THE TECHNIQUE OF RECLAIMING SUBSIDENCE AREAS BY USE OF A HYDRAULIC DREDGE PUMP IN CHINESE COAL MINES[1]

Zhenqi Hu, Longqian Chen, Jiacong Lin and Haibin Liu[2]

Abstract: The technique of reclaiming disturbed lands by use of a hydraulic dredge pump (HDP) (which is a set of hydraulic machines for earthwork), called "digging deep to fill shallow," has been used in the reclamation of subsidence areas in Chinese coal mines. This paper discusses the operation principle of the technique and its available conditions and summarizes its reclamation procedures, which are being used in current reclamation practice. The characteristics of the soil reclaimed by HDP were studied. The results showed that the reclaimed soil by use of HDP resulted in a massive structure soil, which was the mixture of original topsoil and subsoil, and had high clay content and no district horizontal layers. The moisture characteristics of the reclaimed soil was the most severe influence factor to plant growth because of the high moisture content (almost close to saturate) and slow infiltration. The soil fertility assessment indicated that the reclaimed soil was very poor. Therefore, the improvements of the reclaimed soils and the HDP technique are needed. Based on the analysis of the previous technical processes, a new technical process for the HDP reclamation method was presented in this paper. The author thought that the two processes such as "excavation of soil" and "backfill and sedimentation" needed to be improved, and the other important processes such as "removal and backfill of topsoil," "establishment of drainage system," etc., should be added.

Additional key words: mining subsidence, reclamation, hydraulic dredge pump, technical processes, reclaimed soils

Introduction

In China, most of the coal is taken from underground mines, accounting for 96% of the coal output. Underground coal mining has caused a large amount of lands to subside, which has led to farmland losses and caused severe conflicts between farming and mining. According to statistics, the lands subsiding from coal mining total more than 13,300 hectares each year, of which half is located in the plain area, which is all prime farmlands (Sun and Li 1990). It is well known that China has a very large population and the cultivatable land shortage is very serious. The mean of cultivatable and permanent farmland per person in China only equals about one-third of the average value in the world. This situation makes the reclamation of subsidence lands become an urgent task for our country.

---

[1]Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29, 1994.

[2]Zhenqi Hu, Associate Professor, Longqian Chen, Assistant Teacher, Jiacong Lin, Professor, and Haibin Liu, Graduate Student, Department of Mining Engineering, China University of Mining and Technology, Xuzhou, Jiangsu, People's Republic of China.

Proceedings America Society of Mining and Reclamation, 1994 pp 316-323
DOI: 10.21000/JASMR94030316

In the comprehensive treatments for subsidence lands due to coal mining, the method of reclaiming lands by hydraulic dredge pump (HDP) called "digging deep to fill shallow" is being used in our country. Since this reclamation method is easy to operate and has fewer costs, study on the technical procedure of HDP is neglected. Thus, the HDP method usually leads to poor reclaimed soils and fewer benefits. This paper tries to evaluate the technique and develop rational technical procedures for the HDP method.

Operation Principle of HDP and Its Available Condition

The HDP, in fact, is a set of machines, with a high-pressure pump, two hydraulic giants (water syringes), a slurry pump, some steel and plastic pipes, etc. The basic principle of the reclamation method is that using the HDP machine simulates the natural water erosion and turns the mechanical and electrical power into hydraulic power for digging, transporting, and filling of soils. Usually, land reclamation needs five procedures such as excavating, loading, transporting, unloading, and leveling of soils. This method can take four procedures except of the leveling by a HDP. Thus, this method has many advantages: the equipment is simple, the cost is low, the operation efficiency is high, and the operation is convenient and not affected by weather.

It is well known that the surface above a mined area will subside after the excavation of coal, which produces a larger subsidence trough. In China, the resulting subsidence is often very deep (1.5 m - 6.0 m), and water accumulates in some of the subsided areas. We can divide the subsided trough into two parts: "deep area" and "shallow area" based on the particular landscape and reclamation requirements (see figure 1). The purpose of the HDP reclamation method is to make the "deep area" deeper for fish ponds and the excavated soils are filled the "shallow area" for farmlands. Thus, if the HDP method is to be used, the following conditions should be met:

(1) The subsidence depth is not grater than 2.5 m.
(2) The area of accumulating water is not very large so that the HDP is easy to operate.
(3) The amount of soils excavated from the "deep area" is equal to or grater than the needed soils filling in the "shallow area" for farmlands with a designed elevation.
(4) The produced fish ponds meet desired requirements.
(5) Water resource is enough for HDP operation.

