ACTA MONTANA IRSM AS CR (1994)
Series A, No. 5(92), 69–75

DEFORMATION MEASUREMENTS OF CARBONIFEROUS SANDSTONES FROM THE COAL MINE KLADNO II

Jaroslav Vydra

Institute of Rock Structure and Mechanics, Academy of Sciences of Czech Republic
V Holešovičkách 41, 182 09 Prague 8, Czech Republic

ABSTRACT. Laboratory tests of sandstones from the hanging wall of the mine coal seam on the Kladno II mine were aimed at the establishment of the deformational and strength properties of rock samples, taken at the 7th mine level, i.e. about 100 m above the seam mined within the shaft pillar.The course of deformations has been investigated during uniaxial loading and the elasticity and deformation moduli have been determined.

KEY WORDS: Rock mechanics, Yang's modulus, reversible deformation, rock testing, stress–strain curve, Sandstone.

1. INTRODUCTION

With termination of mining on the coal mine Kladno II, the smoothness and safety of the extraction of coal from the shaft pillar had to be secured. Among geodynamical phenomena caused by this exploitation, most dangerous are rock bursts (bumps), deformations and inclinations of the shaft and surface displacements.

The substantial cause of rock bursts is a systematical brittle instability, which originates in the stratified structure of the overlying rock and exploited seam. The site of origin lies most frequently in the relatively thick sandstone layer, which has an intrinsic tendency to sudden brittle failure (at the stress within the linear section of the stress–strain diagram).

The strata series is subjected to a considerable high structural (tectonical) stress, most probably connected with the Tertiary volcanic activity. The mine field is permeated by a tectonic fault with the skip height of about 10 m. When weakening the effective strength of the coal seam by mining operations, the overlying sandstone layer is subjected to increasing the deviator stress component and, when the time limit of the strength is attained, the tensile cracks are being formed or, eventually, the existing cracks begin to widen.

Tests in the Rock Mechanics Laboratory were aimed at the assessment of deformation characteristics of samples of these overlying sandstones exposed to uniaxial compression.

2. Description and preparation of samples

Samples were taken at the 7th level of the mine Kladno II, i.e. about 100 m above the mined seam. They were sandstones of varying grain size from the undermost stations of the Nýřany layers. The choice of the rock type was in agreement with the possibilities of resolution (Šašek 1978) and the entire evaluation and comparison of results were made on the basis of such a distribution.

The following sandstone types were used for tests:

EC – silty (power-like) sandstones
E – fine-grained sandstones
G – medium-grained sandstones
J – coarse-grained sandstones.

The samples were cut into the form of prisms, size $4 \times 4 \times 8$ cm, i.e. to slenderness ratio of 2:1. This length enabled a sufficiently large measuring zone to be obtained in the middle of the height, only slightly affected by friction on compression areas of the specimen.

The loading was carried out on a press with maximum loading force of 3000 kN and deformations were sensed by electronic tensometers and evaluated on the UMP 60 device (by Hottinger Baldwin Meßtechnik). At a bridge connexion, the relative (not absolute) deformation was read directly. Temperature effects were equalized automatically by introducing a compensation tensometer into bridges.

Deformation tests were carried out mostly on a base perpendicular to the layers of the used samples. The reason lies in the fact that the Carboniferous of Kladno is deposited almost horizontally. As the rock samples were loaded by a force perpendicular to layer planes, the axial deformation is measured in the direction perpendicular to layers (strata) and the cross deformation within the strata plane.

3. Measurements

The whole measurement was divided into cycles with consecutive increasing stress, each of them having both a loading and relieving branch. From a single loading branch (i.e. stress increase from zero till the sample failure) only the strain (deformation) modulus E_d can be determined. In order to determine the elasticity modulus E, it is necessary to measure the deformation at least at one complete loading cycle (loading–relieving) to make sure whether the tested rock exhibits – after relieving – also permanent deformations (non-elastic strain).

Volume changes of the rest specimens, graphically illustrated by stress–strain diagrams, can be resolved into two characteristic courses (Polák 1977):

Course I:

The volume change curve illustrates an initial volume reduction, it attains a maximum of reduction (characteristic point A – initial point of structural failure) and then, during the whole course, the increase of the specimen's volume prevails. The intersection point of the volume change curve with the vertical stress axis in the stress–strain diagram is the characteristic point B, showing the stress within the specimen's body, at which the volume changes equalize with the initial condition (before the test start).

The further course of the volume deformation curve beyond the characteristic point B illustrates further volume increase of the specimen (dilatancy until destruction).

