CONSIDERABLE ASPECTS TO SELECT FILTER WELLS FOR DEWATERING OPENCAST MINES USING HDD TECHNOLOGY

TRAN, DUC HUAN [1, 2] ; DREBENSTEDT, CARSTEN[1]

1. Institute for Mining, Freiberg University of Mining and Technology, Germany
2. Hanoi University of Mining and Geology, Vietnam

Abstract

In surface mining activity, dewatering is one of the most important auxiliary tasks. The drainage operation ensures the mining safety and the stability of the slope. In a certain geological condition of thin aquifers which is typical in lignite mines, an innovative approach of dewatering has been developed and experimented. The approach uses the Horizontal Directional Drilling (HDD) technology to install filter screens along the aquifers to catch water from overlying formations. This dewatering system may provide some advantages over the conventional way of using vertical wells by means of efficiency and dewatering effect in the same condition (Eichler and .C). The significantly important task of the novel approach is to place the filter wells inside the boreholes that will be used to dewater the mines. The currently used filter type is PVC wire-wound screen, which is normally used for vertical wells (Müller, Jolas and Mansel). Based on the literature analysis, this paper is to refer to the aspects that should be carefully considered to select the appropriate type of filter wells. The consideration may provide solutions to improve the wellbore design, reduces the expenses and partly deals with challenges that posed by this newly established approach.

Keywords

Filter wells, opencast mines, dewatering, HDD technology

1. Introduction

Water drainage of overburden materials is a prerequisite task of coal mining and lignite mining done by opencast operation. It is not only important to provide a water-free pit, but also in order to ensure the geotechnical safety of benches and mining slopes. Especially, when the overburden consists of lose material of sand and gravel; the water can easily flow into the mining area due to high conductivity that can cause the serious threaten to the mining activities at the excavation face. To maintain the opencast mining operations, a conservative way of using vertical wells has been being widely deployed. Due to this approach, some of vertical wells are installed in advance to keep the water out of the mine. However, in thin aquifers, the vertical wells have short active screen sections and the effective sections will continuously decrease due to dewatering process. The ground water level is lowered with a waved shape as shown in Figure 1 (Eichler and .C). Additionally, every single vertical well should be equipped with some other equipment: such as a pump, electrical equipment, penstock… etc. In this context, a new approach of using horizontal filter wells has been proved its advantages by having longer effective section and non-disturbing mining activities due to equipment removal as with vertical wells. By using this approach, the ground water is lowered gradually and consistently, the dewatering scheme can be seen in Figure 2 (Eichler and .C). The installation of horizontal filter wells is accomplished by HDD technology. To have a successful installation and more economically effective, the filter well should be carefully selected based on the combination of the HDD technology and the characteristic of dewatering opencast mines. This paper analyzes the significant aspects that might affect to the selection of a filter well.

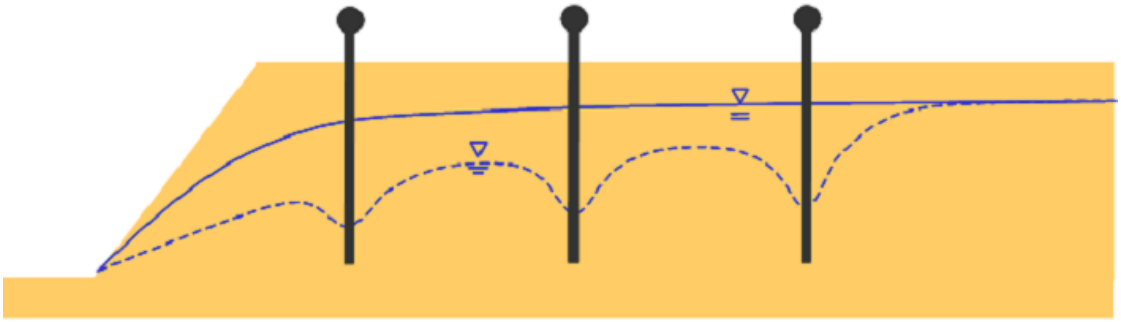


Figure 1: Groundwater is lowered by three vertical wells (Eichler and .C)

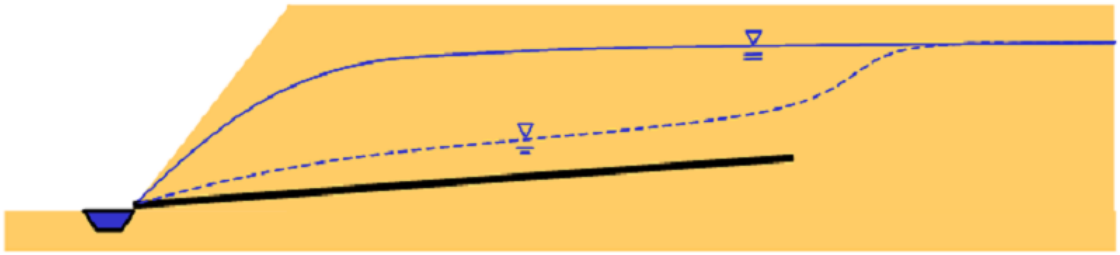


Figure 2: Groundwater is lowered by a horizontal well (Eichler and .C)

