International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 8, Issue 12 [December 2019] PP: 01-09

Relationship Between Weight And Tensile Strength Of Concrete Cylinders Made By Partial Replacement Of Coarse Aggregates From Old Concrete

SagarTanwani, Bashir Ahmed Memon
Quaid-e-Awam University of Engineering, Science and TechnologyProfessor, Department of Civil Engineering

Abstract:-Finding and utilizing alternatives of natural ingredients of concrete is the demand of the day as need of accommodation and associated facilities due to growing population, particularly in urban centers of world is increasing. Therefore, construction of new tall buildings in place of old short height buildings is unavoidable. This results in huge quantum of demolishing waste and possess great problem of dealing and dumping it. One of the best way of dealing this waste is using it in new construction. This research work makes use of this waste by utilizing 50% coarse aggregates from old concrete. Concrete is very good in compressing but is weaker in tensile strength. On the other hand, tensile strength is important as it influence the cracking, bond properties and behavior under shear forces.Quality control of concrete requires determination of its properties. Laboratory analysis is exact but is time consuming. Alternative to it is the numerical analysis which gives ready hand idea. Therefore, in this research paper relationship between weight and tensile strength of concrete cylinders is studied. Concrete cylinders are prepared using 1:2:4 mix with 0.55 water-cement ration. In preparation of concrete cylinders 50% natural coarse aggregates are replaced with coarse aggregates from old concrete. Three modes of compaction viz. no compaction, compaction by rodding and table vibrator are adopted. After 28-day curing weight and split tensile strength are evaluated following standard procedures. The cylinders having 15% or more deviation in tensile strength are discarded. Finally, 30 cylinders for each mode of compaction are used. Trend line analysis is used to develop numerical equations for individual cases. The obtained equations are then used to recalculate the tensile strength values. The comparison of experimental and predicted values shows that the predicted results are in good agreement with experimental results. The research work not only gives ready tool for estimation of tensile strength of concrete cylinders made with partial replacement of natural coarse aggregates.

Keywords:*Old Concrete, Green Concrete, Tensile Strength, Weight, Numerical Equation.*

I. INTRODUCTION

Concrete is most widely used material in modern construction industry due to its fluidity which enables creations of required shapes easily. Lesser maintenance cost of it adds up benefits than other construction materials. However, this material has few drawbacks like lesser tensile strength which is countered by using steel reinforcement. But tensile strength is important property as it influences the cracking, bond properties and behavior under shear forces. On the other hand, growing demand of construction of new building with more capacity to accommodate increasing population particularly in urban center around the globe forces the builders to construct tall buildings by demolishing short height building. This generates the huge quantum of demolishing waste. It needs proper handing and dumping to save the environment. Shortage of space in urban centers become hurdle for proper handling of this waste and sometimes increases the construction cost drastically. Therefore, researchers started working on finding the possibilities of reusing this material in new construction as this is the best use of the demolished waster, saves the dumping problem of the waste and saving of the natural aggregates. Several scholars used different techniques to study the properties of these material and ways to reuse it. But due to scatter in the results the findings are not yet incorporated in the codes of practice for the purpose. Which shows still there is need of more research to reach at sound conclusion for using this material with certain level of confidence.In the following related research work from literature is summarized.

Tanwani and Memon[6]conducted research to study the impact of partial replacement of natural coarse aggregates, with coarse aggregates from old concrete, on tensile strength of concrete. They used 50% replacement and conducted split tensile strength test on concrete cylinders. Based on the obtained results the authors observed only 5% reduction in tensile strength of concrete with reference to control concrete. Therefore, they concluded that the use of coarse aggregates from old concrete has promising effect on the tensile strength of concrete.

Michal[7] in his research work studied effect of loading rate on the tensile strength of concrete. Based on the findings the author concluded that the knowledge of effect of loading on tensile strength and stress-strain behavior of concrete is of key importance as these properties influence the cracking, bond properties and behavior under shear forces.

