Proceedings of the 7th International Conference on Asian and Pacific Coasts
(APAC 2013) Bali, Indonesia, September 24-26, 2013

STUDY OF WAVE PROPAGATION INDUCED BY SEA DIKE BREACHING

Z. P. Zhou [1], Q. H. Zuo [1] and Y. R. Zhou [1]

ABSTRACT: In this paper, wave propagation induced by sea dike breaching is studied by physical model. Two sea dike layouts with seaside slope 1: 2 are applied. For layout A, inland area has the same elevations as the breach, and seaside water depth is 27.4cm. For layout B, inland area is 7cm lower than the breach, and seaside water depth is 34.4cm. Impacts of breach width, inland elevation, water depth and wave period on inundation area and overtopping discharge are carefully examined separately. Four breach widths, 5m, 10m, 15m and 20m, are selected. A series of irregular waves (JONSWAP γ=3.3) with mean wave periods 1.0s, 1.5s, 2.0s, and significant wave height 10 cm are applied at the offshore boundary for each layout. Several empirical formulas are proposed and indicate that change of inland area elevations affects the relationship among inundation area, overtopping discharge and breach width, wave propagation time and wave period. The correlation coefficient between calculated value and experimental data are very large, but some correlative value deviates a little from the ideal line, so in the future work, more factors should be considered, and the accuracy of the empirical formulas will be improved.

Keywords: Wave propagation, sea dike breaching, physical model, empirical formulas.

INTRODUCTION

Sea dike is the front defense line to resist typhoons and storm surges, failure of sea dike may bring with life and property loss, therefore it is very important to study wave overtopping after sea dike breaching. Many researchers did a lot of works on wave overtopping in the past few decades. Such as T. Saville (1955~1958) setup the earliest physical model on regular waves overtopping. A. Paape (1960) designed a series of physical models on irregular waves overtopping on slopes. Goda (1997) developed a relationship among wave depth, wave height and wave overtopping discharge. J. R. Weggle (1976) summarized T. Saville' physical model results and proposed a wave overtopping discharge prediction formula. And then many other different kinds of wave overtopping discharge prediction formulas were proposed by researchers all over the world. In the case of sea dike breaches, overtopping by mean water levels could be estimated by using empirical relations of Van der Meer (1995), Bleck (2000) and Hughes (2009). However, these formulas only gave wave overtopping discharge at sea dikes. The breaching wave overtopping discharges in inundation area can't be estimated with these formulas. In this paper, A series of physical experiments are conducted to study the influences of breach width, inland elevation, water depth, wave period on overtopping discharge and inundation area, subsequently several empirical formulas are proposed.

PHYSICAL MODEL

Wave model tests are set in Nanjing hydraulic research institute, China. The size of wave basin is 70 m*52 m*1.2 m. The wave basin is divided by sea dikes into two parts, one is the deep water area and the other is the land area (fig.1). Gauges are set up on the land area to measure water depth (fig.2).

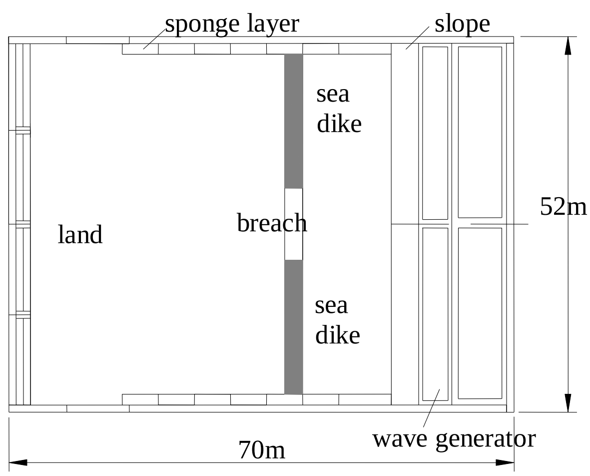

Fig. 1 Model setup

[1] Nanjing hydraulic research institute, NO. 34, Hujuguan Road, Nanjing, 210029, CHINA

