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Editor-in-chief
Ph D. Mirko Ivković, Senior Research Associate
Committee of Undergoind Exploitation of the Mineral Deposits Resavica
E-mail: mirko.ivkovic@jppeu.rs
Phone: +38135/627-566

Co-Editor
Ph.D.Jovo Miljanović
Faculty of Mining Prijedor, RS

Editor
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Printed in: Grafopromet Kragujevac

Web site:
mirko.ivkovic@jppeu.rs

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Phone: +38135/627-566

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CONTENS

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EXPLORATION OF COAL IN THE DESPOTOVAC BASIN

Svetlana Simic
Geological Survey of Serbia, Rovinjska 12, svetlana.simic @ gzs.gov.rs

Keywords: coal, Despotovac basin, geological and geophysical methods

INTRODUCTION

In the middle of the 19th century has began research in Despotovac coal basin. During the long period of research was set aside more deposits, including economically most interesting two : Zabela - Kosa and Cerje – Jovacko polje.

The recent geological surveys were carried out in the period since year 2011 to 2013 with the aim of defining potentially coal-bearing area located near the already discovered and exploited deposits. The tests were carried out geological and geophysical methods of prospecting northwest *Zabela - Kosa* (the exploration area A) and the south and southeast of the bearing *Cerje - Jovacko polje* (the exploration area B). Research in the area of the field, which is located northwest of the bearing Zabela - Kosa has shown that this area is unproductive in terms of expansion and provision of coal reserves in the bay of the same name. Continuity exploitable Sarmatian series has not been confirmed , but it remains unknown develop Baden and Prebaden series, whose presence is hinted by geoelectrical methods. Geological survey south and southeast of the deposit *Cerje – Jovacko polje* determine the continuity of development of Neogene sediments , but the presence of coal seams , their number and thickness must be determined by more precise methods. Financial assets held for research of coal – bearing are very modest and, as such, prevent the application of costly research methods.

Despotovci basin, as part of that bay Greatmoravian basin is formed under conditions of sub-mountainous coastal lowlands near denundation areas which caused the poorly sorted and facial diversity sediments that are cyclically interchanged . Coal deposit sediments were formed in the period of the Carpathians as the youngest floors lower Miocene (M_1^4) to the Sarmatian (M_2^2). Tectonically they are very complex terrain is divided into blocks of larger and smaller lowered to different depths. Breakout and lowering blocks were carried by preneogaean the Pliocene and Quaternary. Since disjunctive deformations are represented : a cross- faults, oriented in the direction of I - Z , are almost parallel to each other , and the distance between them increases to the south and longitudinal faults, the direction - south , lower the intensity , the time they are older , and are related the eastern edge of the basin. Space of the Despotovac basin is the place confrontation two geotectonic units of the second order : *Lužnička* and *Gornjačka - suvoplaninska* zone (Geology of Serbia, 1975) .

In Despotovac basin developed Miocene sediments with a total thickness of about 700 meters. According to the time and circumstances of creation, the B . Maksimovic (1977), were defined as:

- Prebaden freshwater sediments - horizon "D", a thickness of up to 250 meters,
- Badenian marine and brackish sediments - horizon "C", a thickness of about 200 meters,
- Sarmatian sediments - horizons "B" and "A", a thickness of about 250 meters.

Prebaden freshwater sediments was built from the marl and marl clay, then coal-bearing horizon represented with 14 layers and interlayers coal and overlying sand - conglomerated sediments. Coal seam in this series belong to the horizon of "D".

To marine - brackish Baden series, the B . Maksimovic(1977), features a variety lithofacial intensive vertical alternation semisaline , freshwater and marine sediments. Baden series begins basal clastics where Premiocen paleorelief or carbonate sediments when overlaying freshwater Miocene. From the lithological members present were still green, gray-green and blue clay with coal seams (horizon "C").

Conformably over Badenian Sarmatian blue clay lies a complex which consists of gray clay with thin layers of coal (horizon "B"), green and gray clay, clayey sand and sand, over which lie layers of coal and clay horizon labeled "A". The highest parts of the series are presented in sandy sediments.

Sarmatian coal has been the subject of decades of exploitation in Despotovac basin. Prebaden freshwater series exploited in the mine “Manasija”.

Coal layers are complex structure and morphology. Within each horizon of the layers have been developed, of which coal is the small number of economically interesting. Thickness of exploitable coal seams is very variable (note Kosa: layer B / 0.6 m - 5.8 m , layer A2 / 0.7 m - 6.1 m and Cerje - Jovacka field : layer B2 / 1,0 m - 6.0 m , layer B1 / 1.0 m - 6.8 m , layer A2 / 1.0 m - 6.5 m). Coal layers are stratified clays which occurs in the form of lenses or the thickness of different layers.

The coal belongs to the soft brown coal (lignite, the old division), except Prebaden coal series, which, according to the results of technical analysis, hard brown coal. Coal is a dark brown, brown scratched, dull, wooden structure. And proximate analysis of coal from Despotovac basin confirmed that belong to the soft brown coal mines. The moisture content is about 26 % , ash 30% to 45 % . The sulfur content is low at 1.3%. Volatile content ranges from 19 % to 21 % . The mean value of the net calorific value of the deposit Zabel Hair shown do about 10,000 kJ / kg , while in the cradle Nova Manasija is about 14,800 kJ / kg . Bulk density of coal is 1.21 t/m3.

METHODS

Geological research of Despotovac basin, whose results are presented in this paper were carried out during in year 2011 and 2012 (Simic, 2011, 2012) . The goal of complex geological research of Despotovac basin is discovering potentially coal-bearing space in order to increase the raw material base of coal.

Given the complexity of the geological and tectonic characteristics of the basin, which are inevitably affected the morphology of the carbon layers, their thickness, continuity, quality and quantity characteristics, it is necessary to predict geological research in several respects. Research of coal-bearing in Despotovac basin includes defining parameters based on all the existing research (basic research of Greatmoravian regional basin and detailed study districts *Zabela* - *Kosa* and *Cerje* - *Jovacko polje*) and on the basis of geologic (geological mapping) and geophysical (geoelectrical sounding) presented in this area.

Detailed geological mapping research areas A and B was performed by moving into the method of the shoots, the wide coverage of the field. The total area of both exploration area is approximately 20 km^2. All points of observations are documented in a prescribed manner.

Geoelectric methods it is possible to separate the Miocene coal-bearing series of paleorelief. Along the two geophysical profiles were placed ten probes at a distance of 150.0 m to 200.0 m . Measurement of the electrical resistivity and induced polarization, enabling the interpretation of lithological composition to a depth of about 500 - 600 meters .

RESULTS

The exploration area A - the geological survey of the exploration area northwest of deposits *Zabela Kosa* in the 2011th year, showed that the area is unproductive in terms of expansion and provision of coal reserves. Continuity exploitable Sarmatian series has not been confirmed, but it remains unknown develop Baden and Prebaden series, whose presence is hinted resistivity sounding. Within the research of Greatmoravian basin in the eighties, drilled 6 drill holes located in the area of Despotovac basin. Two drill holes (VM -2 and VM -3) are located north from the Resava river, three (VM -4 , 4a -VM and VM -5) to the south and one in the alluvial deposits (VM-1). In the area north of solved only one borehole (VM -2) noted Sarmatian coal negligible thickness (two interbeds of 0.2 m and 0.3 m), and the second occurring 4 interbeds of coal Badenian age. In the area south of Resave no productive layers of Sarmatian age. Interpretation of the results of geoelectric sounding allocated to a depth of 80 to 100 meters from the sandy ground surface - gravel sediments (lithologic environment 1 and 2), according to the lithological composition and stratigraphic position, probably correspond to Sarmatian sediments and Baden - Sarmatian (horizons "A" and "B") at a depth of about 100 to 250 meters separate the clay sediments (lithologic environment 3) at depths ranging from 250 meters to 550 meters of sand is separated - conglomerated series (lithological environment 4). The rim profile paleorelief deposits (lithologic environment 5) are found at depths of 200 to 300 meters.

Geophysical surveys have confirmed that the exploration area located northwest of the bearing *Zabela Kosa*, is the rim of the Despotovac basin.

Accordingly, in this area is not expected to increase the Sarmatian coal reserves that could be followed up on reserves from *Zabela Kosa* deposit.The unknown is the presence of Baden and Prebaden series or layers of coal horizons "C" and "D".

The exploration area B - the geological survey of the area south of the bearing *Cerje Jovacko polj*e in 2012th year, showed that in this area will develop Neogene sediments continuously, as evidenced by the interpretation of geoelectric sounding, but the presence of coal seams , their number and thickness must be determined by more precise methods. Based on the interpretation of the results of geoelectric soundings to a depth of 600 m, identifies four lithological units whose mutual boundaries relatively vaguely defined as it is a gradual transitions one environment to another. According to the results of geoelectric soundings (parameter SER - specific electrical resistance) it is a predominantly clayey- sandy- marly sediments. Lithological environment one is made of clay and clayey sands of the total thickness of 200 m to 500 m. Lithological environment consists of two sandy clay, sand, gravel, clay, total thickness of 50 to 250 meters. Within this environment are separated and lenses, probably, gravel and sand with low participation clay component - this is the lithological environment 4. Lithological environment 3 extends from the surface to a maximum depth of operation is identical to the middle of the two, and lithology are probably very close to, but separated from it due to the specific spatial position. This is probably a continuation of the lithological environment 1 with gradual lateral transitions clay more or less clayey clastic material. In this environment, it is also possible presence of isolated lenses of sand and gravel.

Based on the interpreted lithological composition, we believe that the isolated Sarmatian and Badenian sediments, which further extends to the south and southeast. Geoelectric sounding is not possible to extract the number and thickness of coal seams .

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DETERMINATION MECHANICAL PROPERTIES OF CEMENT STONE FOR PERMANENT TIGHTNESS CEMENTED ANNULUS

Zvonimir Bošković[1],Vladimir Čebašek[2], Sanel Nuhanović[3], Jovana Crnogorac[1]
[1] Rudarski fakultet Prijedor
[2] Rudarsko -geološki fakultet Beograd
[3] Rudarsko –geološko-građevinski fakultet Tuzla

Abstract

Different types of additives for cement stone expansion for several years. Some additives are based on calcium sulfate, sodium sulfate, calcium sulfate hemihydrate, or the creation of ettringite. These expanding cements exhibit more than ten times greater than the spread of them have a Portland cement slurry with the addition of salt. Known are also expanding cements containing calcium or magnesium oxide. The expansion of the cement in connection with the mineralogical and chemical changes that result from hydration and crystallization factors. Size expansion depends on the concentration of additives to the expansion, the particles of cement, of cement slurry design and their implementation of drilling conditions (pressure, temperature), and the types of rocks in which the hardened.

INTRODUCTION

The basic aim of determining the composition of the cement mixtures of oil and gas wells is to provide a solution suitable for application in the field. This means that they can be easily prepared and pumped conventional surface equipment and driven to the required depth with the appropriate setting time. The
solution must maintain stability throughout the process.