Nihal et al[8] in their research work used regression analysis and integral absolute error to evaluate ratio between splitting tensile strength to cylinder compressive strength of concrete for compressive strength from 4 to 120 MPa. The authors used compressive strength and this ratio to establish failure envelope for high strength concrete in Johnston's strength criterion. They also demonstrated their theory using a numerical example.
Ghaffar et al[9] in their research work developed new method of assessing tensile strength of concrete. Based on their results they concluded that their method gives 34% lower results of tensile strength then conventional splitting cylinder strength method of concrete.

Funso[10] used pulverized bone as partial replacement of cement in foamed concrete to study compressive and tensile strength. They prepared beams, cubes and cylinders to evaluate required properties. Based on the outcome of their research work they concluded that the results of proposed material are in good agreement with control concrete. Thus provides an alternative to non-renewable resources and deals with the potentially harmful waste also.Arivalagan[11]in his research work used ballast fiber instead of conventional materials for repair and strengthening of concrete. Based on the research findings the author concluded that ballast fiber gives good mechanical properties and lower cost than conventional repair material.
Vahab et al[12] in their research work developed compression to tensile load transformer device to measure direct tensile strength of concrete. Based on their findings they concluded that their developed device gives 33% better results than Brazilian Test.

Waqas et al[13] in their research work used steel fibers from 0.1% to 1% to improve the compressive and tensile strength of concrete. They used 1:1.5:3 mix to prepare cylinders and short beams for the purpose. Based on their research findings they concluded that using steel fibers slight increase in compressive strength but good increase in tensile strength is observed.
Mohd et al[14] in their research work used waste polyethylene bottles as partial replacement of fine aggregates in dosage of 25% to 75% to develop relationship between splitting tensile and flexural strength from compressive strength of concrete.

Xuzong et al[15] in their research work studied effect of moisture content on compressive and tensile strength of concrete. They also developed relations to determine properties of concrete with different moisture contents. Based on their finding they concluded that moisture content has significant impact on the compressive strength of concrete but has little impact on split tensile strength of concrete.
Bahera[16] in their research work used metallic bottle caps as fiber in the dosage of 0.25% - 1% to improve the tensile strength of concrete. The authors used 3mm x 10 mm strips of bottle caps. They observed 12.59% increase in tensile strength of concrete with dosage of 1% of bottle caps.

Jopseph and Maurice[17] in their research work used lateritic sand and quarry dust as complete replacement of fine aggregates to study the tensile and flexural properties of concrete. The authors used varying percentage of lateritic sand from 0 to 100% at intervals of 25% in 1:1.5:3 mix with 0.65 water cement ratio to prepare cylinders and beams. Based on obtained results the authors observed that tensile strength increases with increase in laterite content. Therefore, concluded that the presence of laterite content has positive effect on the tensile strength of concrete hence may be used instead of river sand as fine aggregates.

Kanawade et al[18] in their research work used artificial sand, natural sand plus recycledaggregate to study compressive and tensile strength of concrete. Based on the obtained results the concluded that constant reduction in both compressive and tensile strength of concrete is observed.
Based on above discussion it is evident that although lot of work to study or enhance tensile strength of concrete using various techniques has already been done yet there is room for more work as wide scatter in the results is observed.

