Міністерство освіти і науки України
Державний вищий навчальний заклад
"Національний гірничий університет"

Гірничий факультет
(факультет)

Кафедра підземної розробки родовищ
(повна назва)

ПОЯСНЮВАЛЬНА ЗАПИСКА
дипломного проекту (роботи)

магістр
(назва освітньо-кваліфікаційного рівня)

галузь знань 0503 Розробка корисних копалин
(шифр і назва галузі знань)
напрям підготовки 6.050301 Гірництво
(код і назва напряму підготовки)
спеціальність 8.05030101 Розробка родовищ та видобування
(код і назва спеціальності)
корисних копалин
освітній рівень вища освіта
(назва освітнього рівня)
кваліфікація 2147.1 Гірничий інженер, дослідник
(код і назва кваліфікації)
на тему: Обґрунтування можливості повторного використання дільничних виробок на базі дослідження напружено - деформованого стану системи «масив - кріплення» на прикладі шахти «Західно - Донбаська» ШУ «Тернівське» ПАТ «ДТЕК Павлоградвугілля»

Виконавець:
студент V курсу, групи ГРг-14м

Бердніков С.О.
(підпис) **(прізвище та ініціали)**

Керівники	Посада, прізвище, ініціали	Оцінка	Підпис
проекту	проф. Ковалевська І.А.		
розділів:			
Оглядовий	проф. Ковалевська І.А.		
Технологічний	проф. Ковалевська І.А.		
Аналітично-дослідницький	проф. Ковалевська І.А.		
Комп'ютерне моделювання	проф. Ковалевська І.А.		
Охорона праці	доц. Муха О.А.		

Рецензент	проф. Бондаренко В.І.		

Нормоконтроль	проф. Ковалевська І.А.		

Дніпропетровськ
2015

Міністерство освіти і науки України
Державний вищий навчальний заклад
"Національний гірничий університет"

ЗАТВЕРДЖЕНО:
завідувач кафедри
підземної розробки родовищ
(повна назва)
_______________ проф. Бондаренко В. І.
(підпис) (прізвище, ініціали)

«_______» ___________________ 2015 року

ЗАВДАННЯ
на виконання кваліфікаційної роботи магістра

спеціальністі 8.05030101 Розробка родовищ та видобування
(код і назва спеціальності)
корисних копалин

студенту ГРг-14м Бердніков С.О.
(група) (прізвище та ініціали)

Тема дипломної роботи Обґрунтування можливості повторного використання дільничних виробок на базі дослідження напружено - деформованого стану системи «масив - кріплення» на прикладі шахти «Західно - Донбаська» ШУ «Тернівське» ПАТ «ДТЕК Павлоградвугілля»

1 ПІДСТАВИ ДЛЯ ПРОВЕДЕННЯ РОБОТИ

Наказ ректора Державного ВНЗ "НГУ" від ________________№ ___________

2 МЕТА ТА ВИХІДНІ ДАНІ ДЛЯ ПРОВЕДЕННЯ РОБІТ

Об'єкт досліджень Напружено-деформований стан гірничого масиву для умов шахти «Західно Донбаська»
Предмет досліджень Модель гірничого масиву, виконана за допомогою програмного забезпечення Solid Works
Мета Створити модель гірничого масиву для умов шахти. Провести аналіз отриманих результатів. Зробити висновки щодо можливості повторного використання гірничих виробок в умовах шахти
Вихідні дані для проведення роботи Гірничо-геологічна характеристика масиву гірських порід; технічна документація з підприємства

3 ОЧІКУВАНІ НАУКОВІ РЕЗУЛЬТАТИ

Наукова новизна Отримані закономірності поведінки системи «масив – кріплення» на базі проведення розрахункового експерименту для умов шахти «Західно Донбаська»
Практична цінність Підвищення стійкості виробок; зменшення трудомісткості робіт. Зменшення фінансових затрат на кріплення виробок.

4 ВИМОГИ ДО РЕЗУЛЬТАТІВ ВИКОНАННЯ РОБОТИ

Результати виконаної роботи представити на базі комп'ютерного моделювання поведінки вуглевміщуючої товщі. Достовірність отриманих результатів в межах 85 – 90%

5 ЕТАПИ ВИКОНАННЯ РОБОТИ

Найменування етапів робіт	Термін виконання
Аналіз актуальності питання про повторне використання дільничних виробок	25.02.15
Аналіз методів рішення задачі геомеханіки з дослідження напружено - деформованого стану системи «масив - кріплення» при повторному використанні дільничних виробок	15.03.15
Побудова моделі структури та обґрунтування властивостей вуглевмісного породного масиву в околиці виїмкової виробки	20.04.15
Дослідження та аналіз напружено - деформованого стану системи «масив - кріплення»	27.05.15
Охорона праці	15.06.15

6 РЕАЛІЗАЦІЯ РЕЗУЛЬТАТІВ ТА ЕФЕКТИВНІСТЬ

Економічний ефект

Зменшення металоємності при кріпленні гірничих виробок, за рахунок збільшення шагу установки кріплення та використання спеціального профілю СВП-22 замість СВП-27.
Такий підхід позитивно відобразиться на економічних затратах кріплення виробок

Соціальний ефект

Полегшення умов праці за рахунок зменшення ваги спеціального профілю.

7 ДОДАТКОВІ ВИМОГИ

Дипломна робота має бути оформлена відповідно до ДСТУ 3008 – 95 "Документація. Звіти у сфері науки і техніки. Структура і правила оформлення", а також згідно з методичними рекомендаціями та вимогами до виконання дипломних робіт студентами освітньо-кваліфікаційного рівня магістра з спеціальності 8.05030101 Розробка родовищ та видобування корисних копалин (підземним способом)

Завдання видав ______________ проф. Ковалевська І.А.
(підпис) (прізвище, ініціали)

Завдання прийняв до виконання ______________ студ.Бердніков С.О.
(підпис) (прізвище, ініціали)

Дата видачі завдання: 26.01.2015 р.

Термін подання дипломної роботи до ЕК: 15.06.2015 р.

Ministry of Education and Science of Ukraine
State Higher Educational Institution
"National Mining University"

Mining faculty
(faculty)

Department of Underground Mining
(full name)

EXPLANATORY NOTE
of graduation project (work)

master
(name of educational qualification level)

branch of knowledge 0503 Mining of mineral deposits
(code and name of knowledge branch)

preparation direction 6.050301 Mining
(code and name of preparation direction)

speciality 8.05030101 Mining and extraction of mineral resources
(code and name of speciality)

educational level higher education
(name of educational level)

qualification 2147.1 Mining engineer, researcher
(code and name of qualification)

on topic: Possibilities validation of the local workings reusing based on studies stress strain state of "massif - support" system for the «Zapadno – Donbasskaya» mine, «Ternovskoe» colliery group, «DTEK Pavlogradcoal» public company

Performer:
student of V course, group GRg-14m

______ **Berdnikov S.O.**
(signature) **(surname and initials)**

Leaders	**Position, surname, initials**	**Grade**	**Signature**
of project	prof. Kovalevskaya I.A.		
of sections:			
Overview	prof. Kovalevskaya I.A.		
Technological	prof. Kovalevskaya I.A.		
Analytical and research	prof. Kovalevskaya I.A.		
Computer modeling	prof. Kovalevskaya I.A.		
Labour protection	prof. Kovalevskaya I.A.		

Reviewer	prof. Bondarenko V.I.		

Compliance assessment	prof. Kovalevskaya I.A.		

Dnipropetrovsk
2015

Ministry of Education and Science of Ukraine
State Higher Educational Institution
"National Mining University"

APPROVED:
Head of Department
of Underground Mining
(full name)
_______________ prof. Bondarenko V. I.
(signature) (surname, initials)

«_______» __________________ 2015

ASSIGNMENT
for Master's Work

speciality 8.05030101 Mining and extraction of mineral resources
(code and name of speciality)

student GRg-14m Berdnikov S.O.
(group) (surname and initials)

Topic of the thesis Possibilities validation of the local workings reusing based on studies stress strain state of "massif - support" system for the «Zapadno – Donbasskaya» mine, «Ternovskoe» colliery group, «DTEK Pavlogradcoal» public company

1 FOUNDATIONS FOR WORK PERFORMANCE

The order of Rector of State University "NMU" from ________________№ __________

2 OBJECTIVE AND INPUT DATA FOR THE WORK

Object of research The stress-strain state of rock massif for conditions of "Zapadno – Donbasskaya" mine

Subject of research A model of rock massif, created by Solid Works software

Purpose Create a model of rock mass for the conditions of mine. Perform an analysis of date from the modeling. Make a conclusion about possibility of working reusing in these conditions

Initial data for work Mining and geological characteristics of the rock mass; technical documentation from the mine for carrying out modeling of rock mass

3 EXPECTED RESEARCH RESULTS

Scientific novelty obtained regularities of behavior for the "massif – support" system, based on the computational experiment for conditions of "Zapadno Donbasskaya" mine
Practical value Reducing the complexity of work. Reducing the financial costs for fixing of workings without loss of bearing ability

4 REQUIREMENTS FOR RESULTS OF WORK PERFORMANCE

To present results of the performed work on the basis of computer modeling of the rock mass behavior. Accuracy is in limit of 85 – 90 %

5 STAGES OF WORK PERFORMANCE

Name of work stages	Deadline
Analysis of the relevance for the question of local workings reusing	25.02.15
Analysis of the methods of solving the problem for geomechanic researches of stress - strain state of "massif - support" for local workings reusing	15.03.15
Construction of the structure model and validation of the properties for the coal massif in the vicinity of the stope	20.04.15
Research and analysis of the stress - strain state of the system "massif - support"	27.05.15
Labour protection	15.06.15

6 IMPLEMENTATION OF RESULTS AND EFFICIENCY

Economic effect Decrease of metal contain in mine, by increasing installation step between arches and use special profile SVP-22 instead of the SVP-27.
This approach appears to mounting economic costs workings
Social effect Relief of work conditions by reducing the weight of the special profile.

7 ADDITIONAL REQUIREMENTS

Thesis must be designed according to GOST 3008 - 95 "Dokumentatsiya. Zvity u sferi nauky i tehniky. Struktura i pravyla oformlennya" and in accordance with methodical recommendations and requirements for the performance of degree works by students of the education and qualification level of Master from specialty 8.05030101 Deposits Development and mineral resources extract (underground mining)

Assignment issued ______________ prof. Kovalevskaya I.A.
(signature) (surname, initials)

Assignment took to perform ______________ stud. Berdnikov S.O.
(signature) (surname, initials)

Issue date of assignment: 26.01.2015
Deadline for submission of thesis: 15.06.2015

РЕФЕРАТ

Тема: Обґрунтування можливості повторного використання дільничних виробок на базі дослідження напружено - деформованого стану системи «масив - кріплення» на прикладі шахти «Західно - Донбаська» ШУ«Тернівське» ПАТ «ДТЕК Павлоградвугілля».

Дипломна робота магістра: 90 с., 24 рис., 2 табл., 27 джерел.

Об'єкт - напружено-деформований стан гірничого масиву для умов шахти «Західно Донбаська».

Предмет дослідження - модель гірничого масиву, виконана за допомогою програмного забезпечення Solid Works.

Мета роботи - створити модель гірничого масиву для умов шахти «Західно – Донбаська». Провести аналіз отриманих результатів. Зробити висновки щодо можливості повторного використання гірничих виробок в умовах шахти.

Методи дослідження – комп'ютерне моделювання, що базується на числовому математичному методі кінцевих елементів; теоретичні дослідження в області механіки гірських порід; шахтні дослідження.

Збудована модель гірничого масиву, на базі цієї моделі було проведено симуляцію гірського тиску. Проаналізовано отриманні результати, на основі яких можна зробити висновок, що запропонована система кріплення гірничої виробки задовольняє гірничо – геологічні умови шахти «Західно – Донбаська». Згідно з проведеним аналізом, доказано, що повторне використання відкотної виробки 1016 Блока №3 можливе. З використанням запропонованої системи кріплення, результат економії 25 комплектів кріплення на кожні 100 метрів.

ГІРСЬКИЙ МАСИВ, НАПРУЖЕННО – ДЕФОРМОВАНИЙ СТАН, ПРОСТОРОВЕ МОДЕЛЮВАННЯ, МЕТОД КІНЦЕВИХ ЕЛЕМЕНТІВ.

ABSTRACT

Topic of the thesis: Possibilities validation of the local workings reusing based on studies stress strain state of "massif - support" system for the «Zapadno – Donbasskaya» mine, «Ternovskoe» colliery group, «DTEK Pavlogradcoal» public company.

Master thesis: 90 p., 24 fig., 2 tables, 27 sources.

Object of research - The stress-strain state of rock massif for conditions of “Zapadno – Donbasskaya” mine.

Subject of research - A model of rock massif, created by Solid Works software.

Purpose - Create a model of rock mass for the conditions of mine. Perform an analysis of date from the modeling. Make a conclusion about possibility of working reusing in these conditions.

A model of rock massif was built; on the basis of model was conducted simulation of rock pressure. Obtained results were analyzed, concluded that the proposed system of support satisfies mining - geological conditions of the mine "Zapadno-Donbasskaya". According to the analysis, proved that reuse of haulage drift 1016, Block №3 is possible. Using the proposed support systems, result of economy is 25 supporting sets for every 100 meters.

ROCK MASSIF, STRESS - STRAINED STATE, SPATIAL MODELING, FINITE ELEMENT METHOD.

TABLE OF CONTENT

INTRODUCTION

Coal in our country is used for electricity generation, iron and steel production. Rapidly expanding its use as a technological raw material for the chemical industry. The increasing volume of coal production and reducing labor intensity of underground workings in the mines promoted by introduction high-mining mechanized complexes and road headers.

Practice has shown that even the most significant improvement in one of the processes of the mine will not increase the productivity. On the increasing of this indicator affects level of performance of all processes of the production cycle, which depends on adopted technical solutions by the process of mining, equipment and organization of work.

The main directions of development of coal mining by underground method are:

- The transition to modern schemes of opening and methods of preparation of mine fields, the progressive development of coal seams, the maximum concentration of mining and manufacturing, the use of efficient equipment;
- Development and serial production of high-performance equipment for coal mining in difficult geological conditions;
- Further development of mechanized excavation without a permanent human presence in the faces;
- The widespread introduction of machinery for mining and attaching of mining workings, remote control of work processes;
- Extension of the scope of flow technological processes, conveyor and other types of continuous transport;
- Reducing the harmful effects of industrial activity on the environment and workers.

1 ANALYSIS OF THE RELEVANCE FOR THE QUESTION OF LOCAL WORKINGS REUSING

1.1. THE EXISTING NOTIONS AND EXPERIENCE OF LOCAL WORKINGS REUSING IN THE WORLD

Worldwide, the issue of strengthening, quality improvement, and the use of combined types of support remains relevant today. There are many examples of fixing of local workings for further use. In this section I will show you below some of them.

- Experience in the application of enhance drift support on "West" mine:

During the last 10 years the development of the depth of the mine has steadily increased. In view of the growth of the depths and the consequent increasing rock pressure, the main question is control of the rock massif in the area of wall face and drift. To create a roof support designed high strength special profile used in conjunction with anchoring technology that should serve as an important factor for the stable operation of mine sites. Working areas 630 and 632 of excavation field WN 1 are on the depth of 1300 m. Yieldable steel arch support begins to function after the load exceeds a certain level and fixing drops so that the plastic deformation becomes impossible. As a result, the bearing capacity of roof support increases. Displacement elements of roof support begin in the overlap profiles interconnected with both kinematic and with force closure. Accordingly, the operational reliability of the system depends on the coupling elements and the steel quality. As for the shape of the steel profile, the special profile TH 70, manufactured by «Bochumer Eisenhutte Heintzmann GmbH und Co. KG », used during many years has well proved itself in such conditions. In all mines of RAG Company, the roof support of the profiles TH 70 erect with «standardized connections» of its elements. Resistance to displacement of standardized connections depends on the efforts in the connecting bolts of compliance nodes.

The applied force of pre-tension connecting bolts should be high enough to provide the carrying capacity of the arch, but at the same time an excessive clamping force should not prevent displacement or mutual slip of connected elements of roof support, which causes premature irreversible deformation of arch support. For reasons related to the properties of the material, the frame of mine arch support should make possible for the plastic deformations.

Therefore, they must meet the following requirements:

- a high yield stress and high strength, providing the possibility of elastic deformation;
- significant elongation at fracture (high deformability) to avoid failure of the material at high values of elongation and contraction;
- high viscosity.

However these requirements of metallurgical point of view are contradictory, because with the increase of yield strength decreases viscosity. On the "West " mine in the haulage drift of mining working 630 with high geomechanical loads, successfully applied advanced drift roof support of the type +QT630. Very extensive and expensive strain measurements clearly showed that after passing stope front of about 600 m improved drift roof supports type 630 + QT subjected considerably less deformation than drift roof support with traditional construction in the haulage drift 632. This positive result is due to increased pliability enhanced of drift support. To minimize the risk of subsequent problems of preparatory works, it is supposed to use only enhanced drift support + QT 630. *(Gluck Auf mining report, 2013 №3 p.38)*

➢ The present state of support technology in the Poland's mines:

In the Poland's coal mines typically used longwall mining combined with single drifts. To maintain continuous coal mining is important to the correct sizing of the workings. That's why in Poland are conducted various studies aimed on providing the stability of the mine workings during the life of the wall face and limiting their deformation to an acceptable level in the mines. The development of coal seams is conducted in Poland in two basins (GZW - in the South and LZW - in the East). The main type of drift support in Poland is the arch support. The basic element of such support is a frame, usually consisting of three or four Part of V - shaped profile. Roof bolting used for drift fixation in Poland, mainly in 1990. However, after two cases of caving, interest to this roof support decreased until 1999 and in 2009 the mines completely abandoned the use of roof bolting as an individual. (Figure 1)

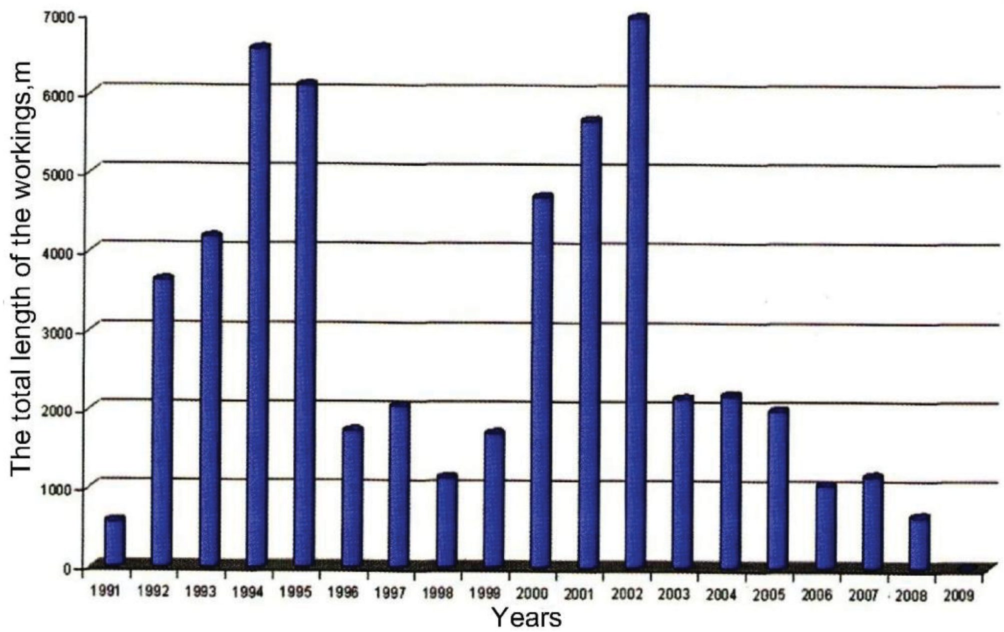

Figure 1.1. The total length of the workings, fixed by anchor support from 1991 to 2009

If necessary to enhance arch support of a drift in front of a face, in most cases used the friction pillars. Depending on what type of enhance of arch support is used; it is possible to dismantle the side sections of the arches in the conjugation zone between drift and wall face, when the drive of the conveyor is located in the drift. All used methods for enhancing arch support of workings in front and behind the face are shown in Figures 2 and 3.