To ensure a long service life borehole cement stone must be mechanically and chemically resistant. Formed from API cement, the cement stone is resistant to aggressive drilling fluids and must be resistant to stress during manufacture or operation of the well, i.e.. tightness testing of pipes, stimulation operations, temperature changes during the production cycle throughout the century wells. It is necessary to analyze the mechanical behavior of cement stone of various types of cement mixtures under downhole conditions to arrive at the optimal composition of the cement mixture. Instead of the previous analysis of strength of cement stone as the main features should be considered a complete mechanical system that consists of protective pipe, cemented and gap formation. Increasing the pressure or temperature in the well is transferred to the first protective tube as a result of which the stresses are transferred, and the cement stone.

COMPOSITION OF TESTED CEMENT MIXTURES

The procedure of mixing the solution and the test was performed in accordance with the API Spec 10 The composition of the cement consists of a mixture of additives for the spread and the standard additives, such as additives for reducing the friction between the particles, for preventing the foaming of a cement solution, additives to control the setting time, and for controlling filtration.

List composition of cement mixtures is given in Table 1

- The following three groups of different specific density of cement-based solution of: The first group consists of a mixture of cement decreased the specific density of 1:45 to 1:55 kg/dm3 for using which indicates a growing need for application in areas where the observed occurrence of loss of circulation during cementing, lowering cement solution to curing stage after cementation and hence loss of tightness of spaces.
- The second group consists of a mixture of cement specific density of 1.70-1.90 kg/dm3 and fall in the group of medium-heavy cement mixtures. They are used in a wide range of specific density
- medium heavy cement mixture hardening spaces far beyond the production formation. The third group consists of heavy cement mixture with a specific gravity of >1.90 kg/dm3 whose use is directed to the space between the bore hole in the area of productive formations in a wide range of specific density.

CHARACTERISTICS OF CEMENT SOLUTION

Determination of rheological properties of cement solution was carried out at 77ºC (API Standard). Conventional cement-based mixtures are used for comparison purposes. In all cement mixtures using the borehole cement Dyckerhoff Class G cement. Mixtures were prepared with tap water. The additive for expansion (added to the system) is essentially the calcium oxide (CaO). Rheology of solution was measured by Fann 35 rheometer after preparation at room temperature and after conditioning for 20 minutes. Setting time of the cement mixture can be controlled and there was no separation of free water.

Rheological properties of cement solution is not interesting for these tests and are shown in Table 1 shows the mechanical properties only to highlight the significance of Young's modulus of elasticity on the stability of cement stone of various cement mixtures.

Table 1.Mechanical properties of cement mixtures composition

Cement mixture	***Aditive for extending (% by weight of cement)***	***Specific density (kg/dm3)***	***T (îC)***	***Young's modulus of elasticity (MPa)***	***Poisson ratio ¬***	***Compressive Strength (MPa)***
X1	0	1.90	77	9200		36.6
X2	0	1.45	77	449	0.142	.7
X3	2	1.45	77	2650	0.163	12.1
X5	0	1.70	77	5200	0.17	21.6
X6	3.5	1.70	77	3700	0.19	21.0
X7	0	1.90	77	9242	0.24	33.5
X8	2	1.90	77	4100	0.22	21.2

SAMPLES PREPARATION

Cement dissolved a few days to harden chamber under heat and pressure to suit well conditions. In doing so, they measured the physical and mechanical properties of hardened cement paste: Tensile strength, compressive strength, elastic properties (Young's modulus of elasticity, Poisson's ratio), permeability and volume change during hydration (expansion / contraction). All the curing are carried out at a pressure of 20.7 MPa as defined in the recommendations of the API 10b at temperature 77 ^{o}C. The samples were cured for a period of at least three days, until (almost) constant compressive strength is not achieved. At the end of this period the samples were cooled

and stored under water.
Cement slurry without the sedimentation of material with 0% of free water. Production of cement solution followed procedure ISO 10426-2, Petroleum and natural gas industries - Cements and materials for well cementing - Part 2: Testing of well cements, July 2005 cement stone samples were subjected to a sufficiently long time to reach a static heating temperature wells. Ultrasonic measurement device were performed to demonstrate when a static temperature reached. Samples of cement stone were cured in molds and then cut to the appropriate dimensions with a length to diameter of 2:1 and according to ISO 10426-2, Petroleum and natural gas industries - Cements and materials for well cementing - Part 2: Testing of well cements, July 2005 and ASTM Method C469-02, Standard test method for static modulus of elasticity and Poisson′s ratio of concrete in compression.

In all the examples, the samples had a cylindrical shape dimensions of 50.8mm diameter and 25.4mm in length. The ends of the samples had to be perpendicular to the axis (allowed deviation of <0.5 °) and align. Before the test measured the length of the sample (allowed deviation of up to 0.1 mm) diameter (allowed deviation 0.05mm). For each cement system is made as a cylindrical three samples. The test for determining the compressive strength was performed on one sample and the remaining two tests to determine Jung elastic modulus and Poisson's ratios. All samples were used for measurement of compressive strength. This means that the compressive strength is shown as the mean of the three samples and Young's modulus of elasticity and Poisson's ratio of the two samples.

TESTING RESULTS AND ANALYSIS

Types of cement mixtures with additives for expansion leads to a decrease in Young's modules in comparison with the standard Cements mixtures and therefore increase the elasticity. A wide range of Young's modules can be obtained for a given specific density. Table 1 shows the values of Young's module of 9242 MPa to 4100 MPa (mixture of cement and X7 X8), which is achieved by changing the concentration of additives to the expansion. The concentration of the additive for controlling the spread of primarily elastic properties of the cured cement (a higher concentration of higher elasticity). However, increasing the elasticity is associated with a reduction in compressive strength (Fig. 1), and must always check that the compressive strength of cement stone sufficient to ensure the stability of the casing. After cementing technical casing string required strength of cement stone to continue drilling to be 3.5 MPa and after the cementing of production casing cement stones at the interface must have a compressive strength of min. 21 MPa. This value allows you to perform perforation works and bring to production.

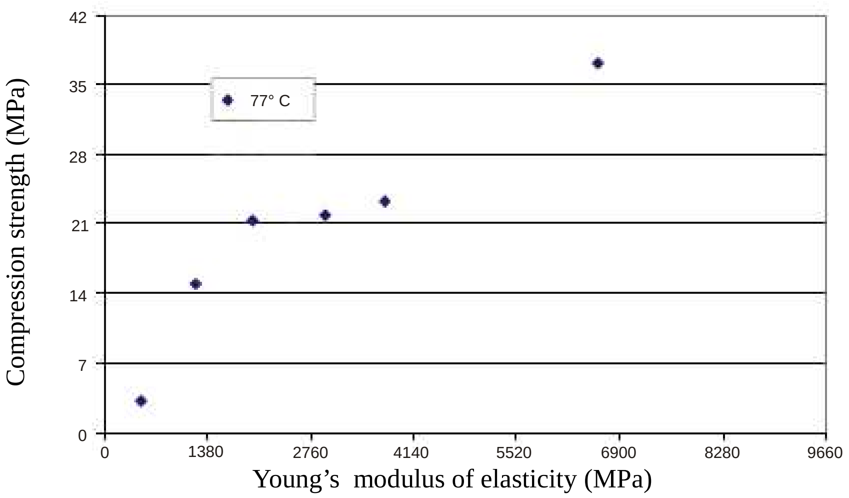

Figure 1. The compressive strength of the hardened cement paste relative to

the Young's modulus of elasticity at 77 C î

Reducing the Young's modules may be achieved by reducing the specific gravity of cement mixtures as shown in Table 1 A cement mixture of a specific gravity of 1.70 kg/dm^3 in the elasticity of the additives (X6) has a lower value of Young's modulus of elasticity than the standard density cement mixture 1.70 kg/dm^3 (cement mixture X5). The cement mixture X2 (1.45 kg/dm^3 without additives for expansion) shows very little value Young's module and an unacceptably low value of compressive strength. The elastic system (cement mixture F with specif. 1.45 kg/dm^3 density) is also of little value Young's module, but with a much higher value of compressive strength. In fact, compared to all the different systems resilient system always shows the highest value of compressive strength for a given value of Young's modules.

The value of the Poisson ratio of hardened cement stone indicates the integrity of the actual cement ties with casing and play. For this reason, efforts are being made to reach a higher value of the Poisson ratio.

CONCLUSION

Cement stone with additives for flexibility in the medium and hard formations have higher stress, while in medium hard has greater strain compared to the cement stone Class G. This indicates that the cement grout with additives for flexibility in these well conditions have favorable mechanical and elastic properties (lower value of Young's modulus of elasticity and Poisson coefficient of hardened cement Class G) affecting the preservation of stability of the protective tube - cement stone - formation, as well as the preservation of tightness of the system. Wall thickness has an important role in the transmission of tangential stresses, and thus the deformation of the cement stone. This means that the wells in which are embedded protective tube with a large wall thickness can be used cement mixture of cement stone whose value is less tensile strength and compressive strength.

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DEFORMATION AND PERMEABILITY OF CEMENT STONE OF DIFFERENT COMPOSITION IN HARD FORMATIONS

Zvonimir Bošković[1],Vladimir Čebašek[2], Sanel Nuhanović[3], Jovana Crnogorac[1]
[1] Rudarski fakultet Prijedor
[2] Rudarsko -geološki fakultet Beograd
[3] Rudarsko –geološko-građevinski fakultet Tuzla

Abstract

It is not always justified the use of cement mixtures with additives for expansion and flexibility. The wells that will not be subjected to cyclic stresses or changes in drilling conditions should be a model to analyze whether the compressive strength of cement stone enough to withstand radial, tangential stresses and deformations. If so, the standard types of cement mixtures, with a corresponding compressive strength of cement stone, provide security for the preservation of the stability of cemented spaces in the working life of the well.

INTRODUCTION

In reviewing the results of certain models of the impact of changes in drilling conditions on the strain hardened cement paste observed an increase in the tangential stress and strain hardened cement paste. The analysis included the results of tangential stress and strain at the contact protective tube - cement stone, because of both the size of its maximum value achieved at this point, while the radial stress does not exceed the value of compressive strength of cement stone. The analysis is carried out for cement stone Class A and Class A + additive for expansion, so that the computation of the most commonly used structures wells. These models are easy adapt to well construction, was the analysis of cemented space between technical column casing or production casing in a variety of geometries wells. Laboratory tests are the same as for the cement mixture in soft to medium hard formations except that ring 7mm simulated Young's modulus of 10,000 MPa. This size is typical of consolidated sands.