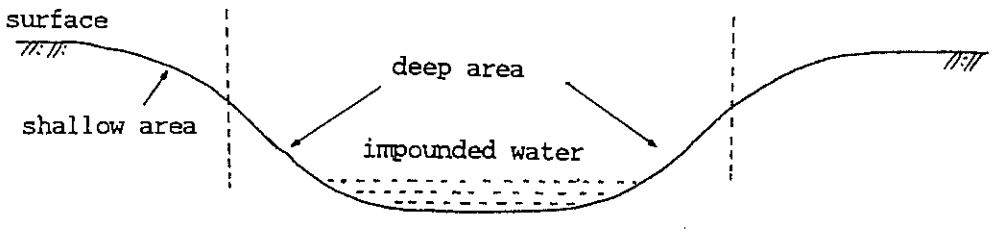

Figure 1. Profile of subsidence trough.

Evaluation of the Current HDP Method in China

Technical Procedures of the Current HDP Method in China

The procedures of the HDP operation used in Chinese coal mining areas can be summarized as follows:

(1) Producing high-pressure and high-speed water by a high pressure pump. Usually, the water speed is 50 m /h.
(2) Excavating soils by use of hydraulic giants (water syringes) with the high-pressure and high speed water, which makes the soil become slurry.
(3) Transporting the slurry to the "shallow area" to be filled through transportation pipes by use of the slurry pump.
(4) Filling and settling; the slurry can be filled in the designed "shallow area" by moving the transportation pipes, then letting the slurry settle down naturally. Generally, the filled lands need more than 5 months for stilling down after the stop of the filling work.
(5) Leveling the reclaimed land by manual work or dozers.

Evaluation of the Reclaimed Soils

Soil is a medium for plant growths (Hillel 1982). The purpose of land reclamation is to restore the soil productivity of the destroyed lands. Thus, the condition of reclaimed soils is the logical criterion for evaluating the effectiveness of reclamation. To evaluate the effectiveness of the HDP reclamation method, we choose two experimental sites (Pingdingshan and Peixian) for testing. In each site, two kinds of lands -- undamaged farmland and reclaimed land by HDP -- were chosen for comparison. The soil tests from the two sites indicated similar results as follows:

1. The soil profile examination showed that soil reclaimed by use of the HDP resulted in a massive structure soil and had no topsoil or distinct horizontal layers, which was the mixture of original topsoil and subsoil from adjacent area. It was easy to recognize that clay and moisture contents were very high, and the surface was hardened and imperious soil. The thickness of the reclaimed soil was about 60-85 cm. The underlying was the original soil profile. But the undamaged farmland had an average of 15 cm of topsoil and distinct horizontal layers. The upper layer of the farmland soil was darker than the underlying layers as well as the reclaimed soil because of the accumulation of organic matter. The granular structure dominated the topsoil of farmland, while the platy and subangular blocky structure were noted in the reclaimed soil.

2. The analysis of soil physical properties (see table 1) of the reclaimed soil indicated that the bulk densities were nearly ideal for plant growth. But the bulk density of the top layer (0-20 cm) was a little larger than that of farmland. The farmland soils had the biggest bulk densities at the depth of 20-40 cm, which revealed a compaction problem due to farming production. But the reclaimed soils had no compaction problem. However, the moisture characteristics of the reclaimed soil were the most severe influence factor to plant growth because of the high moisture content (almost close to saturate) and slow infiltration (see table 1 and figure 2). The moisture content of reclaimed soils was 1.2 - 2.5 times that of farmland soils. The infiltration rates in the reclaimed soils were about one-tenth (Peixian site) and one-fifth (Pindingshan

site) that of farmland soils. This situation may lead to losses of soils and nutrients. Therefore, the establishment of a drainage system is the key to making reclamation success and should be one of the procedures of the HDP operation.

