同行专家业内评价意见书编号：20250859015

附件1

浙江工程师学院（浙江大学工程师学院）
同行专家业内评价意见书

姓名： 李亚博

学号： 22260479

申报工程师职称专业类别（领域）： 土木水利

浙江工程师学院（浙江大学工程师学院）制

2025年05月30日

填表说明

一、本报告中相关的技术或数据如涉及知识产权保护、军工项目保密等内容，请作脱密处理。

二、请用宋体小四字号撰写本报告，可另行附页或增加页数，A4纸双面打印。

三、表中所涉及的签名都必须用蓝、黑色墨水笔，亲笔签名或签字章，不可以打印代替。

四、同行专家业内评价意见书编号由工程师学院填写，编号规则为：年份4位＋申报工程师职称专业类别(领域)4位+流水号3位，共11位。

一、个人申报

（一）基本情况【围绕《浙江工程师学院（浙江大学工程师学院）工程类专业学位研究生工程师职称评审参考指标》，结合该专业类别(领域)工程师职称评审相关标准，举例说明】

1.对本专业基础理论知识和专业技术知识掌握情况(不少于200字)

作为一名土木水利专业的研究生，我认为自己具备了坚实宽广的基础理论知识（数理、力学、水文学、土力学）和系统深入的专业技术知识（水工建筑物、水力学、河流动力学）。尤其宝贵的是，通过两年专注的局部冲刷物理模型试验研究，我在冲刷机理、试验设计、先进测量技术、数据处理分析和工程应用方面积累了深厚的实践经验和专业技能，能够将复杂的理论知识与实际的工程问题（尤其是水工建筑物安全的关键问题——冲刷）有效结合，具备了独立开展相关研究工作和解决实际工程中冲刷问题的能力。
我深知学无止境，将继续保持学习和探索的热情，致力于将所学知识应用于保障水工建筑物安全、推动水利科技进步的事业中。

2.工程实践的经历(不少于200字)

在2023.03-2025.03年间，我在浙江省水利河口研究院（浙江省海洋规划设计研究院）开展工程实践，主要参与了国家重点研发计划项目——多因子作用下典型承灾体的破坏特性与致灾机理（项目批准号：2023YFC3008101-4）。工程实践期间，我主要是完成海堤模型制作、试验参数设计、预试验到记录冲刷过程等主要任务，及时做好试验前准备任务及试验后的处理完善工作。使用声学多普勒流速仪、GS-4跟踪式光栅水位仪等仪器，准确测量和记录实验数据。在试验进行期间，使用三脚架将摄像机固定在水槽侧面，以记录海堤背坡冲刷的瞬时变化。实验开始后，全程使用摄像机对海堤冲刷坑剖面记录，直到冲刷达到平衡状态，停止拍摄并记录冲刷特征。同时能够运用MATLAB图像处理技术获得冲刷坑的深度以及床面剖面变化情况，并进行估计值与实测值的验证与比较。

3.在实际工作中综合运用所学知识解决复杂工程问题的案例（不少于1000字）

工程实践期间，我主要参与了国家重点研发计划项目——多因子作用下典型承灾体的破坏特性与致灾机理（项目批准号：2023YFC3008101-4）。项目期间，我发现当前海堤背水坡防护体系仍值得深入探索，并将其应用于研究生学位论文写作中。
海堤作为海岸常见的水工建筑物，是为防御风暴潮水和波浪对沿海地区的危害而修筑的堤防工程，是沿海地区人类生命及财产安全的重要屏障。但在全球气候变化背景下，极端风暴潮事件持续增加，风暴潮越过堤防和挡浪墙，高速溢流水体平行于海堤背水坡进行冲刷。试验结果和现场分析调查表明，绝大部分的海堤破坏都是溢流水体对海堤背水坡的冲刷侵蚀所致，海堤的溃决和破坏将导致严重后果。风暴潮溢流已成为海堤冲刷防护和安全评估中必需考虑的因素，也是海岸防灾领域亟待解决的问题之一。
海堤按照其结构特点可分为向海侧、堤顶和背水坡护坡。而现有海堤防护体系包括堤顶与背水坡，大多针对越浪作用进行设计，传统的堤防工程往往注重海堤向海侧的防御而忽视了背水坡的防御，缺少对风暴潮溢流的认识和考虑。对于典型的斜坡式海堤，国内外在挡浪墙的设置上存在差异，国外斜坡式海堤堤顶多数不设置挡浪墙，而我国的海堤堤顶大多设有挡浪墙，特别是浙江沿海地区潮位高、波浪大。且国外海堤背水坡护面型式多为草皮护坡，而我国后坡护面型式主要为干砌块石护坡、混凝土板护坡、抛石护坡等防护措施，因而国外斜坡