PERMEABILITY OF CEMENT STONE MIXTURE TYPE CLASS G

Check the stability of the cement stone in terms of annular geometry was carried out laboratory tests. Changes in the downhole conditions, it will result in the collection of, the spread was in the protective tube and may be simulated. Such tests provide an assessment of mechanical properties of hardened cement paste in the conditions prevailing in the borehole. Nature stress generated at the interface (stretching or pressure) is similar to those cement stone has to endure in real bore. The mechanical properties (elastic modulus and compressive strength) were determined on cylindrical test bodies cement stone (diameter 25.4 mm and height 50.8 mm). The solutions were prepared, cured and tested in ambient conditions. Cement solution is poured into the annular space between the simulated and the protective tube formation. Simulate the formation of a metal ring. After hardening of the cement stone, set up a system with a rubber chamber for the purpose of performance measurement bandwidth. It includes a metal ring placed on top of the cement stone and rubber chamber placed around the protective tube. The permeability to air was measured with a differential pressure of one bar, and is defined as the conductivity of the whole system. Therefore, it includes the relative permeability to air hardened cement, fracture permeability and airflow in mikroanulus. The permeability of cement stone for the test system is small and during the test period measured throughput was 0.01 mD. Mechanical damage to the cement stone is caused by an increase in pressure in the borehole (leaking testing of pipes, increase the specific gravity of drilling fluids, casing perforation, stimulation, production of gas), a large increase in temperature in the borehole (geothermal production, steam injection wells and extreme HTHP conditions) or load formation (sliding, compression, faulting ...). Unfavorable situation is in unconsolidated formations because they are not able to monitor the mechanical deformation of cement stone. In case of increase in temperature, in geothermal wells, thermal properties of the steel, cement and rocks, as well as growth temperature must be considered.

The forces generated in the cement stone have little impact on permeability in hard formations because the cement stone prevented the spread of the cracks are consequently smaller. System without additives (Class G) can withstand the strain of 45 µm.

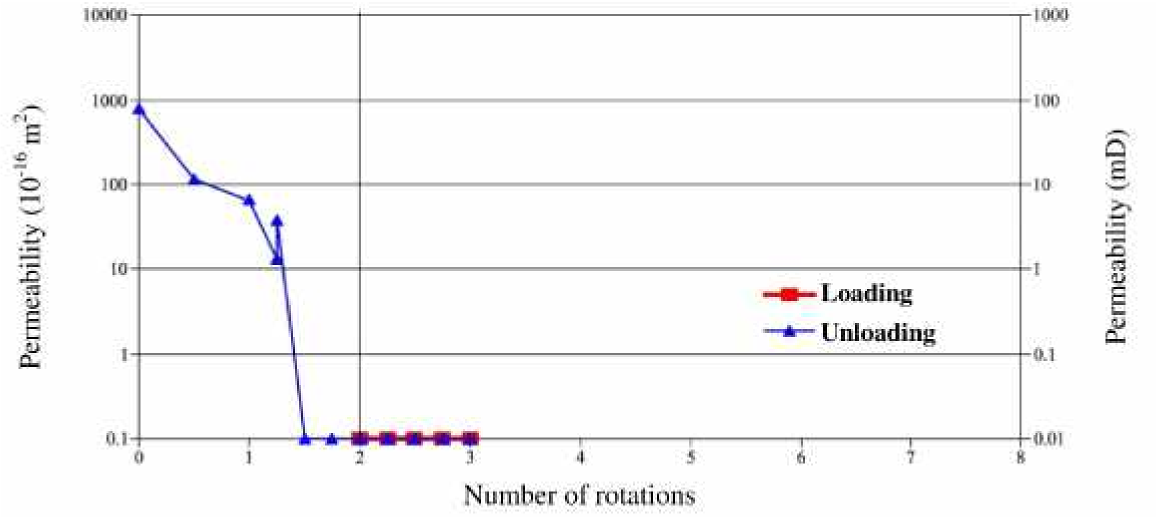

Figure 1. Permeability cement mixture type Class G depending on the load in hard formations

FINITE ELEMENT MODEL

The radial stress, tangential stress and strain are always considered for the two materials. The contemporary design and stress analysis of borehole annulus is usually performed stress-strain methods. From the stress-strain method mostly used is the finite element method. This method is performed to analyze changes of the stress state in a system of protective pipe-cement-rock formations, where the works on drilling and on the basis of defined areas where there has been a change in stress and possibly compromising stability. With this approach it is possible to determine the zone in which there is an increase of stresses and even fracture and thereby examine the influence of the system construction of the solution the casing - cement stone - the formation of stress concentration primarily in the cement stone. In this way, they can consider all the pros and cons of proposed solutions, and predict their impact on the further continuation of the drilling or performing certain operations in exploitation.

Model of the stresses in a well defined geometry of the following:

The geometry of the model

Well:diameter **215,90 mm**
depth **2800,00 m**
Casing: P – 110 (51,8 kg/m')
outer diameter **177,80 mm**
inner diameter **152,90 mm**

Cement stone: ***Class G***
Formation: ***hard***

Table 1. Physical and mechanical material properties for Mohr-Coulomb strength criteria

Materijal	***Young's module of elasticity E_e (MPa)***	***Poisson coefficient «***	***Tensile strength $\pm_t$ (MPa)***	***Angle of friction ¨ (^{o})***	***Cohesion c (MPa)***
Steel	200000	0,27	760,00	53,50	138,77
Cement stone **Class G**	9200	0,20	2,07	42,95	6,05
Formation **hard**	8960	0,29	3,00	30,00	10,50

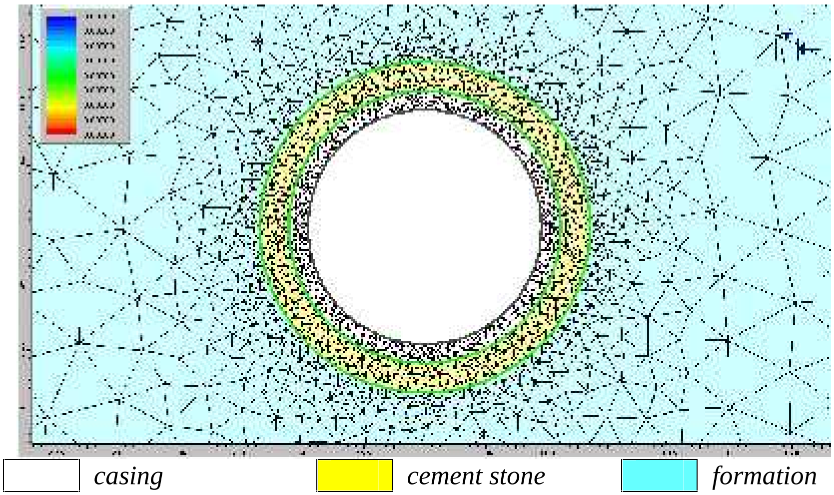

Figure 2. Well finite element model with casing 177,80 mm P-110 (51,8 kg/mà) set up to 2800m (hard formation – cement stone Class G)

Pressure in the casing P = 20 MPa

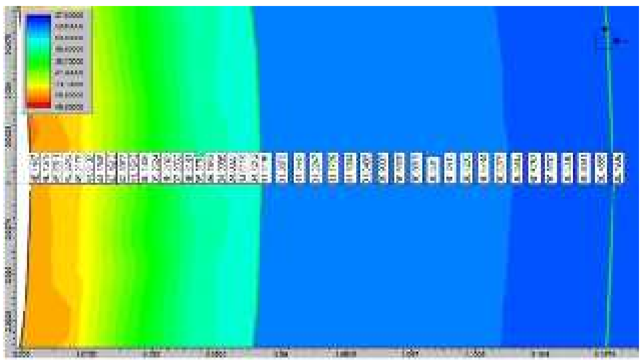

Figure 3. Tangential stress distribution ±–

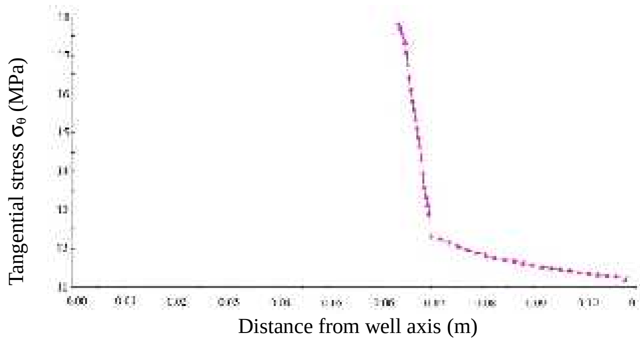

Figure 4. Diagram of tangential stress±– distribution

at cement stone

at cement stone

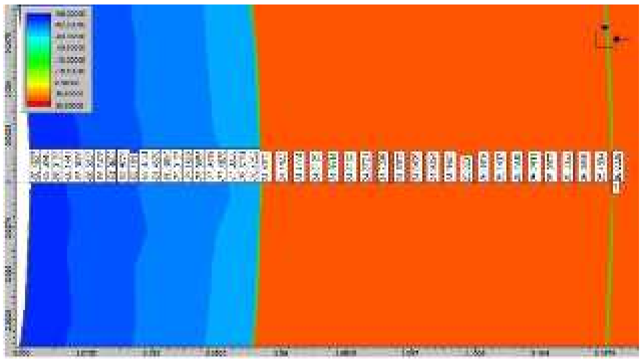

Figure 5. Radial stress ±$_r$distribution at cement stone

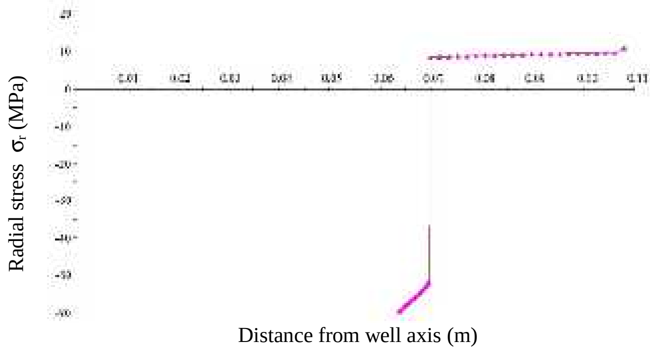

Figure 6. Diagram of radial stress ±$_r$distribution at cement stone

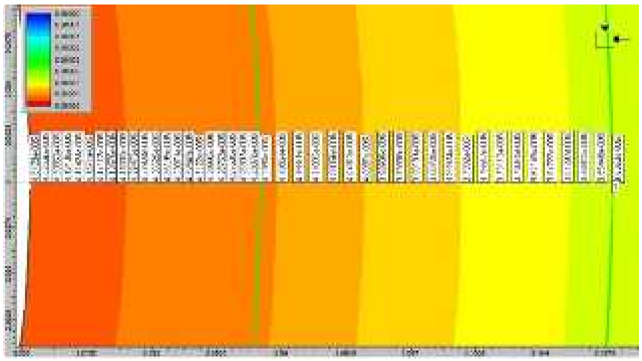

Figure 7. The distribution of deformation at cement stone

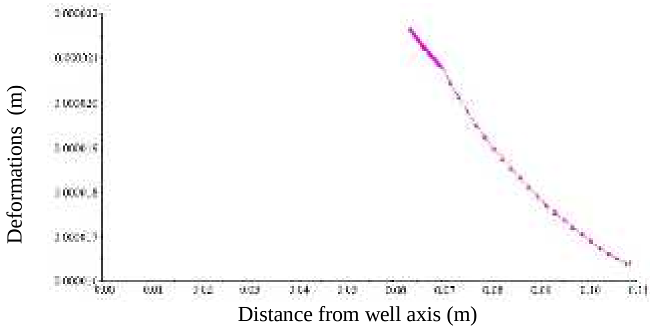

Figure 8. Diagram of deformation distribution at cement stone

LOADING CEMENT MIXTURES TYPE X2

Are shown in Figure 2 cycles of loading and unloading the cement mixture type X2. In the first cycle, the relief, the bandwidth is increased, indicating the creation mikroanulus. The cement mixture of type X2 be closed mikroanulus than 45 μm in such cramped conditions. As expected, the damage was not observed in these load conditions, with minimal bandwidth. In such cramped conditions, X2 system is less effective in closing mikroanulus indicating that the boundary conditions (formation characteristics) can significantly affect the ability of achieving tightness of a given system.