Also for whatsoever construction material testing is the way to monitor and ensure the quality of work. On site observation only gives the rough estimate of quality of the material therefore requires dedicated laboratory for detailed quality tests. For concreting strength test of cubes or cylinders is required to ensure proper strength and durability of structural member. Therefore, cubes or cylinders made from the batch of concrete are sent to laboratory for strength evaluation. Laboratory needs some time to provide these results but in mean time construction goes on and structural elements are built. In case of unacceptable results remedial measures not only are difficult but also are cost intensive. Therefore, this research work aims at finding relationship between tensile strength and weight of concrete cylinders in terms of polynomial. For the purpose 50% replacement of natural coarse aggregates with coarse aggregates from old concrete is used. 50% replacement is selected as proposed by Memon et al[1]-[5].Other than coarse aggregates from old concrete, ordinary Portland cement, natural coarse aggregates and hill sand are used in 1:2:4 mix proportion with 0.55 water cement ratio. Increased water cement ratio is used as recommended by Memon et all[1]-[5] and indeed it is because of the old mortar attached with the coarse aggregates from old concrete. Total of 120 cylinders are cast in three batches of 40 cylinders each. These batches are cast with compaction by table vibrator, rodding and no compaction. After casting using standard procedure are water cured for 28-days.

After curing weight and splitting tensile strength are evaluated using standard procedures. Obtained results are then checked for tensile strength deviation. The specimen having strength deviation beyond 15% are discarded. Finally, 30 cylinders of each batch are selected for trend line analysis. Trend line analysis is performed for all three types of compaction and polynomials are presented for individual cases. Using these equations tensile strength is reevaluated. It is observed that the equation predicts the tensile strength nearly accurate with maximum error of 3.17% in case of no compaction specimen.

It is believed that the research work presented in this paper will not be good benchmark for scholars of the field but also help the practicing engineers to have a very good idea of the tensile strength of concrete having the weight of the cylinder and knowing the type of compaction used to prepare these cylinders.

II. MATERIAL AND TESTING

To achieve the aim of the research old concrete is collected from demolishing of reinforced concrete slab. The large pieces of old concrete were then hammered to smaller pieces followed by sieving to maximum of 1-inch size in line with the natural coarse aggregates used for the research work. Hill sand is used as fine aggregate and OPC is used as binding material. 1:2:4 mix is designed using ACI method of mix design however the water-cement ratio is adopted as 0.55. This increased water-cement ratio used is indeed because of higher demand of water in concrete mix by the coarse aggregate from old concrete. It is believed that higher demand of water is due to old mortar attached with the coarse aggregates from old concrete. Concrete batching is done by weight method.

120 concrete cylinders of standard size are then cast using standard procedure of casting of cylinders. These cylinders are prepared using three methods of compaction viz. no compaction, compaction by rodding and compaction by table vibrator. After removal from the molds these cylinders are cured for 28-day.

After curing first the weight of cylinders is determined and recorded. Then using universal load testing machine split tensile strength of the cylinders is evaluated. Taking tensile strength as the standard parameter, tensile strength values are checked for deviation of 15% or more than mean value. All those cylinders having deviation equal to or more than 15% are discarded. Finally, 30 cylinders of each batch are selected for further analysis. The details of cylinders and average values of weigh and tensile strength are listed in table 1. Table 2 gives the details of weight and tensile strength for all cylinders of all batches. Figure 1 shows the trend of weight versus tensile strength of concrete for all three modes of compaction.

Table 1: Details of cylinders

#	Type of Compaction	No. of Cylinders	Curing	Average Weight (kg)	Average Tensile Strength (psi)
1	No Compaction	30	28 days	10.9	196.5
2	Rodding	30	28 days	12.8	282.9
3	Table Vibrator	30	28 days	13.2	470.3

Table 2: Weight and tensile strength for different types of compaction

#	No Compaction		Rodding		Table Vibrator	
	Weight (kg)	Tensile Strength (psi)	Weight (kg)	Tensile Strength (psi)	Weight (kg)	Tensile Strength (Psi)
1	11.0	203	12.2	274	13.2	477
2	10.8	198	13.0	287	13.2	478
3	11.0	199	12.1	272	13.2	477
4	10.8	197	12.8	284	13.2	476
5	10.8	197	12.8	285	13.2	476
6	11.0	198	12.8	284	13.2	475
7	11.0	194	12.8	286	13.2	478
8	11.0	196	13.0	286	13.2	478
9	11.0	199	13.0	287	13.2	476
10	10.7	197	13.0	288	13.2	477

