Prediction of reflection coefficient of a perforated Quarter Circle Breakwater using artificial neural network (ann)

N Ramesh1, ArkalVittal Hegde2 and Subba Rao3
1PhD Scholar, National Institute of Technology, Surathkal, Manglore, India
2Professor, National Institute of Technology, Surathkal, Manglore, India
3Professor, National Institute of Technology, Surathkal, Manglore, India
4Corresponding Author E-mail: rameshen@yahoo.com

Abstract. A breakwater is structure which is generally adopted in not only protecting the shoreline, but also in creating tranquil zone on the lee side of the structure minimizing the various movements on the anchored ships / vessels due to the wave / tidal action in the region resulting in easy handling of goods. Over the years, breakwater was generally constructed using rubble mounds. Due to the increase in demand for the coastal development all over the world, many innovative Breakwater were evolved as against the rubble mound. In the recent times, in order to economize the innovative breakwater construction, Semi Circular caisson type Breakwater has been studied. Based on Semi circularBreakwater (SBW), Quarter circular Breakwater (QBW) has been evolved. The hydrodynamic performance of a coastal structure is important, because it involves many parameters to be considered while designing a safe and economical structure. The hydrodynamic performance of a Quarter circular breakwater is studied in a monochromatic wave flume in the Department of Applied Mechanics and Hydraulics, National Institute of Technology, Surathkal Karnataka, India. In the present paper reflection coefficient (Kr) of a perforated Quarter circular Breakwater (QBW) with various S/D ( spacing to diameter ratio) values is predicted applying Artificial Neural Network (ANN) technique using MATLAB. Four networks were constructed by varying the number of hidden layers based on the input parameters, which affects the performance of the breakwater. The predicted values of reflection coefficient using ANN, are compared with the experimental results.

Key words: Semi-circular Breakwater(SBW), Quarter circular Breakwater (QBW), Reflection coefficient (Kr),ANN and MATLAB.

1. Introduction
The main purpose of a Breakwater is to reduce the wave disturbance and provide a tranquil area for the development of a Port or Harbor. A Quarter circular Breakwater (QBW) is an improvement over the semi-circular Breakwater (SBW) .The QBW is a caisson with hollow inside, has a flat base with a vertical face on the lee side, whereas, the curvature portion will be facing towards the incoming waves. The total weight of the structure and the material required is considerably reduced. The whole structure is generally placed on a rubble mound base. The QBW can be impermeable or with perforation on the curved surface. In the recent years quite a few laboratory studies have been conducted.

Due to the availability of fast computing, an attempt is made to Artificial Neural networks in predicting the reflection coefficient of QBW using MATLAB to understand the behaviour of the structure.

2. Literature review
Jiang et al. (2008) studied the performance of SBW and QBW in a 2D flume. The study, indicated no significant change in wave reflection coefficient of both QBW and SBW. The reflection coefficient (Kr)
remained same with values less than 1.0 for both types of structures. The value of Kr was observed to increase as the depth of water is reduced i.e., relative freeboard. During overtopping, it is found high flow velocity and vortexes near the rear walls of QBW, and attributed to sharp corner and sudden expansion of flow around QBW.

Shi et al. (2011) studied the hydrodynamic performance of QBW under both regular and irregular wave conditions. The wave reflection is analysed, by two type of wave reflection coefficients as described by Shao et al (2003) such as (i) Kr which represents the whole effect by the breakwater and (ii) Circular-surface reflection coefficient (Krc), reflective effect by circular surface on the adjacent flow field. It was found that at the same relative freeboard, the value of Kr was higher than circular-surface reflection coefficient (Krc) has indicated that the reflective effect of QBW is stronger. The study concluded that the loss of wave energy for emerged breakwater is larger than that for submerged breakwater.

Hegde and Ravikiran (2013) carried out physical model experimental study on quarter circle breakwater in two dimensional wave flumes to understand the effect of radius on reflection characteristics of submergence QBW. The models were fabricated by iron sheets, coated with cement slurry to simulate concrete surface. The study indicated For finding Kr increases logarithmically (best-fit) as incident wave steepness increases.

Hafeeda (2014) conducted experiments in a two dimensional monochromatic wave flume on a seaside perforated QBW model. The data is analysed by plotting the non-dimensional graphs of reflection coefficient, Kr=Hr/Hi (where Hr is the reflected wave height; Hi is the incident wave height) for various values of wave steepness, Hi/gT^2 and R/Hi (R/Hi is the ratio of breakwater radius to incident wave height). The study showed that Kr decreased with increase in d/hs and also as the free board is reduced effect of the curvature is less pronounced, thus, resulting, lesser dissipation energy and hence reflection.