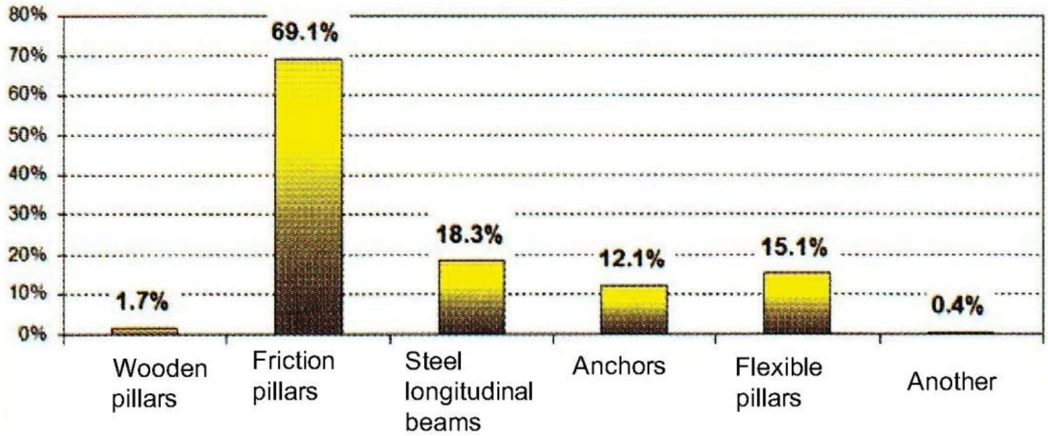

Figure 1.2. Options for enhancing of steel yielding arch support up to pass the wall face to drift in Poland's coal mines

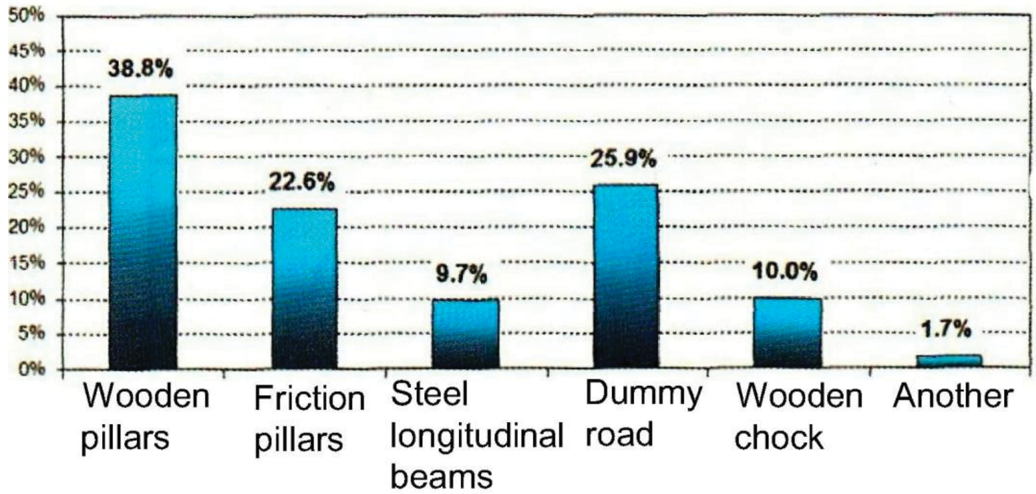

Figure 1.3. The options for strengthening of steel arch support after pass the wall face in Poland's mines

Unlike Germany, roof bolting is less common in Poland. However, the marked increase in its use mainly to strengthen the arch frames and roof rocks between frames. *(Mining report Gluck Auf, 2013, №2, p.48)*

1.2. SITUATION OF THE QUESTION AND PERSPECTIVES OF DEVELOPMENT IN UKRAINE

The issue of re-use and strengthen of local workings for the further exploitation, for the needs of the enterprise is actively developed and it is relevant up-to-date. In Ukraine, in particular, in the coal mines of Western Donbass, such as mine imeni “Geroev kosmosa”, “Blagodatnaya” and other enterprises related to «DTEK Pavlogradcoal» public company. Below are details about re-use of local workings on these mines.

- The mine imeni “Geroev Kosmosa”, maintaining of 1068 air roadway:

1068 airborne drift has roof support created by 3-tier metal arch support KSHPU-11.7, with step installation 0.8m. Length of 1068 airborne drift is equal to 2036m.

In developing the 1068 wall face, for the removing of return air from the 1068 excavation site, are performed additional works to maintain the 1068 airborne drift.

The procedure for fixing and maintenance of wall face with 1068 airborne drift is following:

Daily, workers make locks close-fitting of arch support, in front of and behind of wall face on distance of 20m. If it is necessary they replace a broken tightening and restore missing elements of fastening KSHPU support.

Two rows of 4 meter SVP-27 hang in the middle of working. Setprofile is hanged along the wall face on the distance more than 20 meters ahead of the wall face. Under a special profile sets a hydraulic prop (diameter 18-20cm) chequerwise with increments setting 1.6m (see. Fig. 1.4).

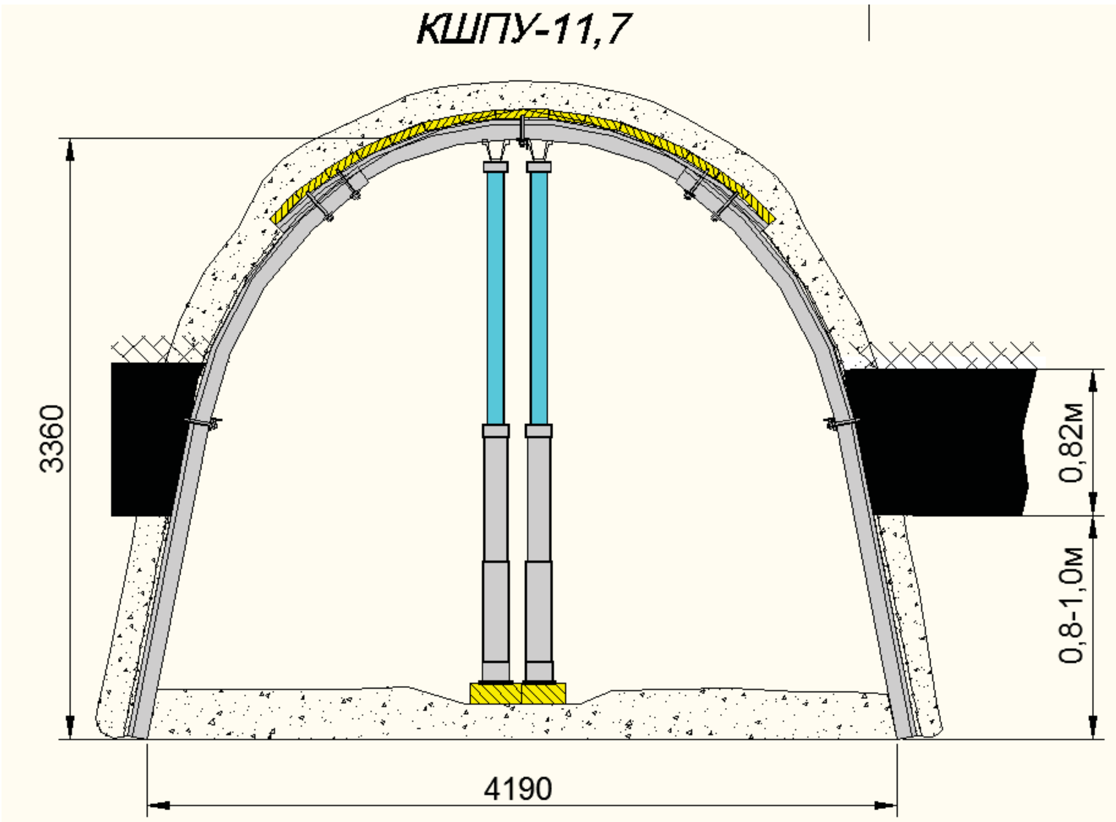

Figure 1.4. Scheme of installation of special profile in the middle of working

Before taking off the 4-meter special profile SVP-27, behind the drive under each roof bar of arch support, next to the hydraulic prop (wooden scaffold) sets a wooden prop (scaffold) with diameter 18-20cm and desired length. Removed special profile and hydraulic props from a blind part of drift set in front of the wall face. Fastening conjugation of a wall face with a supported drift crates by using three rows of bars (3.2 m) and props (diameter 12-14 cm) desired length and hydraulic props.

A single row of bars hangs parallel to the first section of air drift; the second row of bars hangs on the distance not more than 0.7 m after the first row, the third row of bars hangs on the distance not more than 0.7 m after the second row. The distance between the last section and the brow of the drift is 1.7 to 2.3 m.

Under the first row of bars installed parallel to the first section, continuously set wooden racks, keeping the undercarriage compartment and pass into the wall face. At the end of the beam, which is put on the section along the longwall face, sets the rack on the ground of the drift. Support with size 1.3 x 1.3 m with a step of 0.3 m is installed along the brow of the drift, under the second row of the coupled bars hanged parallel to the first row of the air drift sections. Wooden racks are installed under a bar (through one) which lies on the section. Additionally, wooden racks (diameter of 16-18 cm) are installed under the third row of bars. Racks of support from the goaf side are restored and fixed by wooden tightening with the rock backfill of the space between the chock support and the tightening side of the drift. In addition, hydraulic props, installed under a bar on the edge of the drift, are removed in front of the conveyor and installed behind him.

The penultimate section is moved after stopping the shearer on the kerf sections, and then poured out and on it by one end (along the wall face) is installed bar (length 3,8m), and the second end of the bar is installed on the third row of bars, fixed by hydraulic props on the edge of the drift (in the roof).

As the distance between the last section and the edge of the drift is 1.7 - 2.3 m, because of it, additionally, between the bars, stacked on a section (along the wall face) placed another bar (length 3.8 m) to secure the first section. One end of the bar is stacked on a penultimate section, and the second end of the bar is stacked on the second row of bars, fixed by hydraulic props on the edge of the drift. After this, the section is pumped up.

These operations are performed by two face workers: one of them is on the drift, and delivers bar into the wall face, and the second one is under the first (last) mechanized support unit – sets the end of the bar on the second mechanized support unit.

Then move the first mechanized support unit, poured out and on it one end is stacked board (thickness not less than 40mm), and the second end is stacked on the bar, fixed by props on the edge of drift (in the roof). Thus, the board is between the bars, located on the second section. After the second moving of drive of the longwall conveyor, fastening is produced in a similar manner.

A special profile SVP (length L = 1.6 m) sets after moving of support gain (outstripped support of the 4 meter special profile) under roof bar of KSHPU support. Wooden racks ("scaffold» Ø18-20 cm) set on the ground of working under a special profile on both sides of the drift. Run of the special profile SVP and scaffold are installed for gain support (outstripping support), with a lag of no more than 3.2 m (see. Fig. 1.5).

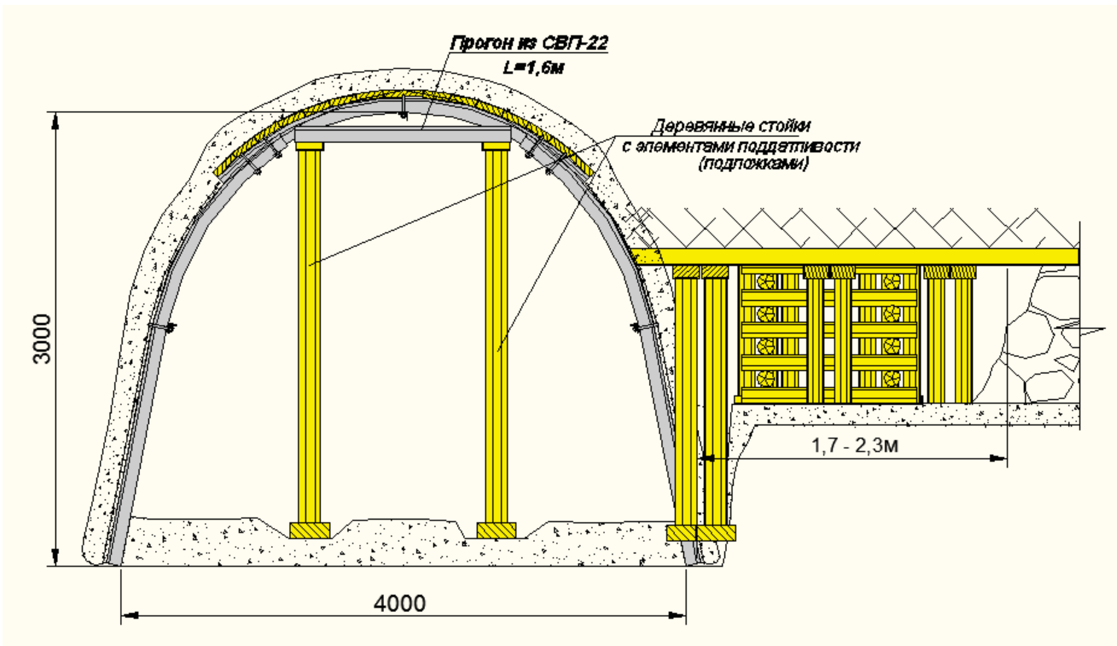

Figure 1.5. Installation scheme of special profile after outstripping support

Hydraulic props ("scaffolds"), installed on the drifts must be reliably tied to the top of the special profile or to roof support.

Supporting works of air drift 1068 during all length were conducted in the zone of inelastic deformation, in a zone of high risk from previously developed coal seam C_{11} within which the coal seam and enclosing fractured rocks are unstable and prone to sudden collapse. Before performing of supporting works for the air drift 1068 in the risky zone are performed following activities:

- produce daily close-fitting staples of interlocks at a minimum distance 20 m ahead of the wall face;
- restore the missing staples and nodes between supporting frames;
- replace the broken and restore the missing tokes;
- daily workers inspect and replace broken wooden racks (scaffold), installed under the SVP run on both sides of working;

The remaining operations are performed according to "Chart of excavation site 1068".

Due to the intensive rock swelling on airborne drift 1068 after passage of wall face to perform supporting works of working and bring it into the chart state is used dinting machine EL 160LS. Footwalling is performed over the entire width of the supported air drift 1068 on the value of daily moving of wall face.

The first step is footwalling after the conveyor drive SP-251 from the mounting side of drift with rocks shipping on the undercarriage side of the drift (from the wall face). The footwalling performs to a depth of 0,2-0,5 m on the value of the daily moving of the wall face.

The second step is footwalling from the undercarriage side of working. The footwalling performs to a depth of 0,2-0,5 m. The footwalling and loading the rock mass on the chain conveyor is performed in divided steps, at the same time is performed shunting operations of the dinting machine EL 160 LS.

- The mine "Blagodatnaya". Supporting of 145 haulage and 145 air drifts:

Haulage and air drifts are supported by roof bolting and frame support. Frame support consist of KSHPU -11.7 frames (step installation is 1.0 m), anchors are installed in gaps between frames of arch support. The roof and the boards are fixed by metal mesh.

Supporting and protecting of the drifts include the following activities:

- the daily close-fitting screw connections of the metal elements of arch support of at least 10 m on either sides from the wall face;

- fastening conjugation of wall face with 145 haulage and air drifts are performed by strengthen support consisted of hydraulic props (wooden racks d = 16-22 cm) installed on bars under the metal beams of the SVP - 22 (27). The beam should pick up at least 2 frames of arch support with full fastening in both sides of the conjugation of preparatory working with the wall face (see. Fig. 1.6). Beams of strengthen support represent pieces of SVP - 22 (27) (length of 3.5 - 4 m) interconnected overlapping by using 2 shackles M-24. The length of the lock not less than 400 mm;

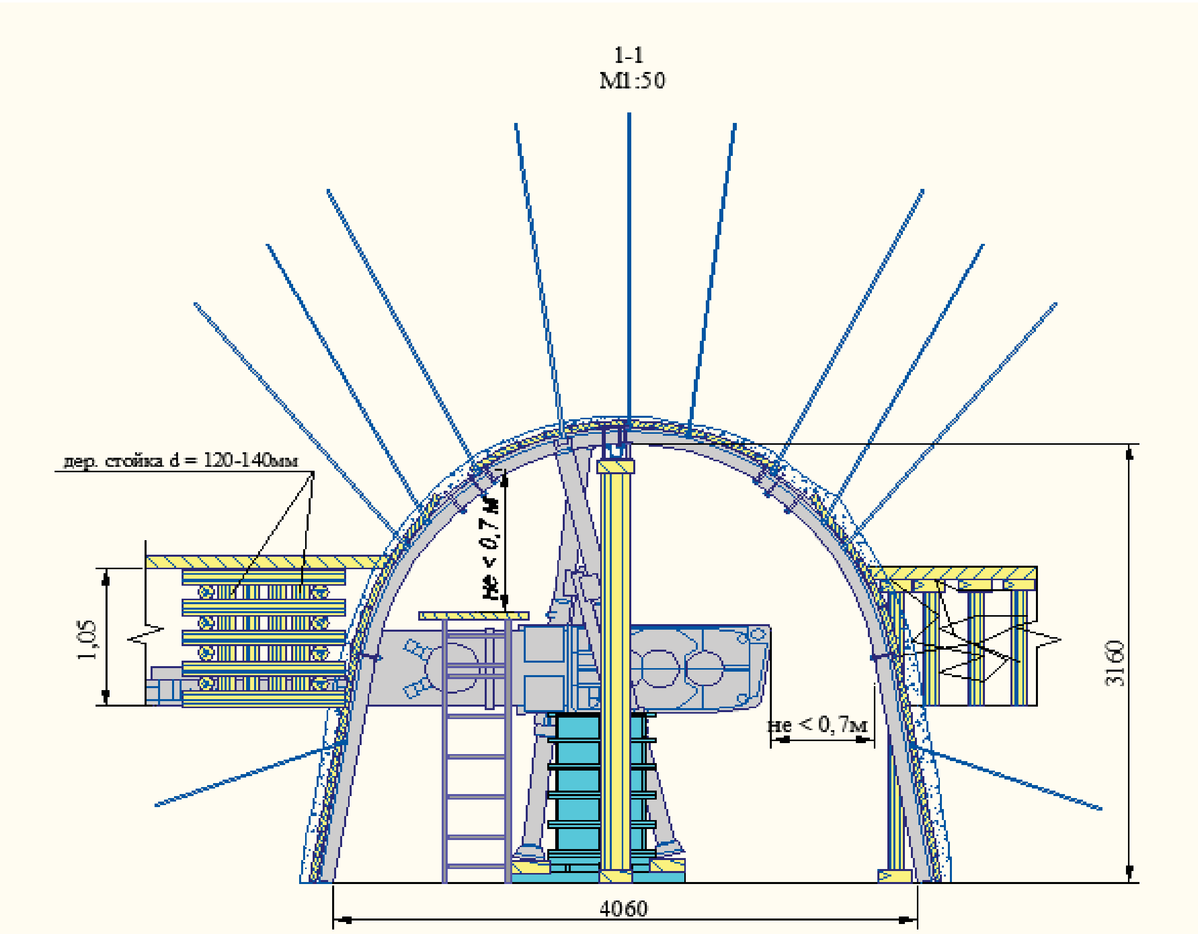

Figure 1.6. Installation scheme of enhancing fastening

- The beam is fasted to roof bars by locks with extra-long staples, the space between the chamber beam and roof bars of arch support carefully wedged by timber (segments of boards or beams);

- the strengthen outstripping support is installed on the axis of the drifts with outstripping of wall face not less than 20 m. Outstripping support is a set of hydraulic or wooden racks (d = 16 – 22 cm) with elements of pliability, installed by the pieces of the SVP – 22 (27). The upper part of hydraulic or wooden racks should be fixed to roof bars of arch support by chain segments or another material.

