EXPERIMENTAL STUDY OF INFILTRATION TRENCH FOR HIGHWAY DRAINAGE

YONG-QIANG XU[i], TAKESHI OSHITA[ii] and SHOICHI TSUTSUMI[iii]

ABSTRACT

Permeable pavement and infiltration trench are presently considered to be more effective countermeasures for controlling storm-water runoff on the roads. Being a continuing research on the infiltration trenches, this study verified the variation of infiltration capability of trench with time by performing three sprinkling experiments in three consecutive years on a trench constructed in a real highway. From the experimental results, it was presumed that clogging occurred in the trench during the progress, and that infiltration from the trench had no marked impact on the surrounding earth structure. In addition, based on an analysis of the variation of water depth under the real rainfall observed in July 2005, it was also found that this trench could perform effectively for controlling the storm-water runoff, even after a torrential storm.

Key Words: Infiltration trench, Highway drainage, Storm-water runoff control, Water injection experiment

INTRODUCTION

In recent years, with the accelerated development of urbanization, more and more urban areas are embarrassed with flooding troubles for lack of effective flood control facilities and systems to drain the storm water out of the roads. Consequently, the damages caused by floods occur frequently and urban environment is getting worse inevitably.

The early storm-water management concentrated on the minimization of downstream flooding caused by storms. This was typically accomplished by constructing dry storm-water-detention ponds to reduce the peak flow. However, since constructing a dry detention pond has higher requirements for funds and space, more and more studies have been shifted their focuses onto the infiltration trench. Presently, permeable pavements and infiltration trenches are considered to be effective countermeasures for controlling storm-water runoff on the roads. The rainwater permeates through the pavement layer and then flows into a trench immediately, in which the rainwater will be stored temporarily and ultimately be removed by percolating slowly into the ground surrounding the trench (Figure-1). Due to the employment of the trench in this measure, the rainwater will not stay in the subgrade for a long time and thus there will be no worries that the subgrade will be weakened.

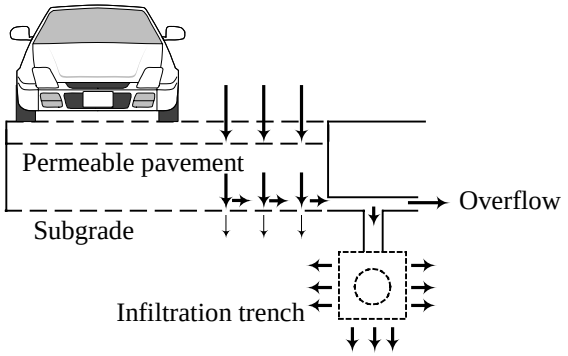

Figure-1 Storm-water control facilities with infiltration trench

Some studies gave good investigation and clear demonstration on the performance of infiltration trench. For example, Okamura J. *et al.* proposed a simple formula to calculate the infiltration speed of the trench and examined its applicability to model experiment. Duchene M. *et al.* used a two-dimensional saturated-unsaturated finite element model to analyse the connections between the infiltration speed of trench with the infiltration time, water depth, groundwater level and soil structures etc. Tsutsumi S. *et al.* examined the variation of capability of infiltration trench over time by employing water injection experiment (constant water level) for a laboratory infiltration trench and gave a detailed investigation on the performance of infiltration trench. In recent years, Nakashima S. *et al.* did a series of studies on infiltration trench. They investigated the impact of the

[i] Dr. Agr., Researcher, Construction Technology Research Team, Public Works Research Institute, Minamihara1-6, Tsukuba City, Ibaraki, Japan.
[ii] Chief Researcher, Construction Technology Research Team, Public Works Research Institute, Minamihara1-6, Tsukuba City, Ibaraki, Japan.
[iii] Researcher, Construction Technology Research Team, Public Works Research Institute, Minamihara1-6, Tsukuba City, Ibaraki, Japan
Manuscript was received for review on June 30, 2007.

infiltration trench on the ground structure by performing a model experiment on a real-size trench constructed in a model ground. Further, they examined the effect of ground permeability coefficients on infiltration capability of trench and infiltration area through a model test. In another study, they performed water injection experiments and examined the infiltration capability of the trench at the early stage, respectively in the case of the constant water depth and variable water depth. From these studies, it was found that employing the permeable pavement and infiltration trench could alleviate the pressure on the established drainage effectively, especially when a heavy rainstorm comes.

Being a continuing research on the infiltration trench, this study intends to test the capability of infiltration trench in practical application by giving a clear investigation on the variation of capacity of an infiltration trench constructed in a real highway. In order to examine how much the infiltration capability of a trench has declined since the construction completion, three sprinkling experiments were performed in three consecutive years from 2004 to 2006 for an infiltration trench which was constructed besides a real highway.