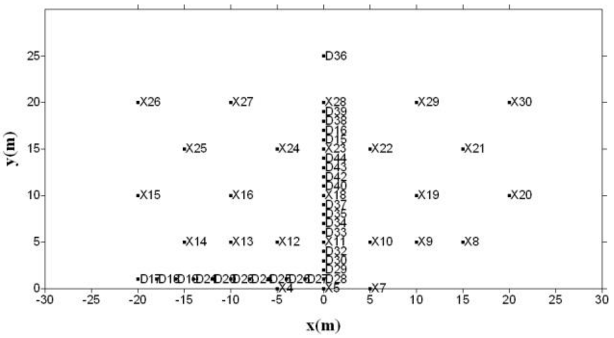

Fig. 2 Gauges layout

In the physical experiment, two sea dike layouts with seaside slope 1: 2 are applied. For layout A, the inland area has the same elevations as the breach, and seaside water depth is 27.4 cm (fig.3). For section B, the inland area is 7 cm lower than the breach, and seaside water depth is 34.4 cm (fig.4). Impacts of breach width, inland elevation, water depth and wave period on inundation area and overtopping discharge are carefully examined separately. Four breach widths, 5 m, 10 m, 15 m and 20 m, are selected. A series of irregular waves (JONSWAP γ=3.3) with wave periods 1.0 s, 1.5 s, 2.0 s, and significant wave height 10 cm are applied at the offshore boundary for each layout.

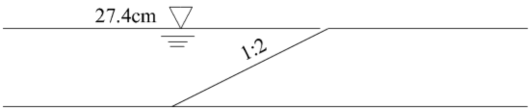

Fig. 3 Layout A, water depth is 27.4 cm

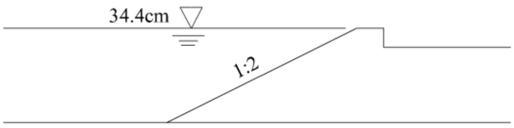

Fig. 4 Layout B, water depth is 34.4 cm

Once the wave passes the breach, it propagates not only in longitudinal direction, but also it spreads to transversal directions in the physical experiment. The overtopping discharge and inundation area can be calculated by interpolating measured water depths from the gauges. Figure 5 to figure 7 give irregular wave (JONSWAP γ=3.3) with significant wave height 10 cm and mean wave period 1.0 s propagating through 20 m wide breach on layout A at different times. And figure 8 to figure10 give the same irregular wave propagating through 20 m wide breach on layout B at different moments.