Mikroanulus was imprisoned at the relief of that system. reducing stress. At the end of the test, no cracking was observed on the surface of the hardened cement.

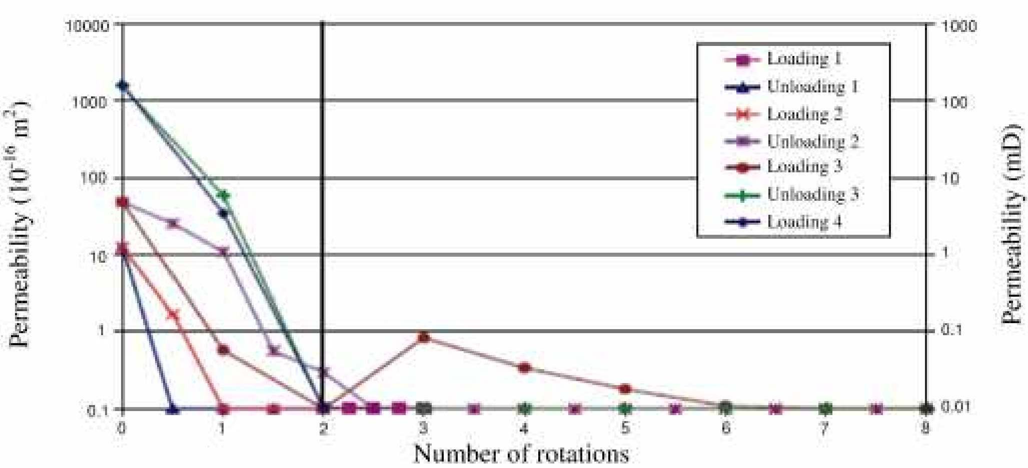

Figure 9. Permeability of the cement mixture type X2 measured depending on the load in hard formations

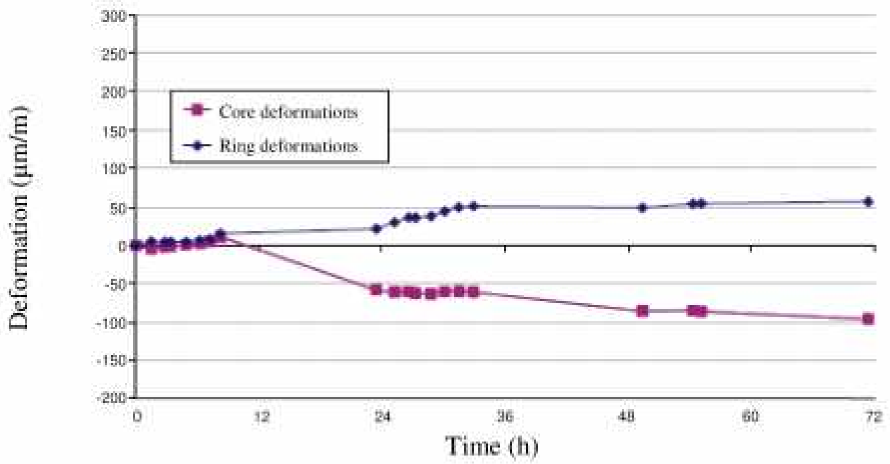

Figure 10. Deformation of the cement mixture type X2 hardening

Model of the stresses in a well defined geometry of the following:

The geometry of the model

Well:diameter ***215,90 mm*** *Cement stone:* ***with aditive for expanding***

depth ***2800,00 m***

Casing: P – 110 (51,8 kg/m') *Formation:* ***hard***

outer diameter ***177,80 mm***

inner diameter ***152,90 mm***

Table 1. Physical and mechanical material properties for Mohr-Coulomb strength criteria

Materijal	***Young's module of elasticity E_e (MPa)***	***Poisson coefficient «***	***Tensile strength ±$_t$ (MPa)***	***Angle of friction¨ (^{o})***	***Cohesion c (MPa)***
Steel	200000	0,27	760,00	53,50	138,77
Cement stone **X2**	4100	0,20	2,07	42,95	6,05
Formation **hard**	8960	0,29	3,00	30,00	10,50

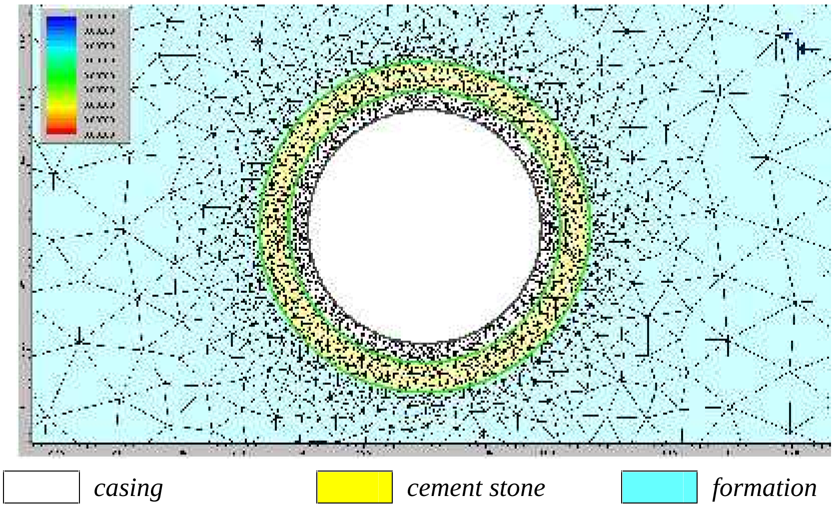

Figure 11. Well finite element model with casing 177,80 mm P-110 (51,8 kg/mà) set up to 2800m (hard formation – cement stone X2)

Presure at casing P = 20 MPa

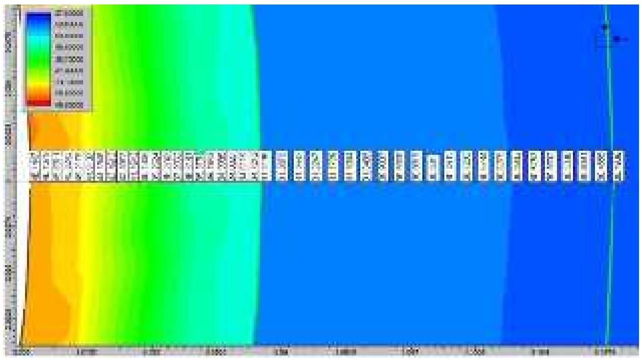

Figure 12. Tangential stress distribution ±– at cement stone

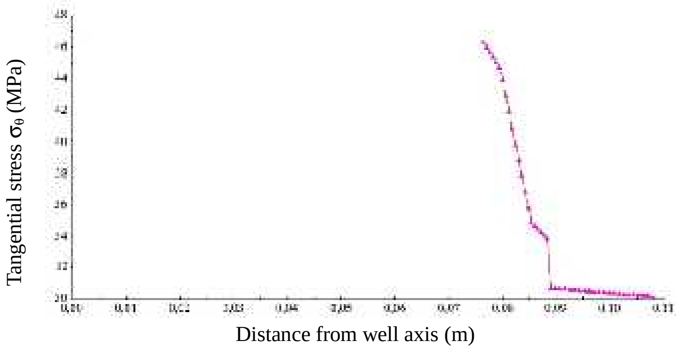

Figure 13. Diagram of tangential stress±– distribution at cement stone

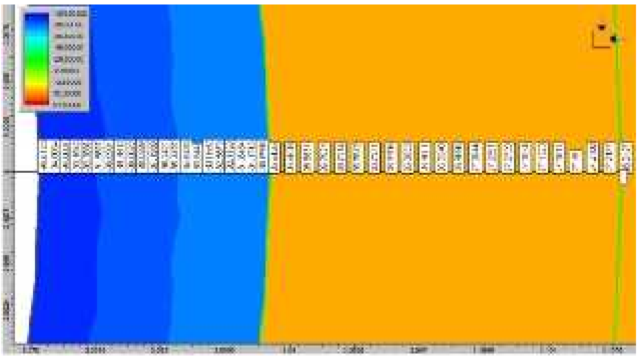

Figure 14. Radial stress ±$_r$distribution at cement stone

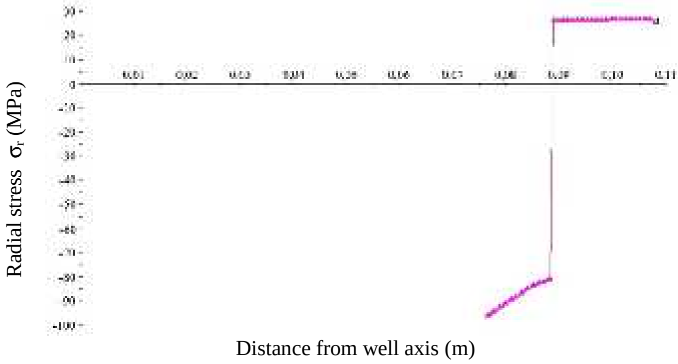

Figure 15. Diagram of radial stress ±$_r$distribution at cement stone

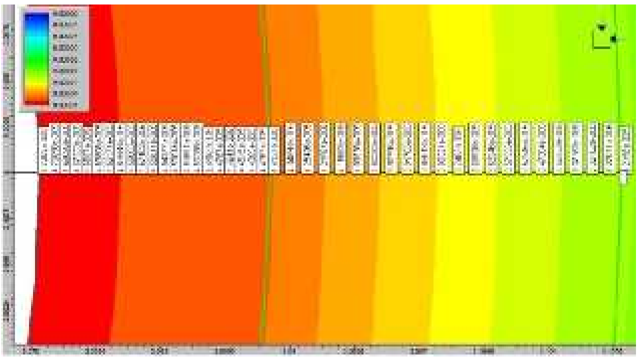

Figure 16. The distribution of deformation at cement stone

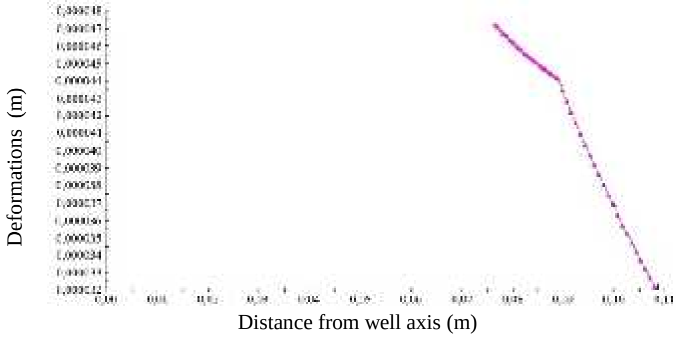

Figure 17. Diagram of deformation distribution at cement stone

General observation on the basis of the findings is that the permeability varies significantly from one loading-unloading cycles due to the formation mikroanulus. In contrast, in the permeability the spread of the central nucleus from its initial position is repeated from one cycle to the next. In case mikroanulusa, the measured throughput significantly affect the way in which creates a deformation established connection cement stone - the central core, ie. cement stone - protective casing.

