Performance evaluation of improved subsurface drainage system

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Outline

1. Background

- Floods are major natural disasters in China, causing significant agricultural losses
- South China is prone to surface and subsurface waterlogging. Surface ponding is common after heavy rainfall events, accompanied by water table rising
- Farmland shortage and agricultural pollution provide more opportunities and high requirements to subsurface pipe drainage

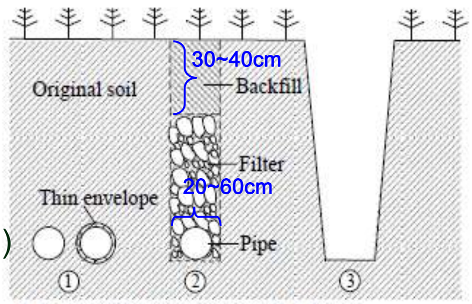
1. Background

- Conventional subsurface pipe drainage is quite limited to reduce flood damage. In order to increase the efficiency of subsurface drainage, an improved subsurface drainage is proposed, with less land occupied, high drain discharge and environment-friendly
- The specific objective of this study was to evaluate the performance of improved subsurface drainage under different ponding water depths, filter widths ,water table depths, soil mediums, and outflow conditions

2.Materials and methods

2.1Structure

- Based on structures of open ditch and subsurface pipe drainage
- Laying high permeability materials (gravels or slags or wood chips or crop stalks et al) as filter above drain pipe
- Backfilling 30~40cm original soil as plow layer
- Similar structure to 'French drain'



1. Conventional subsurface pipe drainage
2. Improved subsurface drainage
3. Surface ditch drainage

Fig 1. Sketch of different drainage forms

2.Materials and methods

2.2Experiment design

Drain discharge is an important index to evaluate the subsurface drainage performance.

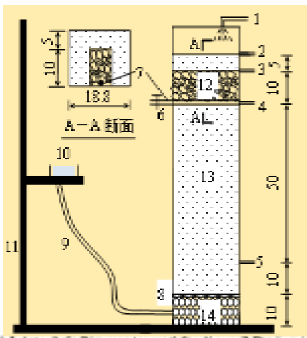
What factors impact the drain discharge? How these factors affect the drain discharge?

Clogging of the drain pipe is the main factor affecting pipe working life and drain discharge.

For graded sand and gravel filter, how to choose its specification? How to lay it ?(layered or mixed, with or without geotextile, around the filter or pipe, et al)

2.Materials and methods

2.2Experiment design for discharge



1.Inlet; 2-5. Piezometers; 6.Sealing; 7.Drain pipe; 8.Support network; 9.Connecting tube; 10.Water tank; 11.Removable support; 12.Filter; 13.Soil medium; 14. High permeability material

Fig 2. Discharge test equipment

Table1 Composite experiment design

Factor	Level 1	Level 2	Level 3	Level 4
A:Water table depth(cm)	0(0*D*/ Saturated soil)	30 (2*D*)	55 (3.7*D*)	75 (5*D*)
B: Filter width(cm)	0	2	4	6
C:Ponding depth	7cm	5cm	3cm	
D: Outflow condition	Free	Submerged		
E: Soil medium	Coarse-sand	Fine-sand		

- Conducted with a plexiglass cylinder.
- 192 group experiments were conducted.
- Drain discharge and hydraulic conductivities were measured.

2.Materials and methods

2.2Experiment design for discharge

Table2 Hydraulic conductivity measurement

Soil texture	Filter width(cm)	Hydraulic conductivity (cm/s): Soil medium(k)	Hydraulic conductivity (cm/s): Filter (k_0)	k_0/k
Coarse-sand texture	0	0.02929	—	—
	2	0.02505	0.2806	11.20
	4	0.02405	0.2917	12.13
	6	0.02475	0.2313	9.35
Fine-sand texture	0	0.00139	—	—
	2	0.00128	0.1024	80.00
	4	0.00144	0.1063	73.82
	6	0.00135	0.0980	72.59

- The ratio of hydraulic conductivity between filter and soil medium is k_0/k=78 in fine-sand and k_0/k= 10 in coarse-sand (on average)