3. The soil fertility assessment indicated that the reclaimed soil was very poor and that amelioration treatments are necessary (see table 2).

Table 1. Results of soil bulk density and moisture content

Site	Plot	depth, cm 0-20	20-40	40-60	60-80
		Bulk density (g/cm^3)			
Pingdingshan	farmland	1.16	1.55	1.56	1.49
	reclaimed	1.33	1.47	1.37	1.08
Peixian	farmland	1.32	1.64	1.42	1.42
	reclaimed	1.41	1.34	1.33	1.46
		Moisture content (%)			
Pingdingshan	farmland	13.8	14.0	15.5	14.3
	reclaimed	26.3	35.5	38.4	31.3
Peixian	farmland	26.4	19.7	22.8	25.2
	reclaimed	31.7	30.9	34.3	43.4
		Infiltration rate (cm/sec)			
Pingdingshan	farmland	0.0033			
	reclaimed	0.0006			
Peixian	farmland	0.0010			
	reclaimed	0.0001			

The Problems Existing in the Current HDP Technical Processes

Based on the above analysis, the problems existing in the current HDP operating processes are:

1. Reclaimed soil is poor. The current HDP method resulted in a massive structure soil, which was the mixture of original topsoil and subsoil and had high moisture content. Thus, the soil productivity was poor.
2. Sedimentation took a long time. Since the reclaimed soils settled down naturally, the water in the reclaimed land was difficult to drain out. Thus, the time for settling was very long (usually more than 5 months), which postponed the procedure of leveling reclaimed lands. This situation affected reclamation efficiency.

Table 2. Some macronutrient contents

type of soil	depth, cm	total N, %	total P, %	rapidly available nutrients N, ppm	P, ppm	K, ppm	O.M., %
			Pindingshan				
farmland	0-20	0.107	0.167	87	14.1	112.5	1.90
	20-40	0.066	0.130	47	3.7	95.0	1.23
reclaimed	0-20	0.042	0.091	25	2.7	97.5	0.49
	20-40	0.042	0.098	27	1.4	95.0	0.54
			Peixian				
farmland	0-20	0.106	0.157	85	8.4	104.0	1.62
	20-40	0.047	0.140	34	3.6	104.0	0.51
reclaimed	0-20	0.045	0.132	30	6.0	117.5	0.70
	20-40	0.040	0.125	26	5.9	104.0	0.41