11	10.7	195	13.0	289	13.2	477
12	10.8	199	13.0	287	13.2	478
13	10.8	198	13.0	289	13.2	478
14	10.8	199	13.0	289	13.2	477
15	10.8	196	13.0	287	13.2	478
16	11.0	200	12.6	282	13.2	476
17	11.0	201	12.6	283	13.2	476
18	11.0	202	12.6	282	13.2	476
19	10.7	196	12.6	281	13.2	476
20	10.7	195	12.6	283	13.2	478
21	10.6	192	12.6	280	13.2	478
22	10.7	197	12.6	281	13.2	477
23	10.8	200	12.8	284	13.2	476
24	10.8	196	12.8	282	13.2	478
25	11.0	202	12.8	284	13.2	478
26	11.0	201	13.0	286	13.0	470
27	11.0	201	13.0	288	13.0	471
28	10.8	198	13.0	289	13.0	476
29	11.0	203	13.0	287	13.2	478
30	11.0	203	13.0	286	13.2	477

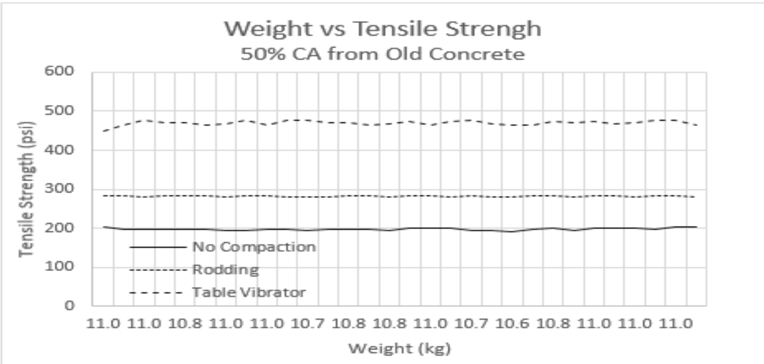

Figure 1: Weight vs tensile strength for all modes of compaction

III. RESULTS AND DISCUSSION

The weight and tensile strength of concrete cylinders is then analyzed. Table 3 gives details of minimum and maximum values of these parameter for all three modes of compaction.

Table 3: Minimum and maximum values for all modes of compaction

#	Compaction	Weight (kg)		Tensile Strength	
		Minimum	Maximum	Minimum	Maximum
1	No compaction	10.6	11.0	192	203
2	Rodding	12.1	13.0	272	289
3	Table vibrator	13.0	13.2	470	478

Results of weight and tensile strength of all three modes of compaction are then analyzed using trend line technique, an inbuilt capability of Microsoft Excel. The feature offers several options for trend line fit, i.e. linear, polynomial up to 6degrees, power, logarithmic, exponential and moving average. All these options are checked individually to obtain the best fit with least error.

For no compaction concrete cylinders, weight vs tensile strength is plotted along x-axis and y-axis respectively in figure 2. The best fit for this category is obtain as polynomial of second order as given in equation (1). In this equation x represents weight of cylinder and y represents tensile strength. This equation is then used to reevaluate the tensile strength and the results are tabulated in table 4. It is observed that tensile strength values obtained by using equation (1) are in good agreement with experimental values with maximum absolute error of 3.17% whereas the minimum absolute error recorded is 0.02%. Figure 3 gives graphical comparison of experimental and predicted values of tensile strength for this category.

$$y = -38.682x^2 + 854.28x - 4516.4 \quad (1)$$

Experimental data for concrete cylinders made using rodding for compaction are plotted in similar pattern as data for no compaction cylinder in figure 4.Trend line analysis gave second order polynomial as best fit. The expression is given in equation (2). This equation is then used to reevaluate the tensile strength and the results are tabulated in table 4. It is observed that tensile strength values obtained by using equation (2) are in good agreement with experimental values with maximum absolute error of 0.9% whereas the minimum absolute error recorded is 0.05%. In figure 5 experimental and predicted values of tensile strength are plotted for comparison.