After moving of face conveyor drive along haulage drift is performed:

- restore the frame of arch support from the side of wall face;

- install four rows of breaker props under the bars in goaf part of the wall face, along a section for fixing the wall face. Racks are installed on the lounger of the bar segments;

Installing the polygonal support is performed in the first shift. Backlog of polygonal support should not exceed the daily moving of wall face. In the mining shifts, after moving of conveyor drive, performed installation of wooden racks in goaf of the wall face (diameter more than 16 cm) under roof bars of the arch support.

After moving of face conveyor drive along air drift is performed:

- restore the frame of arch support from the side of wall face;

- installation of chock support under bars in goaf part of wall face, along mechanized support unit for fastening of wall face;

- in locks of arch support are installed wooden wedges;

- soli cleaning of drift up to the project level is performed manually with loading on loader in front of and behind of drive;

- in the deformation zone of arch support (tilt, twist, gust locks, break elements, excessive drawdown, etc.) is performed an immediate recovery.

- reducing the pipeline before the wall face and restore it after the passage of wall face. *(information was taken from the mine imeni "Geroev Kosmosa")*

1.3. SETTING OF GOAL AND FORMULATION OF THE RESEARCH PROBLEMS

The purpose of this diploma project is:

- a description of the main stages of the practical implementation of the finite element method;

- description of the factors which are affecting on the accuracy of the results of the finite element method;

- A description of finite - element model for system "Massif - support";

- create a model of the structure and properties validation of coal mass in the vicinity of the wall face;

- analyze the stress - strain state of the system "Massif - support".

1.4. CONCLUSION

As we can see, reuse drifts actively developed both in Ukraine and in Europe. The trend of development direction on extending the life of mines until the closure of the mines. Re-supported drifts are used for various purposes of mines: ventilation, transportation, developing the next wall faces.

According to the goals and tasks will be carried analysis, description and modeling of the rock mass for the conditions of "Zapadno Donbasskaya" mine.

2 ANALYSIS OF THE METHODS OF SOLVING THE PROBLEM FOR GEOMECHANIC RESEARCHES OF STRESS - STRAIN STATE OF "MASSIF - SUPPORT" FOR LOCAL WORKINGS REUSING

2.1. VALIDATION OF THE APPLICABILITY OF COMPUTATIONAL EXPERIMENT FOR SOLVING PROBLEMS OF GEOMECHANIC

Growth of knowledge volume and the depth of physical phenomena notion have led to necessity of more complicated model which describes not only objects but also processes. Mathematical modeling became a unique approach in this case. Mathematical model – a model of a real object or process based on a system of mathematical equations, which describe certain process or object. Computational model – math model realized by means of computer resources. If the state of described model is changing in time, models are called dynamic, in other case – static.

Originally, mathematics elements have appeared in order to solve practical problems: changes in terrain, navigation etc. As a result, the math was numerical – its goal was to obtain solution in a numerical form. Numerical solution of applied problems has always been the object of interest of mathematicians. Foremost mathematicians of the past were combining in their research natural phenomenon, obtaining of its math description and its research. Analysis of complicated models required implementation of problem solving numerical methods. Some of them are methods of Newton, Euler, Lobachevskiy, Gauss, Chebishev, Hermit. As you can see, these methods were developed by the greatest scientists.

Computational experiment – method of object or physical processes research using mathematical modeling. It supposes that after construction of math model there is numerical research conducted. It allows to determine behavior of researched system in different conditions or in different modifications. Numerical research of a model allows determining the variety of process characteristics, optimizing constructions and modes of projected devices functioning. Some new processes and properties, which were unknown, are sometimes discovered during computational experiment.

Rock mechanics, studying mainly big objects, uses modeling which is connected with decrease of object absolute sizes. There are two main kinds of modeling, according to their principles: physical and analytical.

Physical – recreates the same physical fields in the model which act for the real object. But their absolute value is changed in accordance with accepted scale.

Analog – switches one physical field in the model for another. For example natural mechanical stress field is replaced by electrical field in the model. Mathematical approximation of the main laws and differential equation fitness describing these processes is used.

Meanwhile it is not always possible to recreate all the details of modeled objects, that is why modeling allows to study processes with certain grade of simplification and schematization of real objects. Generally, with solving of rock mechanics problems using modeling methods, model line with different scales is being tested.

2.2. THE MAIN STAGES OF THE PRACTICAL REALIZATION OF THE FINITE ELEMENT METHOD

The essence of the finite element method (FEM) is that any continuous value can be described by a model consisting of individual sections. At each of these sections investigated continuous value approximates, this is a continuous function, which is built on the values of the studied continuous quantities in a finite number of points for each section.

Typically, the constructions of the discrete models of continuous quantity are performed as follows: first - the area of continuous quantity is divided into a finite number of subareas, called elements. These elements have common nodes and collectively approximate the shape of an area; second - in considered area is fixed finite number of points. These points are called nodular points or just nodes; thirdly - the value of continuous quantities in each node initially is assumed known, but it should be remembered that these values are in fact will be determined by imposing additional restrictions on them, depending on the physical nature of the problem; fourthly – by using continuous values of the investigated quantities at the nodal points and a particular approximating function, determine the value of the study value in the computational area.

The approximating functions are usually chosen as linear, quadratic or cubic polynomial. For each element should be chosen a polynomial, but polynomials are selected in such a way that would preserve the continuity of the value along the borders of the element. This polynomial, associated with this element, is called "member functions".

Solution of the problem of geomechanics using FEM is reduced to perform the following basic steps:

- The first - a generalized statement of the problem (type of solution, a general view of the model of considered load, etc.);
- the second - the creation of the geometry model suitable for use of FEM;
- the third - the creation of finite element mesh for the construction of the geometry;
- the fourth - the application to the geometric model of boundary conditions (fixed to the border or boundary load);
- the fifth - the numerical solution of the system;

- the sixth - the analysis of the results.

From the first to the fourth steps of solving the problem, the fifth and sixth are preprocessing stage.

The constructed model is divided into finite elements rather simple form. There are some typical forms of finite elements in which the displacement field is determined by the displacement of nodes using some interpolation functions. According to the thus displacements are defined stress and strain fields.

During the fifth stage (the numerical solution of the system) is created and solved by numerical methods the system of equations caused by the physical model of the environment which is chosen in the first phase. With proper formulation of the problem and adequately given boundary conditions, this step does not require the intervention of the researcher during the computation.

Analysis of the results of calculations (the sixth stage) is a process of using a set of visualization tools to represent in a convenient form of the results. As a rule, for the presentation of results are used flat and three-dimensional diagrams of the distribution of stresses and strains, vector fields, measurement graph of controlled values at selected points. Often to analyze process associated with time, create animation clips, while viewing that can easily perform the analysis of one or another component in the test of time. Given that the finite - element tasks have unidentified moving in the nodes and in three-dimensional tasks, each node of tetragonal element has three degrees of freedom, the equilibrium system of type $R_1+R_2+F=0$ for simple tasks acquires the dimension which can be a million or more. This system of equations can be solved only with the use of powerful computational tools.

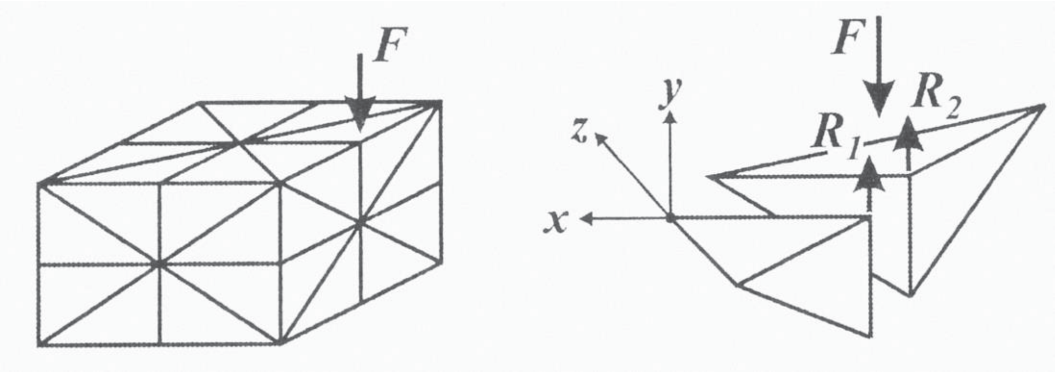

Figure 2.1. Example of the finite - element area for which: F - an external force; R_1 and R_2 - reaction forces in the nodes the finite element; x, y, z - the degree of freedom in a single node of a finite element

In drawing up the equilibrium equation takes into account that the sum of the projections of all forces on each of the axes is equal to zero and the sum of the internal forces is equal to the external force with the opposite sign. In the three-dimensional tasks, the number of nodes is usually greater than the number of elements and the number of degrees of freedom in three times greater than number of nodes. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 6-8)

2.3. FACTORS, WHICH ARE AFFECTING ON THE ACCURACY OF THE RESULTS OBTAINED BY FINITE ELEMENT METHOD

Any model that is used in calculations of numerical methods requires a certain idealization of the real object. Therefore, despite of the development of computer technology, the results of calculations by finite element method are not free of errors. The use of computer technology as a "black box", without understanding the basic steps and calculation process often leads to significant errors. A separate group of errors are errors of object descriptions that arise at the stage of data input to the computing environment. In formulating the problem, it’s possible to minimize input errors to the model by selecting the following parameters: the physical character of the task; the optimal description of the individual parts of the calculation area; adequate conditions to simplify the real object to the calculation model.

Errors can occur at various stages of implementation of the finite element method: the formulation of the problem; the discretization of area; the numerical solution.

Errors of formulation of the task may occur when the selected type of finite elements or the size does not correspond to the real physical behavior of the object material. However, the main source of errors in the formulation of the task is the incorrect boundary conditions. Incorrect assignment of boundary conditions leads to a distortion of the distribution of stresses and strains throughout the volume of the computational area. Thus, the success of computer simulation using the FEM depends on accuracy of reproduction boundary conditions of the model, the geometry and the material properties of the real object.

Discretization errors occur when replacing the real geometry by limited number of finite elements. The lack of total estimated units leads to impossibility of combine them with all singular points which are present in the geometry of the real object. In some cases, the small dimension of the finite elements used for the description of complex geometry can cause distortion in the distribution of displacements on such contour.

The errors associated with the numerical solution of equations are usually not amenable to direct analysis and therefore less noticeable. When performing calculation of the FEM, the unknowns are displacement in the selected node, and the result of the calculation is the displacement vector of a particular node. After approximation, within the finite element, the displacement field corresponding polynomial-called "shape function" can be calculated strain and stress.

This scheme computation shows that the highest calculation accuracy is achieved by determining the displacements in the node. The deformations are calculated by differentiating the corresponding displacements; therefore the maximum accuracy calculation of strain and stress is at the center of the finite element.

When performing non-linear analysis influencing of the type and number of finite element accuracy of calculation is nonlinear character causes by features redistribution of stresses and strains within the computational area. For the simple case of axial tension rod rubber obtained result has already been largely depends on the number of finite elements (Fig. 2.2).

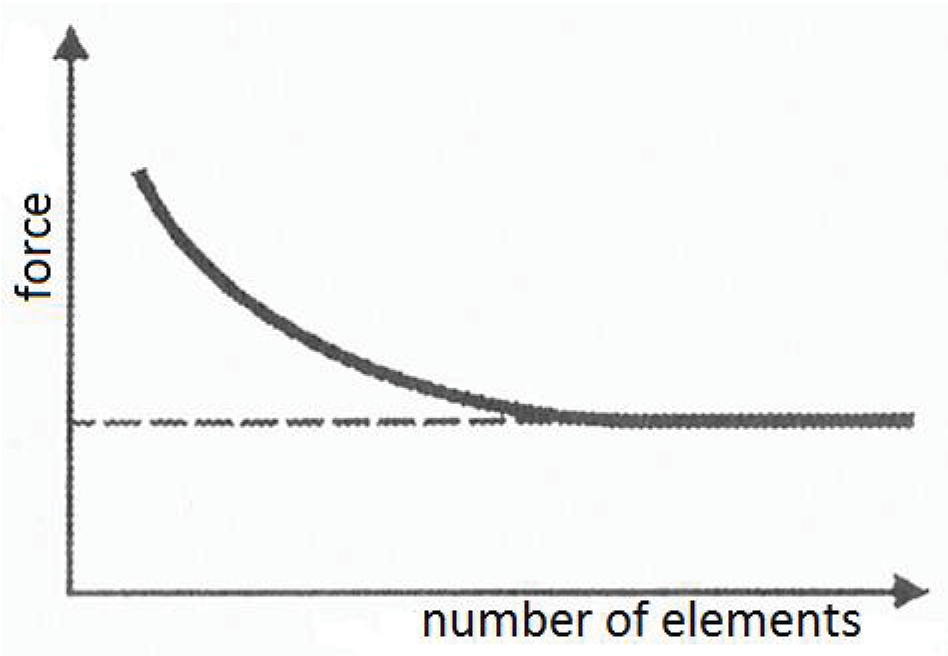

Figure 2.2. Influence of the number of finite elements in the value of the internal forces

As you can see, the graph has two clearly defined zones: the first - non-linear, in this case the number of finite elements is not sufficient to adequately describe the process of dissipation of the internal energy of a rubber rod, which leads to a stable, but incorrect results; second - linear, in this case the number of finite elements has reached the required level and we get physically adequate solution. ((Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 13-15)

2.4. THE FORMATION OF THE FINITE-ELEMENT MODEL OF THE SYSTEM “MASSIF-SUPPORT”

Calculation of the finite element method for modeling of nonlinear media, under the influence of complex stress, is a nontrivial task. Most of tasks of geomechanics refer precisely to this type. In the course of their solution to perform each time to the correcting-calculation model on several parameters, roughly speaking runs multivariate optimization in previously unknown space of available solutions. The simplest way to correcting the calculation model is its maximum simplification. This approach, in some cases, ensures quick results of computational experiment. However, one can’t assert, that the results are fully adequate for the qualitative and quantitative indicators of the real object.

First of all, the simplification of the computational model in tasks of geomechanics associated with the exception of factors and nonlinearity of the medium with a change in SSS (stress-straight state) system in time. Such calculations using FEM (finite element method) requires a deep understanding of the laws of behavior of materials under external load and significant computational resources. As a result, the behavior of the “undermined massif-support of stope” is regarded as a one-stage model of a physical object. However, under real operating conditions of extraction workings stresses and strains in the system are not immediately fixed. On the contrary, during the whole process of exploitation of the mining work geometric and mechanical properties are changing, so the distribution of stresses and strains should be considered as a process. Correcting of such calculating models requires considerable resources of time and computing power. Become necessary to use different methods of describing the complicated physical phenomena in the description of materials and the interaction of individual objects within a single computational model.

At this stage of development of the finite element method there are whole numbers of software products, which include computational systems that implement by variety of mathematical methods the wide range of physical problems. These complexes have different degrees of flexibility and focus on different groups of applied tasks. For solve the tasks of geomechanics, in various productions, usually used SolidWorks Simulation (COSMOS/M), FLAC 2D/3D, ABAQUS and ANSYS.

Currently, the most ample opportunities for the modeling of materials, conditions of interaction of objects, the solution of nonlinear problems and tasks of mechanics destruction has ANSYS. Also this software product has a high level implementation of numerical algorithms for different conditions of media behavior and other characteristics of the modeling. Therefore, implementation features described below correspond to the tasks of geomechanics approaches implemented within a computer system ANSYS. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 48-49)

The basis of adequate and mathematically correct solution of any problem with the help of the numerical grid method is to construct a high-quality computational grid. In FEM – it is creation of the finite element model. During this stage it is necessary to provide two main criteria: the geometric accuracy of the description of objects and choice of physically reasonable parameters of finite elements.

Geometric accuracy is achieved by selecting the right combination of geometric shapes and locations of points of finite elements. In today's software products, the process of building a finite element grid to varying degrees is automated. However, almost all of them used a minimal set of initial conditions, consisting of: linear dimension of a finite element and accuracy description of the geometry. In fact, these parameters represent the average linear dimension of the finite element in the chosen coordinate system and the maximum permissible deviation calculated from the surface of the point or edge of the model. For complex geometries encountered in problems of geomechanics, the manipulation of these parameters may not always lead to the construction of the grid (Basov 2002). In the construction of the grid in the area of contact frame lining and contour of mining work with a large amount of linear elements and a large tolerance can't get an accurate description of the geometry of the frame, but with a small amount of linear elements and the small dimension of the admission of the whole task may exceed the available computing resources.

Therefore, the number of computing systems that implement the finite element method, using an approach that is associated with a change in the size of finite elements in various zones of modeling objects. Thus, objects that have small linear dimensions (Figure 2.2) (anchors, elements of frame lining, cross-bar, pit props, powered roof supports, etc.) are de-scribed by finite elements of small size and peripheral elements of the computational area is described by the large size. This allows us to obtain a satisfactory description of the geometry and reduce the overall dimension of the problem.

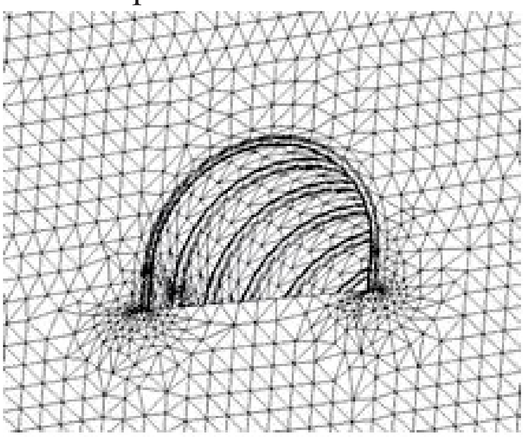

Figure 2.2. Modeling of the grid for mining working, including a frame support

Use of tetrahedra and parallelepipeds as the finite element within a finite element model can most adequately realize the stress field under complicated loading. The elements in the form of parallelepipeds are highly resistant to the computation process and, due to the coverage of relatively large size of the computational area, are ensured savings of computational resources. At the same time, the tetrahedra are good as final elements in areas with possible high stress gradient zones of fracturing and the solution of problems of mechanics of destruction.

