Innovations of subsidence land reclamation for underground coal mines in China

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Outline

1. Background

2. Innovations of subsidence land reclamation for underground coal mines in China
   - technology of concurrent mining and reclamation
   - subsidence land reclamation filled with river sediments

3. Summary
1. Background

• Impact of coal mining on eco-environment

• significance and important role of land reclamation and ecological restoration in promoting green mining

• Some failure cases of subsidence land reclamation (problems of traditional (existing) reclamation technology) for underground coal mines
1. Background

(1). Impact of coal mining on environment in China

Coal yield and growth rate from 1990 to 2010 in China

Coal is the most important resource in China. China’s coal production was 3.8 billion tons in 2014. 85% from underground mining.
Impact of coal mining on environment in China

Coal mining has produced a lot of environmental problems while it makes great contribution to economic growth.
(1). Impact of coal mining on environment in China

1) land damage

• subsidence: over 1 million ha of subsided land; 70 thousands ha of land will be subsided every year

Farmland loss, land degradation and geological disasters
The Overlap Region (OR)

-40% of overlap area between farmland and total coal reserves
-10% of overlap area between proved coal reserves and farmland
1. Impact of coal mining on environment in China

1) land damage

- Occupied by coal wastes: thousands of coal wastes piles, total 6 GT, 0.35 GT/a

- Open pits, dumps: land loss 0.1 ha/10 thousands tons, 3000 ha/a

- Beautiful Pasture
(1). Impact of coal mining on environment in China

2) pollution on air, water and soil, and health problems

- Dust from dumps
- Spontaneous combustion
- Water pollution
- Air pollution
- Explosion and collapse
- Harm to human health
1. Impact of coal mining on environment in China

3) damage of human settlement and rural landscape
----- huge work on village movement and settlement

- Houses damage
- Rural infrastructure damage such as road, bridge, drainage and so on

- it is estimated that: more than 10 million people will have to move and settle in other places
(1). Impact of coal mining on environment in China

4) social problems ---- affect regional social stability and harmonious

Conflicts between farmers and miners

Some conflict events
1. Background

- (2). significance and important role of land reclamation and ecological restoration in promoting green mining

Shall we minimize and repair the environmental damage? Is green mining possible?  Green Mining is the only way for coal industry!

Is green mining possible?

The Canadian mining industry is trying very hard to turn mining’s image around. But is environmentally friendly mining even possible and can we be convinced? Long history to overcome

The Mining Association of Canada (MAC), reeling from the all-too-frequent black eyes that Canadian-based mining companies have received in the press over the past decade, is doing its utmost to convince the public that "sustainable mining" is not an oxymoron. Unfortunately, they're battling a long and dirty history, one fraught with environmental devastation and social indifference. The catalogue of environmental disasters and human tragedies caused by the mining industry

The new idea “green mining” has become the important issue in mining industry. how to implement green mining?
1. Background

• (2). significance and important role of land reclamation and ecological restoration in promoting green mining

How to realize green mining?

Source control?

Process management?

end-of-pipe solution (post – mining reclamation) ?

Reclamation is the key to repair the environmental damage, which is the part of green mining.
In General, Land Reclamation has become an urgent task in China
1. Background

History of mined land reclamation in China

Mined land reclamation has been paid much attention since 1980’s in China.

Milestones of land reclamation in China

- Legalization
- 1980s
- Spontaneous
- 1950s-1970s
- 1990
- State investment
- 1998
- Revised land management law in 1998
- "The stipulation on land reclamation" in 1989
- 2006
- Mining permit approval
- 2011
- Land Reclamation Regulation
After 30 years land reclamation, roughly 25% of the damaged land has been reclaimed, this made significant economic, social and environmental benefits.
1. Background

- (3). Some failure cases of subsidence land reclamation (problems of traditional reclamation technology)

Reclaimed land

Because of multi-seam excavation

Reclamation must be done after complete subsidence?---long time?
1. Background

• (3). Some failure cases of subsidence land reclamation (problems of traditional reclamation technology)

Problems:
1. Poor soil: mixture of topsoil and subsoil;
2. High content of water;
3. Salinization

Subsided land

Reclaiming by hydraulic dredge pump, ----- Popular reclamation technique

Poor soil, low land productivity
1. Background

- (3). Some failure cases of subsidence land reclamation (problems of traditional reclamation technology)