堤在风暴潮溢流期间的研究成果很难直接应用于我国的海堤形式，可能存在较大的偏差。
本研究聚焦于风暴潮溢流作用下海堤背水坡局部冲刷与防护效果，采取缩比尺的方法设置海堤物理模型，借助水槽试验研究方法探索海堤背水坡冲刷特征，调整海堤结构参数，包括堤顶高度、挡浪墙高度、堤顶宽度、背水坡坡度，以及水流参数，如水深、流速、堤顶水头等，从冲刷深度、冲刷长度、堤顶收缩长度等方面，揭示风暴潮溢流作用下海堤背水坡冲刷特征。同时采用不同类型的海堤护坡措施，包括草皮防护与碎石防护，分析风暴潮溢流过程中不同海堤背水坡防护条件下的局部冲刷形态变化，为风暴潮溢流期间海堤背水坡防御提供相关技术参考和理论依据。
本研究中水槽试验在浙江省水利河口研究院的浙江省河口海岸重点实验室进行，试验装置为矩形玻璃水槽，玻璃水槽长26m，宽0.6m，高0.9m。进水口拥有3m的消能段，确保水流平稳流动，能够提供最大为0.6m/s的水流速度。玻璃水槽末端为蓄砂池和尾门，蓄砂池能够将试验所产生的砂土回收，尾门则可以控制水位和流速的大小。测量装置主要有3种：（1）声学多普勒流速仪，（2）GS-4跟踪式光栅水位仪，（3）索尼FDR-AX700高清数码摄像机。试验模型海堤的迎水坡坡度为1:2，以确保上游水头沿海堤的稳定溢流。堤身由粉土均匀建造，中值粒径为0.03mm，在试验海堤模型的下游水槽底部覆盖有均匀的粉土床层，并考虑安装不同种类的海堤护坡，包括碎石和草皮。使用高精度相机记录海堤背坡冲刷过程，并通过图像处理的方法获得堤顶收缩长度、堤脚收缩长度、冲刷坑深度、冲刷长度等参数。在试验进行期间，使用三脚架将摄像机固定在水槽侧面，以记录海堤背坡冲刷的瞬时变化。实验开始后，全程使用摄像机对海堤冲刷坑剖面记录，直到冲刷达到平衡状态，停止拍摄。实验结束后，使用MATLAB进行图像处理获得冲刷坑的深度以及床面的剖面变化情况。本研究主要围绕堤顶宽度、背水坡角度、草皮防护及碎石防护等对海堤背水坡冲刷的影响，设计相应的试验工况并开展试验。
水槽试验的结果表明，在水槽流速为0.1994m/s，挡浪墙高度为0.03m的工况下，冲刷坑深度、冲刷长度、堤顶与堤脚收缩长度都随堤顶宽度增加而呈现出先增大后减小的趋势；冲刷坑深度、冲刷长度、堤脚收缩长度的最大值均出现在堤顶宽度为0.18m时，分别为1.052、0.156、0.121m；堤顶宽度为0.30m时，堤顶收缩长度最大，为0.120m。随着背水坡的坡度从1:2，逐渐增加至1:3、1:4，冲刷坑高度、冲刷长度随背水坡角度的增加而增大，堤脚收缩长度随背水坡角度的增加而逐渐减小，而堤顶收缩长度随背水坡角度的增加而呈现出先减小后增大的趋势。对比无防护措施，草皮和碎石防护均能够减缓海堤背水坡的冲刷侵蚀，能够有效减小堤顶、堤脚收缩长度、冲刷坑高度和冲刷长度。其中，草皮防护在减小堤顶和堤脚收缩长度上效果较好，而碎石防护在减少冲刷坑高度和冲刷长度上效果较好。本研究的发现可为极端风暴潮溢流下海堤背水坡的安全评估和防护提供参考依据。