Another feature of a finite element model – is a task of singular points in the computational area. These points indicate where you want to set the point of finite element. This approach is used to a high degree of accuracy to determine the SSS in particular, critically important point of the modeling object or to change the terms for grid construction of defined element of computational area. In both cases, well-chosen singular point can substantially improve the adequacy of the results obtained at different steps of the solution.

The physical parameters of a finite element should be assigned by the order and type of material, described in it. The choice of the order of the finite element allows not only with a high degree of accuracy to describe the geometric surface of the higher orders, but also to make appropriate calculations of zones of high gradients in the stresses and strains arising in the lining cell expression and processing in the rocks adjacent to its contour.

As you know, all descriptions of physical medium in finite element method are concentrated in the finite element. In the course of computational experiments to select the most appropriate for the specific calculation of the physical medium. On the basis of made choice to describe the desired properties of the material or materials which, in consequence, to bind to specific finite element generated for the computational model. The greatest breadth of capability in this direction is the editor of materials of ANSYS.

Versatile software system of finite-element analysis ANSYS, being one of the world leaders in the field of computer engineering (CAE, Computer-Aided Engineering), ensure the possibility of solving linear and nonlinear, stationary and non-stationary spatial tasks of mechanics of solid deformation and mechanics of construction. At the same time ANSYS has broad capabilities in dealing with non-stationary geometrically and physically nonlinear problems of contact interaction of the elements of computing area.

The implementation of ANSYS to describe the response or reaction to the impact of a complex sys-tem of different physical nature allows you to use the same model for solving such problems of bound, like strength of thermal stress or the influence of magnetic fields on the construction strength.

The rapid growth of computer technology in the early 70s of the twentieth century has allowed a considerable degree of empower ANSYS. The systems made a large number of changes were added to the nonlinearity of different nature, have introduced the possibility of using the method of sub-construction, greatly expanded the library of finite elements. In solving problems of geomechanics, the program offers a wide range of computational tools that allow you to:

- to consider a variety of structural non-linearity;
- to solve the most general case of contact inter-action for three-dimensional bodies of complex con-figuration;
- allow the presence of large (finite) deformations, displacements and rotation angles;
- to perform multi-parameter optimization in interactive mode;

- and much more, along with parametric modeling, adaptive grid re-formation, using the elements and extensive opportunities to create macros using parametric design language of ANSYS – APDL.

All functions performed by the program ANSYS, combined into groups called processors. The soft-ware package has one preprocessor, one processor of solutions, two post-processors and several supports' processors, with the optimizer. ANSYS preprocessor is used for creating finite element models and options for implementation of the solutions process. The processor executes the application solution loads and boundary conditions, and then determines the response of the computational model. Using a post-processor have access to the results of the solution and evaluate the behavior of computational model, as well as carry out additional calculations.

In ANSYS for the entire set of information relating to the model and the results of the solution, used one, central database (Figure 2.3). Model information is stored in the database at the stage of preparation preprocessor. Load and results of solutions are re-cording by solutions processor. Data obtained on the basis of the decision at their post processing, written in the form describes the level of post-processor. The information entered by one of the processors are available, if necessary, for other processors.

When constructing a grid of high-quality CAD-models ANSYS uses many means of quality control of the grid. In the software package provides four ways to generate the grid: to use the method of extrusion, creation of an orderly grid, creation of arbitrary grid and adaptive construction.

The generators of the arbitrary network have a wide range of internal and external operating options of the grid quality. For example, the algorithm is implemented reasonable choice of the finite element size, allowing building the grid of elements, with the curvature of a surface of the model and the best approximation – displaying its real geometry. For a simple model commonly used areas of hexa-hedral elements, and for the rest – tetrahedron.

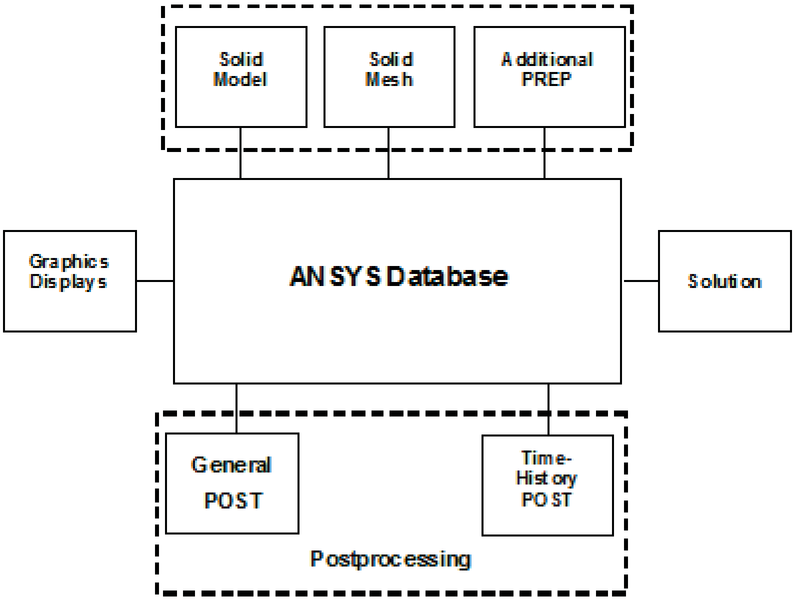

Figure 2.3. Connection diagram of a central database ANSYS

The transition from the hexagonal grid to a tetra-hedral with pyramidal elements is a valuable tool for modeling the geometry at the junction of areas with different grid. The researcher has the ability to automatically stitch the areas without need to enter the conditions-limitations or skip the median node points of elements and avoid the mathematical gaps in sought-for functions.

Adaptive grid construction is that after creating the solid model and the boundary conditions, ANSYS generates a finite element grid and performs calculations based on it. Then, estimates the error introduced into the finite element model and change the grid size from one solution to the other solution as long as the estimated error is less than a predetermined value or will reach the limited of iterations.

With the help of parametric projecting language (APDL) in the solid state module simulation of ANSYS runs parameterization of the model. Parameters are used as objects from which the performance of certain procedures is depend on, they can control the geometrical dimensions of the model, providing an opportunity, in the course of computing experiment, change the size in the following analysis. Attributes of parameterization are entered into the log-file in ASCII format, which contains all information entered during the work. The parameters in this file can be changed, then enter new data into the ANSYS program to rebuild the model with the correct size. Parametric log-file that uses solid modeling tools of ANSYS software for calculating models creation is especially useful during optimizing. By setting the size of the computational area with parameters in the optimization process can change the solid-state and finite-element model. In this case, the boundary conditions, are applying for a new computational model automatically.

Any material creates by selecting from a structured list of the required total characteristics and assigning them specific values. All possible models of physical medium behavior or characteristics of materials are divided into logical groups, which are selected by, or on the basis of the exclusion, or on the basis of superposition, it all depends on the compatibility of selected physical parameters. In the result is a series of spreadsheets to the principle of an inverted tree. The main table is a summary list of selected characteristic of a specific material.

The combination of specific relations for the fluidity condition, flaw of flow and law of hardening defines a particular model of the plastic material behavior. In ANSYS modeled the following types of plastic behavior: a classical linear kinematic hardening, polygonal kinematic hardening, linear isotropic hardening, polygonal isotropic hardening, the anisotropic behavior, materials models of Drucker-Prager and Ananda. Besides that, the user can define own version of the plastic model.

The model of classical linear kinematic hardening describes the behavior of conventional metallic materials, schematic diagram of an elastic deformation which has a plot and a plot of linear hardening. This model is applicable to most common, initially isotropic structural metals at the area of low strains. Used by the induced-modified by Mises' fluidity condition and associated law of flow. Manifestation of kinematic hardening is the Bauschinger effect.

Polygonal model of kinematic hardening also applies to metals, but are more applicable to those of them, that has figure more than one linear section of hardening. This model employs overlay, or Besselinga scheme to describe the complex behavior of polygonal material by combining the individual responses received on the basis of a simple dependency “stress-strain”. Used a modified by Mises yield condition and associated flow law. Manifestation of kinematic hardening is the Bauschinger effect.

The model of a linear isotropic hardening refers to the common, widely used metallic materials with linear hardening. It is applicable to isotropic materials and in-state deformation significantly preferable to a model with kinematic hardening. Mises fluidity criterion is used in conjunction with the equations of the theory of Prandtl-Reuss. Bauschinger effect is not taking into account.

Polygonal model of isotropic hardening describes the behavior of conventional materials, hardening with increasing strain, and describes more accurately for large deformations. Fluidity condition of Mises is used; the Bauschinger effect is not modeled.

The model of anisotropic behavior describes of materials that behave differently in the stretch and compression or differently deform in different directions. The use of isotropic hardening allows using this model to determine the work of hardening in anisotropic material. Use a modified fluidity condition of Mises associated law of flow.

Drucker-Prager model is applicable to such grainy, granular materials such as rocks, concrete or soil. Use Mises fluidity condition, depending on the medium pressure to modeling the increase in the limit of fluidity of stress of the material with the full pressure. Law of flow can be associated or no associated. Hardening is missing.

Anand model describes the behavior of metals at elevated temperatures, but can be used at lower too. It is a model of an isotropic material hardening with increasing loading rate; a model that is usually sets by parameters of state, and not by using the curve “stress-strain”. Anand model uses Mises fluidity condition with associated law of flow.

User’s model can be used to specify any actual non-linearity behavior of the material. Subprogram written by user in the language FORTRAN, is introduced to the program ANSYS, and user’s model can be used with the other.

Select the type of calculation determines which of the characteristics of the material to be used in construction of particular finite element matrix.

In some cases, the solution of nonlinear task of mechanics of solid media cannot be performed using one type of computational model that is we are talking about performing the task in several interrelated stages (Morozov 2010). There are two stages in task of geomechanics, if not taken into account the factors of the original tectonic stress, water production, etc.

The first step is the determination of stresses and strains of the static load, showing its condition at the time of ideal contact of set support and contour of mining opening, formed by rocks of the massif. The second stage is to analyze the processes occurring in the rock massif during the time. These processes include the rheology of rocks.

The behavior of the elements of the frame support (Figure 2.4) depends on the conditions of the problem. When modeling has elastic formulation, response of the lock setting is only possible in recording to dynamic components, which lead immediately to a significant complication of the task, because it re-quires changes in accounting of contact area, and, consequently, frictional force acting in the lock. In the elastic-plastic formulation of the task is possible to model the behavior of the lock, even without large displacement, to model the behavior of the lock by using the so-called “synthetic” approach. The essence of such a solution is to replace the roof support element, in this case -the lock, with geometric objects with physical parameters that allow the most complete display required for the modeling of the real characteristics of the object.

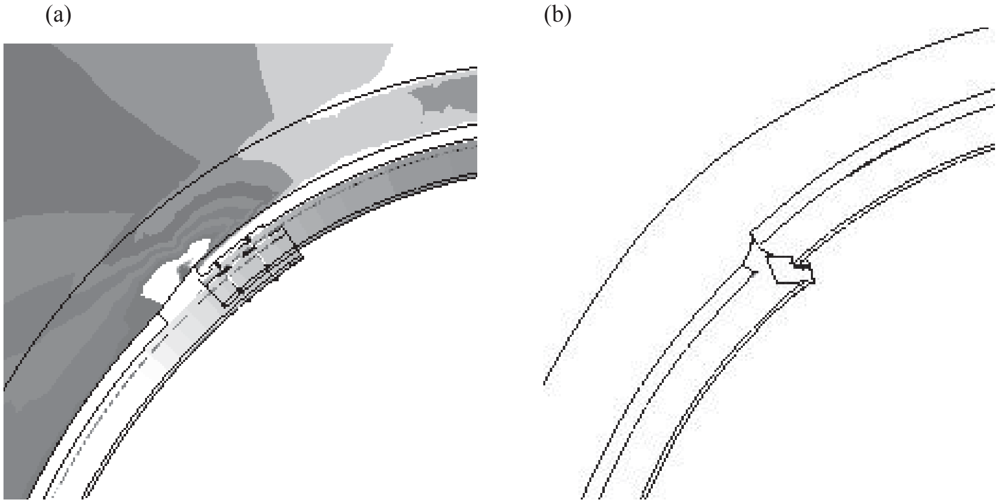

Figure 2.4. Modeling of the node unit of suppleness of the frame support: (a) geometrically accurate model, and (b) model of the node unit, providing its mobility without taking an account the dynamics

In the calculations in the elastic formulation of the distribution of stresses and deformations in a layered rock massif is usually significantly different from the elastic-plastic recording to rheology. As a rule, it is connected with the effect of slip at the boundaries of lithological differences (Figure 2.5). As on the contacting surfaces of the rock layers are modeled two symmetrical non-connected node units, then they move relative to each other a lot more in the modeling of the nonlinear environment than for the deformable environment with small movements. Thus, it becomes possible mediately modeling the local dumped rock into the vesicle of mining opening, without any “synthetic” approaches.

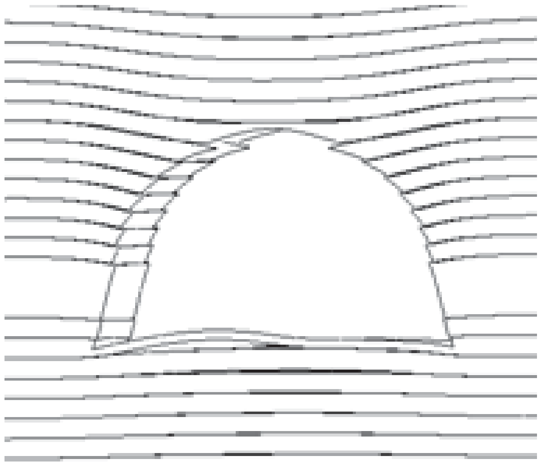

Figure 2.5. Relative slippage of rock layers in the task solution of nonlinear definition

Changing the calculation model, conclude in choosing other rheological characteristics for materials used in the computational experiment, can greatly affect the development process of changing SSS system in time. As shown in the figure presented by the final movement of distribution diagram of replacement of the circular section contour of the mining opening, passed on the coal seam, and surrounded by sandstone, has a different geometry depending on the application of the same rheological characteristics, only applied to different objects of the same computational areas. With an increasing number of rock layers and complication of the geometry of the calculating area, influence of the rheological properties of materials is only increase, which together with time factor brings to significant changes in the distribution pattern of stresses and strains. So, the localization of zones of possible occurrence of cracks can be changed.

The actual physical processes occurring in the immediately adjacent to the mining opening contour processing rock massif, include softening and fol-lowing complete destruction of the rocks. As noted above, these processes occur over time and require consideration of nonlinearity of the medium used in the modeling. That is, the analysis of main cracks becomes the third final step of solutions to describe the behavior of the rock massif in the vicinity of mining opening.

The implementation of this step is fundamentally different for the development workings and working faces. The basis for these differences is the following factors: time of operation, methods of maintaining the original contour of mining opening, the degree of mutual influence and the geometry of the section.

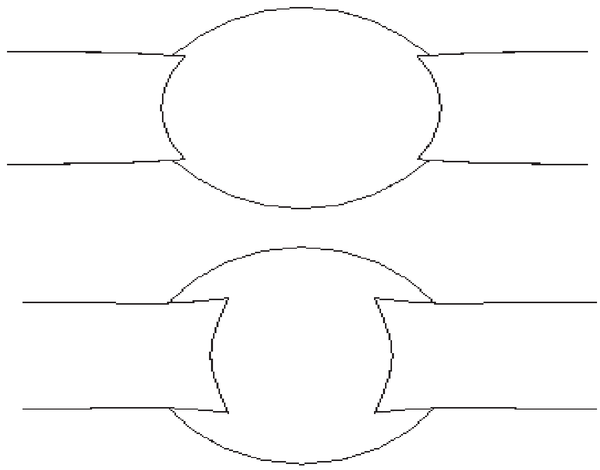

Figure 2.6. Displacement of mining opening contour with different ratios of rheological factors of coal and rocks

The formation of cracks in the roof, for example, the drift with circular cross-section is usually a relatively long physical processes taking place in several stages, from which you want to distinguish two main ones: the development of cracks to the zone of influence of sewage treatment works and the development of cracks in this zone. In the result of re-search by SSS of rock massif around the mining opening should develop in stages to consider the development of cracks in its roof. In the first stage main cracks formed along the axis of the mining opening of the first and second type. Some of these cracks cease to grow. And some that are in the areas of maximum gradient of the strain continued to grow until the meeting in the rock massif, above the roof of mining opening. In such circumstances, the load to frame support of mining opening begins to increase rapidly, which leads to trigger off support's locks.

After entering these cracks in the zone of influence of sewage treatment works in the crack begins to dominate the third type. Moreover, cracks are formed along the cross section of the mining opening, or at small angles to this section. The result is cracking system, it is extremely difficult give in to detailed modeling. Modeling such a system of cracks requires a certain ranging with increasing sampling within a single computational area. This leads to the use in the calculation of “synthetic” approach to the description of geometric cracking, investigated in the course of solving the problem. That in turn means an additional phase of the study with a modified geometry of the computational area.

Cracks, prior to the collapse of the roof in the excavation face, initially developed by the second type, starting to grow on the surface of the roof working face, but with the growth of deformations on a vertically oriented cleaved rocks formed in the top of the development of the crack, confirm to the first type. Joint development of these cracks leads to the formation of packs of loose rocks, within which, in con-sequence, when crossing the front of the crack unit formed rocks, collapsing in the goaf. Thus, in calculating the behavior of roof of excavation face involving mechanics of fracture, task is solved by using two types of analysis of cracks in the rock massif.

As a result of the calculations performed can be considered as a separate phase of the quasi-dynamic modeling with a parametric variation of the lengths of face drift and the magnitude of bottom-hole drifts out space in the plane of the working face. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 49-56)

2.5. CONCLUSION

The finite element method is an acceptable for describing the properties of the rock mass. The accuracy of the results is directly linked to the correctness and accuracy of the entered data. In practice, the finite element method shows good results close to real conditions, which makes it possible to make conclusions about the behavior of working as a result of pressure of the overlying rock mass, the behavior of support and the possibility of choosing the type of supports for the given conditions. Construction of the model is produced by creation a grid (blocks) that are easy to calculate by SolidWorks software.

3 CONSTRUCTION OF THE STRUCTURE MODEL AND VALIDATION OF THE PROPERTIES FOR THE COAL MASSIF IN THE VICINITY OF THE STOPE

3.1. BRIEF INFORMATION ABOUT THE «ZAPADNO – DONBASSKAYA» MINE

- Enterprise’s location:

Field of "Zapadno Donbasskaya” mine is in detail explored area of Pavlograd – Petropavlovsk coal basin of Western Donbass and is located on the territory of the Pavlograd district Dnipropetrovsk region of Ukraine.

Near the mine are the Ternivka city and the Bogdanovka village. Pavlograd city and the railway station are on distance of 15 km. The nearest mining companies are "Ternovskaya", "Pavlogradskaya", "Samarskaya", "Dniprovskaya" mines and mine imeni “Geroev Kosmosa”.