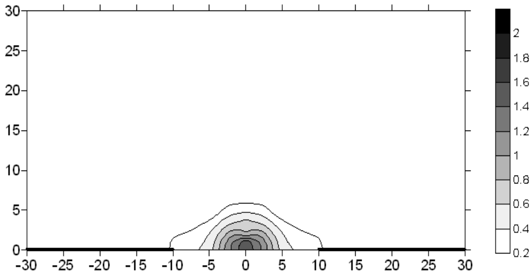

Fig. 5 layout A t =20s

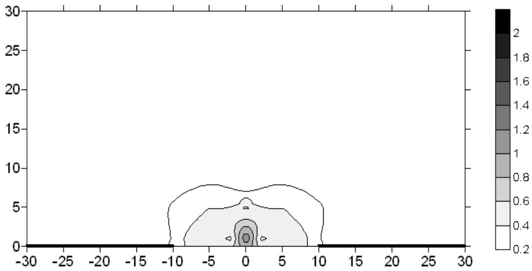

Fig. 6 layout A t =40s

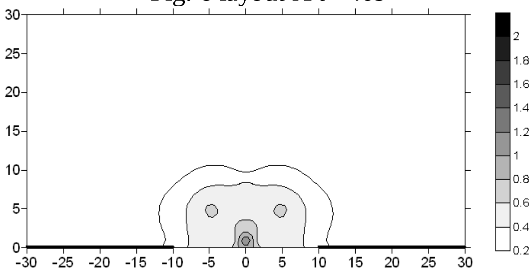

Fig. 7 layout A t =60s

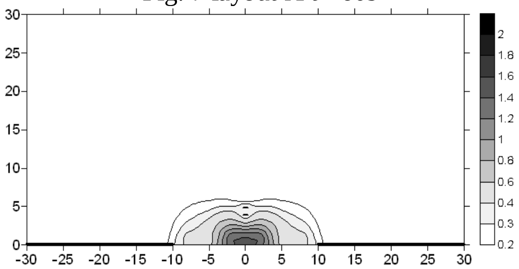

Fig. 8 layout B t =20s

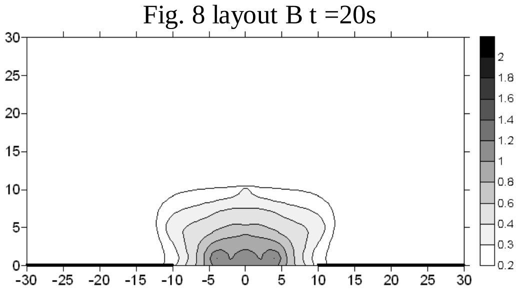

Fig. 9 layout B t =40s

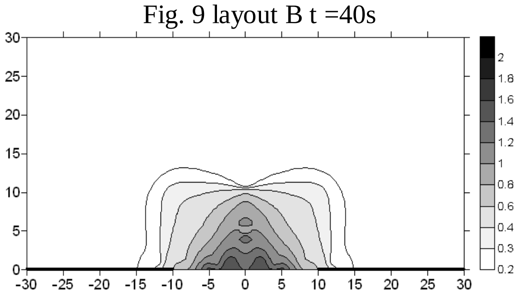

Fig. 10 layout B t =60s

It can be seen from figure 5 to figure 10 that for layout A, the inland water level increases quickly since the inland elevation is the same with the breach. However, with more and more accumulated water, the increase rate of inundation area and overtopping discharge decrease with time. For layout B, the inland elevation is lower than the breach, so the inland water level, inundation area and overtopping discharge increase all the way.

RESULTS ANALYSIS

By analyzing the results of wave propagation model tests, the impacts of wave propagation time (t), breaching widths (B) and wave periods (T) on overtopping discharge (Q) and inundation area (S) can be obtained.

Influence of Time

The relationship between time (t) and overtopping discharge (Q) and inundation area (S) on layout A can be seen in figure 11 and figure 12, respectively. And the relationship between time (t) and overtopping discharge (Q) and inundation area (S) on layout B can be seen in figure 13 and figure 14 respectively.

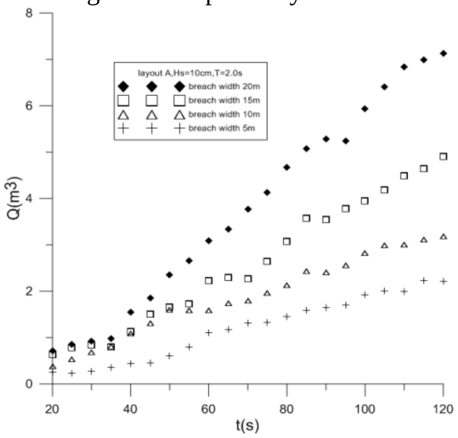

Fig.11 Relationship between time and overtopping discharge on layout A

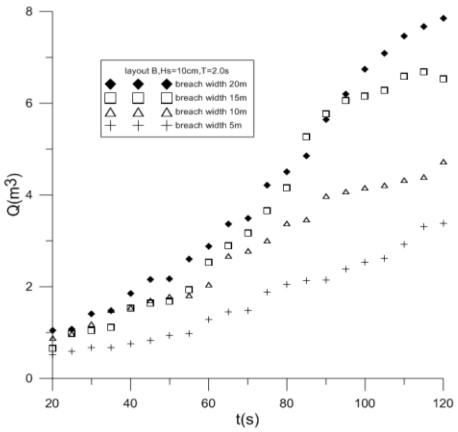

Fig.12 Relationship between time and inundation area on layout A

It can be seen from these figures that overtopping discharge and inundation area increase as time goes by, and both the overtopping discharges and inundation areas of layout B are greater than layout A, Because the inland elevation is the same with the breach for layout A, with more and more accumulated water, which may flow back to offshore. And these figures agree well to figure 5 to figure 10.