（二）取得的业绩（代表作）【限填3项，须提交证明原件（包括发表的论文、出版的著作、专利证书、获奖证书、科技项目立项文件或合同、企业证明等）供核实，并提供复印件一份】					
1. 公开成果代表作【论文发表、专利成果、软件著作权、标准规范与行业工法制定、著作编写、科技成果获奖、学位论文等】					
成果名称	成果类别 [含论文、授权专利（含发明专利申请）、软件著作权、标准、工法、著作、获奖、学位论文等]	发表时间/授权或申请时间等	刊物名称/专利授权或申请号等	本人排名/总人数	备注
Analysis of erosion features on landside slope of a levee during surge overflow based on backpropagation network model	会议论文	2024年09月06日	Conference Series: Sustainable Civil Infrastructures	1/3	
2. 其他代表作【主持或参与的课题研究项目、科技成果应用转化推广、企业技术难题解决方案、自主研发设计的产品或样机、技术报告、设计图纸、软课题研究报告、可行性研究报告、规划设计方案、施工或调试报告、工程实验、技术培训教材、推动行业发展中发挥的作用及取得的经济社会效益等】					

（三）在校期间课程、专业实践训练及学位论文相关情况	
课程成绩情况	按课程学分核算的平均成绩： 86 分
专业实践训练时间及考核情况(具有三年及以上工作经历的不作要求)	累计时间： 1 年（要求1年及以上） 考核成绩： 83 分
本人承诺	
个人声明：本人上述所填资料均为真实有效，如有虚假，愿承担一切责任，特此声明！ 申报人签名： 李玉博	

22260479

二、日常表现考核评价及申报材料审核公示结果

日常表现考核评价	非定向生由德育导师考核评价、定向生由所在工作单位考核评价： ☑优秀　　☐良好　　☐合格　　☐不合格 德育导师/定向生所在工作单位分管领导签字（公章）：　2025 年 5 月 31 日
申报材料审核公示	根据评审条件，工程师学院已对申报人员进行材料审核（学位课程成绩、专业实践训练时间及考核、学位论文、代表作等情况），并将符合要求的申报材料在学院网站公示不少于5个工作日，具体公示结果如下： ☐通过　　☐不通过（具体原因：　　　　　　　　） 工程师学院教学管理办公室审核签字（公章）：　　　　年　月　日

浙 江 大 学 研 究 生 院

攻读硕士学位研究生成绩表

学号：22260479	姓名：李亚博	性别：男	学院：工程师学院	专业：土木水利	学制：2.5年
毕业时最低应获：27.0学分		已获得：29.0学分		入学年月：2022-09	毕业年月：
学位证书号：			毕业证书号：		授予学位：

学习时间	课程名称	备注	学分	成绩	课程性质	学习时间	课程名称	备注	学分	成绩	课程性质
2022-2023学年秋季学期	创新设计方法		2.0	通过	专业选修课	2022-2023学年春季学期	新时代中国特色社会主义理论与实践		2.0	86	公共学位课
2022-2023学年秋季学期	工程技术创新前沿		1.5	85	专业学位课	2022-2023学年春季学期	研究生论文写作指导		1.0	94	专业学位课
2022-2023学年秋季学期	工程数值分析		2.0	84	专业选修课	2022-2023学年春季学期	自然辩证法概论		1.0	90	公共学位课
2022-2023学年秋季学期	工程伦理		2.0	88	公共学位课	2022-2023学年夏季学期	研究生英语基础技能		1.0	免修	公共学位课
2022-2023学年冬季学期	机器视觉及其应用		2.0	84	专业学位课	2022-2023学年春夏学期	高阶工程认知实践		3.0	89	专业学位课
2022-2023学年冬季学期	海洋管理学		2.0	92	专业选修课	2022-2023学年夏季学期	数据科学前沿技术导论		2.0	85	专业学位课
2022-2023学年冬季学期	产业技术发展前沿		1.5	91	专业学位课	2022-2023学年夏季学期	研究生英语		2.0	免修	公共学位课
2022-2023学年春季学期	港口设施规划与布局		2.0	85	专业学位课		硕士生读书报告		2.0	通过	