The area of Western Donbass belongs to the steppe zone and timed to the Samara pool and its tributaries. Relief of coal district is hilly steppe. Maximum absolute mark is + 140m, minimum is + 70 m.

The climate is temperate-continental and is characterized by a relatively short winter and long warm summer. Registered maximum temperature is +40,2 C^0 on July, and the minimum -31 C^0 on February. The average annual temperature is +8.6 C^0. The frost-free period has an average duration of 190 days; the average depth of soil freezing is 500 mm. The annual precipitation is 450 - 480 mm.

The average annual wind speed is 4 m / s, the maximum does not exceed 16-20m / s. During the year, there is an average of six days with sandstorms.

- Mining and geological description:

The geological structure of the mine field has complex of Carboniferous sedimentary rocks, Paleogene, Neogene and Quaternary ages. Retinue deposits are mainly represented by mudstones, siltstones, sandstones and numerous layers of coal with capacity of 0.1 - 1.2 m. The occurrence of gently sloping rocks, the average angle of incidence of 5 °.

Within the field of mine operating capacity reaches eight layers: C^B_{10}, C^B_8, C^H_8, C^H_7, C_6, C_5, C^B_4, C_1. The structures of the layers are mainly simple, rarely complicated. For coal seams C^B_{10}, C_6 and C_1 typical is the splitting, after which one or both packs lose industrial significance. The host rocks of coal seams generally are mudstones and siltstones hardness coefficient from 1.5 to 3, less often sandstone with hardness coefficient of 2 to 5.

Seam C^B_{10}: seam roof is unstable and presented by argillites, siltstones and sandstones rarely. In the small area developed "false" roof (0.1 - 0.5 m). The soil layer is presented by siltstones, rarely volatile and medium stability mudstone, sandstones.

Seam C^B_8: the roof and the ground layer are mainly represented by siltstones from the average stability to unstable, rarely mudstone and sandstone. In some areas there is a "false" roof (0.04 - 0.1 m).

Seam C^H_8: the roof and the ground are represented by siltstone, mudstone (average stable and unstable). In some areas there is a "false" roof (0.05 - 0.19 m).

Seam C^H_7: the roof and the ground are represented by unstable mudstone and unstable siltstone. In some areas there is a "false" roof (0.12 - 0.4 m).

Seam C_6: the roof and the ground are represented by mudstone and unstable siltstone, rarely sandstone. In some areas, there is a "false" roof of 0.1 - 1.8 m. The rocks are exposed to soil heave.

Seam C_5: the roof and the ground are represented mudstone and unstable siltstone. On large area there is "false" roof (0.05 - 0.3 m). The rocks are exposed to soil heave on whole area.

Seam C^B_4: the roof and the ground are represented by mudstone and unstable siltstone. In some areas, there is a "false" roof (0.1 - 0.3 m).

Seam C_1: the roof and the ground are represented siltstones and mudstones unstable, rarely sandstone. Over a large area is developed "false" roof (0.03 - 0.9m). The rocks are exposed to soil heave on whole area.

Within the mine field are surface water and groundwater. Aquifers in the thickness of the overburden are confined:

- to the alluvial deposits up to 11 m.;
- to the deposits of Samara tier and lower parts of sands (capacity of 2 - 11 m.);
- to the deposits of Kharkov tier and sands up to 16 m.

Most water-bearing rocks are layers of Buchakskogo, Kharkov and Triassic-Jurassic deposits. Water-saturated sands have float properties.

These aquifers are fed from precipitation and floods. The possible maximum inflow of water at full development of mining operations is up to 200 m^3 / h.

Tectonics of mine field is characterized by restless bedding rocks and coal seams. In general, mining and geological conditions of seams are complicated, due to the intensified of rock pressure and low strength characteristics of wall rocks (f = 0,7 - 2,0).

The size of the mine field of technical border is down dip from 3.1 to 5.7 km., along the strike of 10 km. The area of the mine field is 38 km^2.

- Technical indicators:

"Zapadno Donbasskaya" mine refers to very gassy mine and explosion hazard of coal dust. The coal dust is explosive, the rock dust can cause silicosis. Coal seams are not dangerous to sudden outbursts of coal, gas, rock bursts. Absolute methane emission is 38.8 m^3 / t. The temperature of the surrounding rocks at the depth of mining operations does not exceed 25 ° C.

The coal dust was tested on explosiveness in the laboratory. According to the results of analyzes of explosive dust and rock, dusting rate is 88%. During mining of coal for dust control should be used irrigation and water or shale barriers.

According to laboratory tests of coal seams C_{10}^{B}, C_8^{B} and C_8^{B} are not prone to spontaneous combustion. During the life period of the mine spontaneous combustion of coal in the pillars were not observed.

- Opening scheme:

Opening of the coal seams carried out by two central twin vertical shafts and crosscuts (cross section S = 14,7 m^2, KSHPU support). In 1998, due to the mining of deposits, as well as to improve ventilation of mine, were created 6/42 opening of the mine field which was also done by two central twin vertical shafts.

Currently, the mine operating horizons are 480 m, 510 m, 585 m and 680 m. The main of them are 480 m and 585 m. The horizon 480 m is for servicing of mining in seams C_8^{B} and C_8^{H}, transport operations and for the implementation of auxiliary operations. The horizon 585 m is drainage; there is the central drainage of mine. The horizon 680 m is for cleaning of dib-hole. On the horizon 510 m is located connection between the shafts, which creates a horizontal connection to the chamber of the coal feeder from the auxiliary shaft. Existing shaft bottom levels are located at the depths of 480 and 585 m. The main and auxiliary shafts completed to the depth of 680 m. The shafts are fixed in watered rocks by iron tubings with concrete filling of space, in the rest rocks used monolithic concrete. Shaft diameter is 7,5 m., Step of reinforcement is 4 m. On each shaft bottom level is located electric locomotive garage (charger, converter and repair shop), expectations area, loading devices for coal and rock. In addition, the shaft bottom level of horizon 480 m has a medical center, and on the horizon 585 m are main drainage and underground storage of explosive material with capacity of 3600 kg.

- Ventilation:

The scheme of ventilation is exhaust ventilation. Methane emissions and sudden outbursts of coal and gas in the mine were not observed. Coals are not prone to spontaneous combustion. By auxiliary shaft goes the fresh air stream into the mine; by the main shaft goes outgoing air stream.

The mine is equipped with two centrifugal fans WRCD-1,5 with asynchronous motors: AKS 16-44-24 (240 rmp, 500 kW, 6000 V); VTS 3-17-41-16 (375 rpm, 1600 kW, 6000 V).

Depression of mine is 330 kgf / m2, and the air flow rate is Q = 305 m^3 / sec.

The scheme of ventilation in mining areas is return ventilation air, and where it is possible to keep the drift after the wall face is used direct flow ventilation scheme with freshening of outgoing air stream.

- Mine hoist:

During the life of the mine coal and rock output from the horizon 585 m through the main shaft. The main shaft is equipped by 2 skips for coal and 1 skip for rock. The auxiliary shaft is equipped with two-cages and a single cage elevator device with a counterweight. Two-cage elevator serves horizons 680and 585 m. Cages of both elevators are double-decker with a maximum raise the weight in one trolley VG - 3.3 with a rock mass is 6300 kg.

➢ Transport system:

Delivery of coal from the mining faces up to the main shaft is carried out:

- conveyor drifts - belt conveyors 1LT80, 1L80, 2LT80, 2L80;
- mainline workings of the horizon 480 m - 1L100K, 1L100K1;

Hauling of rock from mining workings is performed:

- on inclined workings - conveyors 2LT80, 1LT80, 1L80 and 2L80;
- mainline haulage drifts - electric locomotives AM-8D.

For rock haulage is used rock cars VG-3.3. Transportation of people through mainline workings carried out into the man-ridding cars VL-18 with electric locomotives AM-8D.

For the delivery of equipment and materials to the mining workings are used ground cableways DKNL-1 and TKS-22.

➢ Consumers and quality requirements of minerals:

The coal mainly has the average value of the ash content and sulfur content. The coal has average dressability. The main consumers of coal are Zaporozhye hydro – electro plant - 50.7%, and Michaeylovkiy CPP - 49.3%.

The mine has the following quality standards:

- by ash: average - 37.9%, the maximum - 52.1%;
- by sulphur: average - 1.7%, the maximum - 2.2%;
- by moisture: average - 11.0, the maximum - 14.0%.

The natural ash content is 7,7%.

➢ Method of preparation and mining method:

The mine uses horizon-oriented way to prepare a mine field; the system of development is board and-pillar mining system with complete collapse of the roof.

Coal mining is complex - mechanized, transportation of coal is performed by full conveyorization and rock cars.

Within the block №1, work is carried out on seams C^{B}_{8} and C^{H}_{8}. Because these seams are close and the average distance between them is 7 m., the work is carried out on both seams from one horizon 480 m. The wall faces are processed in slope and brake incline parts of a mine field. In slope part, the wall faces are processed by long poles of uprising. In brake incline part, the wall faces are processed by long poles along strike. The length of the wall faces, depends on the geological conditions vary in the range of 170 - 200 m., the length of the pillars in the slope part are up to 1000 m., and in brake incline part are up to 2500 m. The protective pillars with width of 50 m are used for protection of the main mine workings.

- Electric power supply:

Power supply is provided from Pavlograd substation of Dniproenergo. To supply the entire devices on the underground depths of 480 and 585 m constructed underground substation (US), powered by eight inputs (stem cable) 6 kV directly from main surface station (MSS). High-powered cells (RPP-6 kV) are powered from US. And, group of mobile transformer substations are powered from high-powered cells.

- Labor protection:

On the mine, all open moving parts are provided with barriers to prevent dangerous of traumatism of people and to prevent ingress of another things inside of them.

At the loading points and receiving areas are sustained all installation of clearances and left free passes for people, in accordance with the Safety Rules (SR). To ensure safety in the operation of electrical equipment in the mine is provided: flame-proof electrical equipment, cables with a non-flammable cover, leakage relay built-in mobile substations, starting units and rectifier unit of electric haulage, grounding of the electrical equipment, and warning sound and light signals before the remote start of mechanisms at work.

To reduce mechanical noise and vibration are applied parts of noise insulating materials, anti-vibration pads, and flexible couplings. In order to prevent coal dust explosions, drifts are washed by water with a wetting agent DB. To suppress the explosion distribution is used a water barriers. *(information was taken from the mine "Zapadno Donbasskaya")*

3.2. METHODOLOGY VALIDATION OF THE MODEL PARAMETERS FOR THE COMPUTATIONAL EXPERIMENT

The accumulated experience of computer modeling of stress strain state (SSS) indicates the need for pre-working of geomechanical model. It involves a number of sequential tasks with the mandatory testing of the results for compliance with the provisions of the classical mechanics of underground structures and field observations in specific mining and geological conditions. This analysis is needed not only to control the modeling process and eliminate possible technical errors in the technology of calculations.

Task №1 - selecting a location of working that is most relevant to the geological and mining conditions of the project research on the customer's specifications. This area is called the base or control, on which are processed parameters of the future geomechanical model of the "Massif - Support" system. In this model, the observations are carried out to the manifestations of rock pressure on equipped the benchmark station. Then perform the following tasks.

Task №2 - structuring of the coal massif in the vicinity of the base part of working according to the geological investigations.

Task №3 - study of mechanical characteristics of each rock layer and coal seams included in the pre-selected dimensions (vertically and horizontally) of the tested geomechanical model.

Task №4 - building a working and support of the real form, their orientation with respect to the coal seam.

Task №5 – validation of minimum allowable size of geomechanical model in space (in the coordinates Y, X and Z) on the basis of Stress Strain State (SSS) study by minimum acceptable criteria of perturbation (relative to the original untouched massif of non-hydrostatic) of each component of the stress on the boundary of the model. Usually in practice of geomechanical calculations is considered quite satisfactory margin of error up to 10%.

Task №6 - elements modeling of support in accordance with the chart of supports. Validation of assumptions related to structural simplification of individual elements, such as lock pliability. At the same time, any idealization should not introduce distortions in the real characteristics of a particular element of support.

Task №7 - elements modeling of the support in accordance with the chart of mining working, but taking into account a number of proposals to modify the structures aimed at improving the stability of the mining working.

Task №8 - model testing of the base working. It analyzes the distribution field of each stresses component in the massif and compared with date of existing studies in the field of geomechanics, then assessed degree of compliance with the results of calculation.

Corrections to the model are made by results of testing (if necessary) with the refinement the mechanical characteristics of the surrounding rock layers. Re-calculation of the model is carried out (if necessary) and repeated all testing activities. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 59-60)

3.3. STRUCTURE VALIDATION OF THE COAL-THICKNESS IN THE VICINITY OF THE STOPE

Each of these tasks is aimed at development of a mining working model, for example, of the 5th conveyor drift, the block №10 of the "Krasnoarmeyskaya-Zapadnaya №1» mine. The mine should study the process of displacement of the layered rock mass in the vicinity of working with maximum real mining and geological conditions for the improvement of geomechanical modeling technology. The first priority is creating a real structure of coal massif on the 5th conveyor drift, the block №10. This assessment of the massif structure is used from the nearest well №4377, geological forecast from the mining working of 5th southern wall face, block №10 and summary stratigraphic column of the mining field.

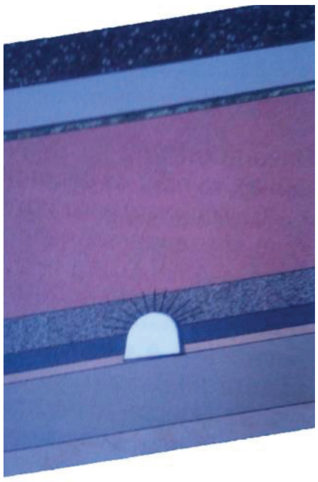

Figure 3.1. Model structure of coal massif, seam d4

Structure model of surrounding rock mass in the vicinity of the seam d4 includes 10 rock layers and coal seams, which are numbered in order of increasing depth to their location: 1 - sandstone with the capacity of 5.0 m; 2 – siltstone with the capacity of 4.5 m; 3 – coal seam d4 with the capacity of 0.3 m; 4 - aleurolite with the capacity of 0.7 m; 5 - sandstone with the capacity of 18.8 m; 6 – aleurolite with the capacity of 3.7 m; 7 – coal seam d4 with the capacity of 2,07 m; 8 - aleurolite with the capacity of 1 m; 9 – sandstone with the capacity of 7.1 m; 10 - aleurolite with the capacity of 2.7 m.(fig. 3.1)

In general the height of the coal massif is 44.9 m; the width of the model is 80 m, 40 m on each side of the vertical axis of the drift.

Conveyor drift performed with combi roof and ground footwalling to an average depth of 1 m. In accordance with the mine plan and the data depth of the well №4377 the depth of the sandstone roof (the upper limit of the model) is H = 800 m.

Conditions at the boundaries of the model: the upper horizontal plane of the model has a point of 797.2 m, with an average volume weight of rocks γ= 25kN/m^3 forms a vertical load on the upper boundary of the model $\sigma_y = \gamma H$ = 19,93 MPa. In calculation is used σ_y = 20,0 MPa. The lowest boundary of the model has a nonyielding support and it is the start of the plane to calculate vertical coordinate Y. In lateral plane of the model entered condition of plane deformation, which corresponds to the real mechanism of massif deformation and it is widely used in the mechanics of underground structures. According to this condition in the intact massif are horizontal compressive stresses:

$$\sigma_x = \lambda \gamma H = \frac{\mu}{1-\mu}$$

where: μ - Poisson's ratio of considered rock layer or coal seam.

By putting in the database information about the mechanical characteristics of coal massif, performs automatically modeling the impact of horizontal stress σ_x on the lateral boundaries of the model. The point of reference in the X-axis coincides with the vertical axis of working.

The third dimension of the model (the thickness of the coordinate Z) coincides with the longitudinal axis working and it is 4 m (in test calculation) for the construction of six sets of arch supports with a pitch setting of 0.8 m. Conditions of plane deformation also putted along planes, where work compressive stresses (untouched massif).

$$\sigma_z = \frac{\mu}{1-\mu}\gamma H$$

The calculation start of the coordinate Z is placed into the middle of the model (by its thickness), on a distance of 2.0 m from the side of the boundary plane. In addition to the components of the stress field in the model is analyzed a value of the stresses σ (stress intensity as an integral parameter SSS, which is used in strength analysis). For rocks Coulomb-Mohr law is:

$$\sigma = \sigma_1 - \frac{1-\sin\varphi}{1+\sin\varphi}\sigma_3$$

where:

σ_1 and σ_3 – the maximum and minimum principal stresses of the elementary volume;

φ - the angle of internal friction of the rock.

For the arch support and reinforcement of anchors the angle of internal friction is zero, in accordance with the classical theory of strength of metals. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 60-62)

3.4. MECHANICAL CHARACTERISTICS VALIDATION OF THE LAYERS ON THE CHART OF THEIR DEFORMATION

The requirement to achieve the maximum possible degree of adequacy of the modeling of geomechanical processes in the vicinity of mining drift implies not only the construction of the real structure of coal seam, but also the description of the most significant (within the ranges of characteristics variation) mechanical properties of the each element of the "massif – support". The greatest difficulties of the modeling are related to reflect real behavior of the rock at all stages of deformation: elastic - plastic, softening and loosening. Accounting of all stages of deformation is particularly necessary for weak and medium strength of rocks constituting coal seam at a depth of H = 800m.

In the developed model of coal seam is used a full diagram of deformation (from the beginning of loading to the complete destruction of the material), which is determined experimentally on the "hard" presses and it shows relationship between relative deformation ε_x and maximum principal stress σ_x.

Full diagram of the deformation of the rock (Fig. 3.2) in accordance with generally accepted assumptions in geomechanical studies presented in the form of three linear segments: OA - elastic-plastic deformation stage, point A - limiting condition, AБ - softening step, БВ - loosening stage.

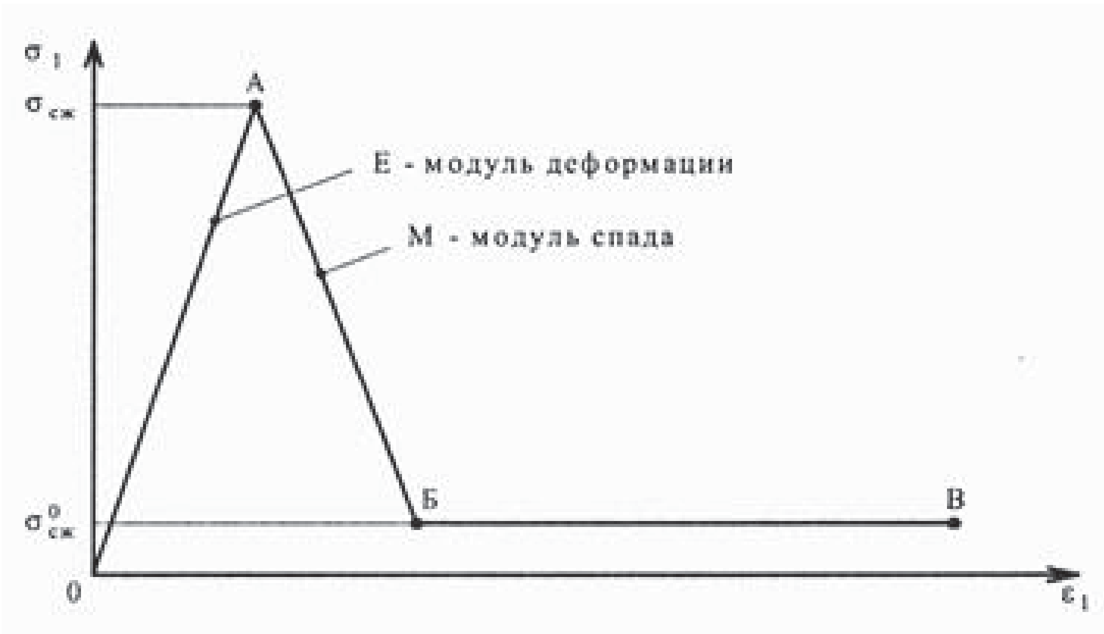

Figure 3.2. Modeling of the full stress-strain diagram of the rock

Such deformation diagram of rock is characterized by four parameters: $\sigma_{сж}$ - tensile strength for the uniaxial compression of intact rock; $\sigma^{\circ}_{сж}$ - residual strength at the end of the process of its weakening; E – modulus of rock deformation; M - modulus of recession.