In Figure 18 shows the calculated values of permeability ideal mikroanulus as function of its width. In the worst case (no closure mikroanulus) mikroanulus than 60 μm should have a permeability of 500 mD.

In most cases, the measured values of permeability were much less likely caused by the irregular shape of mikroanulus the residual layer of cement to the central core of the (protective casing). All of the tests that multiple cycles of loading and unloading there is a trend to reduce this effect (removing roughness) leading to an increase permeability.

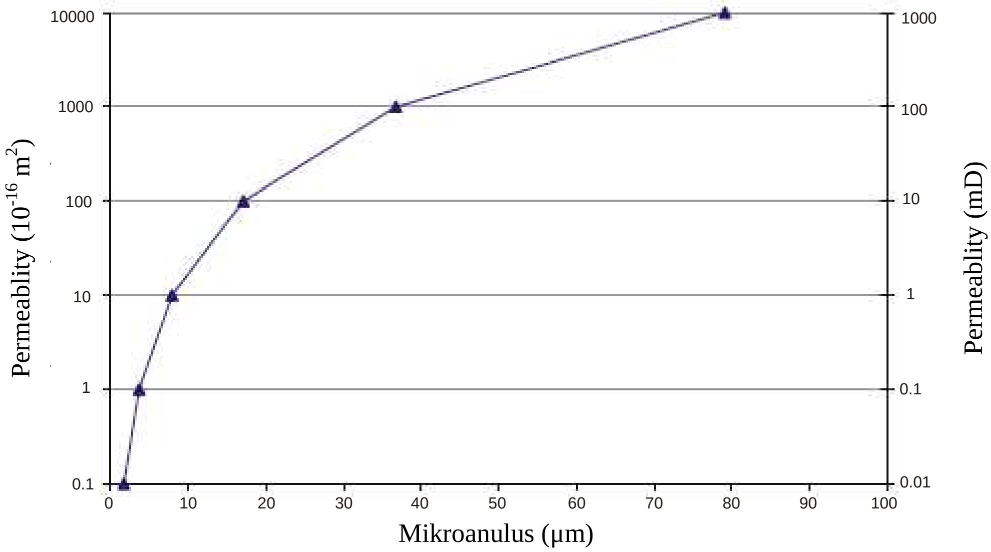

Figure 18. The ratio of the width of the bandwidth micro annulus

Tightness test cemented annulus demonstrated that the mechanical properties of the cement stone (elasticity, strength and expansion) and the formation parameters are the key features in maintaining the integrity of the cement stone during the life of the well.

EFFECT OF EXPANSION CEMENT STONE

Synergy between additives for expansion and elasticity exist and the tightness of the borehole annulus remains stable only if the cement stone is more elasticity than formation. This is achieved by the addition of additives to the elasticity of the cement mixture which reduces the Young's modulus of elasticity of hardened cement stone.

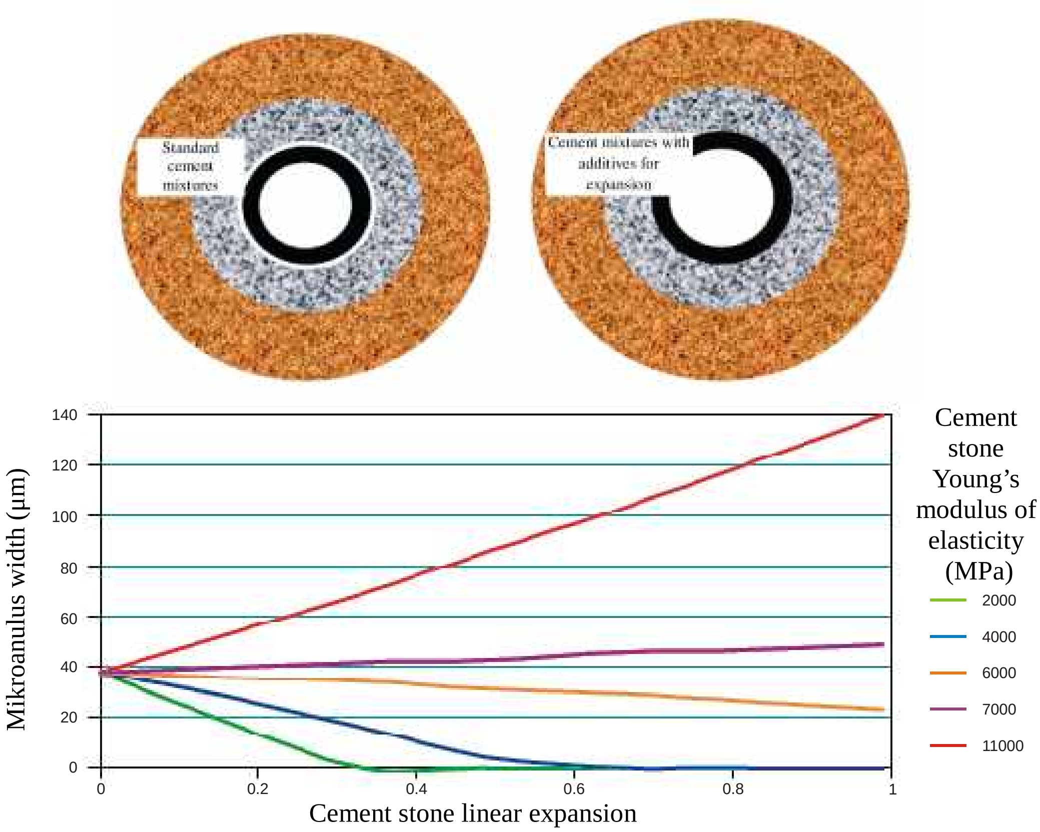

Figure 19. Schematic diagram expansion of the cement stone different values of Young's modulus of elasticity

In Figure 19 shows the results of a simulation created micro annulus between the casing and the cement stone size of 40 microns and the necessary expansion of the cement stone different Young's modulus of elasticity for closure.

CONCLUSION

Tightness test cemented annulus demonstrated that the mechanical properties of the cement stone (elasticity, strength and expansion) and the key features of the formation of parameters in maintaining the integrity of the cement stone over the life of the well.

Cement stone with lower values of Young's modulus of elasticity requires less linear expansion to prevent the occurrence of mikroanuluss than 40 microns. Cement systems containing additives for expansion is the best system to preserve tightness cemented annulus. For the case when the value of Young's modulus of elasticity of cement stone is equal to or greater than the value of Young's modulus of elasticity of the formation expanding cement stone will create an even greater mikroanulus.

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UDK:622.272/550.8.13(0.45)=20

DEFORMATION AND PERMEABILITY OF CEMENT STONE OF DIFFERENT COMPOSITION IN SOFT TO MEDIUM HARD FORMATIONS

Zvonimir Bošković[1], Vladimir Čebašek[2], Sanel Nuhanović[3], Jovana Crnogorac[1]
[1] *Rudarski fakultet Prijedor*
[2] *Rudarsko -geološki fakultet Beograd*
[3] *Rudarsko –geološko-građevinski fakultet Tuzla*

Abstract

Hemical shrinkage of cement or chemical contraction of cement is the main mechanism during the hydration of portland cement. Volume hidrirajućih components such as water and cement particles is greater than the volume of the hydration products. This refers to a contraction of volume in the interior or dry shrinkage of cement. Total chemical shrinkage can be measured by placing a solution of the cement in the reservoir immersed in water. The amount of absorbed water during the hydration of cement corresponds to the total chemical shrinkage. Such experiments often lead to erroneous estimate of the total chemical shrinkage due to the constant decrease in permeability during the hydration of cement stone, which prevents the passage of water creating a complete network of hydrates. Total chemical shrinkage is estimated at approximately 6:25 ml/100 g cement assuming 100% hydration. Additive for expansion in cement mixtures permeability of cement stone is reduced.

Introduction

Cement stone created by drilling cements must be resistant to aggressive media, and must be resistant to stress during manufacture or operation of the well, i.e.. tightness testing of pipes, stimulation operations, temperature changes during the production cycle throughout the century wells. It is necessary to analyze the mechanical behavior of cement stone of various types of cement mixtures under downhole conditions to arrive at the optimal composition of cement mixture. Different types of additives for expansion for several years. Some additives are based on calcium sulfate, sodium sulfate, calcium sulfate hemihydrate, or the creation of ettringite. These expanding cements exhibit more than ten times greater than the spread of them have a Portland cement slurry with the addition of salt. Known are also expanding cements containing calcium or magnesium oxide. The expansion of the cement in connection with the mineralogical and chemical changes that result from hydration and crystallization factors. Size of spreading depends on the concentration of additives to the expansion, the particles of cement, a cement solution and a design test conditions (pressure, temperature). The linear expansion of cement solution as measured by the mold to spread. Additions of expansion prevents the formation of internal microannulus. The expansion may be delayed for several days, even weeks. The bond between cement stone-stone formations and cement-protective tubes will therefore grow with time.

1. THE PERMEABILITY OF CEMENT STONE

The permeability of hardened cement paste was measured by water standard procedure. Disk cement paste is placed in a holder which Hassler is placed under pressure. Water is injected by constant capacity pump. When it reached a constant state recorded a corresponding differential pressure. The measured permeability is shown in Table 1.

Table 1. Permeability of cement stone

Cement mixture	*Additives for expansion*	*Spec. density (kg/dm^3)*	*Permeability (mD)*
Class G	Yes	1.89	0.0271
X2	No	1.89	0.001

2. LABORATORY TESTS

A large number of laboratory tests of cement stone is designed for a variety of well conditions with the aim of investigating the behavior of a cement stone under simulated stress in well conditions. Models damaging cement stone were determined as a function of mechanical properties of the cement stone, parameters and load conditions on a touch surfaces. Loss insulation layer can be caused by mechanical damage to the cement stone was creating microanulus the contact surface protective tube - cement stone and cement stone - formation. Certainly, the behavior of hardened cement paste depends on the specific conditions at the contact surfaces.