2 OUTLINE OF INFILTRATION TRENCH

The placement of the infiltration trench and the permeable pavement employed in this study was shown in Figure-2. The storm water percolates through the permeable pavement and subsequently flowed into the trench, where the storm water will be stored temporarily and afterwards percolate into the surrounding soil over some time. In the case that the infiltration trench is filled up with storm water, the established drainage would take effect to prevent the storm water from flowing backward to the subgrade. A water level meter is used to measure the water depth in the trench and a triangular notch weir is used to measure the overflow from the trench. Figure-3 gives a clear illustration about the infiltration trench from the cross-section and vertical section views. The trench was designed with the infiltration flow when the surrounding ground was saturated. And it was expected to perform effectively for a rainfall of more than 20mm/hr. The ground surrounding the trench is Masa soil (decomposed granite soil).

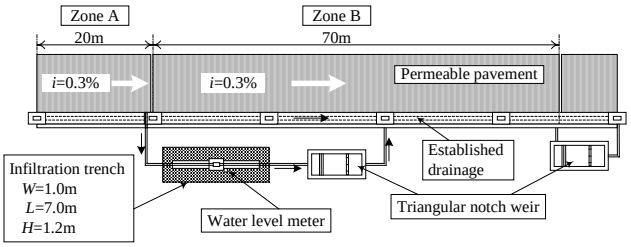

Figure-2 Plan view of the placement of trench

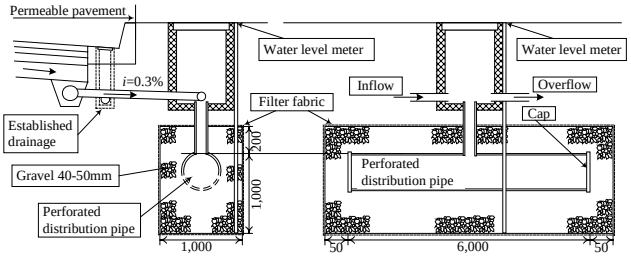

Figure-3 Cross-section and vertical section views of the trench

The infiltration capability of the trench Q_f is calculated with the formula developed by the Association of the Rainwater Storage and Infiltration Technology [1].

$$Q_f = CK_sL(aH+b) \qquad (1)$$

C : Recession coefficient (usually 0.85-0.9)
L : Length of trench [m]
H : Water depth in trench [m]
K_s : Saturated permeability coefficient of soil [m/s]
a, b : Empirical coefficients

$a = 3.093 \quad b = 1.34W + 0.677$

W : Width of trench [m]

All of the data about the trench are shown in Table-1, in which the saturated permeability coefficient of soil was obtained from borehole water injection experiment on the spot.

Table-1 Infiltration trench condition

Location of trench	Highway 54 Shimane Prefecture, Japan
Size of trench	W1.0m$\times H$1.2m$\times L$7m Perforated distribution pipe ϕ 400mm$\times L$6m
Soil condition	Masa soil (Decomposed granite soil)
Saturated permeability coefficient of soil	$K_s = 3.8\times10^{-6}$ m/s
Filling materials	4#Gravel, Diameter 40-50mm
Porosity	0.47

3 SPRINKLING EXPERIMENT FOR HIGHWAY

3.1 Outline of experiment

In order to examine the capability of the infiltration trench, three sprinkling experiments were carried out

respectively in Dec. 2004 (half a year after the completion of construction), Nov. 2005 (1 year after the completion) and Nov. 2006 (2 years after the completion). Table-2 explains the experimental conditions, where the rainfall intensity is the one that occurred in the previous day. Since the maximum rainfall occurred was only 15mm, it is supposed that underground water has no influence on this sprinkling experiment. In all three experiments, the road was sprinkled with the same intensity of 60mm/hr.