2. Horizontal filter wells to dewater opencast mines

An important task of the newly established approach to dewater opencast mines is to install a filter well along the aquifer, under the overburden materials. The installation is done by using HDD technique that typically consists of three successive steps. Firstly, the drilling machine makes a pilot hole along the planed path to get access from enter point to exit point. After that, the pilot hole is widened within reaming step. In this step, a reamer with diameter of 1.3 to 1.5 times larger than the pipe's outside diameter is used, the direction of reaming operation is from the exit point to the entry point. Finally, in the pulling step, a pipe or a cable is pulled back into the borehole in exit-entry point direction (F1962-11). With the classical HDD technique to install utilities under obstacles, the installation finished by inspection and site cleanup. However, due to the characteristic of HDD-wells for dewatering opencast mines, an additional step required to take out the protection pipe (Figure 3). The protection pipes used whether made of HDPE or steel aim to ensure filter well not to break during the pulling back operation.

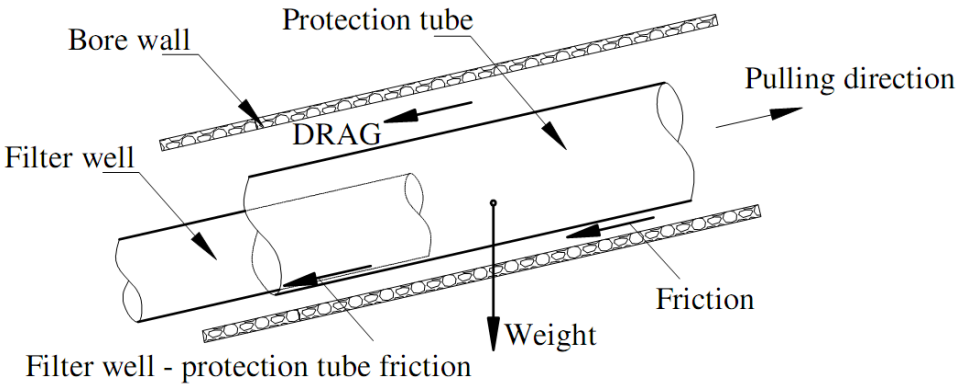


Figure 3: Step to take out protection pipe while installing HDD-Wells

The using of protection layer required bigger diameter of final borehole as well as more working step. That makes this newly established method less economically effective.

After the placement of the filter well into the desired position, the water from aquifers as well as overlying materials is collected into the filter and let to flow out freely to the mine's bottom or a collected basin by its gravity. Then water is pumped out by a larger and more effective pump or treated if required. This is advantages of HDD wells for dewatering opencast mines.

To improve this dewatering method, get more economical effectiveness, a proposal of eliminating the protection pipe has been made by using more appropriate structure of the filter well. If it is successfully implemented, it might reduce significantly the time and expenses to apply HDD wells for opencast mining dewatering. This paper focuses on the aspects that should be examined and considered before selecting a filter for above-mentioned recommendation.

3. Considerable aspects to select a HDD well

3.1. Mechanical strength of the filter well

Similar to the pipe in the classic HDD, the horizontal filter well will be subject to loads during its operation as well as during the installation process, especially when the filter well is installed without the protection pipe (F1962-11). Unlike the long-term operation of the pipeline in the classic HDD, the operation time of a filter well is relatively shorter due to the advance of mining excavation face. Hence, the loads during operation of a filter well might play insignificant role and the load during installation should be more addressed.

To be successfully installed directly, the filter pipe should be strong enough to overcome total loads produced in the installation process that include: tensile force, bending stress, external forces and torsion moment (Figure 4).

