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Prediction of Compressive Strength of Concrete Using Artificial Neural Network Model

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***Abstract* - This study proposes to build a concrete compressive strength development over time (CCSDOT) model by using conventional method combined with the artificial intelligence method. The CCSDOT model performed well in predicting and fitting the compressive strength development in green concrete containing cement, slag, fly ash, and limestone flour. It is concluded that the CCSDOT model is stable through the use of sensitivity analysis. To evaluate the precision of this model, the prediction results of the proposed model were compared to that of the model based on the BP neural network. The results verify that the recommended model enjoys better flexibility, capability, and accuracy in predicting the compressive strength development in concrete than the other models.**

***Keywords* - compressive strength; prediction; model; gelled materials.**

I. INTRODUCTION

Now a day's concrete is one of the most important materials which are used in the construction field all over the world. It consists of two main components which contains cement and aggregates. The aggregate contains sand and blue granite metals. Cement in combination with water is the most important binding material for the preparation of concrete in the construction because it contains good mechanical strength, flow ability, durability and these properties are mainly required for concrete to be cast in any desired shape and resist load applied on it at relatively less cost. This may mostly be attributed lack of proper quality control and supervision during the course of construction. So it has to perform satisfactorily over the reasonably expected life. Cement is one of the main components which plays an important role in concrete and is also a most uneconomical and it causes some impact on environment.

II. PRESENT WORK

In this experimental work, the effect of partially replacing of glass powder in concrete is studied. The cement in concrete is replaced by waste glass powder in steps of 0%, 10%, 20%, 30% & 40% respectively by weight of cement and its effects on slump test, compressive strength, and flexural strength are determined. At 7th, 14th, 21thand 28th day the compressive strength is measured while the flexural strength is measured at 28th day. Concrete Specimens were cured in water for 28 days, through which slump test, compressive strength, flexural strength were tested at ages of 7, 14, 21 and 28 days. For this concrete cube of size 150mm x150mm x 150 mm and beam size 150mm x150mm x 700 mm were casted.
Along with that work analysis of compressive strength and flexural strength through artificial neural network (ANN) is also done.

III. OBJECTIVE OF STUDY

1. Develop ANN from data collected to predict compressive strength and flexural strength.
2. Analysis results of ANN prediction and compare its results with experimental/observed results obtained from laboratory.
3. The aim of this study is to study the behavior of M20, M30 & M40 grade of concrete.
4. Determine the Slump test, compressive strength and flexural strength by partially replacement of cement by waste glass powder.
5. Cement was partially replaced by waste glass powder in 0%, 10%, 20%, 30% and 40 % by weight. All the tests were performed according to Bureau of Indian standards.

IV. METHODOLOGY AND EXPERIMENTAL PROGRAMME

All concrete mixing and testing were performed in the engineering laboratory Along with that analysis of compressive strength on Artificial Neural network is carried out. The main purpose of this work was to investigate the potential of replacing the cement and by glass powder in concrete mixtures and identify the properties of the mixture, its durability, expansion, and also its fresh and hardened properties. In order to achieve this goal a comprehensive laboratory study on the mechanical properties of concrete mixtures with different

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ratios of glass powder as a replacement of cement and fine aggregate was performed. The steps below illustrate the process of completing the thesis including the experimental part of it.

Step 1 Experimental Programmme
Mix Design ISO 10262-2009(M20, M30& M40) and
Step 2 Replacement of cement
0 %, 10 %, 20 %, 30 % and 40 %
Step 3 Casting of cube & beam
Cube dimensions
150 mm x 150 mm x 150 mm
Beam Dimensions
150 mm x 150 mm x 700 mm
Step 4 Curing of cube & beams
Step 5 Test & result
Step 6 Develop ANN model with the help of MATLAB.

Factors To Be Considered For Mix Plan

- The evaluation assignment giving the trademark quality necessity of concrete.
- The sort of concrete impacts the rate of advancement of compressive quality of concrete.
- Maximum ostensible size of totals to be utilized as a part of concrete may be at this very moment conceivable inside of the breaking points recommended by IS 456:2000.
- The bond substance is to be constrained from shrinkage, breaking and web blanket.
- The workability of concrete for palatable setting and compaction is identified with the size and state of area, amount and dividing of fortification and procedure utilized for transportation.

