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## Application of Soft Computing in Breakwater Studies- A Review

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**ABSTRACT:** Ports and harbors play an important role in the development of a country. For the smooth flow of cargo into the harbor, tranquility conditions are to be maintained. This can be achieved only by proper protective measures like breakwater construction. The effective working of breakwater can be made sure only by proper model studies. Physical model studies can be simplified by effective machine learning techniques which are cost effective and less time consuming. Soft computing techniques are used to predict various design aspects of breakwater such as wave height, stability number, scour depth, design armour weight etc. Larger the dataset provided for training, better will be the result. ANN, ANFIS, SVM, Fuzzy Logic, Model tree are some of the machine learning techniques having a vast area of application in different fields of science. The predictive capability of a model for a particular problem is assessed by means of statistical parameters such as RMSE, CC, MAPE, SI. Hybrid models of conventional soft computing techniques are developed using optimizing algorithms such as PSO, GA, ACO which gives more accurate results. This paper reviews various works of soft computing done in the field of breakwater for prediction of various design aspects.

**KEYWORDS:** Breakwater, ANN, Machine learning, SVM, soft computing, prediction.

### I. INTRODUCTION

For the proper functioning of a harbor it is of vital importance to have effective protection from the wave activity which can be attained by the means of protective structures like breakwaters. Breakwaters protect the harbor from wave attack and at the same time provides facilities for cargo loading and unloading. The main function of breakwater is to dissipate the wave energy thereby maintaining tranquility conditions inside the harbor. Breakwaters have application in various other fields such as coastal rehabilitation of mangroves[31] and energy production from overtopping waves[30]. Over the years various types of breakwaters have been developed. The applicability of a specific type of breakwater mainly depends on the site conditions and availability of materials. Prior studies in the form of model studies are to be done for the proper design of breakwater as huge investment is involved in the process.

Machine learning involves the use of various soft computing techniques which can be effectively used in the field of ocean engineering for the design of breakwater. Various physical model studies have been done in the past for design of breakwater [2,3,4,7,8] which were expensive and time consuming. Machine learning approach takes less time and is cost effective. In machine learning, from the data input the system analyses and understands the relation between the input parameters and thus develops a model. Further prior to data input, corresponding output will be provided by the model. The effectiveness of machine learning approach depends upon the quality and quantity of data available. Artificial Neural Network(ANN), Adaptive Neuro Fuzzy Interference System(ANFIS), Support Vector Machine(SVM) are some of the widely used soft computing techniques. Various studies, mainly for prediction, are done in the field of coastal engineering using the above mentioned soft computing tools. Furthermore in order to minimize the error optimization algorithms such as Genetic Algorithm(GA), Particle Swarm Optimization(PSO) are also been used. Hybrid models thus generated provide more accurate and realistic results[15]. This paper discusses various works of soft computing in the field of breakwater studies. This paper can be divided into mainly four sections: Section

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1.Introduction; Section 2.Soft computing in breakwater studies; Section 3.General methodology; Section 4.Discussion and concluding remarks.

## II. SOFT COMPUTING IN BREAKWATER STUDIES

Soft computing is a collection of methodologies that provide effective results for real case scenario problems within minimum time available. Soft computing provides results for problems which are hard to answer analytically. Soft computing techniques finds application in the field of breakwater studies for the prediction of damage level, scour depth, transmitted wave height prediction and so on.