To ensure a long service life borehole cement stone must be mechanically and chemically resistant. Formed from API cement the cement stone is resistant to aggressive drilling fluids and must be resistant to stress during manufacture or operation of the well, i.e.. leaking testing of pipes, stimulation operations, temperature changes during the production cycle throughout the century wells. It is necessary to analyze the mechanical behavior of cement stone of various types of cement mixtures under downhole conditions to arrive at the optimal composition of the cement mixture. Check the stability of the cement stone in terms of annular geometry was carried out laboratory tests. Changes in the downhole conditions, it will result in the collection of, the spread was in the protective tube and may be simulated. Such tests provide an assessment of mechanical properties of hardened cement paste in the conditions prevailing in the borehole. Nature stress generated at the interface (stretching or pressure) is similar to those cement stone has to endure in real bore. The mechanical properties (elastic modulus and compressive strength) were determined on cylindrical test bodies cement stone (diameter 25.4 mm and height 50.8 mm). The solutions were prepared, cured and tested in ambient conditions. Cement solution is poured into the annular space between the simulated and the protective tube formation. Simulate the formation of a metal ring. After hardening of the cement stone, set up a system with a rubber chamber for the purpose of performance measurement bandwidth. It includes a metal ring placed on top of the cement stone and rubber chamber placed around the protective tube. The permeability to air was measured with a differential pressure of one bar, and is defined as the conductivity of the whole system. Therefore, it includes the relative permeability to air hardened cement, fracture permeability and airflow in mikroanulus. The permeability of cement stone for the test system is small and during the test period measured throughput was 0.01 mD.

3. LOAD CEMENT MIXTURES IN SOFT TO MEDIUM-HARD FORMATION

The thickness of the metal ring of 2 mm (soft formations) simulates a Young's modulus of elasticity of 2500 MPa formation. This value can be measured in unconsolidated sandstones.

Load Class G cement mixtures

Deformation of the core (in practice, this is an achievement pressure in protective tubes for example. Hermeticity testing with the internal pressure of protective tubes) was performed with a rotating shaft permeability coefficient remained constant and less than 0.01 mD.

At the core of relief (in practice it is relieving pressure in protective tubes) were created inside micro annulus. Permeability started to increase significantly as a result of initial connection loss (water storage) between the cement paste and the central core (casing). It has thus been observed that the surface of the core is somewhat retarded cement stone. In the second load, throughput is reduced and is a consequence of the closure micro annulus. The expansion of the central core (casing), there was a strain of cement stone. This caused the beginning of a radial crack at the moment when the tensile strength exceeded the tensile strength of cement stone.

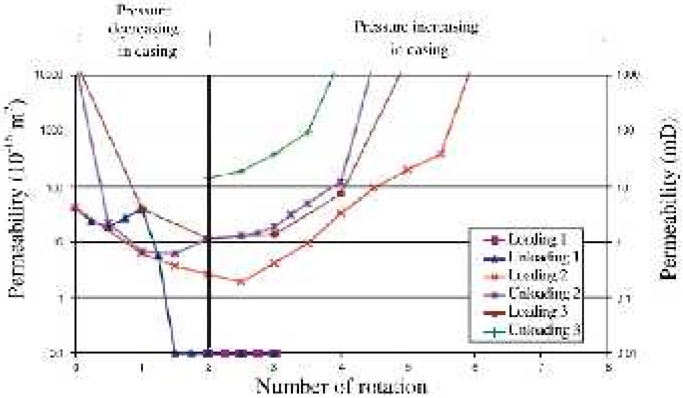


Figure 1. Permeability (air) hardened cement without additives cement mixture type X1 measured during the load of soft to medium-hard formations

Finite element model

Stress in cement stone were analyzed by Finite element model assuming that the steel, cement and stone wall are elastic materials. Also, it is assumed that the connection cement stone - casing and cement stone - the formation is good or not realized.

Model of the stresses in a well defined geometry of the following:

- ***Drilling diameter:*** ***215.9 mm***
- ***Built-exploitation protective tubes:***
  Grad: K- 55 (20.83 kg/m) up to 1100 m
- ***The inner diameter:*** ***127.3 (mm)***
- ***The outer diameter:*** ***139.7 (mm)***
- ***A collector rock:*** ***soft to medium hard***

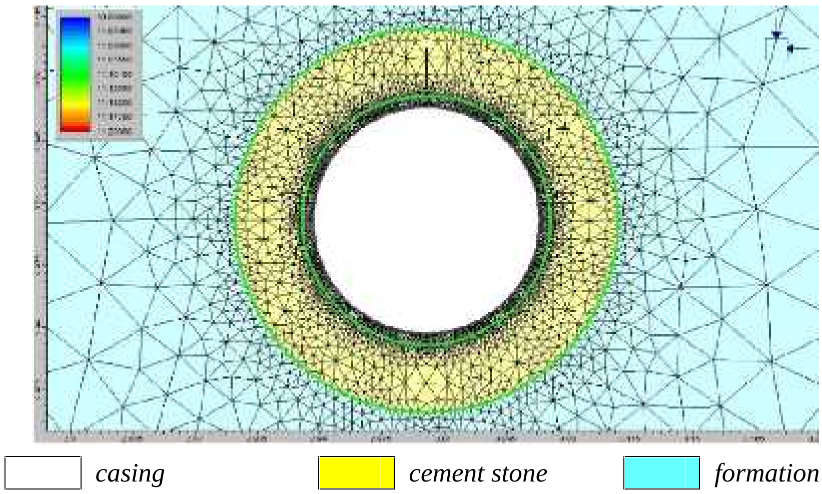


Figure 2. Well finite element model with casing 139.7 mm K-55 (20.83 kg/m') built up to 1100 m (soft to medium hard foration – cement stone Class G)

The geometry of the model

Well:diameter	***215,90 mm***	*Cement stone:*	***Class G***
depth	***1100,00 m***		
Casing: K – 55 (20,83 kg/m')		*Formation:*	***soft to medium hard***
outer diameter	***139,70 mm***		
inner diameter	***127,30 mm***		

Table 2. Physical and mechanical material properties for Mohr-Coulomb strength criteria

Materijal	***Young's module of elasticity E_e (MPa)***	***Poisson coefficient «***	***Tensile strength $\pm_t$ (MPa)***	***Angle of friction¨ (°)***	***Cohesion c (MPa)***
Steel	200000	0,27	760,00	53,50	138,77
Cement stone **Class G**	9200	0,20	2,07	42,95	6,05
Formation **Soft to medium hard**	2500	0,13	3,00	30,00	10,50

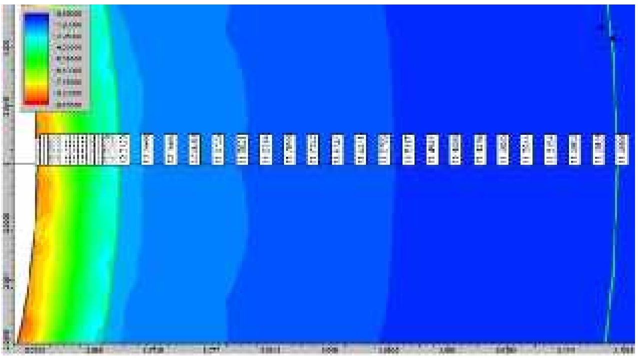


Figure 3. The distribution of the tangential stress ±– at cement stone

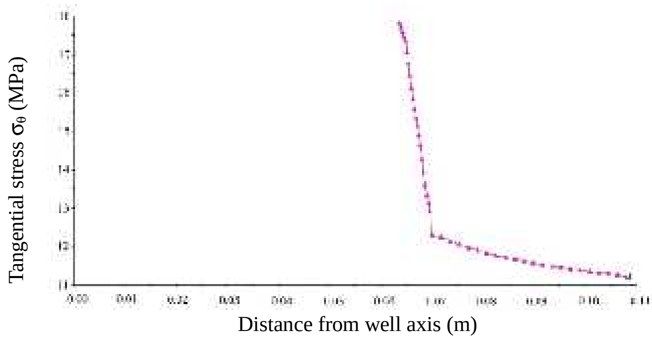


Figure 4. Diagram of tangential stress ±– distribution at cement stone

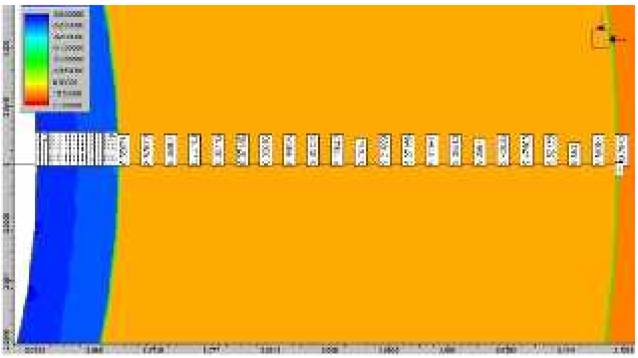


Figure 5. The distribution of the radial stress $\pm_r$ at cement stone

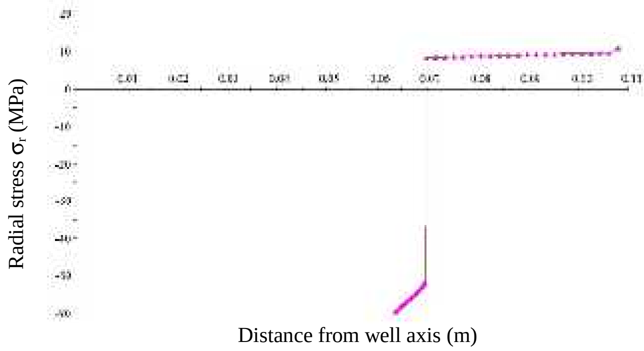


Figure 6. Diagram of radial stress $\pm_r$ distribution at cement stone

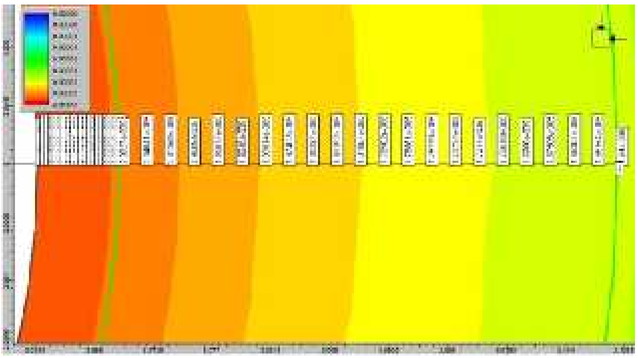


Figure 7. The distribution of deformation at cement stone

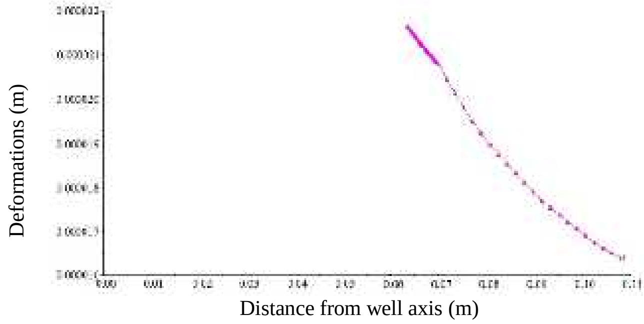


Figure 8. Diagram of deformation distribution at cement stone

Load of cement mixtures type X2

In Figure 9 shows the deformation of the central core and the outer ring during a three-day period of hardening cement stone. In a situation with no restrictions (in the environment of the borehole) expansion will be directed outward (toward formation). In the case of the limited space between the expansion and moves outwards and inwards. The outer ring of the 2-mm is less stiff than the protective tube and therefore more deformed during the expansion of the cement stone. Due to the expansion of hardened cement stone is subjected to compaction during the curing period.