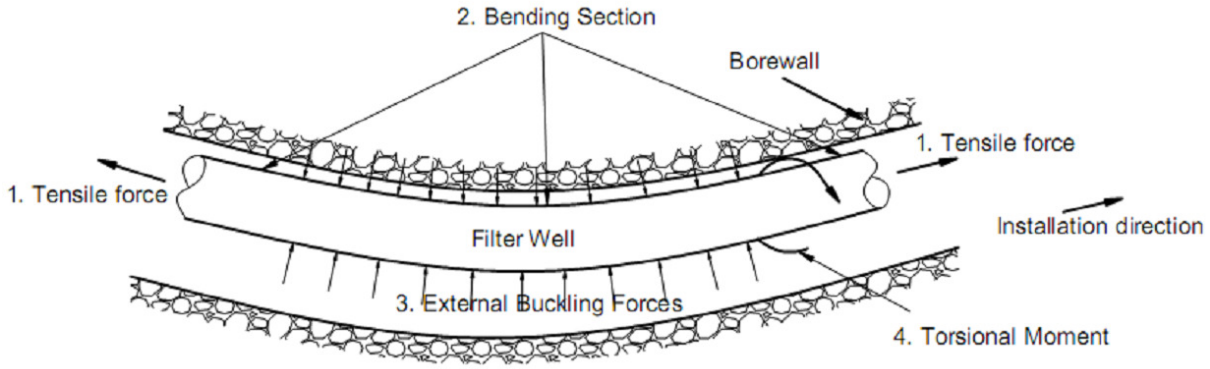


Figure 4: Forces acting on the filter well during installation process

The tensile force on the filter results from the fractional drag forces acting on the sides of the filter due to pulling the weight or buoyancy forces as it is pulled into and along the borehole, force amplifications due to pulling the pipe around the curved sections, and the resistant forces due to the pipe stiffness (F1962-11). The external buckling forces is due to the net external pressure, is the differential pressure between the inside and outside of the pipe. The filter pipe must be sufficient strong to withstand the external pressure without collapsing or deflecting during installation. The filter sometimes experiences the curved section during installation that induces axial bending stress. Last but not least, a small portion of torsion moment is transmitted to the filter well due to the rotation of drilling rod and non-100% efficiency of swivel connection. The combination of these forces may damage the filter well in installation process when it is not thoroughly anticipated or the filter is not properly selected.

So far, to the understanding of the authors, the methods to predict loads during HDD installation and stress analysis for smooth steel pipes, smooth PE pipes or smooth PVC pipes have been developed by a number of researchers (e.g. as in (F1962-11) (Ariaratnam, Botteicher and Ghosh) (Huey and McLeod) (Chu)) and lots of others. However, the works to address the loads and stress analysis for non-smooth pipes (i.e. pipe with perforations or slots on the wall of filter wells) have not yet thoroughly researched. This is an important aspect to consider when choose the type of filter for opencast mining dewatering purpose and should need further investigations.

3.2. Hydraulic performance of the filter well

Different from the normal pipelines for classic HDD that should be put into operation after the installation by suffering external loads from surrounding environment and internal loads from gas or liquid, the filter wells operate by water collecting purpose. This relates to the hydraulic performance of a horizontal filter well that consists of two main aspects: pressure drop of a filter well and dewatering effect (production rate) of a filter well.

As mentioned above, the currently chose type of filter is PVC wire-wound screens that have been used widely in vertical wells. For horizontal wells, it is needed to use an additional pipe layer to protect those screens from damage while installing. From the structure of those screens (Figure 5), it can be easily seen that it might cause huge pulling force and be relatively weak in withstanding tensile force as well as bending stress due to relatively rough and scattered surface. Hence, it should be realized that this kind of filter screen would not be appropriate when installed directly or without the protection pipe.

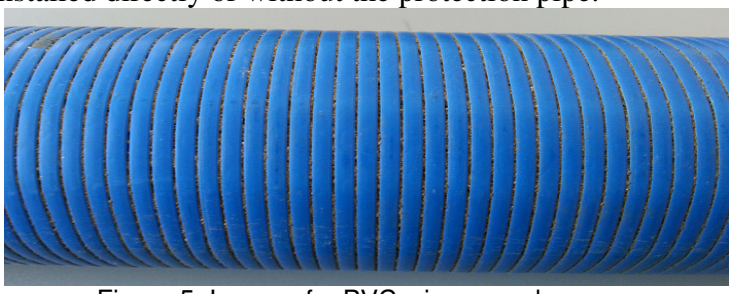
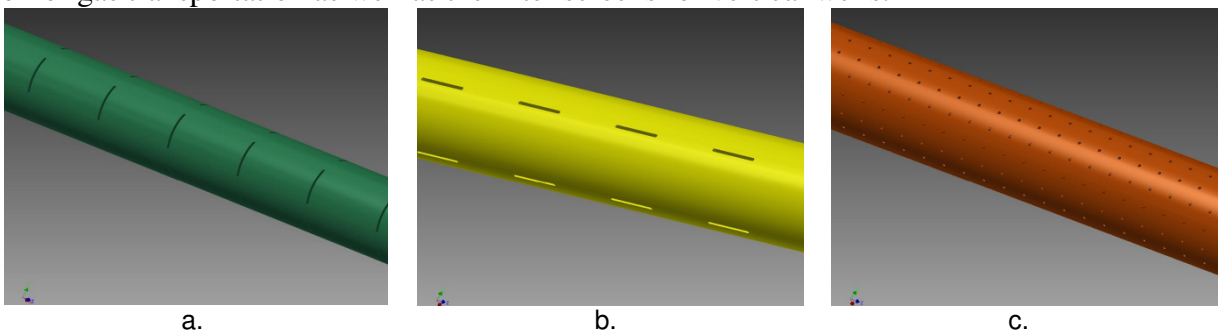