Reclaimed subsidence land filled with coal wastes, fly ash

Problems:
Soil contamination: high contents of heavy metals
Innovagation

Is needed to improve the reclamation technology
2. Innovations of subsidence land reclamation for underground coal mines in China

- Technology of concurrent mining and reclamation
- Subsidence land reclamation filled with river sediments
2. Innovations of subsidence land reclamation in China

(1). Technology of concurrent mining and reclamation
2. Innovations of subsidence land reclamation in China

• (1). Technology of concurrent mining and reclamation

Low percentage of farmland restoration, a end-of-pipe solution

Pre-dynamic reclamation, Do the reclamation before or during the land subsidence

Restore much more land comparing traditional reclamation techniques

Traditional

Concurrent mining and reclamation

Underground coal mines
2. Innovations of reclamation technology in China

(1). Technology of concurrent mining and reclamation

Keys of the technology

- Selecting the position for reclamation and dividing the stages of reclamation
- Determining the optimum time point for reclamation
- Determining the elevation of reclaiming land

Concurrent mining and reclamation for underground coal mines
2. Innovations of reclamation technology in China

• (1). Technology of concurrent mining and reclamation

Too early: damage “good” farmland; land use policy does not permit; farmer does not agree; stocked soil pile is very high, safety problem

Too late: a lot of soil sink into water; soil and farmland loss

Land slight damage, dynamic subsidence

Most important: optimum time point for reclamation
2. Innovations of reclamation technology in China

• (1). Technology of concurrent mining and reclamation

Optimum time point for reclamation

Theoretical Model

\[
T \leq \frac{2H_0(1.03 \frac{H - H_b - h_{\text{水位}}}{mq\cos\alpha}) + 0.08 \sqrt{1.03 \frac{H - H_b - h_{\text{水位}}}{mq\cos\alpha} - 0.4 - 0.4}}{tg\beta v} + t'
\]

Based on subsidence prediction, soil properties and others

Practical Method: comparison among different schemes with different time points
2. Innovations of reclamation technology in China

- (1). Technology of concurrent mining and reclamation

The farmland reclamation percentages at stage (b) and (c) could be increased 37.6% and 32.6%, respectively, compared against traditional reclamation until the land stabilizes (stage (d)).
2. Innovations of reclamation technology in China

(2). Subsidence land reclamation filled with river sediments

Yellow River Sediments Backfilling (YRSB)

The Yellow River: rich in sands
Subsided Farmland: Lack of backfilling materials

Project supported by National Key Technology R &D program (2012BAC04B03)
2. Innovations of reclamation technology in China

(2). Subsidence land reclamation filled with river sediments

- High efficient method of taking sediments from Yellow river
- Pipeline transportation with long distance
- Fast filling, drainage, soil reconstruction and restoration of high quality farming
Process of **one-time** filling reclamation of mining subsidence land with Yellow River sediment.

- **Pipeline for sediment transportation**
- **Dredging boat**
- **Earth dike resulted from occupied surface soil**
- **Pump station**
- **Area needs to be reclaimed**
- **Topsoil**
- **Subsoil**
- **Parent material**
- **Bedrock layer**
- **Coal seam**
The technical process of **one-time filling reclamation of mining subsidence land with Yellow River sediment.**
before reclamation

after reclamation

control farmland

Grow well

Grow bad (not enough thickness of covering soil)
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Serial number</th>
<th>Plant number per square meter</th>
<th>Grain number per plant</th>
<th>Plant height per plant/ (cm)</th>
<th>Root length per plant/ (cm)</th>
<th>Dry weight per plant (g)</th>
<th>Thousand kernel weight (g)</th>
<th>Estimated yield/(kg·hm⁻²)</th>
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<tbody>
<tr>
<td><strong>Control farmland</strong></td>
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<td>635</td>
<td>38.37</td>
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<td><strong>Mean</strong></td>
<td>615 a</td>
<td>39.67 a</td>
<td>71.94 a</td>
<td>81.8 a</td>
<td>2.65 a</td>
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<td><strong>Standard deviation</strong></td>
<td>13.52</td>
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<td>3.37</td>
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<td><strong>Reclaimed farmland</strong></td>
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<td>20.21</td>
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<td>5.32</td>
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Poor productivity                  Why?