The course I of the volume change curve can have, most frequently, the shape according to Ia or, eventually, Ib, when the characteristic point A′ has an indeterminate position within a certain stress range (Fig.1). The curve Ic occurs in specimens, which within a certain stress range do not reduce their volumen, but then after, they increase their volume suddenly – they are lacking practically the characteristic point A″ on their volume change curve.

The course I of the volume change is fulfilled, when the axial compression of the specimen depends on the stress linearly or sightly plastically (plastic or flexible dependence).

The transversal dilatation of the specimen is similar, but an excessive deformation increase can be observed there. Such a course is characteristical, above all, for sandstones, sandy siltstones, conglomerates, etc.

Course II:

The volume change curve shows continuous reduction of volume during starting – almost till the specimen failure (Fig.2). The course of the volume change curve II has either the form of IIa (in strong but brittler materials), or an irregular shape IIb with one or several inflexion points (as in a tectonically failured graywacke slate).

The course of the curve has a practical significance in the case Ia, when the failure of the test specimen can be predicted.

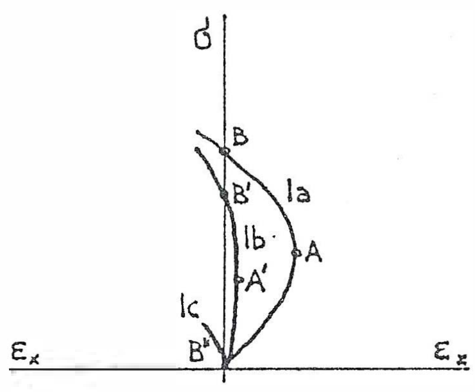

FIG.1

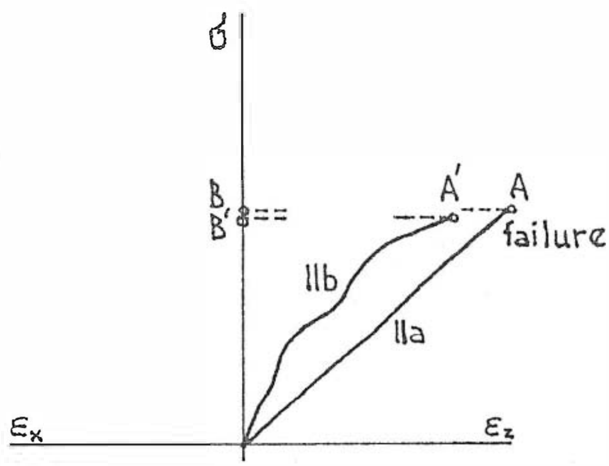

FIG.2

The relative volume change of the specimen has been expressed as:

$$\frac{V_1 - V_0}{V_1},$$

where
V_1 = specimen's volume prior to failure (breakdown)
V_0 = original volume specimen.

The quoted expression may be transformed, by use of relative deformations, into the equivalent of difference ε_z (axial, vertical relative deformation) and $2\varepsilon_x$ (the double of the transversal relative deformation, or the double of two different transversal deformations ε_x; ε_y)

$$\frac{V_1 - V_0}{V_2} = -\varepsilon_z + 2\varepsilon_x .$$

A graphical record of one deformation test of Kladno sandstones is illustrated in Fig.3.
Volume change curve have a similar course for all tested rocks. The peaks of the curves (maximum volume reduction) are found at the load corresponding to 25,9 – 55,4 % of the strength.

The highest deformation moduli were established in fine–grained sandstones (14 299 – 16 178 MPa) – see Tab.1

TAB.1. Results of deformation measurements

sample No	petrograp. type	compression strength [MPa]	inflexion pt. A [MPa]	% from σ_{max}	point B [MPa]	% from σ_{max}	E [MPa]
2	G	13,96	3,62	25,9	8,34	59,7	4081
12	J	14,65	4,88	33,3	12,45	85,0	5893
5	G	17,03	4,35	25,5	12,42	72,9	9146
7	G	18,45	6,67	36,2	15,96	86,5	9740
4	G	20,71	8,63	41,7	16,95	81,8	9921
6	G	24,01	10,52	43,8	22,90	95,4	5708
15	E	25,34	10,55	41,6	21,03	82,9	7078
17	E	27,51	15,42	56,1	chybí	—	11032
18	E	28,11	14,47	51,5	27,11	96,4	11254
19	E	28,57	15,00	52,5	27,14	96,4	9803
42	EC	41,31	24,59	52,5	40,16	97,2	14299
44	EC	49.17	24,91	50,7	43,26	88,0	14904
43	EC	51,22	28,36	55,4	43,52	85,0	16178

The Poisson's ratio is no longer as differentiated according to the rock type and varies within 0,21 and 0,45.