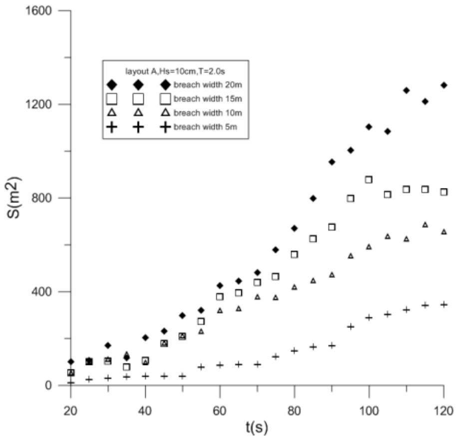

Fig.13 Relationship between time and overtopping discharge on layout B

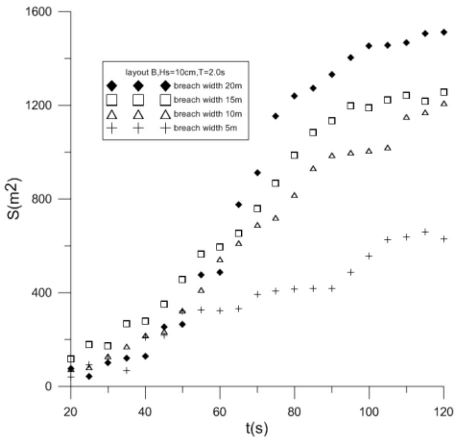

Fig.14 Relationship between time and inundation area on layout B

Influence of Breach Widths

The relationship between breach widths and overtopping discharges on layout A and layout B can be seen in figure 15 and figure16, respectively. And the relationship between breach widths and inundation area on layout A and layout B can be seen in figure 17 and figure 18, respectively. Linear relation between overtopping discharge, inundation area and breach widths can be seen from figure 15 to figure 18.