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2.Materials and methods

2.2Experiment design for clogging defense

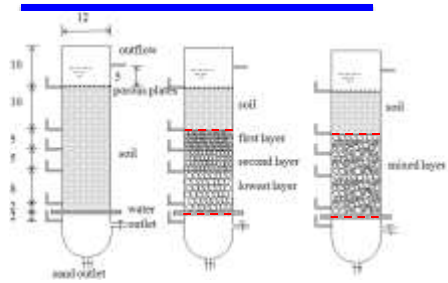

Fig 3. Clogging defense test equipment

Table3 Experiments on clogging defense

Structure	Code	Non	Up-A	Down-A	Up-Down-A	Up-B	Down-B	Up-Down-B
soil	NN							
	NA							
	NB							
layered	LN							
	LAU							
	LAD							
	LAB							
	LBU							
	LBD							
	LBB							
mixed	MN							
	MAU							
	MAD							
	MAB							
	MBU							
	MBD							
	MBB							

Non represents no geotextile, up and down stand for the geotextile around the filter and drain pipe respectively.

➢Filter specification was chosen based on Terzaghi's criteria.

➢17 group experiments were conducted, including three types: no defense (soil), layered filter, mixed filter, two kinds of geotextile A(38g/m^2) and B(75g/m^2).

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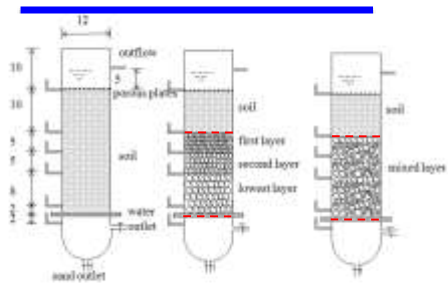
2.Materials and methods

2.2Experiment design for clogging defense



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	MBU							
	MBD							
	MBB							

Non represents no geotextile, up and down stand for the geotextile around the filter and drain pipe respectively.

➢The geotextile was laid around the pipe (down-A or B) or on the filter-soil contact surface (up-A or B) or both, such as LAD(layered-A geotexile-Down)

➢Dynamic discharge and mass of soil clogging and loss were measured

3.Results and discussion

3.1 *Effects of filter width on drain discharge under free outflow and saturated soil*

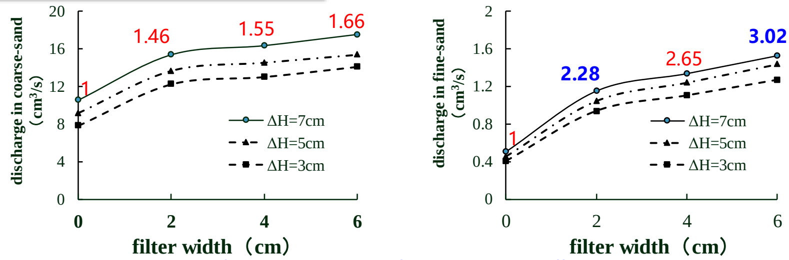


Fig 4. Variation of drain discharg with filter width under different ponding depths

- Drain discharge of improved subsurface drainage increases obviously with increasing filter width.
- The greater the hydraulic conductivity gaps between soil and filter, the more effective the improved subsurface drainage is.
- Trendlines of discharge were roughly parallel among different ponding depths.

3.Results and discussion

3.2 *Effects of submerged outflow on drain discharge in saturated soil*

- Submerged discharge in fine-sand medium decreased about 20% than that of free outflow in both improved and conventional subsurface drainage under the same ponding depth and filter width.