Such rock deformation diagram requires extensive information on the mechanical characteristics of coal seam, which does not have the Geological Survey of any mines in Ukraine. Therefore, there is the following approach to the formation of the baseline data. First of all, is used information about the properties of rocks on nearest wells (within the height of the model): description of the structure of each rock layer and coal seam, their tensile strength in uniaxial compression, elastic modulus, shear modulus, Poisson's ratio, and the angle of internal friction. This data is used indirectly to assess the elastic-plastic properties of the rock and the degree of fragility of its destruction which suggest ranges of parameters {E, M и $\sigma^{\circ}_{сж}$) complete stress-strain diagram. Further, are analyzed the results of studies of the mechanical properties represented in the model of rocks from literature sources. The most wide-ranging study of rocks deformation of full diagram for coal seams of Donbass made in IGTM Polyakova NAS of Ukraine. For each type of rock is selected missing mechanical characteristics; also used the research data obtained directly for the geological conditions of "Krasnoarmeyskaya - Zapadnaya №1» mine. As a result of this integrated approach is created a database of mechanical properties of the rocks on the experimental part of working, which is given in the table below, and used in the calculation of the SSS for "massif - support” system. In geomechanical calculations are commonly used relative residual strength $\frac{\sigma^0_{сж}}{\sigma_{сж}}$ and the relative recession modulus $\frac{M}{E}$.

The main parameters of different types of rock are presented in the table below (Table 3.1).

Table 3.1

Parameters of different types of rock

№	Type of rock	$\sigma_{сж}$, MPa	$E*10^3$ MPa	$\frac{\sigma^0_{сж}}{\sigma_{сж}}$	$\frac{M}{E}$
1	Sandstone	90.0	2.0	0.08	4.0
2	Aleurolite	55.5	0.9	0.12	2.0
3	Coal seam	13.5	0.2	0.2	1.0
4	Aleurolite	33.7	0.9	0.15	1.5
5	Sandstone	90.0	2.0	0.08	4.0
6	Aleurolite	55.5	0.9	0.12	2.0
7	Coal seam	13.5	0.2	0.2	1.0
8	Aleurolite	46.0	0.9	0.15	0.8
9	Sandstone	72.0	1.8	0.1	3.0
10	Aleurolite	46.0	0.9	0.15	0.8

3.5. VALIDATION OF THE GEOMECHANICAL MODEL FOR THE SYSTEM "MASSIF - SUPPORT"

Minimally sufficient size of model (in the coordinates Y, X and Z) are determined by the condition of the stabilization of the stress field at its borders in accordance with the initial none hydrostatic condition of untouched massif. This criterion provides (error up to 10%) a minimal effect of boundary conditions on the model surface of the SSS "massif – support" system. For the implementation of these measures in accordance with these built a test model, the analysis of SSS gave the following results.

Vertical stress σ_y at the upper boundary the model distributed practically uniformly with a deviation not more than 3.9% in relation to the value of untouched massif γH = 20 MPa. On the bottom border of the model, oscillations σ_u do not exceed 4.3% relative to γH = 21,05 MPa (the bottom border depth H = 842,1 m). On the lateral boundaries of the model σ_y monotonically increases from 20 MPa to 21.05 MPa with deviations not more than 6.2% of the corresponding value γH of untouched massif. Thus, the perturbation σ_y close to the formation of working is reduced while moving to the boundaries of the model (on the Y and X) and practically stabilized, approaching to γH of untouched massif with a permissible error for the mining calculations. Consequently, by a factor of the field distribution of vertical stresses σ_y, the model dimensions are sufficient.

Horizontal stresses σ_x (deviations up to 2.5%) are stabilized at the lower boundary models and it is 9.0 MPa, if the Poisson ratio of the lower rock layer (siltstone) is μ = 0,30. More significant oscillations σ_x are observed at the upper and lateral boundaries of the test model because of additional stresses σ_x from bending rock layers in the working direction and they does not contrary to the classical mechanics provisions of underground structures. These perturbations exceed permissible deviations of 10% just for thin rock layers (siltstone in the roof with a capacity of 0.7 m and a seam d^1_4 with a capacity of 0.3 m), which have a low enough section modulus for a bending. However, these perturbations σ_x does not effect on the stresses field in the vicinity of the mining working because they are associated with edge effects of fixing model and are very far from the working, their maximum dimensions are 0.7 m at the left boundary and 3.5 m at the boundary of the model size 44,9x80 m. Shear stresses τ_{xy} have perturbations in the vicinity of working to a depth of 8 m. They practically disappear at the boundaries of the model due to a small dip angle of the seam d_4 (a = 2 ... 3 °). For this reason, no significant difference between the vectors of the principal stresses σ_1, σ_2 and vectors of stresses σ_x, σ_y. Consequently, by a factor of the field distribution of shear stresses $\tau_{xy,}$ the requirement at the model boundaries of untouched massif is performed completely. These stresses σ are a some combination of the component

(σ_y, σ_x and τ_{xy}), therefore they have similar deviations from the initial non-hydrostatic condition on the boundaries of model.

Figure 3.2. The diagram of reduced stresses in the arch support of the test model

Above reviewed the SSS on planes, which is bounded a model in height and width. It is also necessary to assess the sufficiency of the model thickness (6 sets of frames, Z = 4 m) where the main condition is the stability of the stress field in the central part of the thickness (arch №3 and №4). The most vivid indicator is the SSS of arch support, there is the greatest gradient of stress changes in the model. For clarity, the figure shows a diagram of the reduced stresses (intensity) σ, according to the analysis it possible to draw the following conclusions:

- the field σ in the central arches (№3 and №4) practically do not differ from each other;

- the field σ in the arches №2 and №5 has deviation from the central arches (№3 and №4),and does not exceed of 6.8% in the areas of peaks concentration.

Thus, the thickness of model (4 m) is sufficient to avoid edge effects (coordinate Z) and perform reliable calculation of SSS. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 60-70)

3.6. VALIDATION OF THE PARAMETERS FOR THE MODEL OF SUPPORT

➢ Comparative calculation of effective use in the mining workings of arch supports with yieldable and nonyieldable characteristics:

The usefulness of yieldable supports in the influence zone of mining works (the depths of 800 m or more) to support mining workings never been questioned. In the last decade are developed some proposals for the application of supports with increased rigidity and high bearing capacity to limit displacement of the coal layer and maintain a sufficient section of the workings without repair works. Therefore it is necessary to show that the conditions for workings re-use, for example, block №10 rational is to use only yieldable arch support, in particular, support KSHPU-20.3; the calculation was performed on the basis of a regulatory document Ministry of Coal Industry of Ukraine КД 12.01.01.201-98.

According to the stratigraphic column, the first layer immediate roof consists of siltstone and sandstone. The strength characteristics of the surrounding rock layers of the roof within unprocessed areas (block №10) were used in the calculation. They have a certain period of change. Therefore, first of all, was considered a variation range of calculated resistance to compression, those rock layers, which are taken to the calculation according to the КД 12.01.01.201-98 to determine the load on the supports and the installation step of arches. The lower boundary of the estimated compression resistance R_{min} is characterized by flooded siltstone with a capacity more than 6.2 meters (width of the working is 6203 mm), it is not excluded according to the summary stratigraphic column. The minimum compressive strength of the roof rocks equal to 18.4 MPa, the minimum limit of the compressive strength of water-saturated siltstone is 30.6 MPa, the coefficient of structural weakening 0.6. The upper limit of the parameter R is characterized by the occurrence of immediate roof of sandstone (thickness over 6.2 m); similarly, was defined the maximum value Rmax = 66.6 MPa of resistance to compression of the roof rocks with the coefficient of structural weakening of 0.6; the value of maximum resistance to uniaxial compression of sandstone equal to 111 MPa. Thus, the range of the calculated resistance to compression was installed from 18.4 to 66.6 MPa.

A comparison was performed for two types of support:

- yieldable arch support KSHPU-20.3 of the special profile SVP-33, which is used for fixing workings on the block №10;
- metal - concrete support of I-beams №24, with the heaviest profile, which is used in coal mines.

Metal concrete support is one of the most powerful supports of the coal mines. Calculation results are shown in the figure, speak for themselves. With a reduction of calculated compression resistance of the roof rocks, the load on the yieldable support KSHPU - 20.3 increases low intensity. Whereas, a nonyieldable support (yielding is only 40 mm due to shrinkage of concrete) excludes subsidence of roof and takes the load one times more.

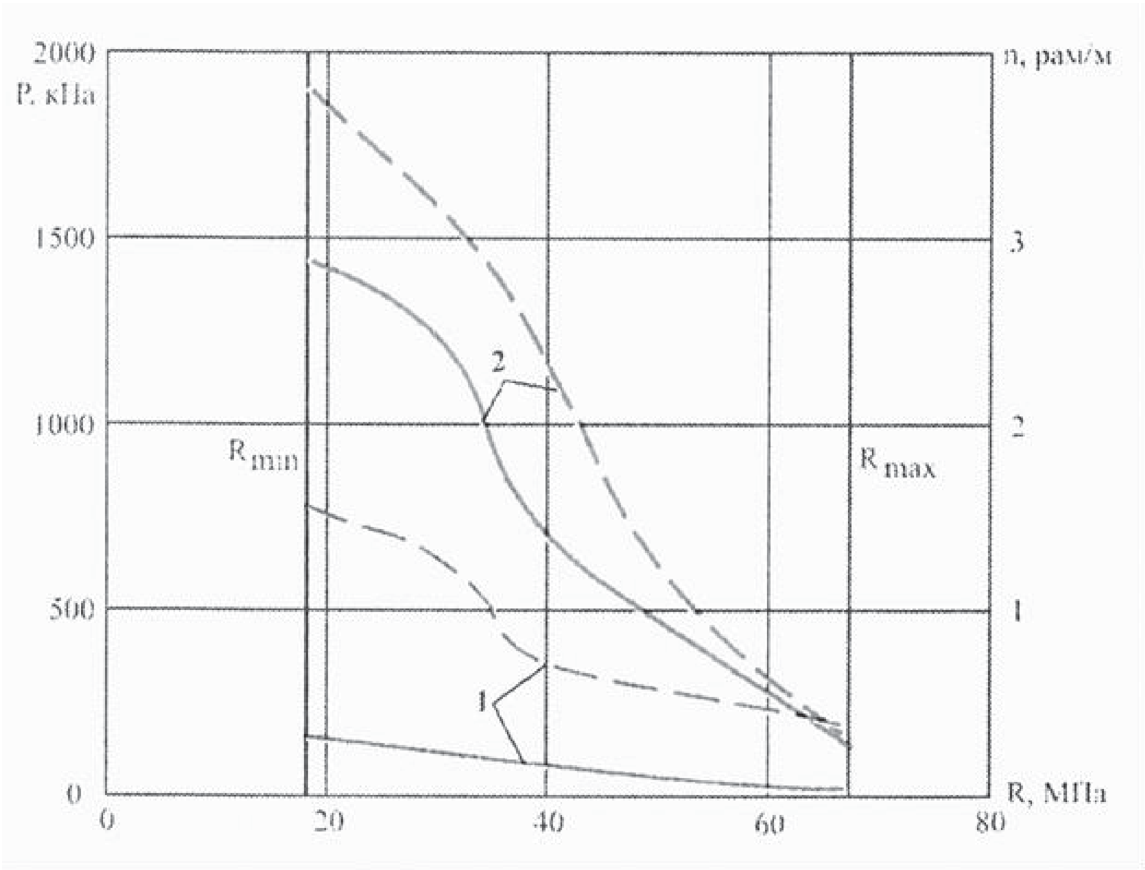

Figure 3.3. A validation of the use yieldable arch support:

1 - KSHPU-20.3; 2 - • metal - concrete support of I-beams №24;

_____ - the dependence of the load on the support to the compression resistance of roof rocks;

_ _ _ _ - the dependence of the number of arches per long meter of working from a parameter R

- Parameter validation for the model of yieldable support :

In these studies is solved the problem of adequately design of arch support KSHPU - 20.3.

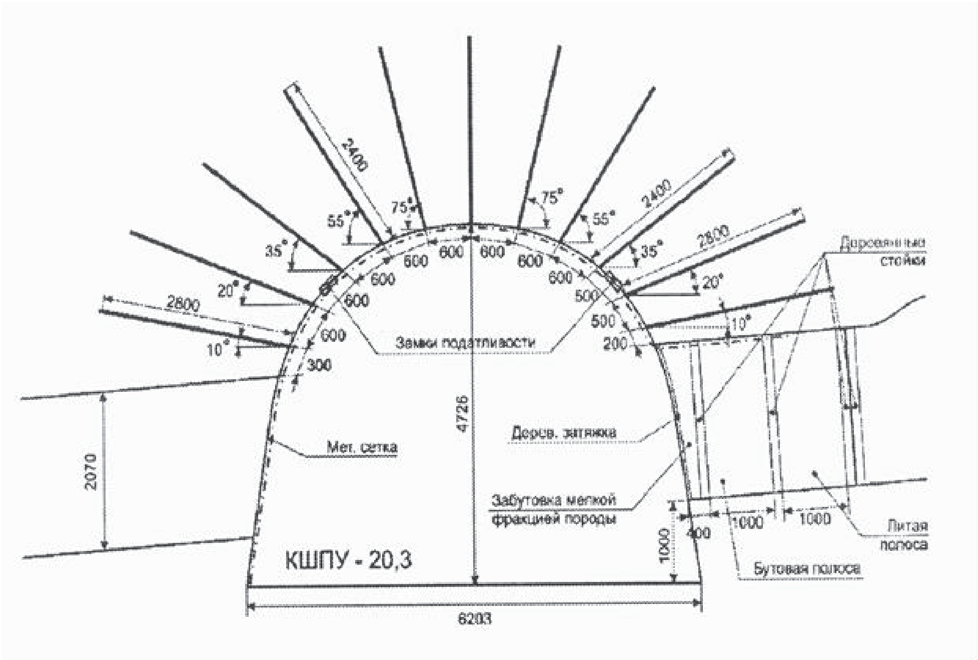

Figure 3.4. The design of roof support and security element of mining workings

The shape and size of support KSHPU-20.3 have shown in the figure 3.4. The arch is created of SVP-27 with the step of installation Z = 0.8 m along the working. ВП-27 instead of the SVP-33 does not reduce the stability of the working because of following reasons:

- reduced rigidity of profile gives a higher adaptation to the maximum external load;
- dense mesh reinforcement of the roof anchors takes a significant part of rock pressure;

➢ Validation of yieldable lock model for arch support KSHPU:

At the first stage of the yieldable lock simulation was attempted to perform full design in relation to the KSHPU support. However, the calculation of the SSS system is made only to the support subsidence, which is characterized by small movements of the working contour. An analysis of the situation revealed that due to a contact "point" of profiles and roof beam with each other in the lock, deformation (displacement) of arch becomes possible a large value (at the coordinates X, Y and Z) with very low load increment, that gives failures in the calculation of SSS. In this situation was made reasonable structural idealization of the yieldable lock imitation, allowing to proceed the calculation of SSS system.

- Validation of anchor model:

Design of anchors, which refer to the variety of resin-grouted roof bolt, displayed as authentically as possible. The anchors manufactured from reinforcing steel St.3, the length is 2400 mm, and their diameter is 22 mm. The mechanical properties of steel St.3 have the following values: yield strength is 220 MPa, a tensile strength is 380 ... 470 MPa, elastic modulus is $21 * 10^4$ MPa, Poisson's ratio is 0.3. Anchors are fixed in holes (diameter is 25 mm, length is 2300 mm). The space between the reinforcement and rock walls of the hole is filled with quick-polymer composition. (Bondarenko V.I., Kovalevskaya I.A. Eksperementalnie issledovaniya ustoychivosti povtorno ispozuemih viemochnih virabotok na pologih plastah Donbassa, 2012. – p. 70-83)

3.7. CONCLUSION

To improve the adequacy modeling of the displacement process of coal massif in the vicinity of the mining working are carried out simultaneous fulfillment of three conditions:

- spatial modeling of spatial objects;
- a reflection of the real structure of coal massif with a describing mechanical properties of each element;
- the most authentic modeling of the support, security structure and properties of their materials.

In accordance with the methodology of computer modeling of spatial systems "array - the supports" were substantiated structure and properties of the rock mass.

Computer model of arch and roof bolting support is created by the condition of the maximum possible reflection of their design features.

Testing of the developed model has proven its adequacy to the real object and the non-contradiction to the existing ideas of geomechanical processes in the vicinity of mining workings.

4 RESEARCH AND ANALYSIS OF THE STRESS - STRAIN STATE OF THE SYSTEM "MASSIF - SUPPORT"

4.1. INITIAL DATA

According to information received from the «Zapadno Donbasskaya» mine, the study was conducted for 1016 haulage drift (seam C^{B}_{10}) in incline part of Block №3 (length of 1469 m).

Supporting of working is performed with arch - roof bolting. Arch support is represented by KSHPU-11.7 with installation step 0.8m (profile type SVP-27). Sides and roof are fixed with metal grid. Roof bolting is installed in two rows of right side in the gaps between the arches and presented with anchors (diameter 22mm and length 2,4m). For the study, in order to improve economic, social indicators, and reusability of drift, used the following type of support:

- KSHPU-11.7, step of installation is 1m;
- type of profile SVP-22;
- 5 rows of anchors;
- fixing of the roof and sides - metal grid.

4.2. CREATING A MODEL OF THE ROCK MASS AND THE RESULTS OF THE STUDY

The sequence of the modeling:

- according to initial data was built rock massif (width 25 m, depth 1 m);
- working was created in coal seams;
- roof and sides were fixed with metal grid;
- support KSHPU - 11.7 was installed with installation step 1 m (2 frame);
- wells for the anchors were drilled with a diameter of 22 mm (5 rows);

- anchors were installed in the wells (5 rows);
- material parameters for each element of model were given (elasticity modulus, Poisson's ratio, density, tensile strength and compression strength, yield strength).

After the above mentioned, the model is ready to investigation.

