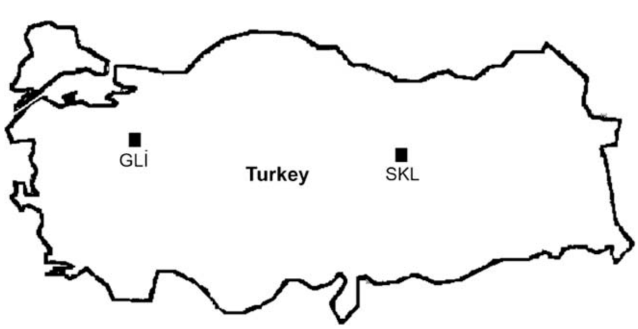

Fig. 1. Location map of research areas.

Sediments of terrestrial and lagoonal environment contain half cemented conglomerates, clay, marl, siltstone, sandstone, lacustrine limestone, strata with sand and gypsum, and of course coal. As the consequence of volcanic activity from the upper Miocene till the Pliocene lava, tuff and agglomerate were intercalated in the sediments. Lower and upper series of Tuncbilek region, Neocene sediments are illustrated in Figs. 2 and 3.

The lowest bed of Tuncbilek series is clastic sediment showing a decreasing grain size from bottom to top. The claystone lying on this layer exhibits intercalations of coal, which are not mined for economical reasons. The main coal seam is interbedded in the clay–marl unit, which is several hundred meters thick. The upper boundary of Tuncbilek series is the lacustrine limestone containing chert nodules on the top due to the volcanic activity. Concurrent tectonic activity has increased the dip angle of Tuncbilek series and caused formation of faults. Therefore, Domanic series, which are almost horizontal, lie in discordance on the Tuncbilek series.

Domanic series begin with agglomerate rocks and marl. The thick-lava formation on the top of the marl layer shows that volcanic activity that begun in Tuncbilek series has reached its climax. The lava contains andesites and basalts. Domanic series end with calcareous rocks containing chert nodules [29].

3.2. Sivas Kangal

Widely extending coal seams have been found within the young Neocene (Pliocene) formations. Starting from the oldest, the following rock units may be observed [30].

1. *Jurassic–Cretaceous massive limestones:* Base forming massive limestones form island-like outcrops at several places within the Pliocene deposits. These bluish-gray limestones correspond to the base of the productive Pliocene formations.
2. *Pliocene formations:* These formations are widely distributed at and around Kangal. Lithologically, they can be divided into two units:
   (a) *Upper measures (series):* Main rocks of this series are light colored and mostly white lacustrine limestones. These 40-m-thick limestones include marl intercalations and overlie lower series.
   (b) *Lower measures (series):* Main units are coal bearing marl, clay and conglomerates: These series contain coal seams in the upper part and clay, marl and conglomerate alternations in the lower part. The thickness reaches a maximum of 180 m at the investigation site. Toward north and northwest, conglomerates grade into sandstones and marls.