说明：1. 研究生课程按三种方法计分：百分制，两级制（通过、不通过），五级制（优、良、中、及格、不及格）。

2. 备注中“*”表示重修课程。

学院成绩校核章：

成绩校核人：张梦依

打印日期：2025-06-03

浙江大学研究生（60）成绩校核章

2024 International Conference on Geotechnics and Hydro Structure

09/06/2024 - 09/08/2024 Qingdao • China

Acceptance Letter

Dear Author(s):

Congratulations! Your manuscript has passed the peer review (the reviewers' comments are available in the attached file on AIS) and has been accepted by the 2024 International Conference on Geotechnics and Hydro Structure. The conference will be held in Qingdao • China from 09/06/2024 - 09/08/2024. We are glad to invite you to attend the conference and make an oral report.

Manuscript No.: I3U3UVISSU

Author name(s): Yabo Li, Zhiyong Zhang, Zhiguo He

Manuscript title: Analysis of erosion features on landside slope of a levee during surge overflow based on backpropagation network model

Your manuscript, after presented in the oral report or poster in the conference, will be published on Conference Proceedings, after which it will be submitted for index in EI Compendex、Scopus.

2024 International Conference on Geotechnics and Hydro Structure

Committee

09-05-2024

Notices:

1. Authors need to revise the manuscript as per the reviewers' comments before re-uploading the final version (in Word or PDF) to the AIS system.
2. Authors need to ensure that the submitted manuscript is an original paper with a similarity lower than 20%. Once the manuscript is submitted to AIS, the authors are not allowed to re-submit it to other journals for publication.
3. Authors need to confirm their attendance one week before the conference is held. If the authors are not able to be present on the conference after agreeing to attend the conference, the authors need to reach the conference secretary for re-arrangement.

Again, congratulations and we look forward to meeting you in Qingdao • China

Analysis of Erosion Features on Landside Slope of a Levee during Surge Overflow Based on Backpropagation Network Model

Yabo Li[1, 2], Zhiyong Zhang[2] and Zhiguo He[3*]

[1] Polytechnic Institute, Zhejiang University, Hangzhou 310015, China
[2] Zhejiang Institute of Hydraulics and Estuary, Hangzhou, 310072, China
[3] Institute of Port, Coastal and Offshore Engineering, Ocean College, Zhejiang University, Zhoushan 316021, Zhejiang, China
[*]Corresponding author's e-mail: hezhiguo@zju.edu.cn

Abstract The landside slope of levees was exposed to the scour erosion induced by storm surge overflow with more typhoons. This study aimed to reveal the erosion features on landside slope of a levee during surge overflow. Different experimental conditions based on flume test were designed to explore the influence of levee structural parameters on landside slope of a levee, including levee crest width and landside slope. Experimental data was used to predict the erosion features of levees landside slope by backpropagation network (BPN) model. Different performance metrics were employed to assess the model fitness and accuracy of BPN model in predicting different erosion features. Results indicated that increasing the width of levee crest and landside slope led to the increase of equilibrium scour depth and length. And BPN model could predict these erosion features accurately and effectively. This study could provide a scientific basis for the safety assessment and protection of levees under extreme conditions.

Keywords Local scour; Backpropagation network model; Surge overflow; Levee; Flume test

1 Introduction

Climate change significantly brought about the sea level rise[1] and increased the intensity[2] and frequency[3] of storm surges in recent years. Storm surge overflow could lead to the scour erosion and complete destruction of levees around coastal areas. Most studies[4–6] pointed out that most levee damage occurred on the levee crest and landside slope during surge overflow. Landside slope of levees was exposed to fast-flowing, turbulent water velocities[4] and much greater erosive forces than seaward-side slope[5]. However, traditional studies mainly focused on the local scour on seaward-side slope designed for wave overtopping[7] and paid less attention to landside slope of a levee during surge overflow. And the limited studies explored the effect of different levee structural parameters on the erosion features of landside slope, including levee crest elevation, wave wall height, landside slope and levee crest width.

