
MANUAL V/S MECHANICAL MIXING: ITS IMPACT ON CEMENT STRENGTHS

ABSTRACT

Cement testing as per Indian standards IS: 4031, i.e., primarily determination of Normal Consistency of cements and subsequently gauging of cement mortar is carried out manually and requires skill and experience for better accuracy, precision and reproducibility. In the changing times with less skilled manpower the manual methods result in issues of reliability and reproducibility

At the authors' lab, substantial test data were generated, so as to have comparison of cement mortar tests' results for OPC, PPC & PSC gauged with manual and mechanical mixing (using Hobart mixer) & with normal consistency water being determined manually, as per BIS specifications. The paper discusses these results in details.

Detailed analysis of the available test data of different types of cements (OPC, PPC and PSC) indicated that although the testing was based on normal consistency water, the normal consistency is a function of the type of cement; and it was observed that OPC, PPC and PSC exhibited a clear consistent value of W/C of 0.38, 0.43 and 0.41 respectively.

Further tests were conducted at authors' labs to compare the tests results of the three varieties of Cement (OPC, PPC, PSC) tested using the fixed W/C ratios (0.38, 0.43 and 0.41 respectively) with mechanical mixing and gauged manually as per BIS guidelines. For some of the select cement samples the mortar tests were conducted at W/C ratio of 0.5 and mechanical mixing as used in European standards.

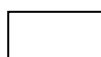
The paper discusses the comparison of the test data in details and finally concludes that the mechanical mixing has high reproducibility, reliability and precision. Another observation made is that taking a fixed W/C for OPC (0.38), PPC (0.43) and PSC (0.41) and with Mechanical mixing, the mortar results are comparable to test results of these cements tested as per IS 4031 methods. These observations could be useful from the angle of aligning BIS methods of testing with EN/ISO methods.

1.0 Introduction

The Physical properties of cement mortar tested as per Indian standards IS: 4031, primarily determination of Normal Consistency of cements and subsequently gauging of cement mortar is carried out manually and requires skill and experience for better accuracy, precision and reproducibility. Many a times changes in operators tend to affect the determined values of Normal consistency and resultantly the tested values of Compressive strengths for cement under evaluation. To maintain the repeatability and accuracy of the physical properties, the parameters like Normal Consistency and cube casting play vital role.

Studies were carried out at authors' lab initially to compare the results of compressive strengths of cement mortars with different types of cements viz :OPC, PPC and PSC, tested by manual mixing and mechanical mixing using Hobart mixer, with the normal consistency (%NC) determined manually as per the procedures of Indian standards. The detailed results are discussed in this paper. The studies had indicated that by changing the procedures from manual mixing to mechanized mixing the determined compressive strengths were similar, the test results with mechanized mixing showed reproducibility and repeatability, irrespective of operators.

The paper further discusses the studies carried out to look at possibilities of taking a fixed water cement ratio, which would thus eliminate the manual determination of %NC (as per Indian Standards). These studies initially indicated that taking a fixed W/C ratio of 0.5 (as in EN



Standards) with OPC, PPC & PSC using vibration (instead of jolting as in EN Standard) with the BIS standards mould showed bleeding and so was not possible to be used.

Detailed analysis of the available test data at authors' labs for different types of cements from different markets, (OPC, PPC and PSC) tested as per the Indian standards, indicated that although the testing was based on normal consistency water, *the normal consistency is a function of the type of cement*; and it was observed that OPC, PPC and PSC exhibited a clear consistent value of W/C of 0.38, 0.43 and 0.41 respectively. These W/C ratios are derived on the basis of the average of the normal consistency of more than 1000 market samples of each type of cement. This paper discusses the test data of 30 samples each of OPC, PPC & PSC gauged manually as per IS: 4031, with the same set of cements again gauged by mechanical mixing method using fixed W/C ratio depending on the type of cements. The results indicate a very good correlation with the test results for OPC, PPC and PSC tested as per IS: 4031.

The paper concludes that it is possible to move from the manual mixing to mechanized mixing of cement mortars using water based on %NC, determined as per IS: 4031, or as a step towards alignment of Indian standards to EN /ISO standards for use of fixed W/C ratios depending on the type of cements.

2.0 Experimental Procedures, Results & Discussions-

2.1 Materials

Cements samples, i.e., OPC, PPC and PSC collected from different markets of India with different brands. Standard sand as per IS: 650 is used for mortar preparation.