The study begins with the creation of the contact zones between all elements of the model (the software automatically searches contact zones and creates them). Then, install fastening of the model: lower plane of model - fixed geometry; for the lateral planes are defined symmetry conditions. Then, install pressure on the upper plane 8 MPa (maximum pressure for the given conditions). The next step of modeling is creation a mesh, that is, divide the whole model into small plots (figures) for calculation. Run the study. In automatic mode, the program performs calculations and then gives results.

4.3. ANALYSIS OF THE STRESS - STRAIN STATE OF THE ROCK MASSIF AND ANALYSIS OF THE STRESS STATE OF THE WORKING SUPPORT

Analysis of the SSS within the dimensions of the model is needed to identify regularities behavior of the rock mass and its impact on the combined support. To fully assess state of the rock mass, the investigation was conducted for each of the main stresses component: vertical, horizontal, and reduced stress.

- Analysis of the SSS for horizontal stresses (Fig. 4.1):

The diagram of horizontal stresses in the rock mass has following features. Thanks to deformability of C_{10} coal seam in areas above the working, significant perturbation of bending stresses is not observed.

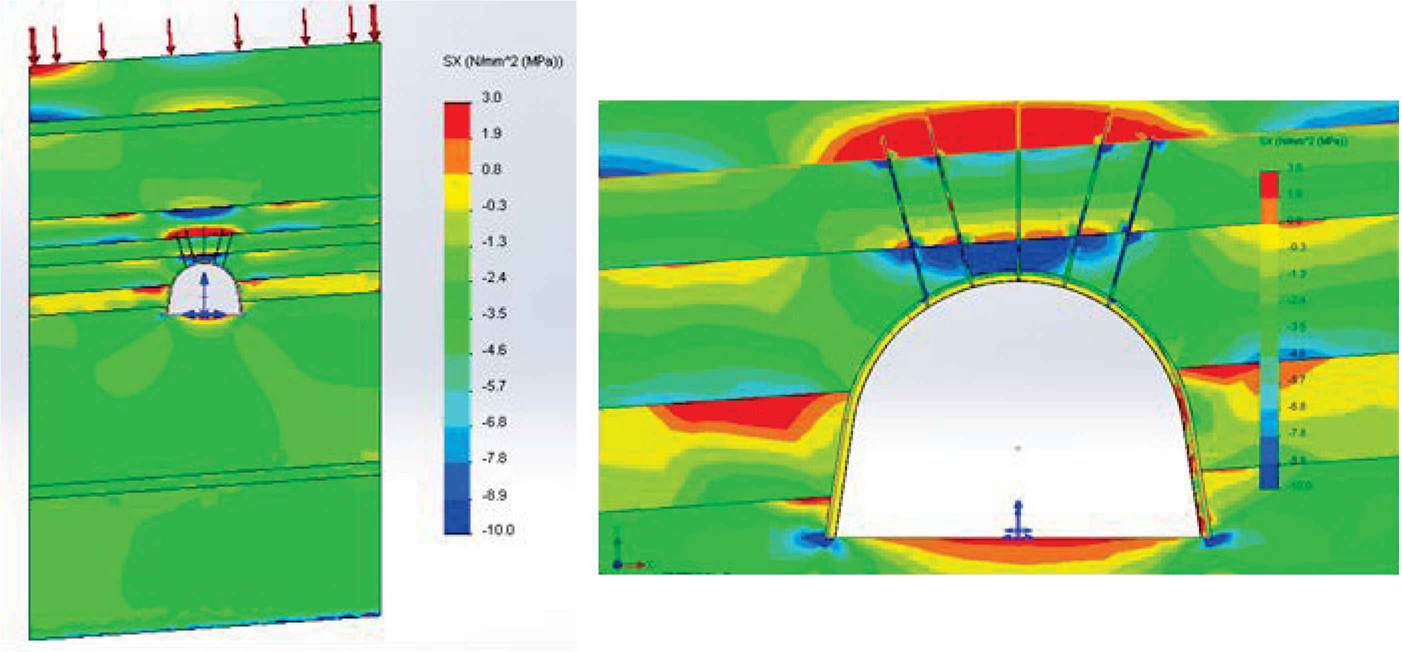

Figure 4.1. The diagram of the horizontal stresses in the rock mass

In the immediate roof is installed the field of horizontal compressive stresses of 6...10 MPa. On the sides of drift appears local area, there are small tensile stresses 0 ... 3 MPa. At the ground of working appear small tensile stresses 0...2MPa. In the area of the anchors, layer of sandstone, appear tensile stresses 0...3MPa. And accordingly, in the same layer of sandstone, at the upper boundary, appear compressive stresses 5 ... 10 MPa, indicating that there is a deflection of sandstone in the direction of the drift cavity. Practically across the entire massif there are small compressive stresses 0 ... 4 MPa.

According to the results in the installation zone of anchors appear compressive stresses 5 ... 10 MPa. Arches are exposed to small tensile stresses. According to the analysis of horizontal stresses, dangerous and destruction zones are not observed.

➢ Analysis of the SSS for vertical stresses (Fig. 4.2):

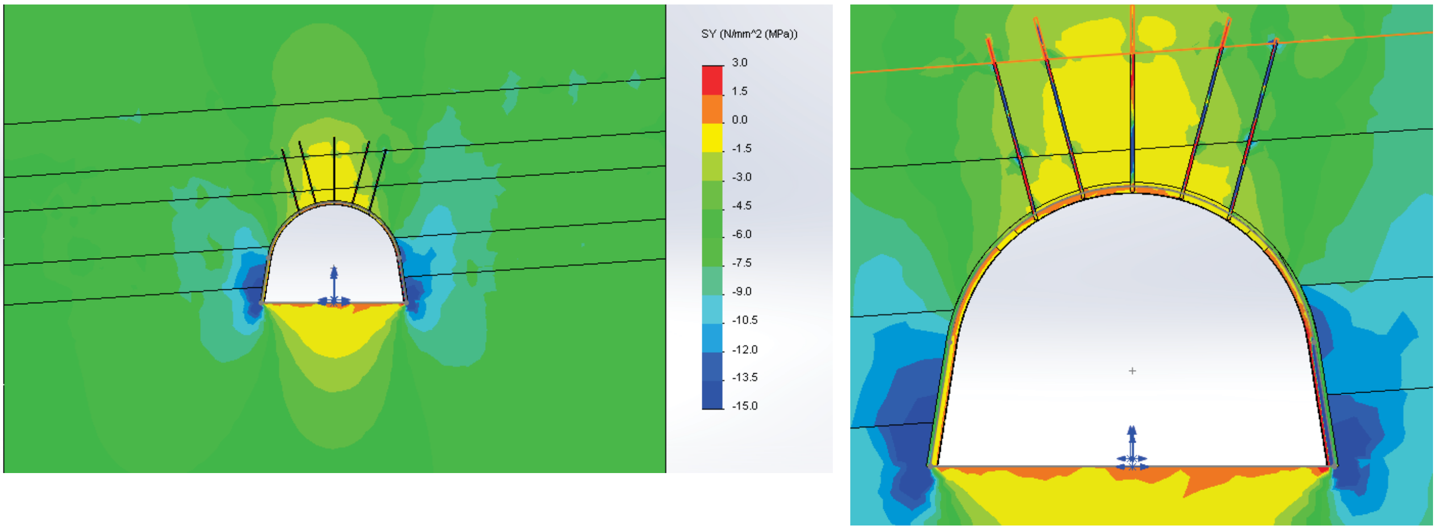

Figure 5.2. The diagram of vertical stresses in the rock mass

By results of research, it is seen that large vertical stresses around the rock massif are not appear. On the sides of working appear compressive stresses 9...15MPa. At the ground of drift appear tensile stresses 0 ... 2 MPa. Above working in the zone of immediate roof and main roof appear compressive stresses 0 ... 6 MPa. In the area of anchors are tensile and compressive stresses. Arches are exposed to tensile stresses 0 ... 3 MPa.

➢ Analysis of the SSS for reduced stresses (Fig. 4.3):

In the upper and lower layers of the massif is observed relative homogeneity of the stresses distribution 0 ... 5 MPa. On the sides of working, reduced stresses are increased almost 3 times (8 ... 14 MPa). Above the drift is observed heterogeneity distribution of reduced stresses 0 ... 8 MPa.

In all cases, the maximum stresses appear in the zones where arches have a contact with ground (3... 20 MPa). But such result is quite acceptable and dangerous zones or destruction zones do not appear.

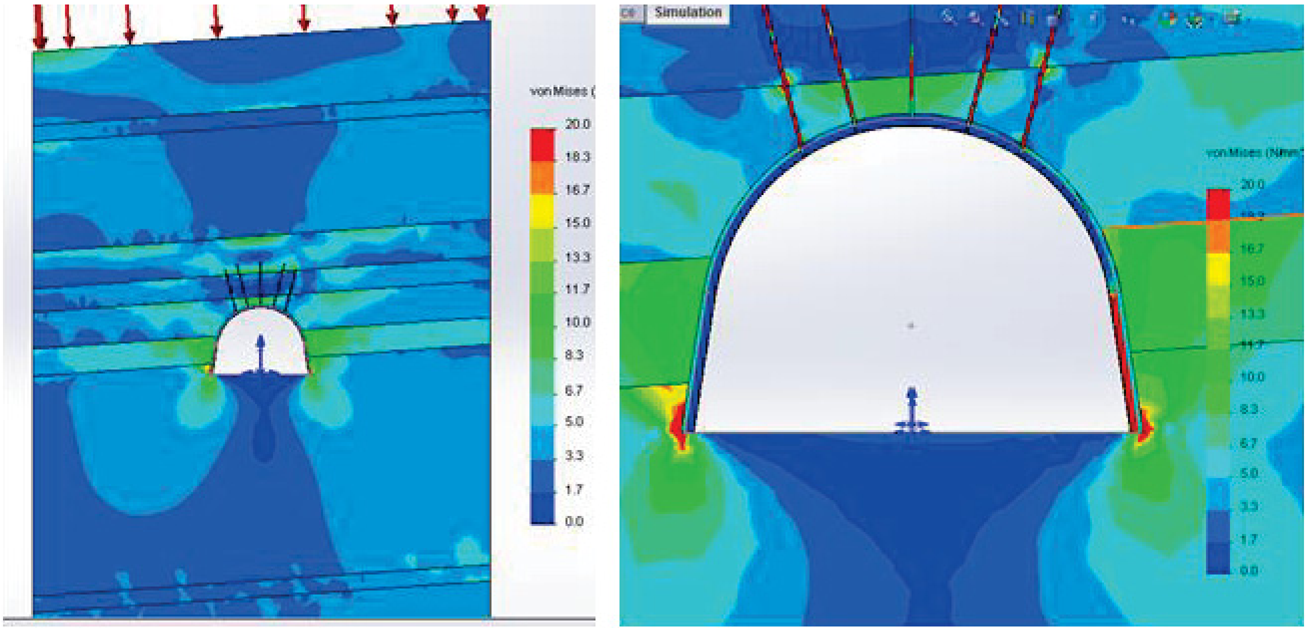

Figure 5.3. The diagram of reduced stress in the rock mass

As a conclusion it can be noted that the selected type of supporting and positioning of anchors shows good results for the given conditions and is recommended for use.

May also be noted, that the working is modeled without a wall face. Of course, when wall face will be in work, the stresses in rock mass will increase by several times, but they are, according to the forecast of mine will not be critical.

4.4. CONCLUSION

According to the simulation results it is seen that the selected type of roof support shows excellent results. The stresses in the rock mass do not exceed the critical values, which mean that the bearing capacity of the combined roof support will be sufficient to maintain working for further reuse.

As for changes in the selection of installation step of support and type of special profile, such solution is economically profitable because the number of sets is reduced on 25 arches per 100m of working, thus reducing the initial investment in the carrying out of working. These solutions will reduce the metal content of working, and facilitate the work of miners for fixing a drift.

The idea of working reusing contributes to a significant reduction in cost for creation a new one. Maintaining technology of a working during the passage of wall face is described in detail on the example of “Geroev Kosmosa” mine, and it is completely suitable for mining - geological conditions for “Zapadno Donbasskaya” mine.

5 ИССЛЕДОВАНИЯ И АНАЛИЗ НАПРЯЖЕННО – ДЕФОРМИРОВАННОГО СОСТОЯНИЯ СИСТЕМЫ «МАССИВ – КРЕПЬ»

5.1. ИСХОДНЫЕ ДАННЫЕ

Согласно полученным данным с шахты Западно Донбасская, исследование проводилось для 1016 сборного штрека пласта $С^{в}_{10}$ в бремсберговой части Блока №3 (длина 1469 м согласно паспорту проведения 1016 сборного штрека).

Крепление выработки производиться рамно - анкерной крепью. Рамная крепь представлена КШПУ-11,7 с шагом 0,8м (тип профиля СВП-27). Тип затяжки – кровля – деревянная затяжка, бока – металлическая решетка. Анкерная крепь устанавливается в два ряда правого борта в промежутках между стойками штрекового крепления выработки и представлена сталеполимерными анкерами диаметром 22мм и длиной 2,4м. Нижний анкер устанавливается под углом 60° к горизонту и в 150 мм от кровли пласта, верхний анкер устанавливается под углом 70° к горизонту и в 200-300 мм от нижнего анкера.

Для исследования, с целью улучшения экономических, социальных показателей и повторного использования штрека, используем следующий тип крепления:

- крепь КШПУ-11.7 с шагом установки 1м;
- тип спецпрофиля - СВП-22;
- 5 рядов анкеров;
- затяжка кровли и бортов – металлическая сетка.

Описание пород вмещающих массив показано ниже в таблице 5.1.

Таблица 5.1

Состав породного массива

	мощность, м	описание пород	$\sigma_{сж}$,	$\sigma_{раст}$,	f	Плот-ность
1	1.30-6.00	Песчаник серый, кварцевый, мелкозернистый, на глинисто-известковистом цементе, крепкий, абразивный, водоносный, трещиноватый, текстура слоистая, грубая, линзовидно-волнистая	30-60	1.6	3-6	2.32
2	0,42-1,02	Угольный пласт С11в -черный, крепкий, вязкий, полуматовый, штриховато-полосчатый, влажный, трещиноватый, контакты с боковыми породами ровные, резкие, слабые	30	1.6	3	1,26
3	2,35-12,55	Аргиллит т/серый, с горизонтальной слабо выраженной слоистостью, с включением сидиритовых почек, с остатками обугленной пиритизированной флоры.	20	1,9	2	2,4
4	0,0-0,10	Угольный пласт С11н -черный, крепкий, вязкий, полуматовый, штриховато-полосчатый, влажный, трещиноватый, контакты с боковыми породами ровные, резкие, слабые	30	1.6	3	1.26
5	0,0-3,0	Песчаник серый, кварцевый, мелкозернистый, на глинисто-известковистом цементе, крепкий, абразивный, водоносный, трещиноватый, текстура слоистая, грубая, линзовидно-волнистая	30-60	1.6	3-6	2.32
6	0,0-2.10	Алевролит серый, тонкозернистый, слюдистый, горизонтально-слоистый за счет наличия тонких линз песчаника	25	1,8	2,5	2,36
7	0,0-0,25	Угольный пропласток С10в1 -черный, крепкий, вязкий, полуматовый, штриховато-полосчатый, влажный, трещиноватый, контакты с боковыми породами ровные, резкие, слабые	30	1,6	3	1,26
8	0,0-3,5	Алевролит серый, слюдистый, мелкозернистый, текстура слоистая, тонкая, полого-волнистая, неустойчивый, влажный, трещиноватый	25	1,8	2	2,34
9	0,96-1,0	Угольный пласт С10в -черный, крепкий, вязкий, полуматовый, штриховато-полосчатый, влажный, трещиноватый, контакты с боковыми породами ровные, резкие, слабые	30	1,6	3	1,26
10	3,20-22,7	Аргиллит темно-серый, влажный, текстура слоистая, на контакте с почвой угольного пласта С10в мощностью до 0,5-0,7м имеет комковатую текстуру и весьма неустойчивый	9-18	1,2	0,9-1,8	2,4
11	0,0-0,90	Песчаник серый, кварцевый, мелкозернистый, на глинисто-известковистом цементе, крепкий, абразивный, водоносный, трещиноватый, текстура слоистая, грубая, линзовидно-волнистая	30-60	1,6	3,0-6,0	2,32
12	0,0-19,20	Алевролит серый, слюдистый, мелкозернистый, текстура слоистая, тонкая, полого-волнистая, неустойчивый, влажный, трещиноватый	25	1,8	2	2,34
13	0,0-4,10	Аргиллит т/серый, с горизонтальной слабо выраженной слоистостью, с включением сидиритовых почек, с остатками обугленной пиритизированной флоры.	20	1,9	2	2,4
14	1,0-1,05	Угольный пласт С9 -черный, крепкий, вязкий, полуматовый, штриховато-полосчатый, влажный, трещиноватый, контакты с боковыми породами ровные, резкие, слабые	30	1,6	3	1,26

5.2. ПОСТРОЕНИЕ МОДЕЛИ ГОРНОГО МАССИВА И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ

Последовательность выполнения моделирования:

- по исходным данным был построен горный массив (ширина 25 м, глубина 1 м);
- проведена выработка по пласту угля;
- кровля и борта затянуты металлической сеткой;
- установлена крепь КШПУ-11.7 с шагом установки 1 м (2 рамы);
- пробурены скважины для установки анкеров диаметром 22 мм (5 рядов);
- установлены анкера в скважины (5 рядов);
- заданы параметры материала для каждого элемента модели (модуль упругости, коэффициент Пуассона, плотность, предел прочности на растяжение и сжатие, предел текучести).

После выполнения выше указанного, модель готова к исследованию.

Исследование начинается с создания контактных зон между всеми элементами модели (программа выполняет автоматический поиск контактных зон и создает их). Затем, устанавливаем крепления модели: нижняя плоскость модели – фиксированная геометрия; для боковых плоскостей заданы условия симметрии. Далее, устанавливаем давление на верхнюю плоскость 8 МПа (максимальное давление для заданных условий). Следующим этапом моделирование является построение сетки, то есть деление всей модели на небольшие участки (фигуры) для проведения расчета. Запускаем исследование. В автоматическом режиме программа производит расчет, после чего выдает результаты.

5.3. АНАЛИЗ НАПРЯЖЕННО – ДЕФОРМИРОВАННОГО СОСТОЯНИЯ УГЛЕВМЕЩАЮЩЕГО ПОРОДНОГО МАССИВА И НАПРЯЖЕННОГО СОСТОЯНИЯ КРЕПИ ВЫРАБОТКИ

Анализ НДС в пределах размеров модели необходим для выявления закономерностей поведения горного массива и его влияния на комбинированную крепь. Для всесторонней оценки состояния породного массива исследование проведено по каждой из основных компонент напряжений: вертикальных, горизонтальных и приведенных напряжений.

- Анализ НДС массива по эпюре горизонтальных напряжений (рис. 5.1):

Эпюра горизонтальных напряжений в горном массиве имеет следующие особенности. Благодаря деформативности угольного пласта C_{10} в областях над штреком значительных возмущений напряжений изгиба не наблюдается.