$$y = -3.8709x^2 + 114.12x - 541.99 \quad (2)$$

Weight and tensile strength of concrete cylinders made using table vibrator for compaction is plotted in figure 6. This time trend line analysis gave linear equation as relationship between weight and tensile strength as best fit. However, all other options are also evaluated but linear equation remained best with minimum error. The same is given in equation (3). This equation is then used to recalculate the tensile strength using weight of cylinder as independent variable. Predicted values along with percentage absolute error is listed in table 4 and plotted in figure 6. It is observed that the equation gives result with minimum error of 0.01% and maximum error of 0.77%, which reveals that the predicted values of tensile strength are in good agreement with the experimental results. Both experimental and predicted values of tensile strength are plotted in figure 7 for comparison.

$$y = 23.519x + 166.59 \quad (3)$$

Table 5 summarizes the average values along with minimum and maximum error for all three cases of compaction. This table also gives details of the R^2 value. From these values it may be noted that the best fit is for rodding which is commonly used in most of the cases of casting of the concrete specimen. For other cases this value is not near to 1 which is considered the best outcome of the regression / trend line analysis. However absolute error computation for all the cases shows good agreement between the experimental and predicted values.

Table 4: Experimental and predicted tensile strength values for all modes of compaction

#	No Compaction				Rodding				Table Vibrator			
	Experimental		Predicted		Experimental		Predicted		Experimental		Predicted	
	W (kg)	TS (psi)	TS (psi)	Error (%)	W (kg)	TS (psi)	TS (psi)	Error (%)	W (kg)	TS (Psi)	TS (Psi)	Error (%)
1	11.0	203	200.16	1.40	12.2	274	274.13	0.05	13.2	477	477.04	0.01
2	10.8	198	197.96	0.02	13.0	287	287.39	0.14	13.2	478	477.04	0.20
3	11.0	199	200.16	0.58	12.1	272	272.12	0.05	13.2	477	477.04	0.01
4	10.8	197	197.96	0.49	12.8	284	284.54	0.19	13.2	476	477.04	0.22
5	10.8	197	197.96	0.49	12.8	285	284.54	0.16	13.2	476	477.04	0.22
6	11.0	198	200.16	1.09	12.8	284	284.54	0.19	13.2	475	477.04	0.43
7	11.0	194	200.16	3.17	12.8	286	284.54	0.51	13.2	478	477.04	0.20
8	11.0	196	200.16	2.12	13.0	286	287.39	0.49	13.2	478	477.04	0.20