2.2 Methods

2.2.1. Mechanical mixing methodology adopted:

For mechanical mixing, a set SOP, detailed below, was followed for all the samples under tests. Optimum time for mixing was decided as 4 minutes. First one minute dry mixing of cement and sand followed by three minutes wet mixing after addition of water & using first gear of Hobart mixer. (at 136 rpm) Immediately after mixing the mortar, placed the mortar in the cube mould and prod with the poking rod. The mortar is prodded 20 times in about 8 seconds to ensure reduction of entrained air and honeycombing. The remaining quantity of mortar in the hopper of the cube mould prodded again for the first layer and then compacted the mortar by vibrations. Vibrations were given for two minutes at the specified speed of (12000 ± 400) vibrations per minute. At the end of the vibrations, removed the mould along with the base plate from the machine and finished the top surface of the cube in the mould by smoothing the surface with the blade of a trowel. The filled moulds were kept in moist closet for 24 hours at (27 ± 2) °C temperature & ~ 95% R_H. After 24 hours, removed the cubes from the moulds and immediately submerged in clean, fresh water and kept there until taken out for breaking (at 3, 7 & 28 days respectively). The water in curing tank renewed every 7 days and maintained at a temperature of (27 ± 2) °C.

2.3. Manual mixing v/s mechanical mixing at manually determined %N C. based W/C ratio

Cement samples (OPC, PPC & PSC: 30 samples of each type) were tested twice; once as per IS: 4031 (manually) and secondly by using mechanical mixer (planetary mixer like Hobart mixer) with the manually determined N.C. based W/C ratio.

The manual mixing is carried out as per IS: 4031. For mechanical mixing, a set SOP as indicated was followed (Refer Sec. 2.2.1.). Results from all three sets of experiments are discussed below.

The data generated indicate that there exists good correlation between these two methodologies of manual mixing and mechanical mixing, which is true for all types of cements.



Fig 1.0 presents the correlation between manual mixing & mechanical mixing for OPC 1, 3, 7 & 28 days.

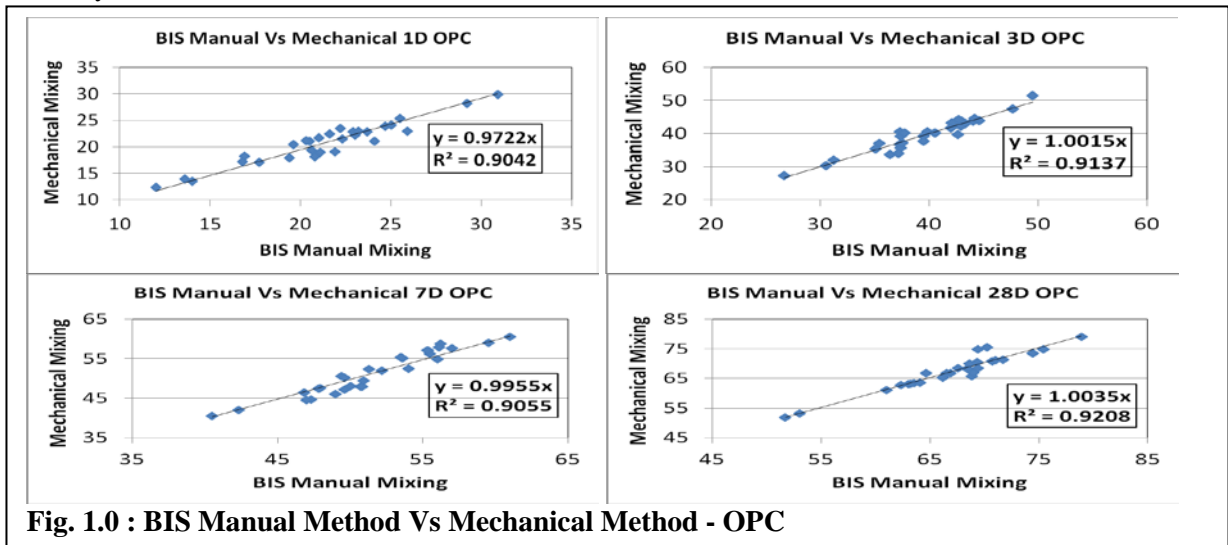


Fig. 1.0 : BIS Manual Method Vs Mechanical Method - OPC

Fig 2.0 & Fig 3.0 illustrates the correlation for PPC & PSC respectively at 1, 3, 7 & 28 day.