Table-2 Experimental condition

	2004	2005	2006
Date	13th Dec.	23rd Nov.	8th Nov.
Rainfall	0mm	1mm	15mm
Sprinkling-water volume	60mm/hr×1hr		
Sprinkling area	70m^2		

3.2 Experimental results

Figure-4 shows the variation of water depth in the trench with time. Figure-5 illustrates the peak water depth and its arriving time in each experiment. From these two figures, the followings were found:

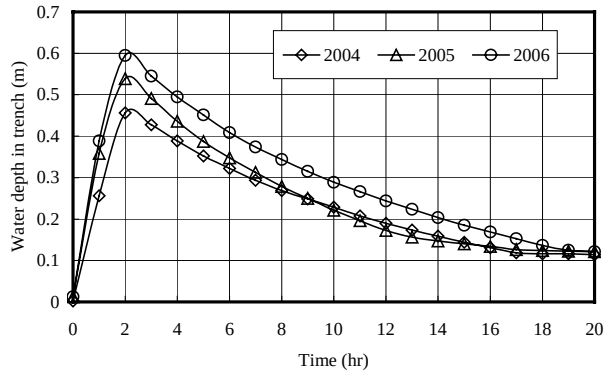

Figure-4 Variation of water depth with time

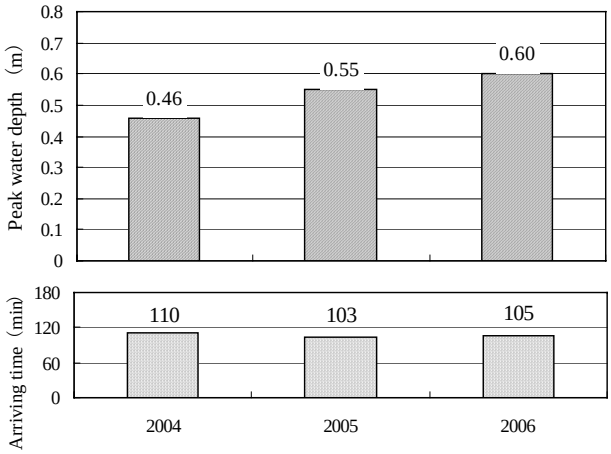

Figure-5 Peak water depth and the time

(1) In all experiment, water depth in the trench reached the peak almost at the same time.

(2) The peak water depth in the trench tended to be increased from 2004 to 2006. It is presumed that void ratio of the trench has decreased due to clogging.

(3) The storm water stored in the trench decreased with time by percolating into the soil around the trench, and almost drained away after 18 hours. From this result, it can be confirmed that setting the infiltration trench will not have a negative impact on the subgrade.

In addition, the declining speed of water depth was used to valuate the infiltration capability of the trench. The infiltration flow q was calculated by the following formula.

$$q = -nWLu \qquad (2)$$

where, n is porosity ($n = 0.47$), W is width of trench, L is length of trench and u is declining speed of water depth. The water depth data during the declining process in Figure-4 was approximated by an exponential curve using the exponential function $h = Ae^{-\alpha t}$ (A, α are regression constants), as shown in Figure-6. The declining speed of water depth can be obtained from the exponential curve.

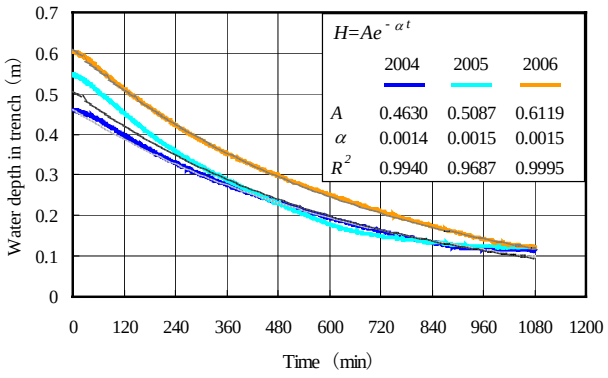

Figure-6 Process of water depth decline

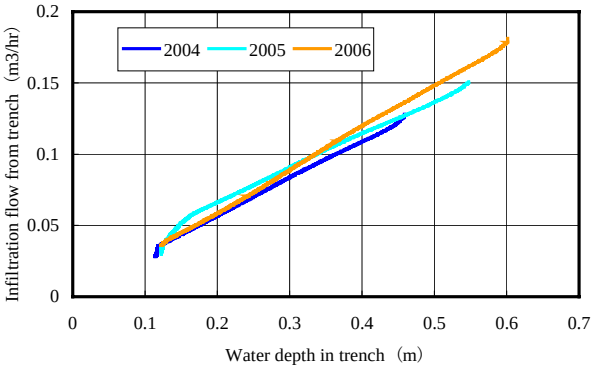

Figure-7 Relationship between water depth and infiltration flow of trench

The relationship between infiltration flow calculated by formula (2) and water depth was shown in Figure-7. As seen from Figure-7, the infiltration flow has a linear relationship with the water depth in the trench and

tends to increase with the rise of water depth. Figure-7 also shows that the curves of infiltration flow and water depth has a good coincidence in three years. There is, however a comparatively greater difference presented in the stage of high water depth. It is presumed that the difference is due to the saturated degree of ground at the beginning.