V. INTRODUCTION OF ANN TECHNIQUE

Artificial Neural networks (ANN) or neural networks are computational algorithms. It intended to simulate the behavior of biological systems composed of "neurons". ANNs are computational models inspired by an animal's central nervous systems. It is capable of machine learning as well as pattern recognition. These presented as systems of interconnected "neurons" which can compute values from inputs. An Artificial Neural Network is an information processing technique. It works like the way human brain processes information. ANN includes a large number of connected processing units that work together to process information. They also generate meaningful results from it. We can apply Neural network not only for classification. It can also apply for regression of continuous target attributes. Neural networks find great application in data mining used in sectors. For example economics, for ensics, etc and for pattern recognition. It can be also used for data classification in a large amount of data after careful training.

1. Artificial Neural Network Layers

Artificial Neural network is typically organized in layers. Layers are being made up of many interconnected 'nodes' which contain an 'activation function'. A neural network may contain the following 3 layers:

2. Input layer

The purpose of the input layer is to receive as input the values of the explanatory attributes for each observation. Usually, the number of input nodes in an input layer is equal to the number of explanatory variables. 'input layer' presents the patterns to the network, which communicates to one or more 'hidden layers'.

The nodes of the input layer are passive, meaning they do not change the data. They receive a single value on their input and duplicate the value to their many outputs. From the input layer, it duplicates each value and sent to all the hidden nodes.

3. Hidden layer

The Hidden layers apply given transformations to the input values inside the network. In this, incoming arcs that go from other hidden nodes or from input nodes connected to each node. It connects with outgoing arcs to output nodes or to other hidden nodes. In hidden layer, the actual processing is done via a system of weighted 'connections'. There may be one or more hidden layers. The values entering a hidden node multiplied by weights, a set of predetermined numbers stored in the program. The weighted inputs are then added to produce a single number.

4. Output layer

The hidden layers then link to an 'output layer'. Output layer receives connections from hidden layers or from input layer. It returns an output value that corresponds to the prediction of the response variable. In classification problems, there is usually only one output node. The active nodes of the output layer combine and change the data to produce the output values.

The ability of the neural network to provide useful data manipulation lies in the proper selection of the weights. This is different from conventional information processing.

5. Structure of a Neural Network

The structure of a neural network also referred to as its 'architecture' or 'topology'. It consists of the number of layers, Elementary units. It also consists of Interconchang end Weight adjustment mechanism. The choice of the structure determines the results which are going to obtain. It is the most critical part of the implementation of a neural network.

The simplest structure is the one in which units distributes in two layers: An input layer and an output layer. Each unit in the input layer has a single input and a single output which is equal to the input. The output unit has all the units of the input layer connected to its input, with a combination function and a transfer function. There may be more than 1 output unit. In this case, resulting model is a linear or logistic regression. This is depending on whether transfer function is linear or logistic. The weights of the network are regression coefficients.

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By adding 1 or more hidden layers between the input and output layers and units in this layer the predictive power of neural network increases. But a number of hidden layers should be as small as possible. This ensures that neural network does not store all information from learning set but can generalize it to avoid over fitting.
Over fitting can occur. It occurs when weights make the system learn details of learning set instead of discovering structures. This happens when size of learning set is too small in relation to the complexity of the model.
A hidden layer is present or not, the output layer of the network can sometimes have many units, when there are many classes to predict.

6. Advantages and Disadvantages of Neural Networks

Let us see few advantages and disadvantages of neural networks:
Neural networks perform well with linear and nonlinear data but a common criticism of neural networks, particularly in robotics, is that they require a large diversity of training for real-world operation. This is so because any learning machine needs sufficient representative examples in order to capture the underlying structure that allows it to generalize to new cases. Neural networks works even if one or few units fail to respond to network but to implement large and effective software neural networks, much processing and storage resources need to be committed.

While the brain has hardware tailored to the task of processing signals through a graph of neurons, simulating even a most simplified form on Von Neumann technology may compel a neural network designer to fill millions of database rows for its connections – which can consume vast amounts of computer memory and hard disk space. Neural network learns from the analyzed data and does not require to reprogramming but they are referred to as black box" models, and provide very little insight into what these models really do. The user just needs to feed it input and watch it train and await the output.