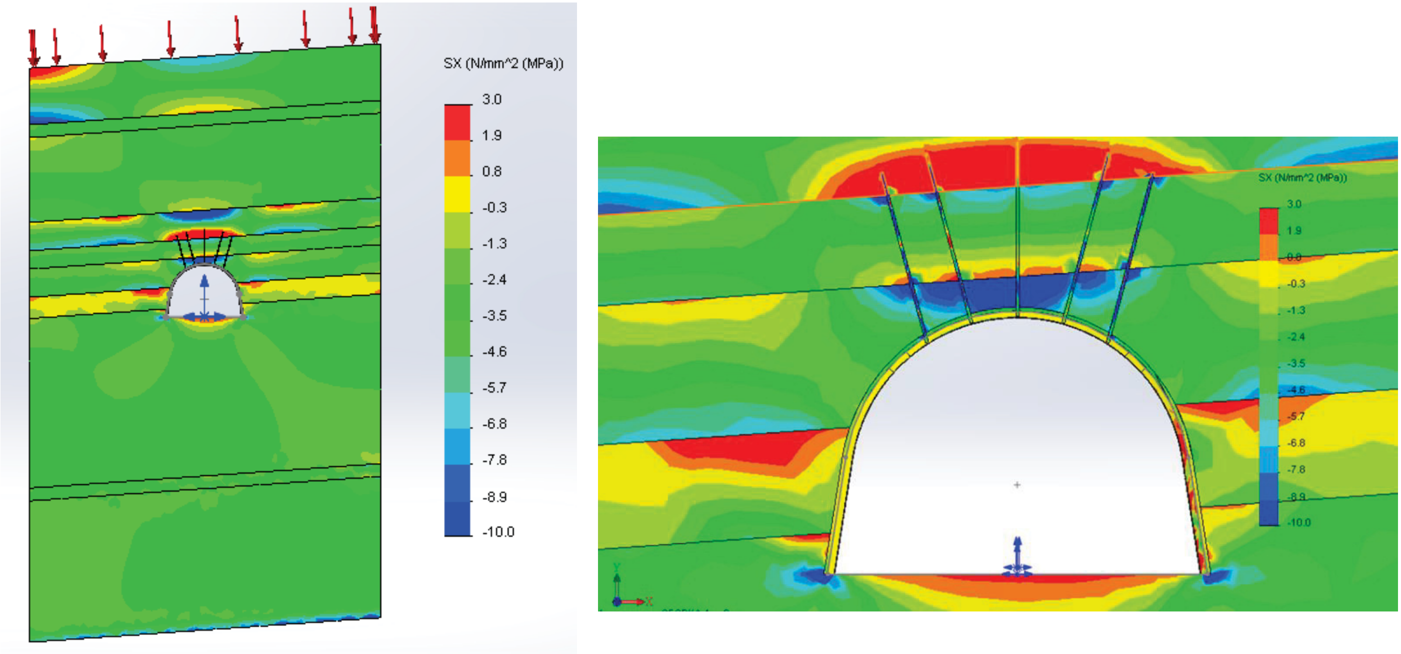

Рисунок 5.1. Эпюра горизонтальных напряжений в породном массиве

В непосредственной кровле устанавливается поле сжимающих горизонтальных напряжений на уровне 6…10 МПа. По бокам штрека появляются локальные области, где возникаю небольшие растягивающие напряжения 0…3 МПа. В почве выработки возникают небольшие растягивающие напряжения 0…2 МПа. В зоне работы анкеров, в песчанике, появляются растягивающие напряжения 0…3 МПа. И соответственно, в этом же слое песчаника, на верхней границе, появляются сжимающие напряжения 5…10 МПа, что свидетельствует о прогибе песчаника в направлении полости штрека. Практически по всему массиву возникаю небольшие сжимающие напряжения 0…4 МПа.

Согласно полученным результатам в зоне работы анкеров возникаю сжимающие напряжения 5…10 МПа. Рамы подвержены не большим растягивающим напряжениям.

По оценке горизонтальных напряжений опасных зон и зон разрушения не наблюдается.

- Анализ НДС массива по эпюре вертикальных напряжений (рис. 5.2):

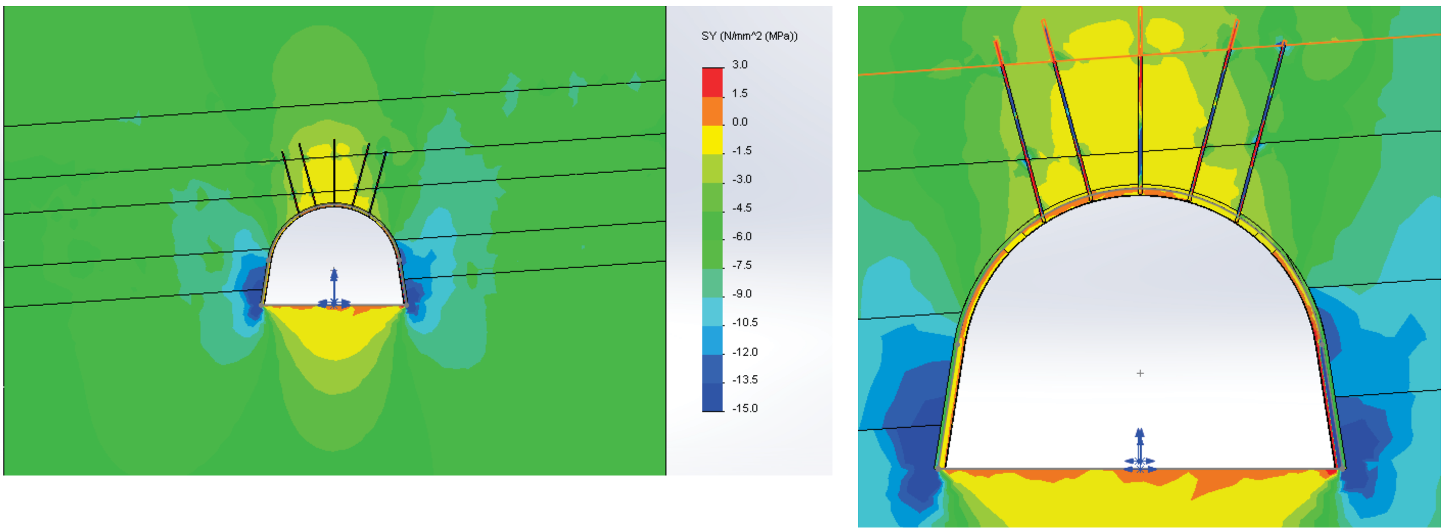

Рисунок 5.2. Эпюра вертикальных напряжений в породном массиве

По результатам исследования видно, что больших вертикальных напряжений по всему горному массиву не возникает. По бокам выработки появляются сжимающие напряжения 9…15 МПа. В почве выработки появляются растягивающие напряжения 0…2 МПа. Непосредственно над выработкой в зоне непосредственной и основной кровли возникают сжимающие напряжения 0…6 МПа. В зоне работы анкеров растягивающие и сжимающие напряжения. Рамы подвержены растягивающим напряжениям 0…3 МПа.

По оценке вертикальных напряжений опасных зон и зон разрушения не наблюдается.

- Анализ НДС массива по эпюре приведенных напряжений (рис. 5.3):

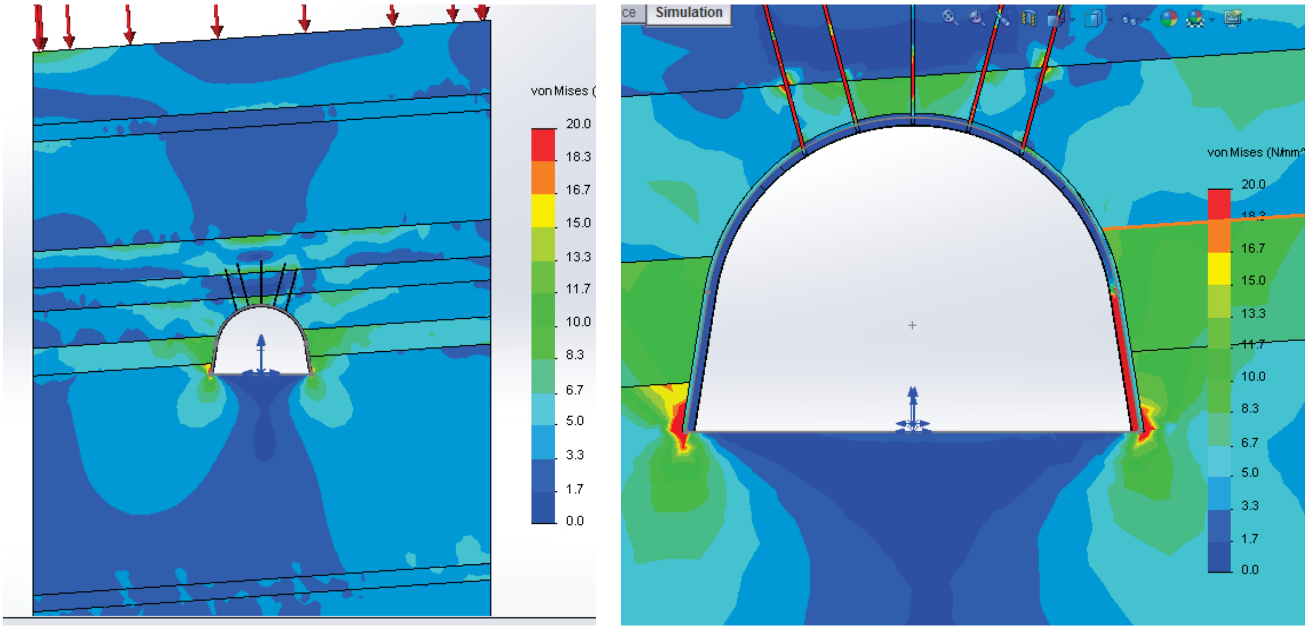

Рисунок 5.3. Эпюра приведенных напряжений в горном массиве

В верхних и нижних слоях массива наблюдается относительная однородность распределения напряжений 0…5 МПа. По бокам выработки приведенные напряжения увеличиваются почти в 3 раза (8…14 МПа). Над выработкой наблюдается неоднородность распределения напряжений 0…8 МПа.

Во всех случаях оценки состояния горного массива максимальные напряжения возникают в зоне давления рамы на почву 3…20 МПа. Но такой результат весьма приемлем, опасных и зон разрушения не возникает.

Как вывод можно отметить, что выбранный тип крепления и расположения анкеров показывает хорошие результаты для данных условий и рекомендуется для использования.

Что можно отметить, что выработка смоделирована без учета работы лавы. Конечно, в результате работы лавы напряжения в горном массиве увеличатся в несколько раз, но они, согласно шахтному прогнозу, не будут критическими.

5.4. ВЫВОД

По результатам моделирования видно, что выбранный тип крепи показывает позитивные результаты. Напряжения в горном массиве не превышают критических значений, а значит, несущая способность комбинированной крепи будет достаточная для поддержания выработки.

Что касается изменений в выборе спецпрофиля и шага установки крепи, то такое решение является экономически выгодным, так как количество комплектов рам уменьшается на 25 на каждые 100 м выработки, что позволит уменьшить капиталовложения в проведение выработки. Данные решения приведут к уменьшению металлоёмкости выработки, и облегчат работу шахтеров по креплению штрека.

Сама идея повторного использования выработки способствует существенному снижению затрат на проведение новой. Технология поддержания выработки во время прохода лавы детально описана на примере шахты имени Героев Космоса, и она полностью подходит для горно – геологических условий шахты Западно Донбасская.

6 LABOUR PROTECTION.

Mining workings must be fixed and supported whole lifetime accordance with technical and project documentations (TPD).

In case of changes of geological and production conditions TPD, carrying and fixing of underground workings must be revised during a day.

Not allowed mining without approved project.

Allowed operation without fixing of ventilation wells, drilled in strong stable coal (f > 1.5 on a scale of prof. Protodiakonov).

When working is fixed by anchors, are not allowed to hang on anchors fixing of cables, pipes and other equipment. Mandatory is to use a sensor control of massif condition.

Backlog of constant fixing of wall face is determined by TPD, but cannot be greater than 3 m, thus must be installed temporary fixing.

In case of carrying out of preparatory workings with datalling, backlog of rock face from coal face should not exceed 5 m.

In the case of carrying out of preparatory workings behind wall face, backlog of rock face from coal face should not exceed 5 m in mining working with individual fixing, 8 m - mechanized fixing and 11 m - when mining of coal is performed by a plow.

During the carrying out of preparatory workings in a goaf or carrying out works in weak rocks to prevent a rock rash should be provided the use of advanced fixing or other special fixing.

Not allowed to use any kind of fixing without their full complete set.

In case of deepening or repair inclined working, workers (who work in it) should be protected from fall hazards of trolleys (skip) and other items at least two strong veils (barriers).

Cross-sectional area of horizontal and inclined workings in the light is determined by calculating the permissible speed of air jet (ventilation), the size of mobile equipment and equipment with the minimum permissible clearances. (Safety rules in coal mines, 2010.)

Duty to secure safety of each working place:

It should be the duty of the manager of every mine to take such steps to control movement of the strata in the mine and support the roof and sides as may be necessary to keep each working place secure.

It should be the duty of the manager of every mine to ensure that he is at all times in possession of all information necessary for him to keep each working place secure.

It should be the duty of the manager of every mine to formulate Support Rules which should specify, for each working place, the maximum intervals between:

- supports on roadways;
- each row of props, roof bolts or other supports at the face;
- adjacent props, roof bolts or other supports in the same row;
- the last row of supports and the face;
- powered supports;
- holing props or sprags;
- chocks;

- packs.

The Support Rules should clearly state that the specified intervals are maximum distance and that, where additional supports appear to be needed, it should be the duty of those engaged in that place to set them or, if such persons are not competent to do this, to report to the supervisory official.

At every place where machinery is used for cutting, conveying or loading, the system of support should require cross supports (bars) to be set above every prop that the

Where armoured conveyors are used on the coal face, the props, bars and powered supports should be of an approved type.

The competent authority should determine the approval standards for these supports.

Support Rules for each mine should include such plans, sections and diagrams as to make them readily understood by those required to carry them out.

Copies of the Support Rules relative to each working place should be posted where they can be easily seen at the entrances to the district to which they apply.

Where withdrawal of support is required, it should be done in accordance with the method which should be specified in the Support Rules. The procedure should cover the use of the appropriate tools and safety contrivances, the setting of extra supports to control the collapse of roof from which supports are being withdrawn, and the safe positioning of those persons engaged in the operation. Such persons should be competent in this type of work.

In thick or steeply inclined seams, holing props or sprags should not be removed except in accordance with the requirements of the Support Rules.

It should be the duty of each mine operator and mine manager to provide supports of suitable material, adequate strength and in sufficient quantity where they are readily available for use.

Every prop set to support the roof or sides of working faces or roadways should be set securely and on a proper foundation. Whenever such props become broken or otherwise unstable, they should be replaced forthwith. If this cannot be done, it should be immediately reported to the supervisory official.

All chocks forming part of a system of support should be built on a proper foundation and made tight to the roof.

All packs forming part of a system of support should, so far as is practicable, be made tight to the roof over their whole area.

All roadway supports should be securely set so as to maintain maximum stability. Where practicable they should be fixed by ties or struts to the neighbouring support. Cavities above the supports should be filled in so far as is practicable.

The supervisory staff and the workers concerned should examine and test the roof, sides and supports as often as is necessary to ensure their safety and particularly before work is resumed after an interruption.

In inclined seams, the supporting props or chocks should be set to ensure maximum support having regard to the inclination of the seam or road and probable strata movement.

Where necessary, such supports should be reinforced to prevent displacement.

Overhanging coal or sides should be taken down. Where this is not practicable, suitable sprags or other means of support should be set.

A person using roof bolts to form part of a system of support in a mine should ensure that the roof bolts are securely fixed in place.

Powered supports: general provisions

No powered support should be used below ground unless it has been certified as being constructed to an appropriate standard. It should be the duty of the competent authority to specify the tests and examinations to which supports should be subjected before they are certified.

Where the competent authority of an importing country does not have the necessary facilities to carry out the specified tests and examinations, it should be the responsibility of the exporting manufacturers to provide the documentation certifying that the supports and equipment are in compliance with the importing country's requirements. Such tests and examinations should cover:

- the mechanical strength of individual structures to ensure that they will withstand, without damage, the forces imposed on them;
- the expected life of individual components as simulated by cyclic testing;
- the performance of the complete support;
- the reliability of the valve gear and the extent to which it can be operated from a safe place;
- the ability of hose lines and connectors to meet the demands made on them with a specified factor of safety;
- the ratio of soluble oil to water in the hydraulic fluid to ensure that the mix does not contain less than 5 per cent soluble oil and also to ensure that mineral oil is not used as hydraulic fluid;
- the specification of the hydraulic fluid tank to check that the tank is equipped with devices to ensure its safe operation;

- the specification of the pump to ensure that the pump is suitable for the system;
- acquisition of the information required to determine the maximum interval between supports.

Where, by reason of any irregularity in the roof, floor or sides, the powered supports are ineffective in ensuring safety, and, notwithstanding the Support Rules should make provision for the use of conventional supports until such time as the conditions allow normal use of the powered supports.

Any person whose duties include the setting of powered supports should ensure that they are set securely. When it appears that a powered support is defective, it should be reported forthwith to the supervisory official. It should be the duty of a supervisory official, who becomes aware of a defective powered support, to have it repaired as soon as possible and to ensure that the roof at that place is effectively supported.

The provisions of the Support Rules relative to powered-support faces should specify the intervals between adjacent supports and should require that supports be advanced as soon as practicable after a web of coal of stated thickness has been taken by the power loader, so as to ensure that the area of unsupported newly exposed roof is kept to a minimum.

Persons should not normally work on the face side of an armoured face conveyor. However, provisions should be included in the manager's Support Rules for the support of roof and sides during any period it becomes necessary for persons to work on the face side of an armoured face conveyor for whatever reason. The system of work should be so organized and the equipment provided so designed and used that the need for persons to cross to the face side of the armoured conveyor is minimized.

Installation and withdrawal of powered supports in every mine where powered supports are used, it should be the duty of the manager to draw up a scheme for the installation of powered supports and a scheme for their withdrawal and transport. The scheme for the installation of powered supports should cover:

- the method of transportation of the powered supports from the surface to the coal face where they are to be used, with special emphasis on the correct use of the safe-handling and lifting points;
- the provision of suitable vehicles, purpose-built where necessary, for the transport of supports;
- the provision of a suitable winch equipped with load-limitation facilities for hauling the powered supports along the face line;
- the provision of haulage equipment of ample size, strength and design;
- the method of supporting the face line during the installation of the powered supports.

The scheme for the withdrawal and transportation of powered supports should cover -

- the method of support of the face line during the withdrawal operation;
- the method of transportation of the powered supports from the face line to their new site;

Where practicable, diesel-, battery- or mains- powered self-propelling machinery, including shuttle cars, used at or in the vicinity of the coal face, should be provided with roof canopies or cabs which give adequate protection against falls of ground from the roof or sides.

Where any fall of roof or side breaks or otherwise renders ineffective any support at any place where any person has to pass or work, it should be the duty of the supervisory official to ensure that any roof or side exposed or adjacent thereto is, if necessary, dressed and secured by supports. Such work should be done before any work of clearing debris is begun, except such work as is necessary for the setting of supports.

Where the above provisions cannot be observed, no persons should pass or work be done at that place except under the supervision of a supervisory official. (International Labour Organisation: Safety and health in coal mines, 1986. – p. 68 – 74.)

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