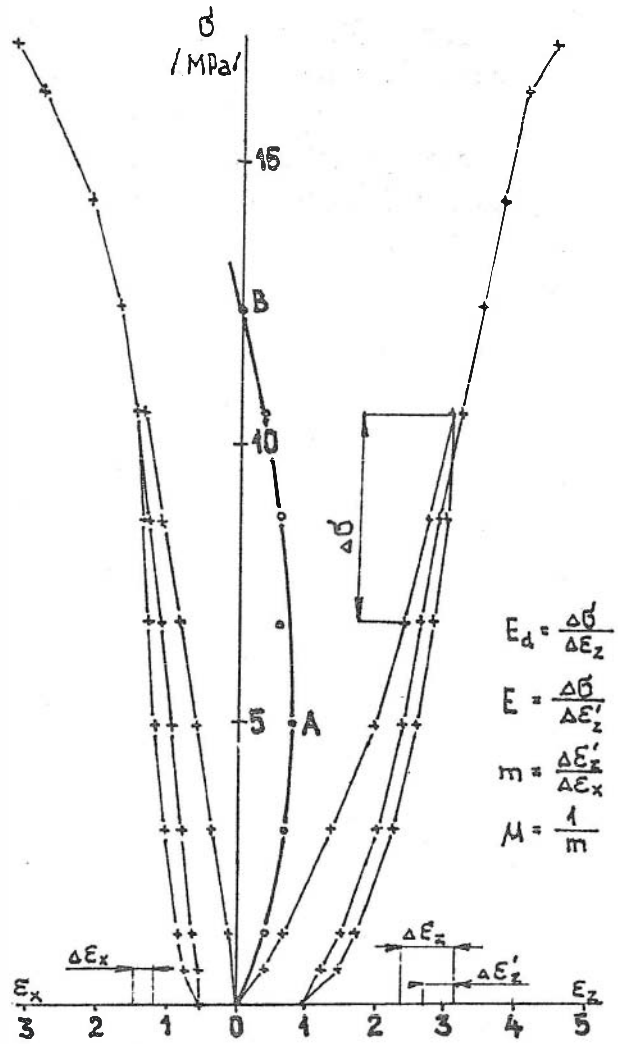

FIG.3. Volume deformation of a medium-grained sandstone

All measurements of deformation characteristics are carried out so that all deformations have the chance of free development (no deformation is limited in its natural manifestation).

The volume changes of rock specimens proved, in most cases, to follow the type Ia curves with an expressively situated characteristic point A (maximum volume compression) fairly distant from the strength value. They involve thus throughout the cases, when it would be able to predict or judge about the breakdown moment of the test specimen, if the deformation would be recorded together with the simultaneous recording of the relative volume change. As it has already been said, this point varied, during the uniaxial loading, within the stress range of 25,9 – 55,4 % of the strength value, most frequently.

The maximum of the volume compression of the test specimen designates the load, at which a structural alteration of the test rock takes place, while failure phenomena of the test specimen are still not evident! Since that moment, the change of the physical condition of rock is fairly different from its original condition and becomes more and more evident with subsequent loading.

With increased strength, which means – in our case – with increased granularity (grain size) of the tested sandstones, the volume compression becomes higher, which increases the time,where, by the formation of cracks, the volume becomes equal to its original value and subsequent breakdown (destruction) is imminent (see Fig.4).