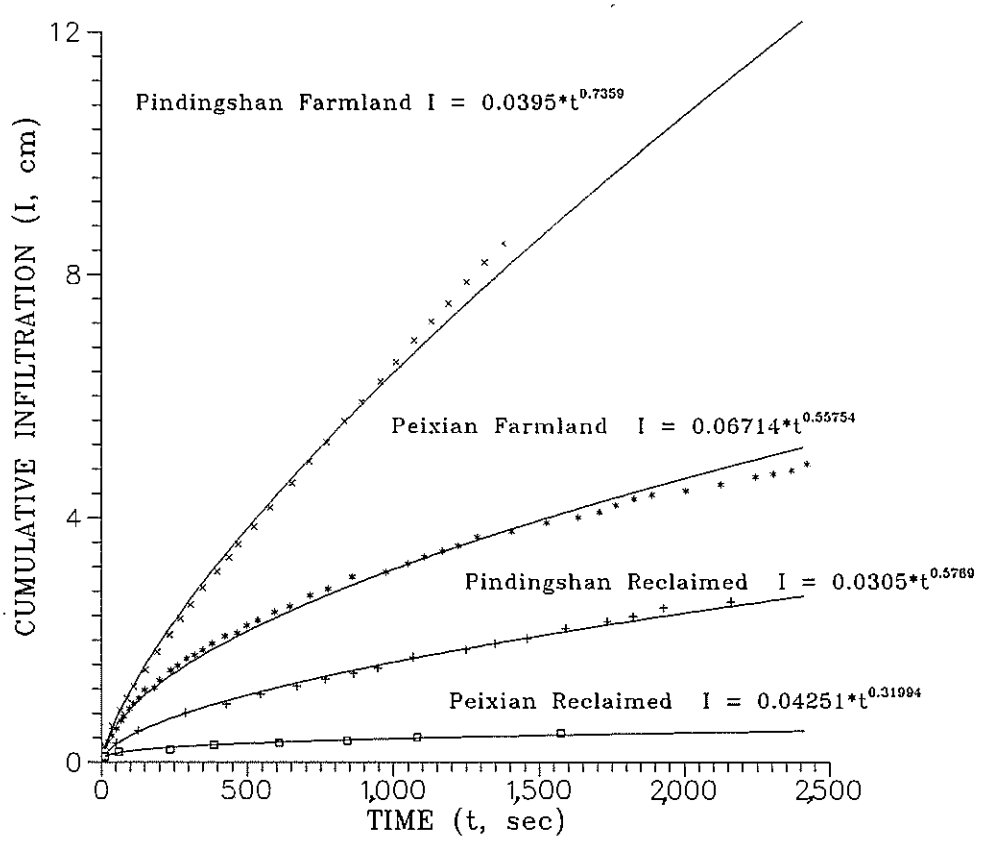

Figure 2. Comparison of infiltration (farmland and reclaimed)

Development of a New HDP Technical Process

For solving the problems in the current HDP reclamation method, a new HDP technical process was developed as follows:

(1) Removal of the topsoil of the "shallow area".
(2) Establishing drainage ditches and return ditches.
(3) Producing high-pressure and high-speed water by a high-pressure pump.
(4) Hydraulic excavating soils by use of hydraulic giants (water syringes) in a new excavation procedures.
(5) Hydraulic transporting soils through transportation pipes by use of the slurry pump.
(6) Filling and settling in a new filling orders explained as followings.
(7) Completing the drainage system.
(8) Leveling of the reclaimed land.
(9) Backfill of the topsoil.

The new HDP technical process adds some procedures such as (1), (2), (7), and (9), and improves (4) and (6), i.e., the new excavating and filling orders. Other procedures are the same as the current HDP method. The following will explain some added and improved procedures:

A. Adding the procedures of removal and backfill of the "shallow area" topsoil. The topsoil has high organic matter and nutrient contents, which takes a long time for its formation. Thus, the removal and backfill of the topsoil are needed for rapidly restoring the productivity of reclaimed soils. Although the treatment has been used in surface mined land reclamation, the current HDP method does not use it. Therefore, the added procedures (removal and backfill of the "shallow area" topsoil) are effective treatments for improving the HDP method.

B. Establishing drainage ditches and return ditches: Since the characteristics of the HDP reclamation method are hydraulic excavation and hydraulic transportation, the drainage is the key to affect the settling speed of the slurry and reclamation time. Thus, the establishment of drainage ditches and return ditches before HDP operation is needed. The return ditches are from the reclaimed land (i.e., "shallow area") to the water resource for the use of the high-pressure pumps, which makes the water reutilize. The purpose of establishing drainage ditches and return ditches is to drain the water in the reclaimed soils immediately, which turns the natural settling into accelerating settling. Thus, reclamation efficiency is high.

C. Completing the drainage system: After or close to the complement of HDP operation, the drainage system should be completed immediately so that the rest of the water in the reclaimed soils is drained out for early leveling of the land and planting crops.

D. Improving the orders of excavating and filling soils: The current HDP method resulted in the mixture of topsoil and subsoil and may sometimes lead to that subsoil covered on the topsoil. Topsoil in the "shallow area" can be removed, but the topsoil in the "deep area" is difficult to remove because of wet or water accumulation. For constructing good root medium, the order of excavation and filling of the "deep area" soil should be improved to keep similar

soil layers. Based on the principle of constructing new root medium in the surface mined land (Hu 1991), the new excavating and filling method is (see figure 3):

a. Dividing the "deep area" and "shallow area" into several blocks based on the landscape and reclamation plan. After the removal of topsoil from the "shallow area," the low banks between blocks should be built for filling.