Binumol (2015) conducted physical model studies of QBW with three different radii and S/D (spacing to diameter of perforations) ratio. The data is analysed from the graph of dimensionless wave run up and dimensionless wave rundown for different wave steepness. It is reported that wave run up increases with increase in wave steepness. This was because as wave height increases there is increase in wave energy and hence run up increases with increase in wave steepness. At larger water depths, effect of curvature is more resulting in lower run up and hence increase in wave rundown.

Balakrishna (2015) investigated reflection coefficient (Kr) and dissipation (loss) coefficient (KL) for physical models of quarter circle caisson breakwater for different radii with constant S/D ratio. It is reported that dissipation coefficient decreased with increase in wave steepness and also the loss coefficient decreases. Also, it was observed that as hs/d increases, dissipation increases which is a reverse trend in the case of reflection, this trend is found to be true for all values of d/gT^2 values.

Generally, computational intelligence techniques viz., Artificial Neural Network (ANN), adoptive neuro fuzzy interface system, support vector machine regression, genetic algorithm, etc., have been efficaciously proposed as an efficient tool for modelling and predictions in coastal engineering problems (Amr et al., 2011). In the present study, Artificial Neural Network is applied different algorithm such as Levenberg – Marquardis applied and compared the results based on the correlation coefficient.

3. Methodology

Artificial neural network (ANN) techniques are generally adopted in solving problems of complexity both in input-output patterns. The accuracy of the method depends on the availability of data. Figure 1 shows the architecture of ANN that consists of input layer, hidden layer, and output layer (Tokar and Markus, 2000).
From figure 1, it is understood that input data is given from an external source to the network, and pass the data to the hidden units in the hidden layer, in turn, the hidden units process send and receive data from other units in the network. The output generated by the network, which goes out of the system. In the process, it estimates / predicts the output as a function of the input. Generally, the unknown function is approximated by certain activation functions such as tangent, sigmoid, polynomial, and sinusoid in ANN. A common threshold function used in ANN is the sigmoid function ($f(S)$) expressed by Eq. (1), which provides an output in the range of $0 \leq f(S) \leq 1$.

$$f(S) = \frac{1}{1 + \exp(-S)}$$

and $S_i = \sum_{j=1}^{M} I_i W_{ij} + O_j$, $j=1,2,3,\ldots,M$ (1)
where $S_i$ - characteristic function of $i^{th}$ layer,
$I_i$ - input unit of $i^{th}$ layer, $O_i$ is the output unit of $i^{th}$ layer,
$W_{ij}$ - synaptic weights between input and hidden layers, $N$ - number of observations and
$A$ - number of neurons of hidden layer (Kaltech, 2008).

Generally, while applying ANN, 70% of data are used for training (TRG) and 30% of data for testing (TET) in arriving the regression equations of the predicted variable and for validation (VAL). Table 1 gives the descriptive statistical parameters (i.e., Standard Deviation (SD), Coefficient of Variation (CV), Coefficient of Skewness (CS) and Kurtosis) of the observed data of the variables that are considered for prediction for evaluation of reflection coefficient of a perforated QBW.

### 3.1 Levenberg-Marquard algorithm

In this paper Levenberg-Marquard algorithm is used with for predicting reflection coefficient ($K_r$) of a QBW. Generally, trans-sigmoidal and purling as function are used during processing of the data from input to hidden nodes and from hidden nodes to output along the network. The network output is compared with the target output and error is calculated.

### 3.2 Performance analysis

The performance of the network using LM algorithm used in predicting reflection coefficient ($K_r$) is evaluated by model performance indicators such as correlation coefficient ($C_c$), Mean square error (MSE).

### 3.3 Application:

In this paper a study on comparison of experimental values and the predicted values of reflection coefficient of a quarter circular breakwater (QBW) is carried-out. The experimental data viz., depth of water ($D$), wave period ($T$), incident wave height ($h_i$), transmitted wave height ($h_t$), reflected wave height ($h_r$), wave length ($L$), reflection coefficient ($K_r$), incident wave steepness ($H_i/gT^2$) and relative free board collected from the experimental studies are considered.

### Table 1 Statistical Parameters of the predicted reflection coefficient ($K_r$)

| Statistical variable | Reflection coefficient ($K_r$) | For $S/D = 3$ |
|----------------------|-------------------------------|---------------|
|                      | 5-5-1                        | 5-8-1         | 5-10-1        | 5-12-1        |
| SD                   | 0.052279                     | 0.377576      | 0.06074       | 0.355503      |
| Cs                   | -0.29782                     | 0.138283      | -0.21989      | -0.41978      |
| CC                   | 0.94656                      | 0.827023      | 0.94273       | 0.812694      |
| Kurtosis             | -0.26783                     | 0.721324      | -0.62381      | -0.34947      |
| RMSE                 | 0.836925                     | 0.691883      | 0.846258      | 0.571856      |
From the above plots it is very clear that the coefficient of correlation between the experimental values of reflection coefficient and the predicted values using LM algorithm show good match indicating coefficient of correlation (CC) to be 0.98963 for 5-10-1 network compared to other networks.
Figure 3. Time series plot of Experimental and Predicted values of Kr
4. Discussions and Conclusions

Breakwater is a structure constructed for not only to protect the shoreline, but also for creating a tranquil zone lee-side for parking and handling of ships / vessels. The performance of these structures are very vital, since huge financial implications are involved. Laboratory studies for each breakwater require lot of time, money and man power. These constraints can be overcome by applying self-learning data driven techniques like the Artificial Neural Networks.