7. Why Matlab?

Matlab is intended primarily for Mathematical Computing. Matlab contains a huge collection of predefined algorithm which is used for image processing. An algorithm can be tested immediately without recompiling it again. Matlab provides an interactive environment which helps you to work innovatively with your data and helps to keep track of the files and variable etc.

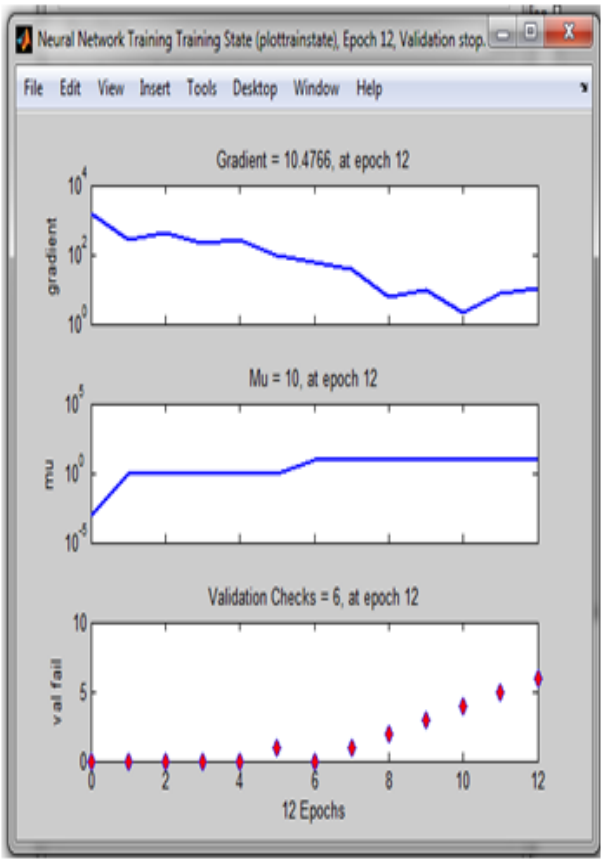

Fig. 1.NN Validation State.

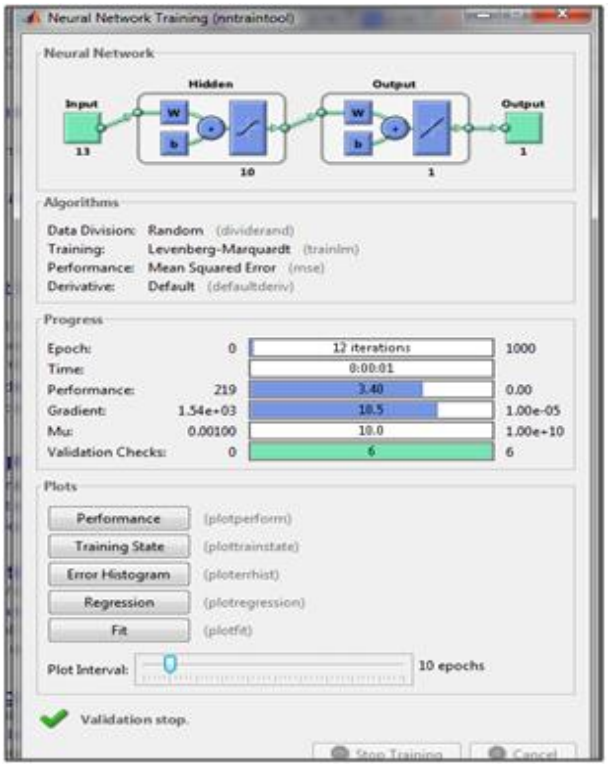

Fig.2. NN Training State.