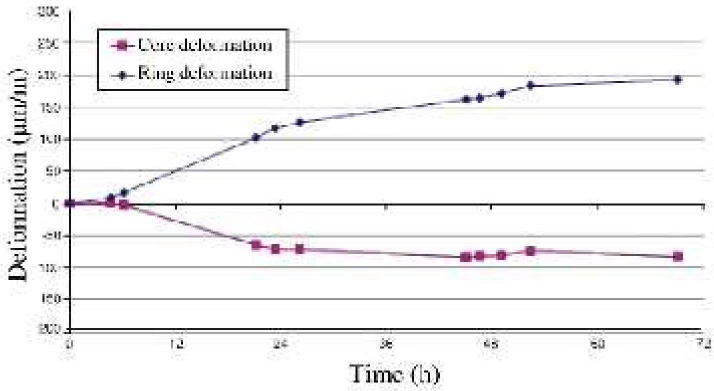


Figure 9. Deformations and casing pipe and the ring during the curing cement stone mixture type X2 in soft to medium hard formations

Shown in Figure 10 is the change of the coefficient of permeability in cement stone mixture type X2 during load cycle. Throughput is not changed during mechanical testing. The cement mixture of type X2 had the same mechanical properties as well as the X1. Part of the energy produced by the expansion was released in relief on 0 turns and thereby prevent the formation mikroanulusa. The initial compressed state allows the system X2 greater resistance to deformation than the Class A system and thus larger tensile stresses that give rise to the formation of radial cracks. During the examination of the surface of the cement were observed no cracks.

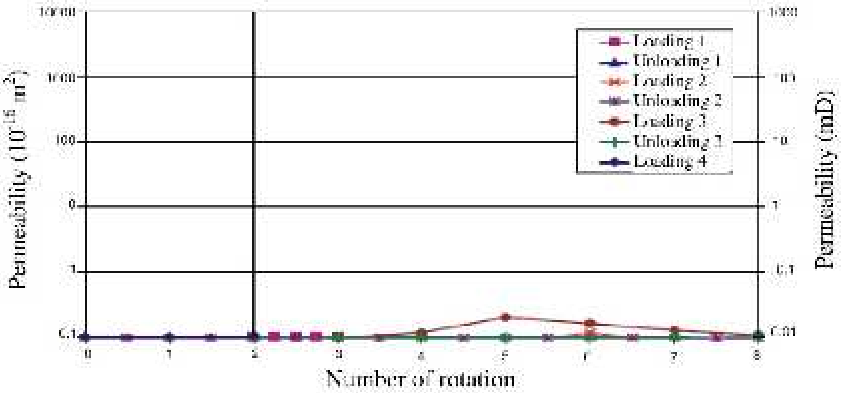


Figure 10. Change the coefficient of permeability in cement stone mixture type X2 during load testing

Finite element model

The geometry of the model

Well:diameter	***215,90 mm***	*Cement stone:*	***X2***
depth	***1100,00 m***		
Casing: K – 55 (20,83 kg/m')		*Formation:*	***soft to medium hard***
outer diameter	***139,70 mm***		
inner diameter	***127,30 mm***		

Table 3. Physical and mechanical material properties for Mohr-Coulomb strength criteria

Materijal	***Young's module of elasticity E_e (MPa)***	***Poisson coefficient «***	***Tensile strength $\pm_t$ (MPa)***	***Angle of friction¨ (°)***	***Cohesion c (MPa)***
Steel	200000	0,27	760,00	53,50	138,77
Cement stone **X2**	2600	0,20	2,07	42,95	6,05
Formation **Soft to medium hard**	1580	0,13	3,00	30,00	10,50

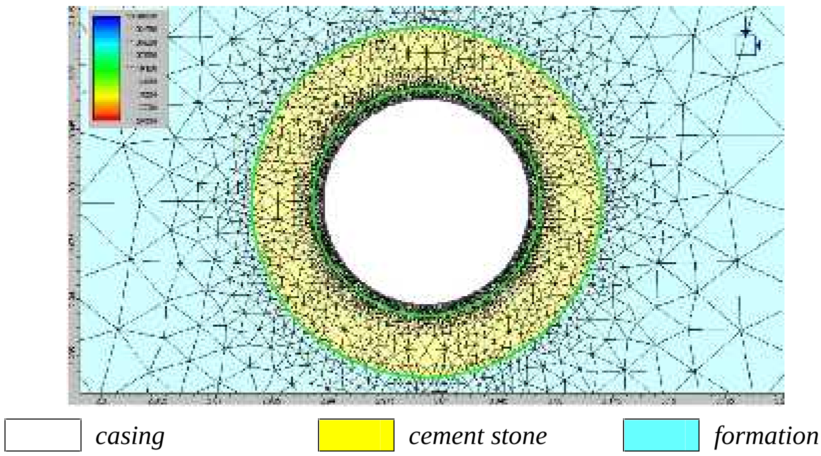
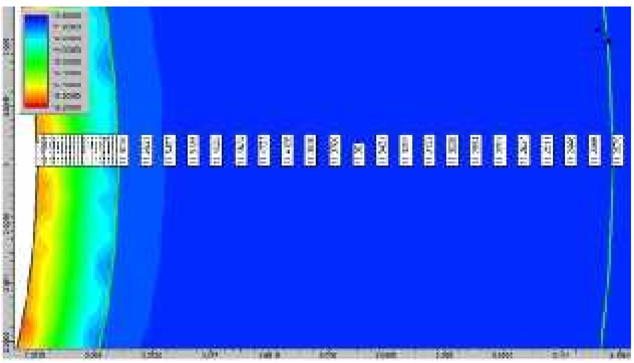


Figure 2. Well finite element model with casing 139.7 mm K-55 (20.83 kg/m') built up to 1100 m (soft to medium hard foration – cement stone X2)



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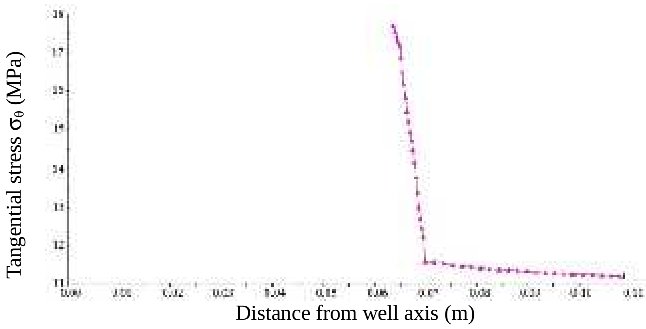


Figure 13. Diagram of tangential stress ±− distribution at cement stone

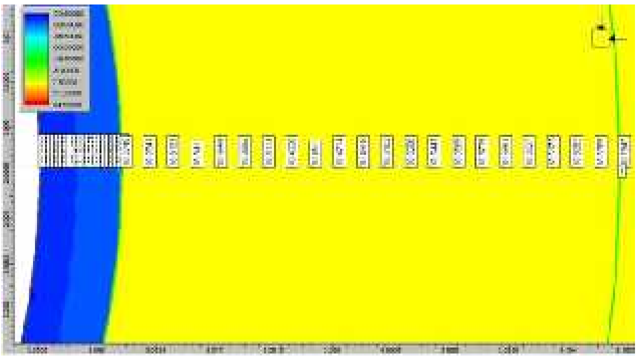
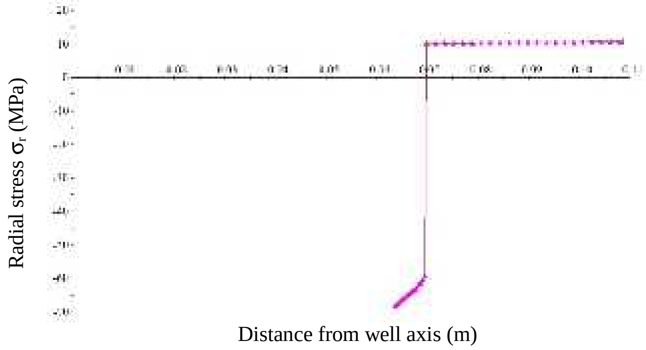


Figure 14. Radial stress $\pm_r$ distribution at cement stone



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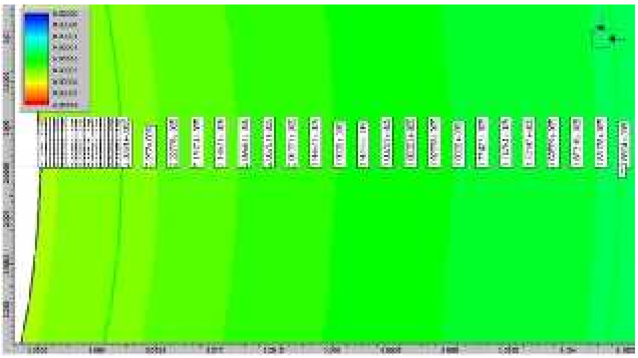

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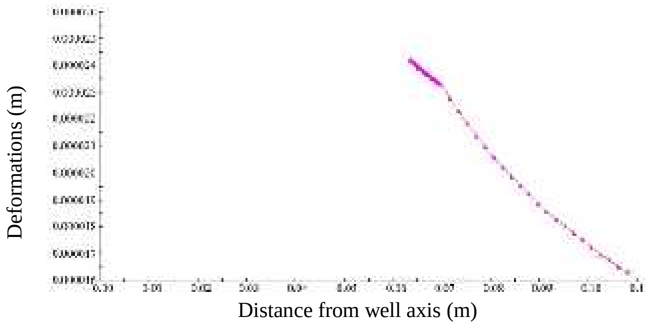

Figure 17. Diagram of deformation distribution at cement stone

4. **CONCLUSIONS**

Stress values are in linear depending on the pressure in the well, which means doubling the increase of pressure results in twice the magnification of stress in cement stone. Pictures also show that the radial stress on the pressure and the tangential tensile strength.

The highest value of the tangential stress of cement stone is at steel - cement stone contact which usually leads to distortion of actual connections. The value of the tangential stress at the contact of steel - cement stone is the tensile strength of cement stone that you must possess in order to prevent disconnection with increasing pressure in the borehole. This stress increases with increase of pressure in the borehole.