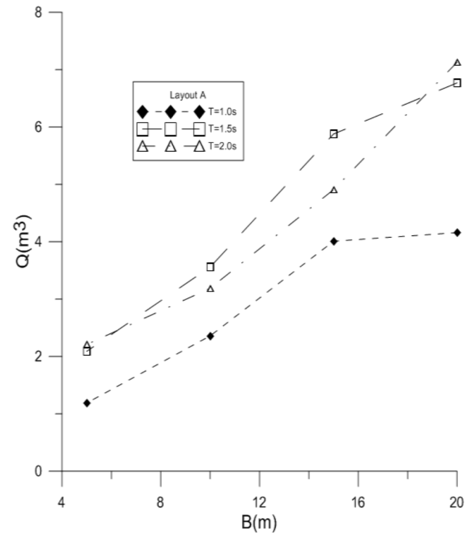

Fig 15 Relationship between breach widths and overtopping discharge on layout A

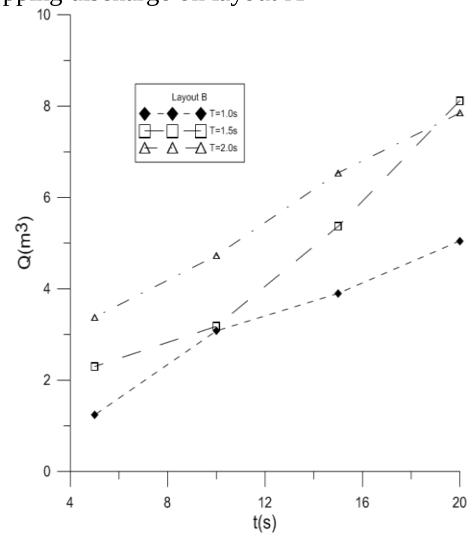

Fig. 16 Relationship between breach widths and overtopping discharge on layout B

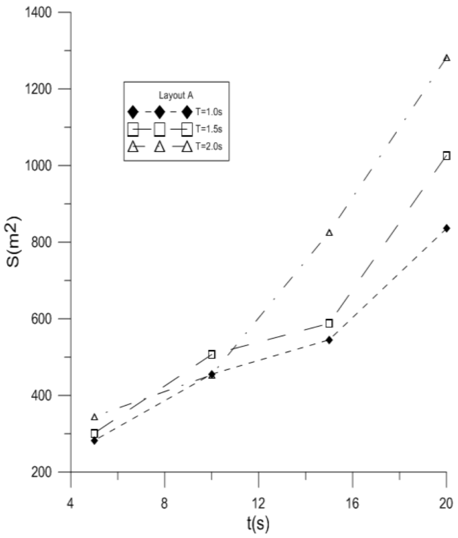

Fig. 17 Relationship between breach widths and inundation area on layout A

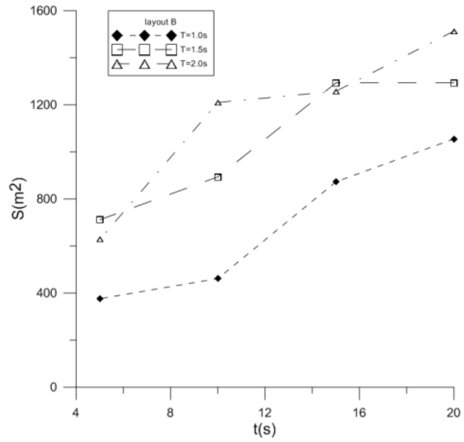

Fig. 18 Relationship between breach widths and inundation area on layout B

Influence of Wave Periods

The relationship between wave periods and overtopping discharges on layout A and layout B can be seen in figure 19 and figure 20, respectively. And the relationship between wave periods and inundation area on layout A and layout B can be seen in figure 21 and figure 22 respectively.