9	11.0	199	200.16	0.58	13.0	287	287.39	0.14	13.2	476	477.04	0.22
10	10.7	197	195.69	0.66	13.0	288	287.39	0.21	13.2	477	477.04	0.01
11	10.7	195	195.69	0.36	13.0	289	287.39	0.56	13.2	477	477.04	0.01
12	10.8	199	197.96	0.52	13.0	287	287.39	0.14	13.2	478	477.04	0.20
13	10.8	198	197.96	0.02	13.0	289	287.39	0.56	13.2	478	477.04	0.20
14	10.8	199	197.96	0.52	13.0	289	287.39	0.56	13.2	477	477.04	0.01
15	10.8	196	197.96	1.00	13.0	287	287.39	0.14	13.2	478	477.04	0.20
16	11.0	200	200.16	0.08	12.6	282	281.38	0.22	13.2	476	477.04	0.22
17	11.0	201	200.16	0.42	12.6	283	281.38	0.57	13.2	476	477.04	0.22
18	11.0	202	200.16	0.91	12.6	282	281.38	0.22	13.2	476	477.04	0.22
19	10.7	196	195.69	0.16	12.6	281	281.38	0.13	13.2	476	477.04	0.22
20	10.7	195	195.69	0.36	12.6	283	281.38	0.57	13.2	478	477.04	0.20
21	10.6	192	192.66	0.34	12.6	280	281.38	0.49	13.2	478	477.04	0.20
22	10.7	197	195.69	0.66	12.6	281	281.38	0.13	13.2	477	477.04	0.01
23	10.8	200	197.96	1.02	12.8	284	284.54	0.19	13.2	476	477.04	0.22
24	10.8	196	197.96	1.00	12.8	282	284.54	0.90	13.2	478	477.04	0.20
25	11.0	202	200.16	0.91	12.8	284	284.54	0.19	13.2	478	477.04	0.20
26	11.0	201	200.16	0.42	13.0	286	287.39	0.49	13.0	470	472.34	0.50
27	11.0	201	200.16	0.42	13.0	288	287.39	0.21	13.0	471	472.34	0.28
28	10.8	198	197.96	0.02	13.0	289	287.39	0.56	13.0	476	472.34	0.77
29	11.0	203	200.16	1.40	13.0	287	287.39	0.14	13.2	478	477.04	0.20
30	11.0	203	200.16	1.40	13.0	286	287.39	0.49	13.2	477	477.04	0.01

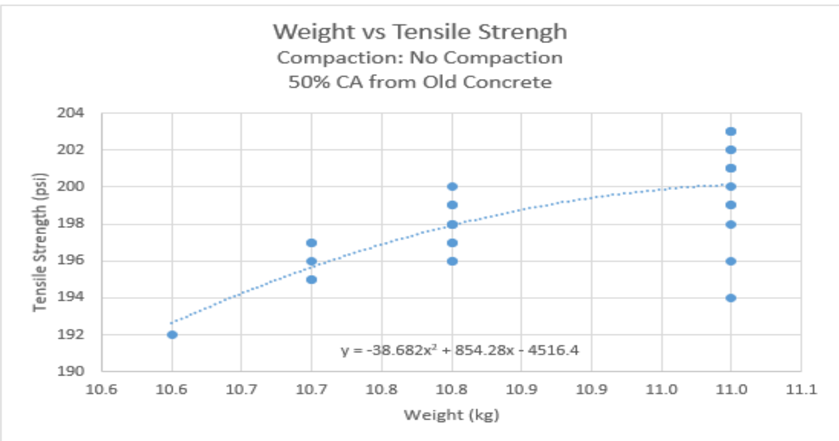

Figure 2: Weight vs tensile strength for cylinders made using no compaction

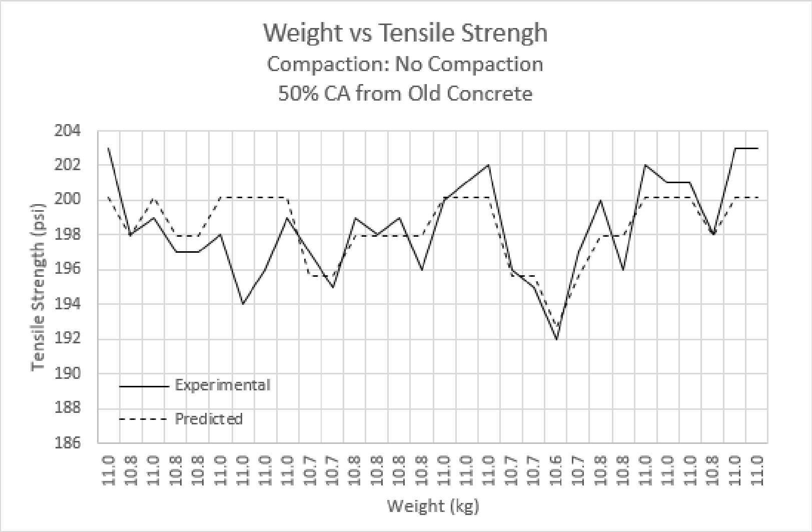

Figure 3: Experimental and predicted values of tensile strength for no compaction cylinders