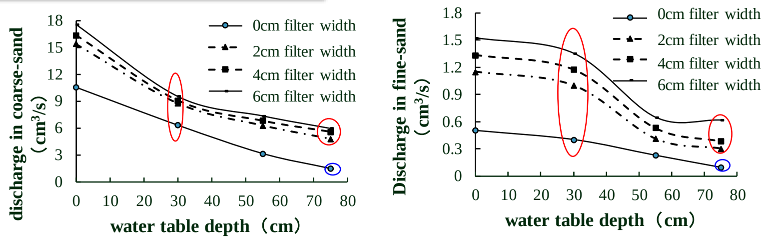
Table 4 Drain discharge under 7cm ponding depth(cm^3/s)

Outflow condition	Conventional	Improved		
		2cm	4cm	6cm
free	0.505	1.152	1.337	1.527
submerged	0.401	0.879	1.029	1.203

- Submerged discharge of improved subsurface drainage was obviously larger than conventional ones.
- When filter width varied from 2cm to 6cm, submerged discharges were corresponding to 1.74, 2.04 and 2.38 times of free discharge in conventional subsurface drainage.

3.Results and discussion

3.3 *Effects of water table depth on drain discharge under free outflow*



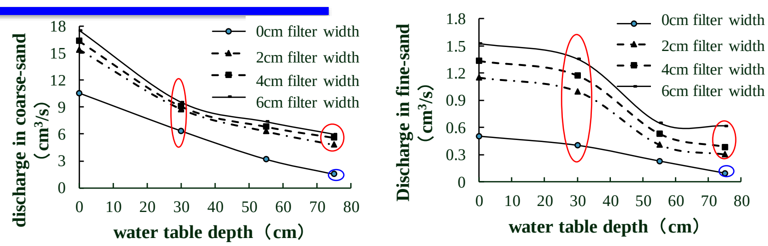
◯ **Having drainage function still** ○ **Almost lost drainage function**

Fig 5. Effects of water table depth on free discharge under 7cm ponding depths

- Drain discharges decreased with water table depth increase for both improved and conventional subsurface drainage.
- When water table depth was 2*D*, the discharge of conventional subsurface drainage was about 80% of that at 0cm (0*D*) water table depth in fine-sand texture.

3.Results and discussion

3.3 *Effects of water table depth on drain discharge under free outflow*



◯ **Having drainage function still** ○ **Almost lost drainage function**

Fig 5. Effects of water table depth on free discharge under 7cm ponding depths

- Conventional subsurface drainage was quite limited in a deep GW area. The improved subsurface drainage was still functioning until water table depth was 5 times of drain depth.
- For conventional subsurface drainage, the curves presented as a straight line with a reverse slope.

  While for improved subsurface drainage, the curves were divided into two phases in coarse-sand and three phases in fine-sand.

3.Results and discussion

3.4 *Effects of water table depth on submerged discharge*

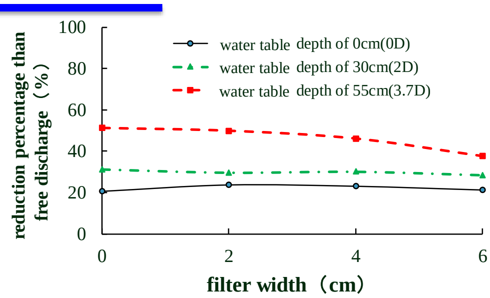


Fig 6. Effects of water table depth on submerged discharge

- The reduction percentage increased with increasing water table depth.
- The greater the water table depth, the more obvious the influence of submerged outflow is.

3.Results and discussion

3.4 *Effects of water table depth on the ratio of drain discharge and seepage quantity into GW*

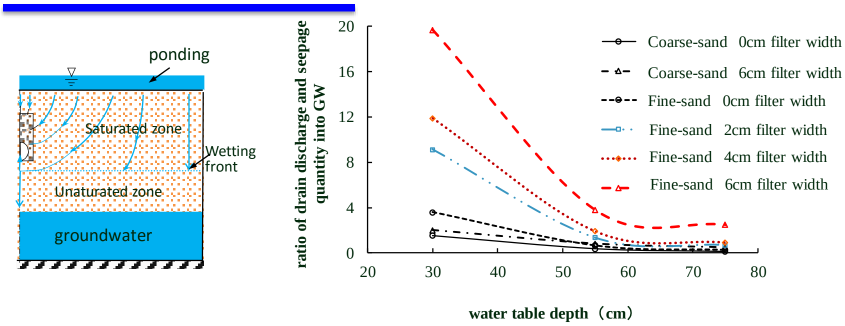
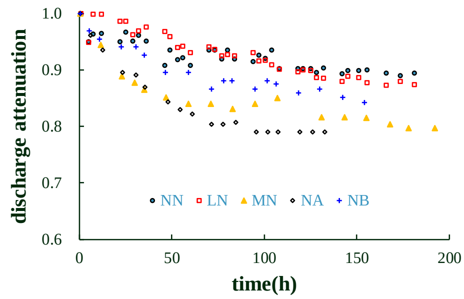