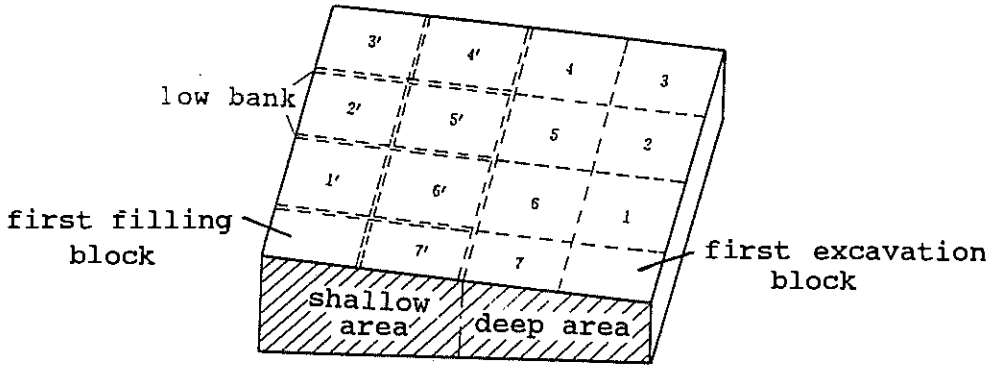

Figure 3. New order of excavating and filling soils.

b. Excavating the "first excavation block" first by use of HDP, and the excavated soils are filled in the "first filling blocks." This procedure is similar to the current HDP method, which may lead to the mixture of topsoil and subsoil in the "first filling block." Thus, the "first excavation block" and "first filling block" should be as small as possible. The purpose of this procedure is to create a condition for excavating the "deep area" soil layer by layer.

c. Dividing the "deep area" soils into two layers: upper (30-50 cm) and lower (deeper than 30-50 cm) first, then following the orders to excavate and fill soils (assume: "deep area" has n+1 blocks and "shallow area" has n'+1 blocks):

"deep area" excavating ...		"shallow area" filling ..., (to be ...)
1 block upper layer	---->	"first filling block"
1 block lower layer	---->	1' block, (1' block lower layer)
2 block upper layer	---->	1' block, (1' block upper layer)
2 block lower layer	---->	2' block, (2' block lower layer)
3 block upper layer	---->	2' block, (2' block upper layer)
	.	
	.	
	.	
n block upper layer	---->	(n-1)' block, ((n-1)' upper layer)
n block lower layer	---->	n' block, (n' block lower layer)
1 block upper layer piled on the "first filling block	---->	n' block, (n' block upper layer)

The order of excavating and filling of soils can be summarized as follow:

$$\begin{cases} \text{soil structure of i' block} = \text{"(i+1) block upper layer"} + \text{"i block lower layer"} \\ \qquad\qquad\qquad\qquad (i=1,2,\ ..\ n-1) & (1) \\ \text{soil structure of n' block} = \text{"1 block upper layer"} + \text{"n block lower layer"} & (2) \end{cases}$$

According to the new order of excavating and filling of soils, the new constructed soil structure keeps the similar original soil layers except for the "first filling block." After the complement of the water drainage from the new constructed land, the original "shallow area" topsoil should be backfilled. Therefore, this new method may create a new root medium with almost two topsoil layers, which is much better than the old HDP method.

Concluding Remarks

HDP reclamation method is being widely used for subsidence land reclamation in China, but the technical process has not been studied in detail. This paper is the first to explore the principle of the HDP method and the soil condition reclaimed by HDP, and developed a new HDP technical process. Although the new HDP technical process needs further reclamation practice, the exploration of the HDP method may make many experts pay grater attention to the improvement of the HDP technique.

References

Hillel, D. 1982. Introduction to soil physics. Academic Press Inc., London.

Hu, Z. 1991. Physical properties of reclaimed mine soils and their amelioration via deep tillage, Ph.D dissertation, China University of Mining and Technology, Xuzhou, Jiangsu, People's Republic of China.

Sun, S. and S. Li. 1990. Techniques for land reclamation of coal mine and for comprehensive improvement of subsidence area. China Land Reclamation, V. 4, No. 4, pp.41-46 (in Chinese).