Furthermore, extensive studies[8–10] generally analysed and predicted the erosion features of local scour around levees by fitting an empirical expression of equilibrium scour depth based on large amounts of experimental data. But most of these empirical formulas were limited to the similarity of hydraulic conditions or levee structural parameters. The accuracy of prediction results was not stable and consistent for landside slope of levees in different regions. Since the local scour evolution of levees was a complex nonlinear dynamic system problem, more and more machine learning methods [10,11] have been applied to erosion features in recent years, such as the prediction of local scour depth downstream of submerged weirs by backpropagation network (BPN) model. There was lack of adequate researches that focused on predicting the erosion features on landside slope during surge overflow.

This study aimed to explore the influence of levee structural parameters on erosion features and reveal the applicability of BPN model to the prediction of local scour features of a levee. By adjusting the hydraulics condition, levee structural parameters and protection measures, this study designed and carried out different experimental conditions based on flume test to explore the erosion features on landside slope of a levee under surge overflow. We mainly analysed the effect of levee crest width and landside slope on landside slope of a levee in this work. This study used experimental data to predict the erosion features of levee landside slope by BPN model. We also compared the model performance and accuracy in predicting different erosion features by statistical metrics.

2 Materials and Methods

2.1 Experimental Setup

The flume test was carried out in a rectangular glass flume with the size of 26m×0.6m×0.9m (length × width × height) at the key Laboratory of Estuary and Coast of Zhejiang Province of Zhejiang Institute of Hydraulics & Estuary. The hydraulic parameters are converted based on Froude Criterion. The test levee model had the model scale of 1:100, the same width as the flume, a seaward-side slope of

1H:2V, levee crest elevation of 0.05m, wave wall height of 0.03m and landside slope of 1H:2V. The levee body was uniformly constructed of sand with a mean average size (d_{50}) of 0.3 mm (**Figure 1**). The flume bottom downstream of test model was also covered with sand with a mean average size (d_{50}) of 0.3 mm. Two different protection conditions, including turf and gravel protection (d_{50}=5mm), were considered to performed on the landside slope of test levee model. The data collected during each test included discharge, flow velocity (U_0), headwater depth (h_0), temporally eroded bed profile, equilibrium bed profile, and erosion features (**Figure 2**), including scour length on the crest of levee (L_t), scour length at the toe of landside levee (L_b), maximum scour depth at equilibrium (h_s), equilibrium scour length (L_s). The duration of each test lasted 120min. Experimental parameters were shown in **Table 1** and 68 groups of experiments were eventually designed and conducted in this study.

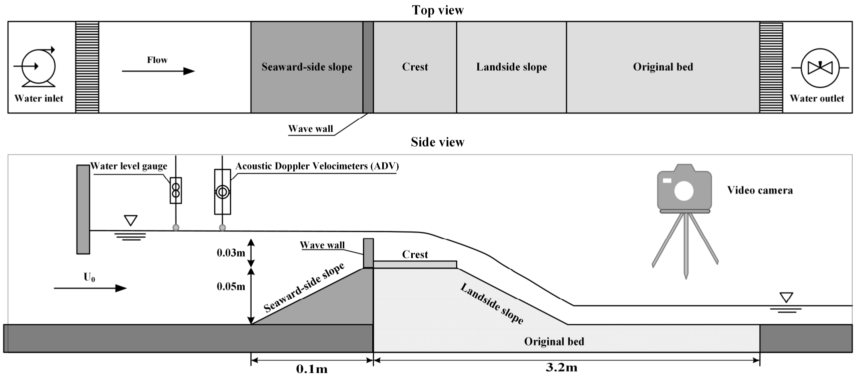

Fig 1. Schematic view of experimental setup.

Table 1. Experimental conditions of this study.

Headwater depth (h_0)/m	Flow velocity (U_0)/m*s^{-1}	Elevation of levee crest (h_1)/m	Wave wall height (h_2)/m	Width of levee crest (L_m)/m	Landside slope (α)	Protection conditions
0.09	0.10	0.05	0	0.09	1:2	none
0.12	0.15	0.07	0.03	0.18	1:3	gravel
0.15	0.18	0.10	0.05	0.24	1:4	turf
0.17	0.20			0.30		
0.20	0.25			0.36		
	0.30			0.45		

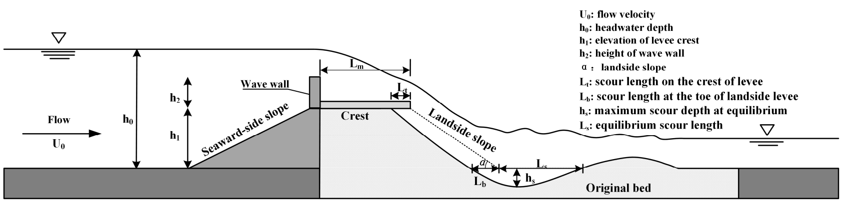

Fig 2. Schematic sketch of a scour hole around a levee during surge overflow.