Fig 7. Effects of water table depth on the ratio of drainage and seepage quantity

- The ratio decreased with the increase of water table depth and increased with the increase of filter width.
- More water recharged the groundwater when soil permeability was large.

3.Results and discussion

3.5 *Clogging defense by geotextile or filter measure*



NN: no defense
NA: geotextile A around the pipe
NB: geotextile B around the pipe
LN: layered filter without geotextile
MN: mixed filter without geotextile

Fig 8. Discharge attenuation under single clogging defense measure

- The attenuation of drain discharge from small to large was LN<NB<MN<NA . The effect of LN defense was the best, next was NB.

3.Results and discussion

3.5 *Clogging defense by the combination of filter and geotextile*

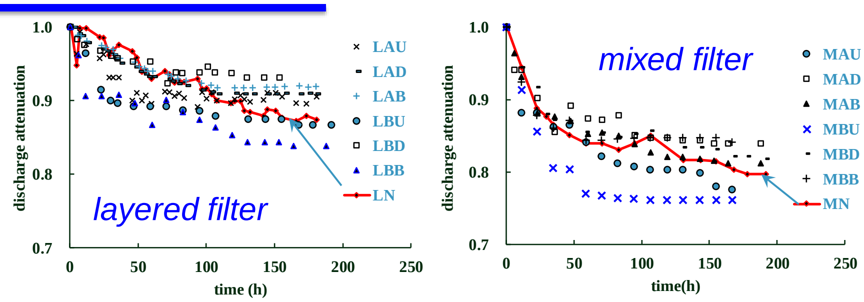


Fig 9. Discharge attenuation under multiple clogging defense measures

- The effect of clogging defense by layered filter was better than mixed one
- No matter for layered or mixed filter, setting geotextile around the pipe is more effective than single clogging defense measure
- The discharge attenuation by setting the geotextile both around the pipe and filter-soil contact surface was the largest (LBB and MBB)

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3.Results and discussion

3.5 *Soil clogging and loss*

- No defense measure leads the largest soil loss.
- Soil clogging is larger when geotextile is on the filter-soil contact surface.
- In view of discharge attenuation, soil clogging and loss, LBD is the best defense measure, next is LAD

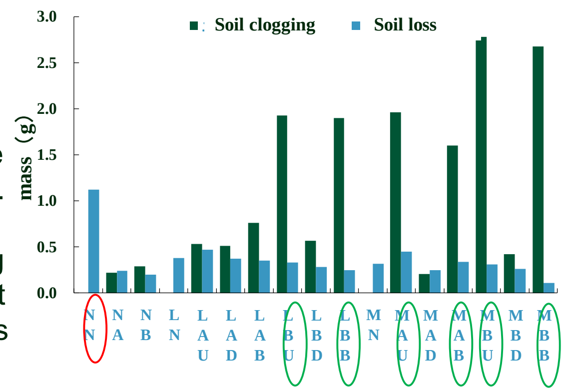

Fig10. mass of soil clogging and loss

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4. Conclusion

- Improved subsurface drainage has a larger drain discharge than conventional subsurface pipe drainage. It has advantages of less land occupied and lower maintenance costs.
- Filter width impacts drain discharge remarkably, which should be chosen by comprehensive considering the cost and benefit.
- Terzaghi's criteria could be used effectively in filter design of improved subsurface drainage. And layered filter with reasonable geotextile around drain pipe is the most effective structure for preventing clogging and soil loss.

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4. Conclusion

- It can be predicted that the improved subsurface drainage, combined with open ditches, will be an effective way for surface and subsurface waterlogging control in farmland.

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5. Acknowledgement

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Thank you for your attention !