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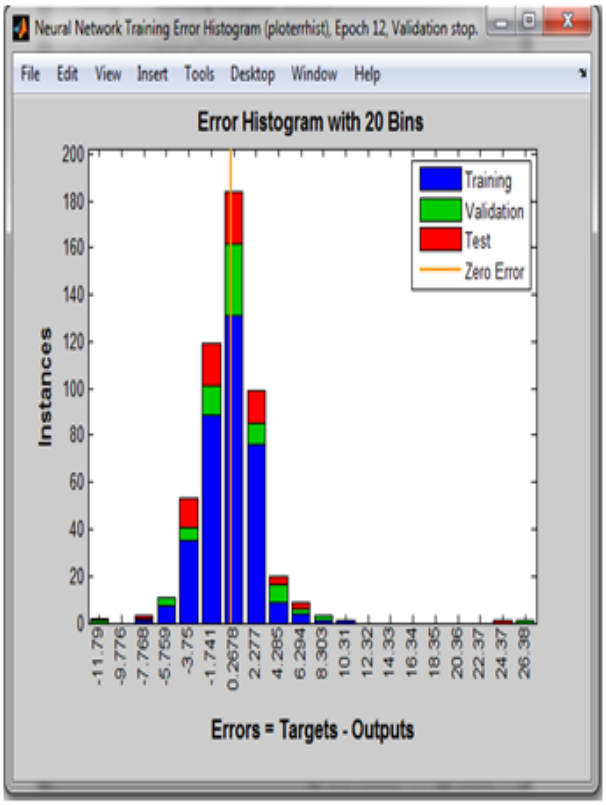

Fig.3. Error of histogram.

MSE Analysis represents histogram for multiple layer option. The irregular result provide to neural network. So 0.2678 Error histogram with 20 bins is the highest value of this graph represent.

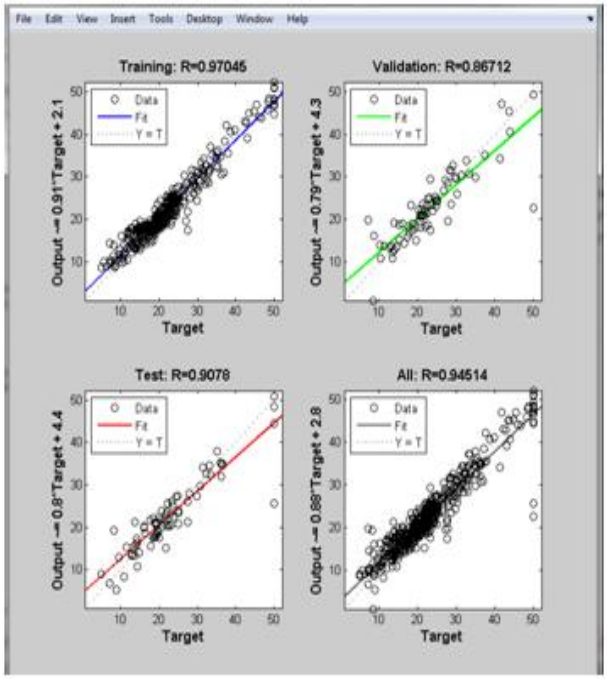

Fig.4.output Error.