2.2 Backpropagation Network Model Setup

This study used 68 sets of experimental data from flume test to predict the erosion features of levee landside slope by BPN model. These variables were considered as the input data: flow velocity (U_0), headwater depth (h_0), elevation of levee crest (h_1), height of wave wall (h_2), landside slope (α), width of levee crest (L_m), protection conditions of landside slope, waterhead of levee crest (h_0-h_1-h_2) and median diameter of sediment (d_{50}). Four different erosion features were taken as the output data respectively, including scour length on the crest of levee (L_t), scour length at the toe of landside levee (L_b), maximum scour depth at equilibrium (h_s) and equilibrium scour length (L_s). Sample data was randomly divided into two parts (80% training set and 20% test set), and the input data and output data were normalized. This study set these parameters in BPN model respectively: learning rate (0.01), target minimum error (0.001) and the maximum number of iterations (1000). Tanh function was employed as the transfer function in the optimal network. This study used these statistical metrics to assess the overall performance of BPN model, including mean absolute error (MAE), mean bias error (MBE), root mean square error (RMSE) and coefficient of determination (R^2). This study repeated the development process of BPN model to determine the optimal number of neurons in hidden layer. Optimal configuration of BPN model was identified with the minimum values of RMSE, MBE and MAE and the maximum value of R^2.

$$MAE = \frac{1}{n}\sum_{i=1}^{m}|(y_i - \hat{y}_i)| \tag{1}$$

$$MBE = \frac{1}{n}\sum_{i=1}^{m}(y_i - \hat{y}_i) \tag{2}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{m}(y_i - \hat{y}_i)^2} \tag{3}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{m}(\hat{y}_i - y_i)^2}{\sum_{i=1}^{m}(\bar{y}_i - y_i)^2} \tag{4}$$

3 Results & Discussion

3.1 The Influence of Levee Crest Width

This study conducted the test conditions without protection measures, including levee crest elevation of 0.05m, wave wall height of 0.03m, landside slope of 1:2, headwater depth of 0.15m and flow velocity of 0.20m/s. As shown in Figure **3(a)**, as the width of levee crest increased from 0.09m to 0.45m, L_t showed an increasing trend, while L_b, h_s and L_s increased and then decreased. We also performed the test conditions of levee crest elevation of 0.05m, wave wall height of 0.05m, landside slope of 1:2, headwater depth of 0.17m, flow velocity of 0.18m/s and no protection measures. As shown in Figure **3(b)**, with the increasing width of levee crest, L_t, L_b, h_s and L_s showed a trend of first increasing and then decreasing. Increasing the width of levee crest led to the increase of L_t and L_b, but it also reduced h_s and L_s. When the width of levee crest reached 0.36m, these erosion pattern indicators were smaller. And with the flow velocity of 0.20m/s, L_t, L_b, h_s and L_s reached 10.80, 9.70, 12.60 and 94.70cm while these were 9.70, 8.80, 13.40 and 96.10cm respectively with the flow velocity of 0.18m/s.

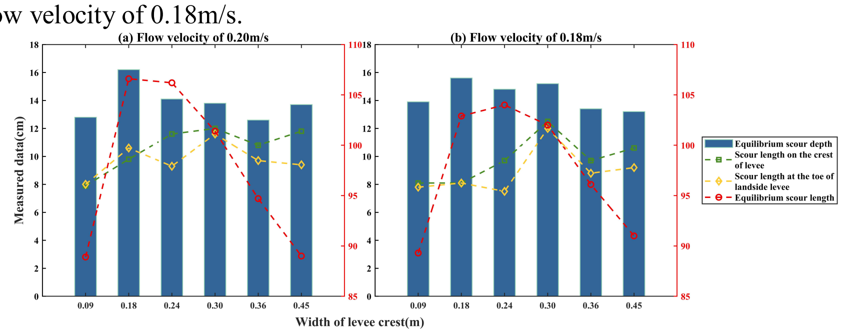

Fig 3. The influence of levee crest width on erosion features.