Mase et al(1995) used the technique of neural network in predicting the damage level and stability of a rubble mound breakwater[1]. The results obtained from the model were compared with the results obtained from experiment carried out by Van der Meer(1998) and Smith et al(1992). The damage level results were similar ,however, stability number needed improvement. In this study feed forward back propagation method was used to train the neural network. ANN was later used in the field of rubble mound breakwater design, which gave accurate results compared to conventional empirical method[10]. Also, the structure of neural network affects the accuracy of model developed. The available information in the training data is also a factor determining the efficiency of ANN model developed. The learning ability of ANN can be improved by increasing the training data.[11]. Even when ANN showed better performance than empirical method, the more computational time for training and difficulty in determining the effective structure of the network stood as drawbacks of neural network technique. Kim et al(2008) used probabilistic neural network (PNN)to overcome the drawbacks of neural network technique[22]. PNN defines the structure of network in the form of a probability distribution function and is easy to implement. PNN was used in the study to predict the stability number of rubble mound breakwater. According to them PNN gave better results compared to empirical model and previous neural networks. Data representation is an important factor in the performance of a neural network. Effective data representation can be achieved by using principal component analysis(PCA) along with neural network. Can et al(2010) used ANN based on PCA for stability number prediction of rubble mound breakwater. According to them, the hybrid model showed enhanced performance compared to the neural network without PCA[13]. Garrido et al(2011) used pruned neural network for predicting the wave reflection for Jarlan-type breakwaters. Evolutionary Strategy(ES) was used for optimizing the parameters of the NN model[19]. The hybrid model modified the empirical formulas and gave better values for statistical parameters. Tidal level variation is an important factor to be considered in damage analysis of breakwater. Dong et al(2014) used ANN to predict the shallow wave height in front of breakwater. Near shore tidal level and offshore wave height were used as inputs for the model. Dimensional analysis also has its influence in prediction[12]. Raju et al(2015) used parametric data and non-dimensional values in predicting the reflection coefficient of an emerged perforated quarter circle breakwater. The result showed that prediction with dimensional parameters has better accuracy[23]. Mehmet et al(2015) used genetic programming(GP) for stability assessment of rubble mound breakwater, which gave good results[27]. Ali et al (2017) used GP and ANN in predicting the scour depth at trunk section of breakwater for non-breaking waves. Models used non-breaking wave steepness, relative water depth at toe, reflection coefficient and shisseld parameter as input parameters and predicted scour depth[26]. Based on the value of the statistical parameters obtained, GP model outperformed ANN model in scour depth prediction. Bharat et al (2016) used ANN for the prediction of transmitted wave height for submerged reef of a tandem breakwater. According to them ANN using Levenburg-Marquardt updated algorithm yields accurate values, with correlation coefficient (CC) values in the range of 0.97 to 0.98 for different model configurations[14].

Fuzzy logic based models are also effective in design of breakwater and provides better results in the prediction of stability number . ANN based on fuzzy neural network and fuzzy systems can be used for better prediction of stability number of rubble mound breakwater[13].Apart from ANN and fuzzy logic, model trees based approach of machine learning was also used in area of breakwater studies. Model tree method gives better accuracy and is moreover transparent. The model tree method provides rules which are easy to understand and signifies the importance of various parameters used[16]. Amir et al(2011) used M5' model tree in the stability analysis of rubble mound breakwater. The M5' model developed used  $H_{50}$  instead of  $H_s$  and results obtained were found to be more accurate compared to general

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M5' model for stability prediction[28]. Model tree technique also had application in wave run-up prediction. Lisham et al(2011) used M5 model tree to predict the wave run-up for a rubble mound structure using Stam's and Van der Meer (1992) experimental data. Relative water depth parameter, surf similarity parameter and permeability of structure were the various input parameters considered for the study[24]. The main drawback of fuzzy systems is its inability to learn and adjust, which was overcome by development of Adaptive Neuro Fuzzy Inference System(ANFIS) [6].Patil et al(2012) used ANFIS for transmitted wave height prediction and compared the results with ANN[18]. The results were more accurate in the case of ANFIS model. An optimization algorithm based hybrid fuzzy neural network (FNN) show better predictive performance. Mehmet et al(2012) developed genetic algorithm based FNN (GA-FNN) and hybrid genetic algorithm based FNN (HGA-FFN) in stability analysis of rubble mound breakwater. According to them HGA-FNN showed better optimization and hence more accurate results[17].