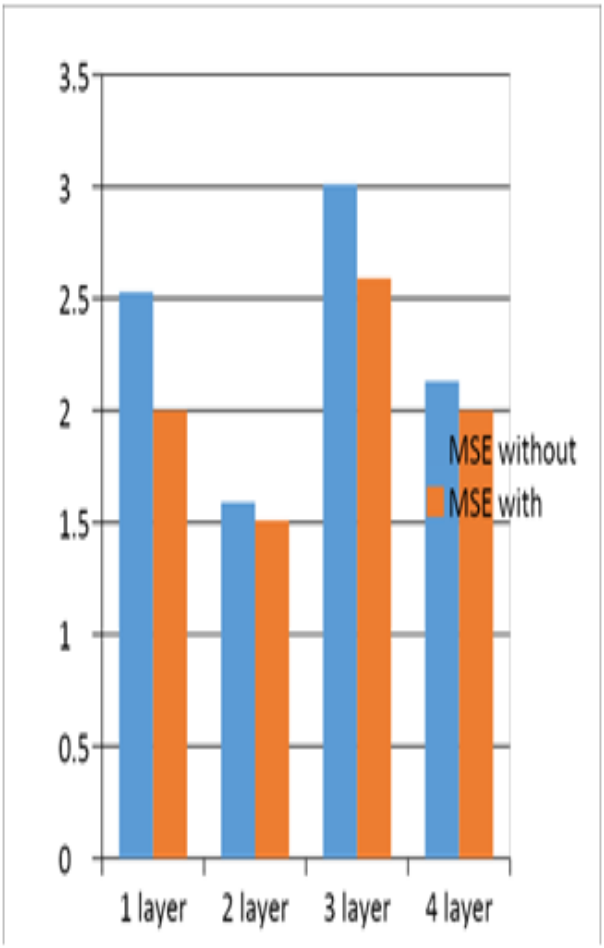

Fig.5. MSE Layer of Analysis Neural Network.

The previous chapter introduces the proposed methodology. This chapter describes the related future work and schedule plan of excursion.

Table I: MSE Analysis of Neural Network

Layers	MSE Analysis Without Neural Network	MSE Analysi With Neural Network
1Layer Training	2.53	0.2678
2Layer Training	1.59	-0.127
3Layer Training	3.01	0.739
4Layer Training	2.13	-0.1447

Table II: Accuracy and Precision of our proposed work.

S.N.	Accuracy	Proposed ANN based Accurac
1.	96.2	98.24

The previous chapter introduces the proposed methodology. This chapter describes the related future work and schedule plan of excursion.

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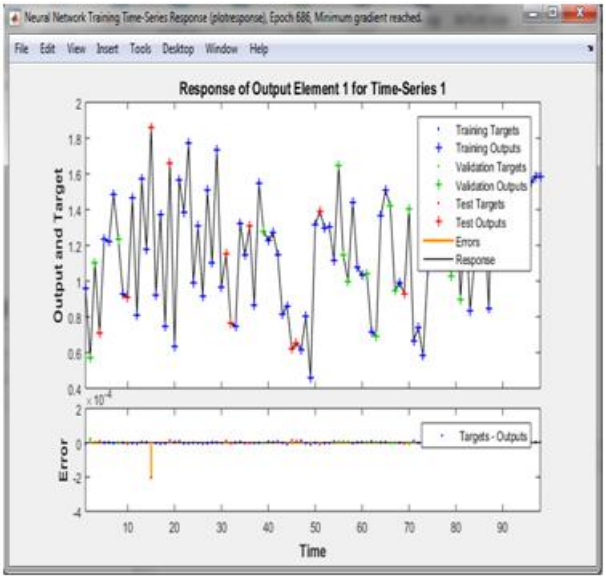

Fig.6. Time series Analysis of ANN.

2. ANN Prediction outcomes

Table III: Compressive strength of cement concrete for M20 grade ANN prediction.

S.No.	Mix	Compressive strength, N/mm²					
		Experimental values for 7 Days	ANN predicted value for 14 days	21 Days	ANN predicted value for 26 days	28 Days	ANN predicted value for 56 days
1	M20 GP0	12.51	16.98	17.26	19.32	20.22	21.32
2	M20 GP10	13.23	18.02	18.22	20.63	22.33	23.31
3	M20 GP20	15.69	19.36	20.78	22.65	24.56	26.52
4	M20 GP30	12.44	17.88	18.67	20.68	21.61	22.47
5	M20 GP40	11.88	15.55	16.44	18.98	19.75	20.54

Table IV: Compressive strength of concrete for M30 grade ANN PREDICTION.

S.No.	Mix	Compressive strength, N/mm²					
		Experimental value of 7 Days	ANN predicted value for 14 days	21 Days	ANN predicted value for 26 days	28 Days	ANN predicted value for 56 days
1	M30 GP0	19.22	26.74	27.26	28.96	29.23	31.95
2	M30 GP10	20.56	27.85	28.87	29.21	30.77	32.58
3	M30 GP20	22.77	28.95	30.64	32.54	33.50	35.68
4	M30 GP30	20.43	26.54	27.58	27.95	29.22	33.05
5	M30 GP40	18.88	23.94	25.52	26.11	27.03	29.52

Table V: Compressive strength of cement concrete for M40 grade ANN prediction.