3.2 The Influence of Landside Slope

This study carried out the test conditions without protection measures, including levee crest elevation of 0.05m, wave wall height of 0.03m, headwater depth of 0.15m, levee crest from 0.09 to 0.45m, and flow velocity of 0.20m/s. As illustrated in **Figure 4**, as the landside slope increased from 1:2 to 1:3 and 1:4, L_t decreases first and then increases while L_b presented a gradual increasing trend. And h_s and L_s showed a gradually increasing trend. When the width of levee crest reached 0.24m and landside slope increased to 1:4, L_t, L_b and L_s achieved the largest, 12.3cm, 18.9cm and 114.2cm respectively. When the width of levee crest was 0.09m and landside slope was 1:4, h_s reached the maximum, with the scour depth of 16.2cm. Increasing landside slope would lead to the augment of L_t and L_b, and increase h_s and L_s.

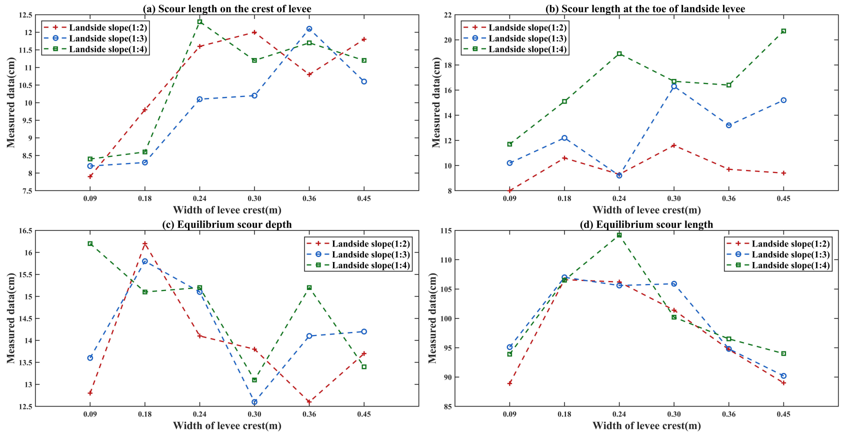

Fig 4. The influence of landside slope width on erosion features.

3.3 Prediction Results of BPN Model

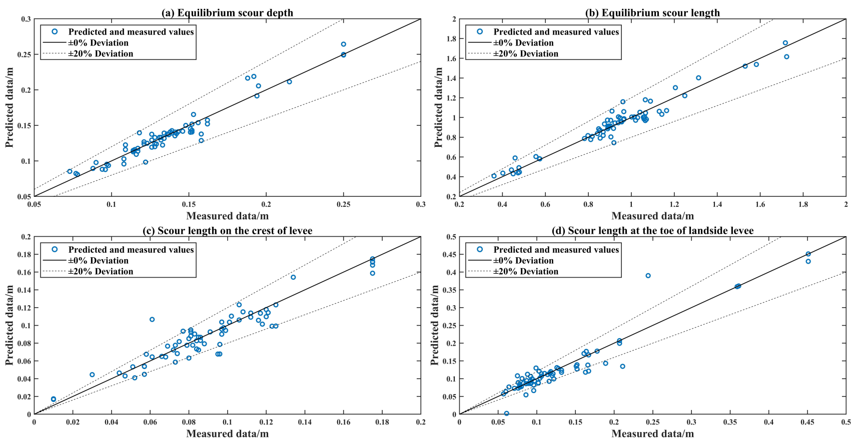

Fig 5. Comparison between predicted values with measured values in erosion features.

Table 2. Performance metrics of training and test set.