Figure 5: Image of a PVC wire-wound screen

Instead of using wire-wrapped screen, it might be more proper to use perforated/slotted pipes as filter wells due to the wide range applications of perforated/slotted pipes as horizontal well in gas and oil industry (Tang, Ozkan and Kelkar) (Yildiz) , as water wells for irrigation systems (Boman and Hardin) (Clark), or as drain tubes in drainage system (Schwab). The common types of perforated/slotted pipes are shown in Figure 6.The hydraulic performance of perforated/slotted pipes as HDD wells includes two main aspects which are pressure losses and dewatering productivity. They are different from the normal pipelines that used for water, oil or gas transportation as well as the filter screens for vertical wells.



a. b. c.

Figure 6: Common types of perforated/slotted pipes

The pressure drop in a normal circular pipe mainly depends on Reynolds number and the roughness of the pipe's wall. However, with the perforated/slotted pipes, besides those factors, the pressure losses are also dependent on perforations/slots roughness and the mixing effects due to the existing of cavities on the pipe's wall and the entering of influx through the wall, respectively (Clemo). Based on the restriction of the percentage of the open area (cavity ratio) of the perforated/slotted screens, that should be ranged from 2% to 5% (Boman and Hardin), the investigations of pressure drop with different kinds of perforated/slotted filters as HDD wells should be accomplished. The dewatering productivity of a horizontal well is a function of different parameters, such as water table, conductivity of surrounding environment, pressure drop along the well, diameter of the pipe, annular space... etc. To figure out the proper type of perforated/slotted pipe for HDD wells in term of dewatering effect, an important task is to investigate the permeability of those different types while other parameters restricted. This is a subject of an ongoing research.

4. Discussion

Selection proper type of filter wells from perforated/slotted pipes is the combinations of mechanical strength and the hydraulic performance. To find out what kind of perforated or slotted pipe should be used for HDD wells while being installed directly (without protection layer), more investigations are required. Beyond the mechanical strength, the investigation of interaction between the perforated/slotted pipes and the surrounding environment should also be addressed.

5. Conclusions

The new approach of dewatering opencast mines based on horizontal filter wells installed by HDD technology promises bringing great advantages in term of energy, materials saving and dewatering effect compared with vertical wells, particularly in the geological condition of thin aquifers. The successful application of HDD wells mainly depends on the installation process, in which the filter wells should be carefully selected based on its mechanical properties and the hydraulic performance. The deficiencies of criteria to select those filters well under mining conditions and in combined with HDD technology, especially when they are installed without protection layer, should need further works to deal with. The appropriate selection of filter wells might help to improve the wellbore design, shorten working steps and gain more economical effectiveness.

References

Ariaratnam, Samuel T., et al. "Predictive Modeling of Installation Loads for Directional Drilled Fusible PVC Pipe." (2009).

Boman, Brian and Sanjay Shukla and J.D. Hardin. "Design and Construction of Screened Wells for Agricultural Irrigation Systems." Circular 1454, Institute of Food and Agricultural Sciences, University of Florida 2013.

Chu, Maria Anna Polak and Dennis. "Pulling Loads for Polyethylene Pipes in Horizontal Directional Drilling: Theoretical Modeling and Parametric Study." (2005).

Clark, Dorota Z. Haman and Gary A. "Water Wells for Florida Irrigation Systems." CIR803, Agricultural and Biological Engineering Department 1988.

Clemo, Tom. "Flow in Perforated Pipes: A Comparison of Models and Experiments." SPE 89036 (May.18, 2005).

Eichler, Richard A. and Drebenstedt .C. "Innovative Dewatering Concepts for Open Cast Mines Using Horizontal Wells (HDD-Wells)." Springer, 2014.

F1962-11, ASTM. "Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings." (2011).

Huey, David P. and John D. Hair and K. Brett McLeod. "Installation Loading and Stress Analysis Involved with Pipelines Installed by Horizontal Directional Drilling." (1996).

Müller, Mike, et al. "Dewatering of Multi-aquifer Unconsolidated Rock Opencast Mines - Alternative Solutions with Horizontal Wells." Sydney, 2010.

Schwab, Glem O. "Subsurface Drainage with Small Perforated Flexible Tubes in Mole Drains." Retrospective Theses and Dissertations. Paper 13178 (1951).

Tang, Yula, et al. "Performance of Horizontal Wells Completed with Slotted Liners and Perforations." (November, 2000).

Yildiz, Turhan. "Productivity of Selectively Perforated Horizontal Wells." SPE 90580 (April. 28, 2005).