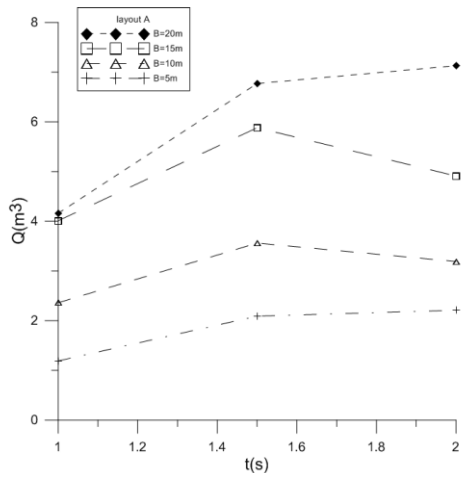

Fig. 19 Relationship between wave periods and overtopping discharge on layout A

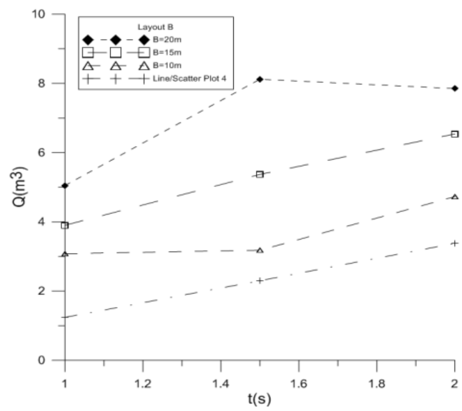

Fig. 20 Relationship between wave periods and overtopping discharge on layout B

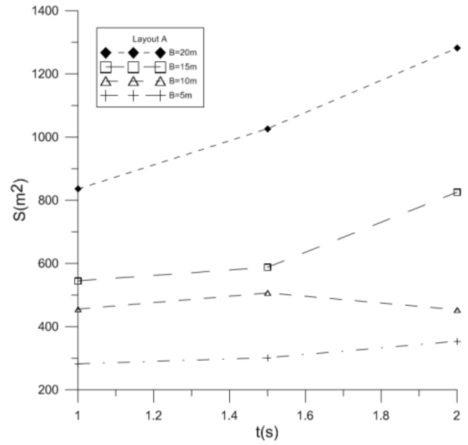

Fig. 21 Relationship between wave periods and inundation area on layout A

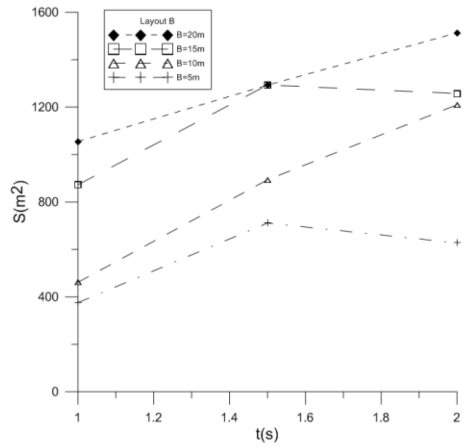

Fig. 22 Relationship between wave periods and inundation area on layout B

When the incident wave heights are the same, overtopping discharge and inundation area all grow linearly with the growth of the wave periods. But for layout A, the increase rates of overtopping discharge and inundation area are smaller than layout B.

Empirical Formulas

From the above analysis, the overtopping discharge (Q), inundation area (S) and wave propagation time (t), breach widths (B), wave period (T) present linear relationship. According to Van der Meer's overtopping formula (Van der Meer 1995), this paper just takes above mentioned factors into consideration and assume the equations as follow,

$$Q = a\sqrt{gH_s^{\ 3}}tB + b \tag{1}$$

$$S = c\sqrt{gH_s}tB + d \tag{2}$$

The applicable range of the above formulas is

5 m≤B≤20 m; 1.0 s≤T≤2.0 s

The fitting overtopping discharge formula for layout A

$$Q = 0.02\sqrt{gH_s^{\ 3}}tB + 0.16 \tag{3}$$

The fitting inundation area formula for layout A

$$S = 0.43\sqrt{gH_s}tB + 91 \tag{4}$$

The fitting overtopping discharge formula for layout B

$$Q = 0.04\sqrt{gH_s^{\ 3}}tB + 0.20 \tag{5}$$

The fitting inundation area formula for layout B

$$S = 0.97\sqrt{gH_s}tB + 62 \tag{6}$$

The comparison between overtopping discharge (Q) which is calculated by formula (4) and experimental data for layout A is shown in figure 23, and the correlation coefficient between the calculated value and experimental data is 0.93.

The comparison between inundation area (S) which is calculated by formula (5) and experimental data for layout A is shown in figure 24, and the correlation coefficient between the calculated value and experimental data is 0.90.

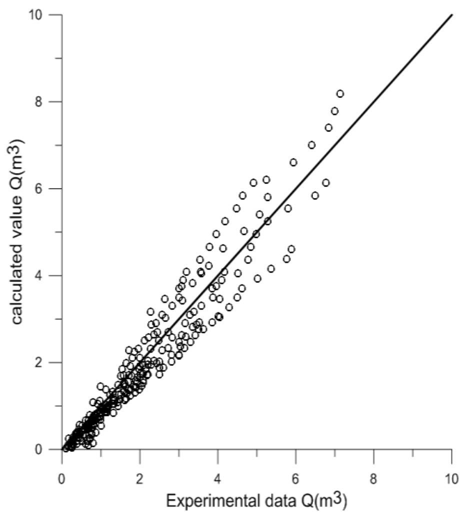

Fig. 23 Comparison of Q calculated value and experimental data, layout A correlative value(circle), ideal line(solid line)

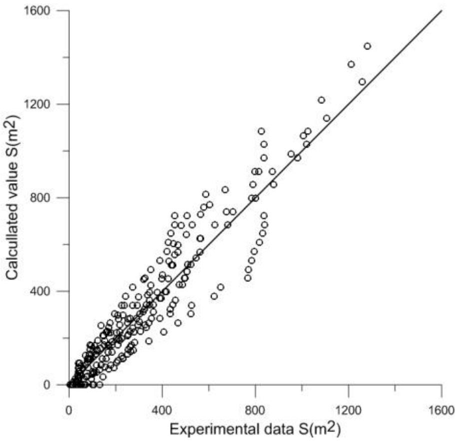

Fig. 24 Comparison of S calculated value and experimental data, layout A correlative value(circle), ideal line (solid line)

The comparison between overtopping discharge (Q) which is calculated by formula (6) and experimental data for layout B is shown in figure 25, and the correlation coefficient between the calculated value and experimental data is 0.93.