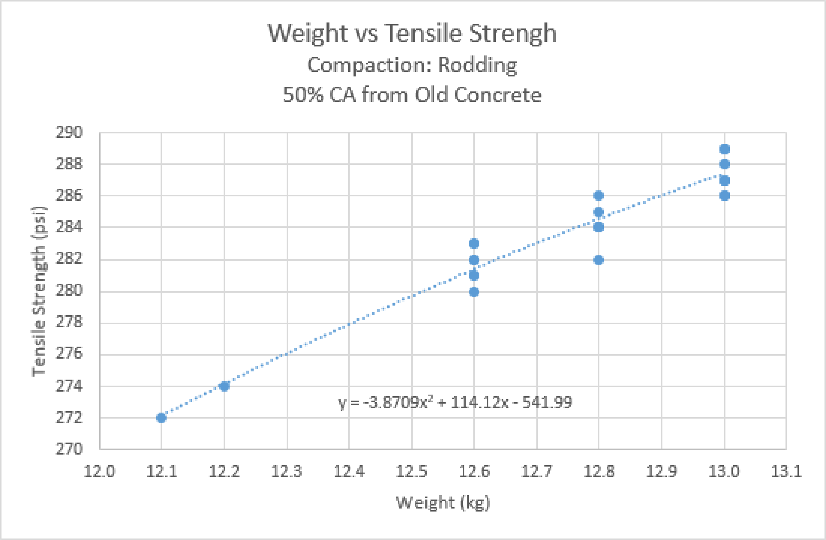

Figure 4: Weight vs tensile strength for cylinders made using rodding

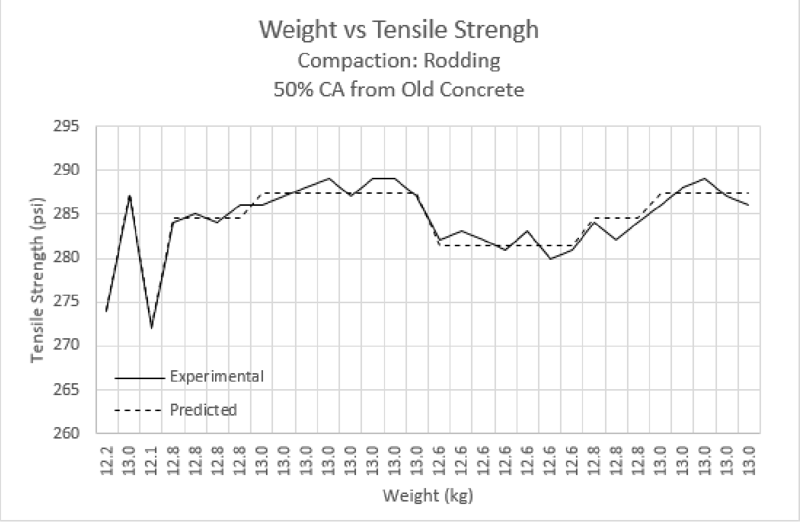

Figure 5: Experimental and predicted values of tensile strength for cylinders made by rodding