In the present study ANN network using LM algorithm in predicting reflection coefficient of perforated Quarter Circle Breakwater is analyzed by varying the number of hidden nodes and also number of epoch. Descriptive statistical parameters are considered for choosing a better network while arriving at reflection coefficient.

From the results obtained following conclusion are drawn:
(a) The optimum network is 5-12-1, which indicates that more the number of hidden nodes in the hidden layer better will be the output and hence the reduction in error.
(b) The absolute mean difference of the predicted values of Kr are less during testing and training.
(c) Model performance analysis had indicated 5-12-1 network is better among the four networks tested.
(d) Though, all the four networks have shown the coefficient of regression (C,) to be around 0.98, the network having architecture of 5-12-1 has yielded 0.9887 and also the time series plot has given better trend.

Acknowledgement:
The authors are grateful to Dr. (Mrs.) V.V. Bhosekar, Director, Central Water and Power Research Station, Pune, for encouraging to carry out the study. The authors are thankful to National Institute of Technology, Surathkal, for making available the experimental data used in the study.

References
[1] Amr, H.E., El-Shafie, A., Hasan, G.E., Shehata, A., and Taha, M.R. (2011). “Artificial neural network technique for rainfall forecasting applied to Alexandria”. International Journal of the Physical Sciences, 6 (6), 1306-1316.
[2] Balakrishna, K., and Hegde, A.V. (2015), “Reflection and dissipation characteristics of non-overtopping quarter circle breakwater with low-mound rubble base”. Journal of Advanced Research in Ocean Engineering, 1(1), 44-054.
[3] Binumol. S., Subba Rao., and Hegde, A.V. (2015). “Runup and rundown characteristics of an emerged seaside perforated quarter circle breakwater”. Aquatic Procedia, 4(1), 234 – 239.
[4] Chen, J., and Adams, B.J. (2006). “Integration of artificial neural networks with conceptual models in rainfall-runoff modeling”. Journal of Hydrology, 318 (1-4), 232-249.
[5] D’Agostino, B.R., and Stephens, A.M. (1986), “Goodness-of-Fit Techniques”, M/s Marcel Dekkar Inc., New York 10016, USA.
[6] Deshpandey, R.R. (2012). “On the rainfall time series prediction using multilayer perceptron artificial neural network”. International Journal of emerging technology and advanced engineering, 2(1), 2250-2459.
[7] Hafeeda, V., Binumol. S., Hegde, A.V., and Subba Rao. (2014). “Wave reflection by emerged sea side perforated quarter circle breakwater”. International journal of earth sciences and engineering, 7, 454-460.
[8] Hegde, A.V., and Ravikiran, L. (2013). “Wave structure interaction for submerged quarter circle breakwaters of different radii – reflection characteristics”. World Academy of Science, Engineering and Technology, 7, 1367-1371.
[9] Jiang, X.L., Gu, H.B. and Li, Y.B. (2008). “Numerical simulation on hydraulic performances of quarter circular breakwater”. China Ocean Engineering, 22 (4), 585-594.
[10] Kaltech, M. (2008). “Rainfall-runoff modelling using artificial neural networks: modelling and understanding”. Journal of Environmental Sciences, 6 (1), 53-58.
[11] Ramesh N et al (2017) “Comparison of Hydrodynamic Performance of Quarter Circular Breakwater using ANN and Auto Regression Methods – Hydro 2017, India

[12] Ramesh N et al (2018) “Evaluation of Hydrodynamic Performance of Quarter Circular Breakwater Using Soft Computing Techniques” – ICOE2018, Chennai India
[13] Shao, L.M. (2003). “Separation of incident waves and reflected waves and study of reflection coefficient”. Dalian: Dalian University of Technology press (in Chinese).

[14] Shi, Y. J., Wu, Mi-Ling., Jiang Xue-Lian and Li, Yan-bao. (2011). “Experimental research on reflection and transmitting performance of Quarter circle Breakwater under regular and irregular waves”. China Ocean Engineering, 25(3), 469-478.

[15] Tokar, S., and Markus, M. (2000). “Precipitation runoff modelling using artificial neural network and conceptual models”. Journal of Hydrologic Engineering, 5 (2), 156-161.

[16] Xie, S.L., Li, Y.B, Wu, Y.Q and Gu, H.B. (2006). “Preliminary research on wave forces on quarter circular Breakwater”. The Ocean Engineering, 24 (1), 14-18.