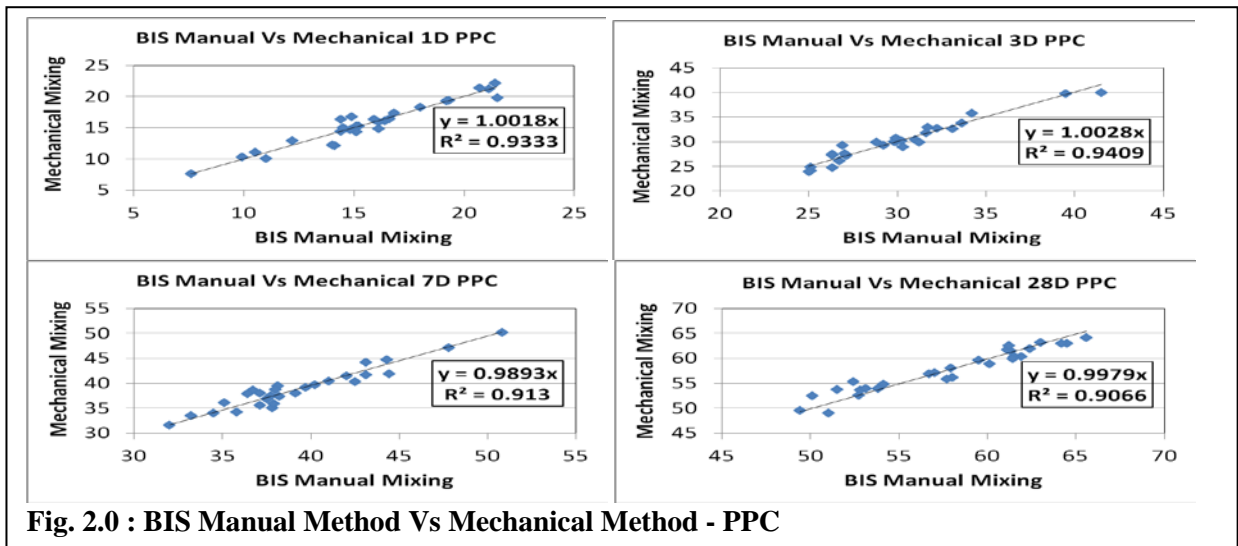


Fig. 2.0 : BIS Manual Method Vs Mechanical Method - PPC

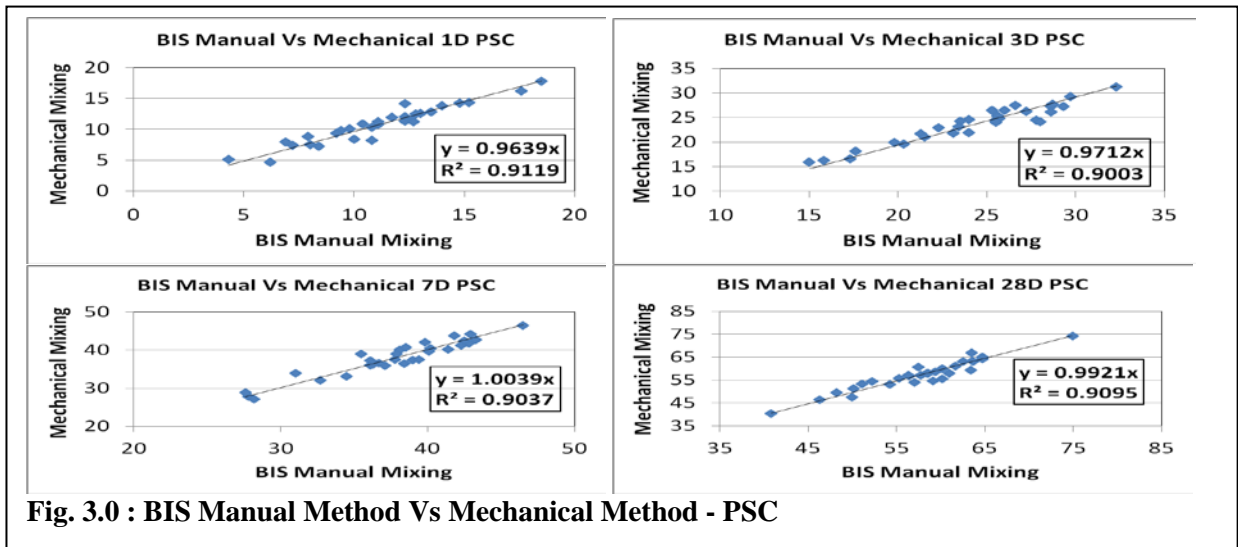
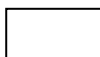


Fig. 3.0 : BIS Manual Method Vs Mechanical Method - PSC



Cement Type	1D	3D	7D	28D
OPC	1.0	1.1	1.4	1.0
PPC	0.6	0.8	1.1	0.9
PSC	0.8	1.1	1.2	1.5

Fig. 4.0 : Average difference between Compressive Strengths of manual mixing & mechanical mixing with N. C. based W/C ratio

The above studies indicate that the mortar strengths results by BIS method (IS: 4031) & by mechanical mixing with W/C ratio used determined from manually determined %NC are similar for all the three types of cements. The values of R^2 (> 0.9) in all cases also indicate that there is a good co-relation between the manual mixing & mechanical mixing (with N.C. based W/C ratio) methods of testing mortars. The average difference in compressive strengths is within limits of variability of any mortar testing.