S.No.	Mix	Compressive strength, N/mm²					
		Experimental value of 7 Days	ANN predicted value for 14 days	Experimental value of 21 Days	ANN predicted value for 26 days	Experimental value of 28 Days	ANN predicted value for 56 days
1	M40 GP0	26.23	34.32	36.01	38.96	40.58	42.62
2	M40 GP10	27.31	35.62	37.58	39.68	42.24	43.65
3	M40 GP20	29.23	37.25	39.88	42.62	45.66	47.63
4	M40 GP30	27.44	33.24	34.41	36.34	38.31	40.31
5	M40 GP40	25.74	28.95	30.31	31.32	35.16	37.66

Table VI: Flexural strength of cement concrete for M20 grade ANN Time series prediction DATA set(MSE)

S.No.	Mix	Flexural strength N/mm² at 28 Day	ANN PREDICTION
1	M20 GP	3.33	3.35
2	M20 GP10	3.68	3.59
3	M20 GP20	4.74	4.70
4	M20 GP30	4.12	4.15
5	M20 GP40	3.75	3.70

Table VII: Flexural strength of cement concrete for M30 grade ANN Time series prediction DATA set(MSE)

S.No.	Mix	Flexural strength N/mm² at 28 Day	ANN PREDICTION
1	M20 GP0	3.33	3.35
2	M20 GP10	3.68	3.59
3	M20 GP20	4.74	4.70
4	M20 GP30	4.12	4.15
5	M20 GP40	3.75	3.70

Table VIII. Flexural strength of cement concrete for M40 grade ANN Time series prediction DATA set(MSE).

S.No.	Mix	Flexural strength, N/mm at 28 Days	ANN PREDICTION
1	M30 GP0	3.8	3.77
2	M30 GP10	3.78	3.80
3	M30 GP20	4.65	4.68
4	M30 GP30	4.36	4.38
5	M30 GP40	3.86	3.89

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The effect of glass powder on the properties of cement has been studied in this research. The various properties of concrete such as compressive strength and flexural strength are studied. The tests are performed for three grade of concrete, M20, M30and 40. As the glass content increases (i.e. cement content decreased) workability decreases. As there is a reduction in fineness modulus of cementations material, quantity of cement paste available is less for providing lubricating effect per unit surface area of aggregate. Therefore, there is a restrain on the mobility.

There was an appreciable increment in the compressive strength of concrete when the percentage of glass powder was increased upto 20% at 7th, 21st and 28th dayfor M 20, M30 and M40 grade of concrete. Similarly the flexural strength of concrete increases upto 20% waste glass powder. For M 20 grade of concrete the flexural strength is 4.74N/mm2, for M30 it was 4.65N/mm2while that of M 40 is 4.82 N/mm2.

VI. CONCLUSION

1. Distructive Tecnique (Ndt)

From the above test results the following point are concluded:-

- As the percentage of glass powder increases the workability decreases. Use of super plasticizer was found to be necessary to maintain workability with restricted water cement ratio.
- Compressive strength increases with increase in percentage of glass powder upto 20% replacement and beyond 20% strength decreases.
- At the replacement of 20% of cement by glass powder meets maximum strength as compare to that of normal concrete and other percentage of replacement of cement.
- Flexural strength also increases with increase in percentage of glass powder upto 20% replacement and beyond 20% strength drops down.
- The present study shows that ANN can predict the strength very close to the actual strength of material. It has been concluded that-
- We are observed that MSE reduction of each data sample to collected different M20, M30 and M40. Hence our prediction accuracy is increasing 98% for given data sample.
- Generally the time required for the development of compressive strength is 28 day but with the help of this model compressive strength can be predicted in short period of time.
- In this model prediction of strength of concrete is done by developing ANN model so material can also be saved with this model hence it is partially NON.

VII. FUTURE SCOPE

ANNs has performed satisfactorily in predicting compressive strength in this study, and it can be employed in predicting other characteristics of concrete like shrinkage, creep, its splitting tensile strength etc.

There are several points that were noted through the process of this thesis, which are worthwhile investigating in order to extend and get more accurate results of the desired concept of the inclusion of glass powder as either partial replacement of cement. Further investigation can be done by using plasticizers to improve the workability and strength. Also durability investigation can be done to see the long term effect of glass powder replacement. More studies on the ANN model can be done depending upon the type of material which is replaced by cement.

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