Along with ANN, GP, model tree and ANFIS, another learning technique that is widely and effectively used in the field of classification and regression is Support Vector Machine(SVM). The working principle of an SVM is structural risk minimization, which has higher generalization ability compared to the conventional empirical risk minimization principle followed in neural networks. The effectiveness of the model in prediction is estimated using various statistical parameters, such as Root Mean Square Error(RMSE), Correlation Coefficient(CC), Mean absolute Error(MAE) and so on. Kim et al (2008) devised support vector regression for predicting the stability number of armorblocks[22]. Balas et al(2010) used SVM for rubble mound breakwater design and the result was compared with Van der Meer(1988) stability equations and ANN[13]. According to them SVM had better prediction ability compared to ANN and the stability equation. Mandal et al(2012) used SVM to predict the damage level of non-reshaped berm breakwater and the results were compared with ANN and ANFIS models. Hybrid SVM models developed using optimizing techniques have gained popularity and are widely used[15]. Patil et al (2012) developed GA-SVM regression model for predicting the transmitted wave for a horizontally interlaced multi-layer moored floating pipe breakwater. GA was used as a tool for parameter optimization. According to them, performance of the model developed depend upon the type of kernel function and its good setting with SVM parameters[18]. Linear, Polynomial, radial basis function(rbf), sigmoid, Gaussian, b-spline are some of the commonly used kernel functions. Harish et al(2014) used particle swarm optimization based support vector machine(PSO-SVM) in predicting damage level of non-reshaped berm breakwater. The model was compared using various kernel functions and accurate results were obtained using polynomial kernel function. The PSO-SVM model also showed better predictive performance when compared to SVM, ANN and ANFIS models[29]. Jithin et al(2016) predicted the transmitted wave height of submerged reef of a tandem breakwater using support vector regression. According to their study, best result was obtained for SVM using quadratic kernel[20].

### III. GENERAL METHODOLOGY

The main function of the soft computing technique is to predict the data output by learning from the input provided. The various methods or techniques of soft computing uses various methods for the same. However the general methodology followed remains the same. Fig.1 shows the general methodology followed by soft computing techniques in prediction.



Fig.1.General methodology for prediction using soft computing techniques

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The effectiveness of the model developed is evaluated from the values of statistical parameters. Root Mean Square Error(RMSE), Correlation Coefficient(CC), Scatter Index(SI), Mean Absolute Error(MAE) etc. are some of the commonly used statistical parameters. Randomness nature of the data used is also ensured by plotting data time series graph.

## IV. DISCUSSION AND CONCLUDING REMARKS

Analysis, design and construction of breakwater is a process involving a great deal of time and expenditure. So it is of prime importance to ensure the safety of the structure. The complexity associated with mathematical modelling and the time consuming nature of physical modelling makes soft computing the better option in prediction in the field of breakwater studies. However the data input and the influential parameters can be determined only by proper physical model studies. So applying soft computing techniques along with prior physical model studies can give effective and immediate results. Based on the review on various works done on soft computing in the field of breakwater studies the following conclusions are drawn:

- The review focused on application of various soft computing techniques in predicting the design parameters of a breakwater.
- The predictive efficiency of a machine learning approach depends upon quality and size of the data set available.
- ANN takes more computational time and finds difficulty in determining the effective structure of the network.
- ANN model with PCA yields better results compared to ANN without PCA.
- For scour depth prediction of a rubble mound breakwater GP model performs better compared to ANN.
- Model tree machine learning approach provides specific rules which are easy to understand and signifies the importance of various parameters.
- Model tree machine learning approach has better transparency and generalization compared to ANN model.
- ANN and SVM are widely used in the field of breakwater studies.
- Hybrid SVM models with optimizing algorithms provide better results compared to ANN and ANFIS models. Selection of kernels plays an important role in development of an effective SVM model.
- Selection of proper kernel and model parameters play an important role in the effectiveness of the model developed.

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