2.4. Manual mixing v/s mechanical mixing at fixed W/C ratio of 0.5 for all types of cements

OPC, PPC & PSC samples were gauged with mechanical mixing (planetary mixer like Hobart mixer) using a fixed W/C = 0.5, followed by compaction using vibrating machine (12000 \pm 400) RPM, when bleeding was observed. The possible factors resulting into the bleeding could be as below –

- 1) **Mould shape /size:** BIS Moulds (cube of 70.7 mm) as well as EN moulds (prism of 40.0 mm x 40.0 mm x 160.0 mm – 3 units) in both the moulds for mortar mixing, both, jolting table & vibrating machine were used. *Both these moulds showed bleeding on vibrating machine*, while no bleeding was observed when jolting table was used for compaction, however compaction was not uniform in BIS moulds.
- 2) **Sand:** To study the effect of sand on bleeding phenomenon, we used mortar mix [cement / sand = 1 / 3 (W/W)] with W/C ratio = 0.5 with BIS sand as well as EN sand, on both, jolting table & vibrating machine. Both these mortar mixes showed bleeding on vibrating machine, while no bleeding was observed when jolting table was used for compaction.

The sand fractions in 'EN – sand' & 'BIS sand' are given below for reference.

Sieve size (mm)	+2.0	-2.0/+1.6	-1.6/+1.0	-1.0/+0.5	-0.5/+0.16	-0.16/+0.08
EN sand (% Retained)	0	7 \pm 5	33 \pm 5	67 \pm 5	87 \pm 5	99 \pm 1
BIS sand (%Retained)	0	5.9	33.3	66.7	97.4	100

Fig. 5.0 : Sand fractions of BIS & EN sand

Bleeding was observed above the mortar mixes of all cements in Fig 6.0.

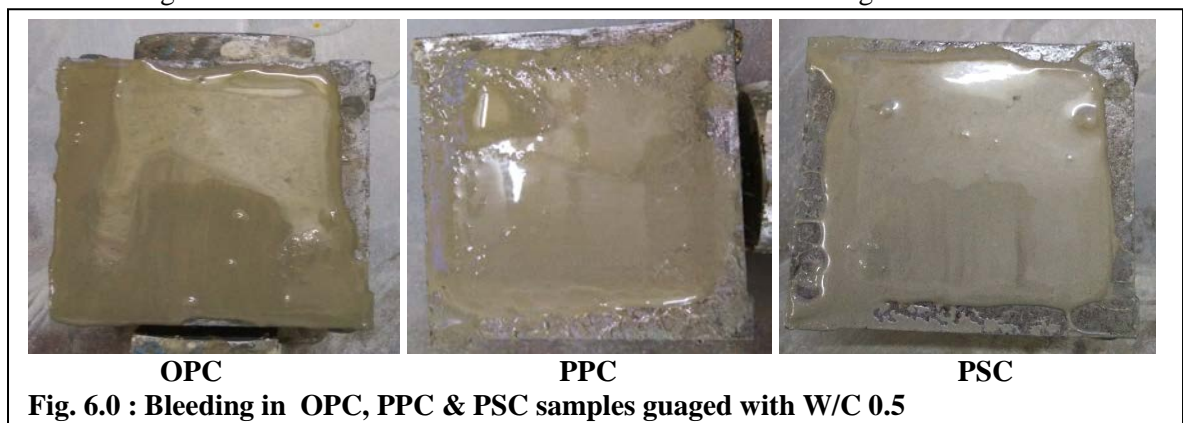
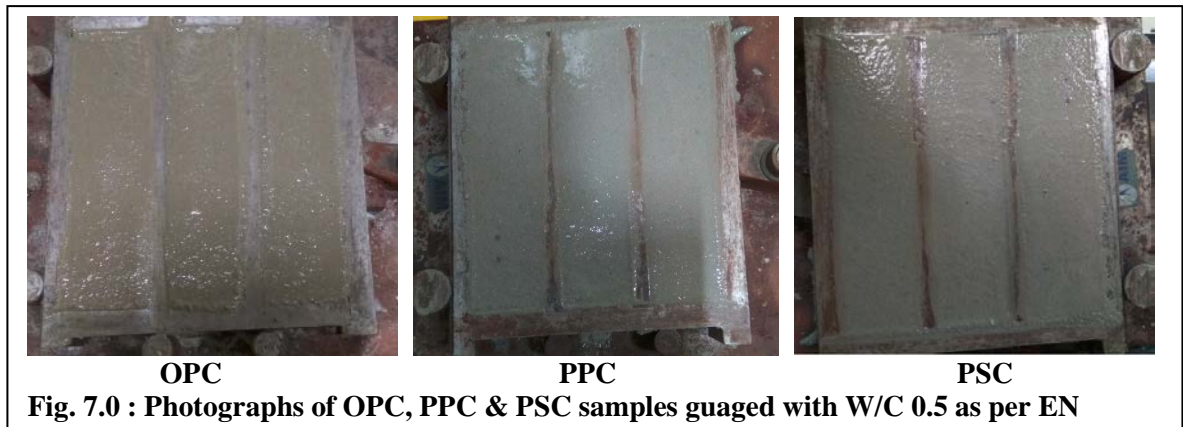