2012-2-19

2012-9-18

2013-4-2

2013-9-24

2014-4-15

2014-9-24
Traditional filling reclamation method was: 1) stripping the soils to be reclaimed land; 2) filling the subsided land materials at once; 3) backfilling the soils. This kind of simple soil profile is an unfavorable profile type in pedology, resulting in poor productivity.

Topsoil is not good. Thickness of soil cover is not enough.

Diagram of Traditional filling soil-sediment profiles
Optimum thickness of soil cover?

*traditional profile “Yellow River sediment covered by soil*

Laboratory experiment —— The optimal thickness of soil in filling reclamation with Yellow River sediment

**Planting corns in laboratory:**

Form 04/25/2013 to 07/05/2013

**Soil thickness:**
0 cm, 20 cm, 40 cm, 60 cm, 70 cm, 80 cm, CK

**Stages:**
Seedling stage;
Elongating stage;
Flare opening stage;
Tasseling stage;
Flowering stage,
Then, stop the experiment.

CK soil profile
Optimum thickness of soil cover?

*traditional profile “Yellow River sediment covered by soil*

Laboratory experiment —— The optimal thickness of soil in filling reclamation with Yellow River sediment

T0 has the min dry biomass of root and shoot system is 30.72 g, 5.67 g, respectively.
CK has the max dry biomass of shoot system is 50.21 g.
T80 has the max dry biomass of root system is 10.24 g.

If no enough soil for cover? How to handle this problem?
A new reconstruction method for reclaiming subsided land with Yellow River Sediments

**New idea: sandwich profile**

Multilayered soil profiles were favorable for maize growth, water-holding and storage capacity and nutrient preserving capability.

Diagram of multilayered soil-sediment profiles
Laboratory simulation test design of different multilayered soil-sediment profiles
Results and Discussion: Compared to CK2 (traditional soil reconstructed profile, i.e. filling materials of Yellow river sediment cover with 70cm soil), T8 and T11 had an increase of 22.60%, 15.50% for plant growth, respectively. Compared to CK1, T8, T10, T11 had an increase of dry biomass of root system at 36.64%, 29.78%, 29.96%. The results illustrate that multilayer soil profiles were favorable for maize seed germination and root growth.
Field experiment design of different multilayered soil-sediment profiles
Results and Discussion: Compared to contrast (traditional soil reconstructed profile, i.e. filling materials of Yellow river sediment cover with 70cm soil), T7, T8 and T10 had an increase of 3.68%, 1.59%, 2.42% for maize yield, respectively.
There was no difference between filling reclamation and normal control farmland for the landscape.

How to implement the sandwich soil profile?
This technology focuses on soil stripping, multiple filling, multiple drainage, multiple backfill, leveling, and other links.

Process of **multiple filling reclamation of mining subsidence land with Yellow River sediment.**

1. Determining the soil thickness in the area to be filled, dividing the strip.
2. Determining the soil profile, the number and thickness of sediment filling.
3. Determining the sequence of filling strip and number of synchronous alternating filling.
4. Determining area of soil stripping and stacking.

![Diagram]
Technology of alternating multiple filling reclamation

synchronous alternating strips successively filling sediment - drainage - covering subsoil
3. Summary

• Reclamation is part of green mining, which is the key to repair the environmental damage.

• Concurrent mining and reclamation is a new technology and idea for underground coal mining, which could restore much more land, which is the innovation of subsidence land reclamation, might increase more than 30% of reclaimed land.
3. Summary

• innovation on filling reclamation: subsidence land reclamation filled with river sediments instead of coal wastes and fly ash, which is environment-friendly reclamation method.
  – Sandwich soil profile is new idea for soil reconstruction for high soil productivity.
  – New technical process for reconstructing sandwich soil profile: synchronous alternating strips with multiple filling, multiple drainage, multiple backfill
Thanks!!
Welcome! The second International Symposium on Land Reclamation and Ecological Restoration
Xi’an, Shanxi Province, China
October 20-23, 2017

Xi'an is the capital of Shanxi province, is one of the birthplaces of the ancient civilization in the Yellow River Basin area of China. It has more than 3,100 year’s history with 13 dynasties.