4 STORM-WATER RUNOFF CONTROL FOR REAL CONDITION

In order to verify the effectiveness of infiltration trench on controlling the storm water runoff, an investigation also has been done for a real rainstorm occurred during July 1st through July 6th, 2005. The Figure-8 shows the infiltration process of the trench during this rainfall.

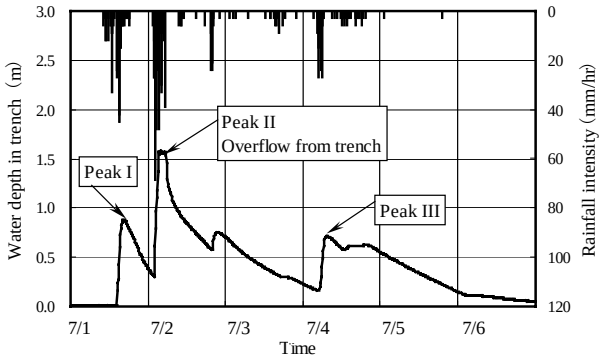

Figure-8 Rainfall and water depth of infiltration trench

The maximum rainfall intensity was 69mm/hr, and total rainfall was 224mm. The peak of water depth of the infiltration trench occurred three times. For the biggest peak, rainfall of about 9.4mm overflowed from the trench into the drainage way. From Figure-8, it can be seen that the storm water stored in the trench were removed away in two days after the rain stopped. The maximum rainfall intensity and water depth etc. corresponding to each peak are explained in Table-3.

Table-3 Rainfall and water depth for each peak

Item	Peak I	Peak II	Peak III
Maximum rainfall intensity	45mm/hr	69mm/hr	27mm/hr
Peak water depth in trench	88cm	157cm	71cm
Rainfall from each valley to each peak	28mm	77mm	13mm
Increase of water depth	87cm	127cm	54cm

5 CONCLUSIONS

Capability of infiltration trench was examined using 3 sprinkling experiments, and verified in a real torrential storm. According to these results, the followings were found:

(1) In each sprinkling experiment, no overflows occurred. This demonstrates that the storm water has successfully percolated through the infiltration trench and into the surrounding soil after a temporary storing.
(2) The peak water depth tended to rise year by year. It is presumed that the trench has been rendered to be ineffective with time as a result of clogging.
(3) Seen from the infiltration for a real torrential storm (maximum rainfall intensity: 69mm/hr, total rainfall: 224mm), the effectiveness of the infiltration trench was also verified to be great. In this example, most of storm water was removed by percolating into the surrounding soil except a small amount of overflow was drained away into the drainage.

In the practical application of an infiltration trench, many factors have to be taken into consideration, such as effects of rainwater seepage on the durability of pavements, stability of earth structures, and long-term performance and maintenance of these facilities etc. Therefore, future studies should be focused on the maintenance management and function-recovery techniques for infiltration trench so as to make the application of the infiltration trench come into a wide use.

REFERENCES

1) Association for Rainwater Storage and Infiltration Technology, Manual for technology of rainwater infiltration facilities -planning & investigation-, 1995. (in Japanese)
2) Duchene, M., Mcbean, E.A. and Thomson, N.R. (1994): Modeling of infiltration from trenches for storm-water control, *Journal of Water Resources Planning and Management*, Vol.120, No.3, 276-293.
3) Nakashima, S., Oshita, T. and Tsutsumi, S. (2006): Experimental study on the effect of storm-water infiltration facilities on the subgrade and filled up ground, *Proceedings of the 41st conference of the Japan Geotechnical Engineers*, 639-640 (in Japanese)
4) Nakashima, S., Tsutsumi, S. and Oshita, T. (2006): Infiltration trenches for highway drainage, *Proceedings of 12th Road Engineering Association of Asia and Australasia (REAAA) conference*.
5) Nakashima, S., Tsutsumi, S. and Oshita, T. (2006): Water injection experiment on infiltration trench in the filed, *Proceedings of the 61st Annual Conference of the Japan Society of Civil Engineers*, III, 251-252. (in Japanese)
6) Okamura, J. and Mushiake, K. (1990): Practical estimation method for calculation of infiltration flow of infiltration trench, *Proceedings of the 45th Annual Conference of the Japan Society of Civil Engineers*, II, 168-169. (in Japanese)
7) Tsutsumi, S., Oshita, T. and Nakashima, S. (2004): A study on the capability variation of infiltration trench over time using water injection experiment with constant water level, *Proceedings of the 59th Annual Conference of the Japan Society of Civil Engineers*, III, 322-323. (in Japanese)