The comparison between inundation area (S) which is calculated by formula (7) and experimental data for layout B is shown in figure 26, and the correlation coefficient between the calculated value and experimental data is 0.90.

From these four comparison figures people can see that the calculated values are highly correlated with the experimental data. But some correlative value deviates a little from the ideal line. It might be because of the gauge instability caused by unsteady wave velocity.

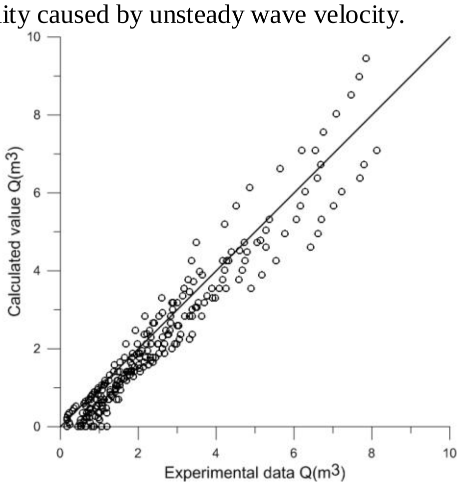

Fig. 25 Comparison of Q calculated value and experimental data, layout B correlative value(circle), ideal line(solid line)

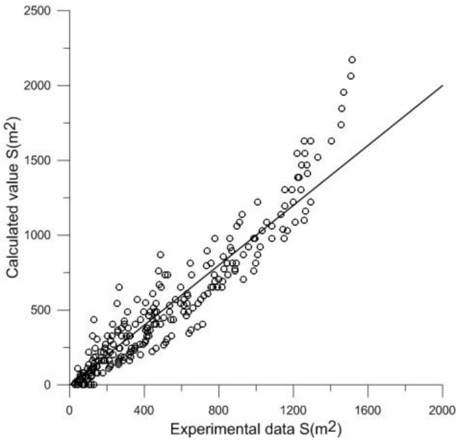

Fig. 26 Comparison of S calculated value and experimental data, layout B correlative value(circle), ideal line(solid line)

CONCLUSION

In this paper, a series of physical tests of wave overtopping through breach have been carried out, the tests results show that the overtopping discharge, inundation area and wave propagation time, breach widths, wave period present linear relationship. The overtopping discharge for layout A can be calculated in formula (4), the inundation area for layout A can be calculated in formula (5). The overtopping discharge for layout B can be calculated in formula (6) and the inundation area for benched-layout can be calculated in formula (7),the applicable scope is formula (3). The comparison figures tell that the calculated values are highly correlated with the experimental data. But some correlative value deviates a little from the ideal line, so in the future work, more factors should be considered, and the accuracy of the empirical formulas will be improved.

REFERENCES

Bleck, M., Oumeraci, H., and Schuettrumpf, A. (2000). “Combined wave overtopping and overflow of dikes and seawalls.” Proc., 27th Int. Conf. on Coastal Eng., ASCE, Reston, VA.

Hughes, S. A., and Nadal, N. C. (2009). “Laboratory study of combined wave overtopping and storm surge overflow of a levee.” J. Coastal Eng.,56(3), 244–259.

J.W. Van der Meer, and J.P.F.M. Janssen, 1995. Wave run-up and wave overtopping at dikes, Published in: Wave Forces on inclined and vertical Structures. Ed. Z.Demirbilek. pp. 1-27.

T. Saville, 1955, Laboratory data on wave runup and overtopping, Lake Okeechobee Levee Sections, U.S.Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., Oct, 1955.

T. Saville, 1958, Large-scale model tests of wave run up and overtopping on shore Structures, TM-64, U.S.Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., Oct, 1958.

A. Paape, 1960, Experimental data on the overtopping of seawalls by waves, Proceedings of 7th Conference on Coastal Engineering, ASCE, Vol.2, No.4, pp674-681.

Yuichi Iwagaki, Akira Shima, Masao Inoue, 1965, Effect of wave height and sea water level on wave overtopping and wave run-up, Coastal Engineering in Japan, JSCE, Vol.8, pp 141-151.

Y. Goda,1971, Expected rate of irregular wave overtopping of seawalls, Coastal Engineering in Japan, JSCE, Vol 14, pp 45-51.