The radial stress in cement stone increases from contacting steel - cement stone to the contact cement stone - formation. This stress to the change of pressure in the well is linearly decreasing. Cement mixtures with additives to achieve the expansion of tightness cemented spaces in terms of cyclic stress wells (increasing and decreasing pressure in protective tubes

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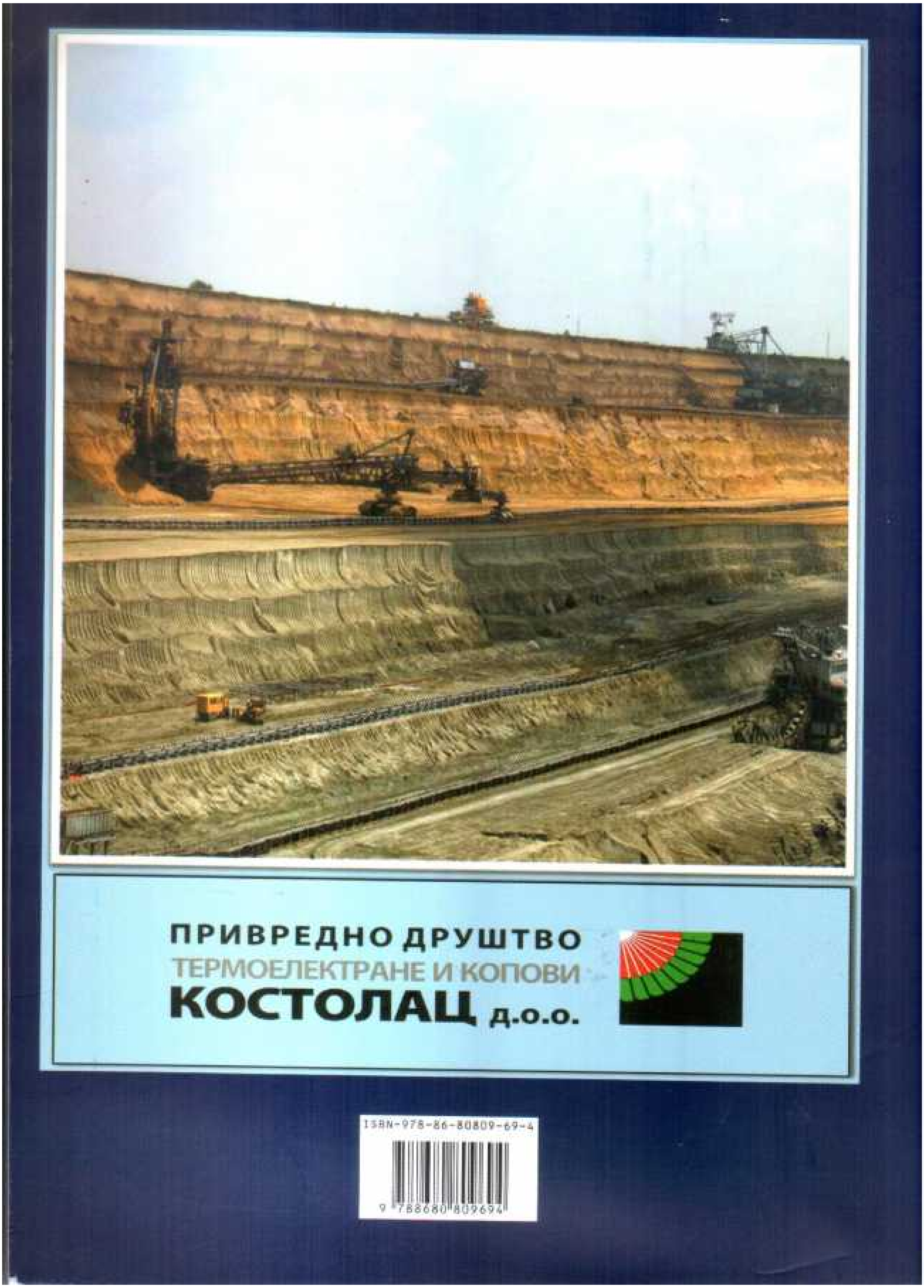
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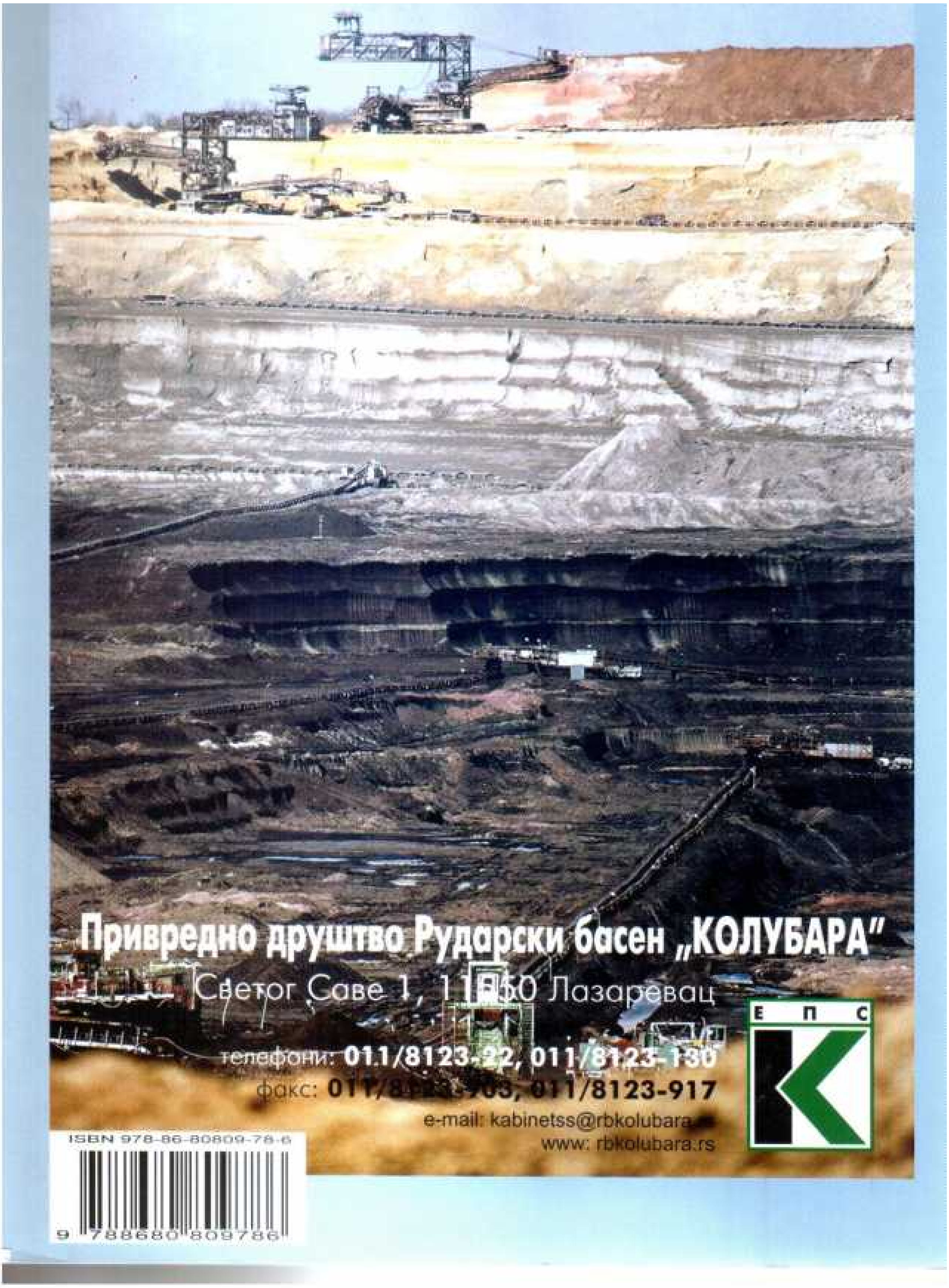

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Produktion, Lieferungen und Reparaturen der folgenden Geräte und Komponenten:

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- sohlengebundene Schienenflurbahnen,
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- Kabeltrommelwinden,
- Einschienenhängebahnteile,
- Seilbahnenantriebsteile,
- Senklader und Sohlensenklader sowie deren Komponenten,
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- hydraulische Pumpen, Motoren und Servomotoren sowie deren Teile,
- Wettersperrenbanddurchführungen für Bandförderer,
- Panzerfördererteile und Komponenten,
- Metallschneiden mit einem numerischen Plasmaschneider.

Untertagearbeiten, Vortriebsarbeiten, Vorrichtungs und Montagearbeiten:

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- Umbauten von Abbauräumen,
- Kreuzungsumbauten,
- Schachtarbeiten,
- komplexe Wandvorrichtungsarbeiten mit eigener Ausstattung,
- komplexe Förderanlagenmontage,
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- Montage von Rohrleitungen aller Art.

Zum ausführen der o.a. Arbeiten, beschäftigt Firma VACAT ca. 500 ausgebildete Untertagearbeiter zusammen mit fachmännischem Leit und Aufsichtspersonal mit durch das Bergamt bestätigten Qualifikationen.

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Die hydraulische Verankerungsmaschine VT KH-1 ist für das Bohren von Ankerlöcher mit Druckfähigkeit bis zu 150MPa im Fels oder Boden (Kohle, Schiefer und Sandstein) bestimmt, wie auch zum anbringen von Ankern in dazu vorgesehene Löcher.
Die Verankerungsmaschine ist an die Arbeit in Grubenbau, mit Bogen und Rechteckschnitt mit Längsneigung von 45° so wie von 2m bis zu 5m höhe, angepasst.
Die VT KH-1 Verankerungsmaschine kann in Räumen mit erhöhtem Methanexplosionsrisiko und/oder Kohlenstaubexplosionsgefahr als ein Gerät der I Gruppe der Kategorie M2 unter der Bedingung, dass die Wahl der elektrischen Ausrüstung an die gesetzlichen Bestimmungen angepasst werden.
Die Verankerungsmaschine kann genauso überall da genutzt werden, wo es Bedarf für eine Verankerung oder Bohrung gibt, mit Nutzungsparametern die sich im Nutzungsbereich des Gerätes bewegen.

Technische Charakteristik der Verankerungsmaschine:

Motorspeisungsdruck	- 8,0 ÷ 17,5 MPa
Servomotorspeisungsdruck	- 0 ÷ 10 MPa
Drehmoment	- 300 ÷ 370 Nm
Drehgeschwindigkeit	- 10 ÷ 475 u/min
Durchmesser des Bohrgestänges	- max Ø 42 mm
Bohrersitz	- 6kt 22
Max. Bohrtiefe	- 25 m
Bohrwinkel	- 70 ÷ 90 °
Druckkraft	- 12,5 kN
Min./ Max. Länge der Verankerungsmaschine	- 1700 / 2700 mm
Gewicht der Verankerungsmaschine (Tragrahmen)	- 90 kg

Technische Charakteristik der Stromerzeugungseinheit:

Nennstrom	- 11,5 oder 7,5 A
Elektromotor	- 7,5 kW - 500/1000 V
Tankvolumen	- 97 l
Abmessungen L/B/H:	- 830/400/400 mm

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