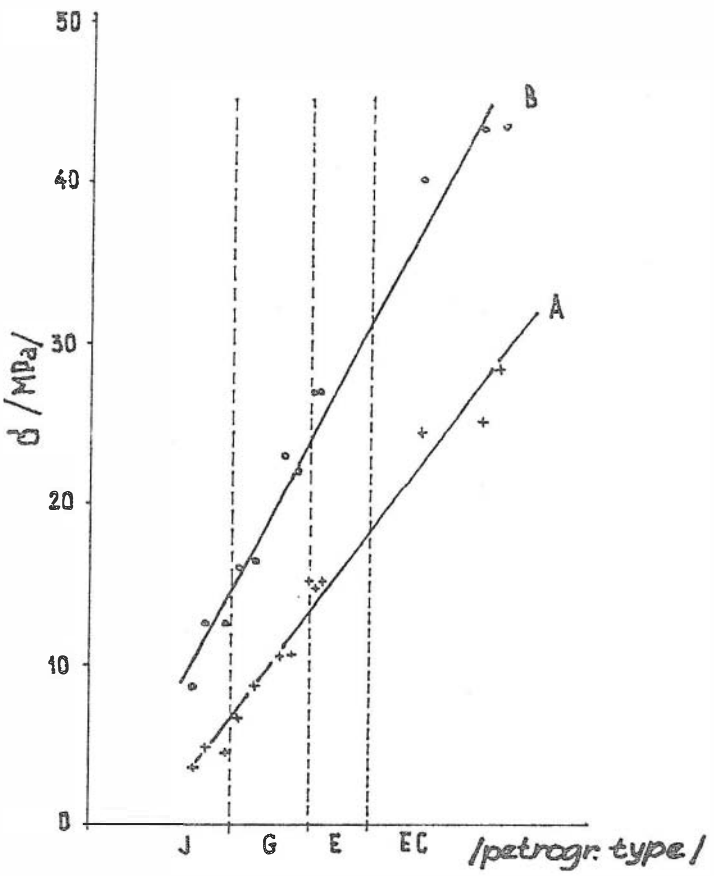

FIG.4: Dependence of the points A and B values on the petrographic rock type

The character of deformation of all sandstone types remains equal even after preceding relief. Almost elastic properties have been proven at standard tests. Except the initial phase of sample compression (when some creep becomes evident), the entire intermediate and frequently also the final phase (prior to failure) exhibit almost linear deformations. However, the different physical condition of samples (humidity, fissures etc.) affects the values of Poisson's ratio and deformation modulus E_d.

In all cases, the breakdown took place along the slip surfaces, which means that combinations of normal and tangential forces asserted themselves within the fault planes.

4. Conclusions

The laboratory tests carried out could not offer an unambiguous and exhaustive base for conclusions, how to prevent the rock bursts. As far as the mining operations are concerned, the quality of rocks is assessed by their strength, i.e. maximum resistance offered by the rock within the mine working against external forces, which deform and finally

quantity, being rather the opposite, a variable depending on all conditions of the environment (surrounding rock mass). Deformation measurements with the same samples and using the same methods would yield only a relative evaluation of rock layers, because the physico-technical properties are affected by the physical condition of samples or the rock massif and by external load. They represent therefore a factor, which is given similarly as the geological structure of the territory, but which may also be changed easily by human intervention during the choice of mining methods.

References

Šašek P. (1978), *Final report on some physical properties of rocks encountered during prospect holes in the area of Slaný*, PÚDIS – HÚ ČSAV, Praha. (in Czech)

Polák V. (1977), *Study of the effect of volume stress on mechanical properties of some rock kinds*, HOÚ ČSAV, Praha. (in Czech)

Deformační měření karbonových pískovců z dolu Kladno II

Jaroslav Vydra

Článek popisuje deformační zkoušky pískovců různé zrnitosti z nadloží hlavní kladenské sloje na dole Kladno 2. Práce byla zaměřena na stanovení přetvárných vlastností horninových vzorků, odebraných na 7. patře dolu, tedy cca 100 m nad slojí dobývanou v jámovém ohradníku. Byl sledován vztah napětí a deformace, průběh deformační křivky při jednoosém zatěžování a zjišťovány moduly pružnosti a přetvoření.

Vzhledem k tomu, že kladenský karbon je uložen téměř vodorovně, byly deformační zkoušky prováděny převážně kolmo na vrstvy odebraných vzorků. Objemové změny zkušebních tělísek graficky znázorněné přetvárnými diagramy je možno rozdělit do dvou charakteristických průběhů I a II. Křivky objemových změn se u všech zkoušených hornin podobaly průběhem tvaru I. K největšímu zmenšení objemu dochází při zatížení rovnému 25,9–55,4 % z hodnoty pevnosti.

Moduly přetvoření byly jako největší zjištěny u jemnozrnných pískovců (14 229 – 16 178 MPa).

Se zvětšující se pevností je objemové stlačení větší a tím se prodlužuje i doba, při níž dojde tvorbou trhlin k vyrovnání objemu na původní hodnotu a k následné destrukci.

U všech typů zkoušených pískovců zůstává charakter přetvoření i po předchozím odlehčení stejný. Byly dokázány téměř pružné vlastnosti při standardních zkouškách.

Ve všech případech zkoušek probíhalo porušení podle smykových ploch, čili v ploše porušení se uplatňovaly kombinace složek normálových a tangenciálních.