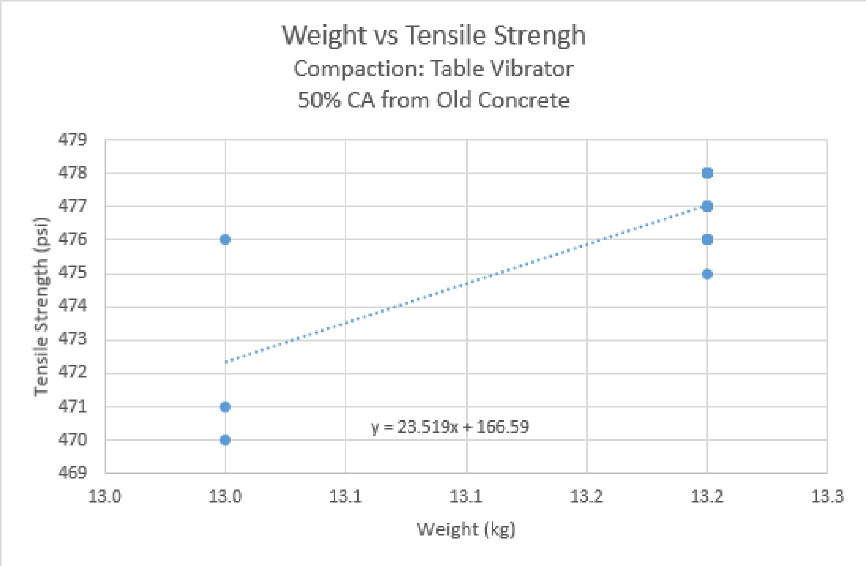

Figure 6: Weight vs tensile strength for cylinders made using compaction by table vibrator

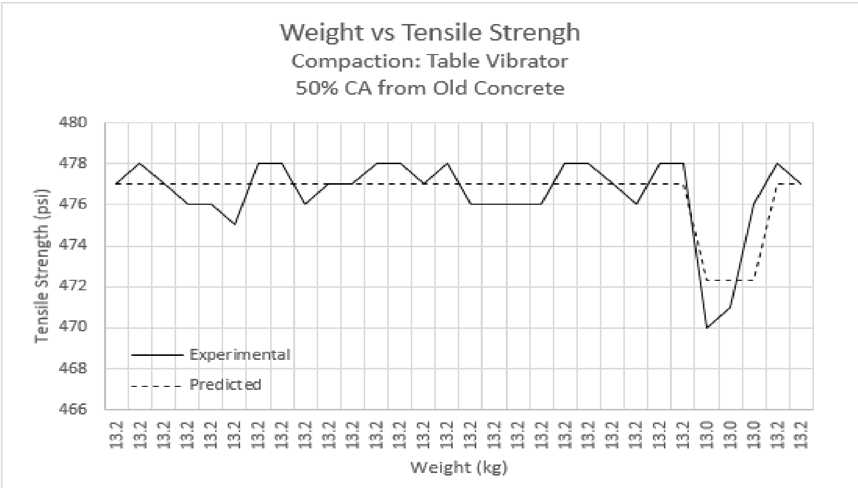

Figure 7: Experimental and predicted values of tensile strength for cylinders made using table vibrator

Table 7: Average values of tensile strength with error in predicted results.

#	Compaction	Experimental		Predicted Results			
		Weight (kg)	Tensile Strength (psi)	Tensile Strength (psi)	Minimum Error (%)	Maximum Error (%)	R^2
1	No compaction	10.9	192	198.43	0.02	3.17	0.4964
2	Rodding	12.8	272	284.37	0.05	0.90	0.9255
3	Table vibrator	13.2	470	476.57	0.01	0.77	0.5779

IV. CONCLUSION

This research paper present relationship between weight and tensile strength of concrete cylinders made by replacing 50% natural aggregates with aggregates from old concrete. Maximum size of aggregates in both cases is 1-inch whereas other ingredients of concrete mix are OPC and hill sand with 0.55 water cement ratio. Three modes of compaction viz. no compaction, compaction by rodding and table vibrator are adopted. After 28-day curing weight and split tensile strength are evaluated following standard procedures. After discarding concrete cylinders with strength deviation of 15% or more, 30 cylinders for each mode of compaction are used. Trend line analysis is used to develop numerical equations for individual cases. The obtained equations are then used to recalculate the tensile strength values. The comparison of experimental and predicted values shows that the predicted results are in good agreement with experimental results. The research work not only gives ready tool for estimation of tensile strength of concrete cylinders made with partial replacement of natural coarse aggregates.

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