Prediction data	Number of hidden nodes	Training set				Test set			
		MAE (m)	RMSE (m)	MBE (m)	R^2	MAE (m)	MBE (m)	RMSE (m)	R^2
L_t	6	0.008	0.012	-0.001	0.894	0.010	-0.004	0.012	0.817

L_b	7	0.012	0.026	0.000	0.909	0.023	-0.018	0.029	0.915
h_s	6	0.006	0.009	-0.001	0.923	0.008	0.002	0.010	0.949
L_s	7	0.048	0.065	0.011	0.945	0.053	-0.024	0.065	0.909

This study employed BPN model to predict the different erosion features, and BPN model demonstrated the good performance in both the training and test sets (**Table 2**). All the values of RMSE, MAE and MBE and reached a minimal number, indicating the closer relationship between measured and predicted data. R^2 for the prediction of L_b, h_s, and L_s exceeded 0.9, while the R^2 for the prediction of L_t was over 0.8, which reflected the good network fitting effect. BPN model primarily showed the accurate prediction effect in different erosion features (**Figure 5**). The predicted data for h_s and L_s fell within the ±20% error line in all cases. There were 5 data beyond the error line of ±20% in predicting L_t, while 11 data was beyond the error line of ±20% in predicting L_b. And BPN model showed the better prediction effect for h_s and L_s, compared with L_b and L_t.

4 Conclusions

This study mainly explored the erosion features on landside slope of a levee under surge overflow by flume test. This study designed different test conditions, and mainly focused on the influence of levee width crest and landside slope. This study also predicted these erosion features by BPN model based on the experimental data. We found that the increase in the width of levee crest contributed to the improvement of L_t and L_b and the reduction of h_s and L_s. But increasing landside slope led to the augment of L_t, L_b, h_s and L_s. BPN model could predict these erosion features accurately, but showed the better prediction effect for h_s and L_s, than L_b and L_t. It was inevitable to avoid the influence of scale effect on research results in physical model experiments, which could lead to deviations with the experimental result extrapolated to the prototype. Numerical simulation technology had a good advantage to overcome the scale effect. Future researches should study the erosion features on landside slope of a levee combined numerical simulation and model experiments.

Acknowledgments This work was supported by the National Key R&D Program of China 2023YFC3008100.

References

[1] Wang P, Li Y, Yu P and Zhang Y 2021 The analysis of urban flood risk propagation based on the modified susceptible infected recovered model *J Hydrol (Amst)* 603 127121.

[2] Zhang Z, Pan C, Zeng J, Chen F, Qin H, He K, Zhu K and Zhao E 2022 Hydrodynamics of tidal bore overflow on the spur dike and its influence on the local scour *Ocean Engineering* 266 113140.

[3] Pachev B, Arora P, del-Castillo-Negrete C, Valseth E and Dawson C 2023 A framework for flexible peak storm surge prediction *Coastal Engineering* 186 104406.

[4] Pan Y, Zhou Z J and Chen Y P 2020 An analysis of the downward-flushing flow on the crest of a levee under combined wave and surge overtopping *Coastal Engineering* 158 103701.

[5] Pan Y, Kuang C P, Li L and Amini F 2015 Full-scale laboratory study on distribution of individual wave overtopping volumes over a levee under negative freeboard *Coastal Engineering* 97 11–20.

[6] Yuan S, Tang H, Li L, Pan Y and Amini F 2015 Combined wave and surge overtopping erosion failure model of HPTRM levees: Accounting for grass-mat strength *Ocean Engineering* 109 256–69.

[7] Wang Y, Xu D, He Z and Wu W 2020 Experimental Study on Sand Dike Breaching by Wave Overtopping *Applied Ocean Research* 101 102195.

[8] Kumar S, Goyal M K, Deshpande V and Agarwal M 2023 Estimation of time dependent scour depth around circular bridge piers: Application of ensemble machine learning methods *Ocean Engineering* 270 113611.

[9] Nandi B, Patel G and Das S 2024 Prediction of maximum scour depth at clear water conditions: Multivariate and robust comparative analysis between empirical equations and machine learning approaches using extensive reference metadata *J Environ Manage* 354 120349.

[10] Guan D, Liu J, Chiew Y-M, Hong J-H and Cheng L 2023 A comparison between artificial neural network algorithms and empirical equations applied to submerged weir scour evolution prediction *International Journal of Sediment Research* 38 105–14.

[11] Shadkani S, Abbaspour A, Samadianfard S, Hashemi S, Mosavi A and Band S S 2021 Comparative study of multilayer perceptron-stochastic gradient descent and gradient boosted trees for predicting daily suspended sediment load: The case study of the Mississippi River, U.S. *International Journal of Sediment Research* 36 512–23.