Fig. 6.0 : Bleeding in OPC, PPC & PSC samples gauged with W/C 0.5

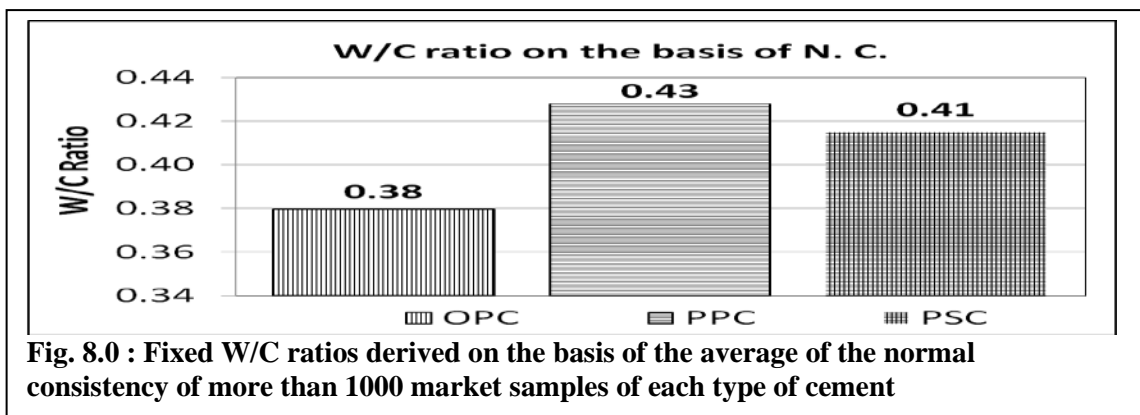


However, after mechanical mixing, procedure of tapping is followed using jolting table (as done in EN method); no bleeding is observed as indicated in Fig 7.0.



2.5 Data Analysis of the fixed W/C ratios are derived on the basis of the average of the normal consistency of more than 1000 market samples of each type of cement.

In order to decide the W/C ratio for mechanical mixing of cements, analysis of the available test data at the authors labs of about thousand market cement samples of each type of cement OPC, PPC & PSC tested as per BIS method (IS: 4031). The evaluation data of each type of cement indicate that for OPC, PPC & PSC the average W/C ratio is on an average 0.38, 0.43 & 0.41 respectively. The details of these data in the form of graphs are attached below -



2.6 Manual mixing v/s mechanical mixing at fixed W/C ratios of 0.38, 0.43 and 0.41 for OPC, PPC and PSC respectively

30 samples each of OPC, PPC & PSC are tested twice, once as per IS: 4031 and secondly by mechanical mixing (planetary mixer like Hobart mixer) with fixed w/c ratios of 0.38, 0.43 and 0.41 for OPC, PPC and PSC respectively.

90 sets of experiments with 30 samples each of OPC, PPC & PSC gauged with mechanical mixing (Hobart mixer) using a fixed W/C ratio for OPC (0.38), PPC (0.43) and PSC (0.41). The mortar results of mechanical mixing are comparable to test results of these cements tested by IS: 4031, & are presented in Fig 9.0, Fig 10.0 & Fig 11.0 respectively.

Fig 9.0 presents the correlation of compressive strengths for OPC between mechanically mixed mortar & mortar prepared as per IS: 4031 method for 1, 3, 7 & 28 day.



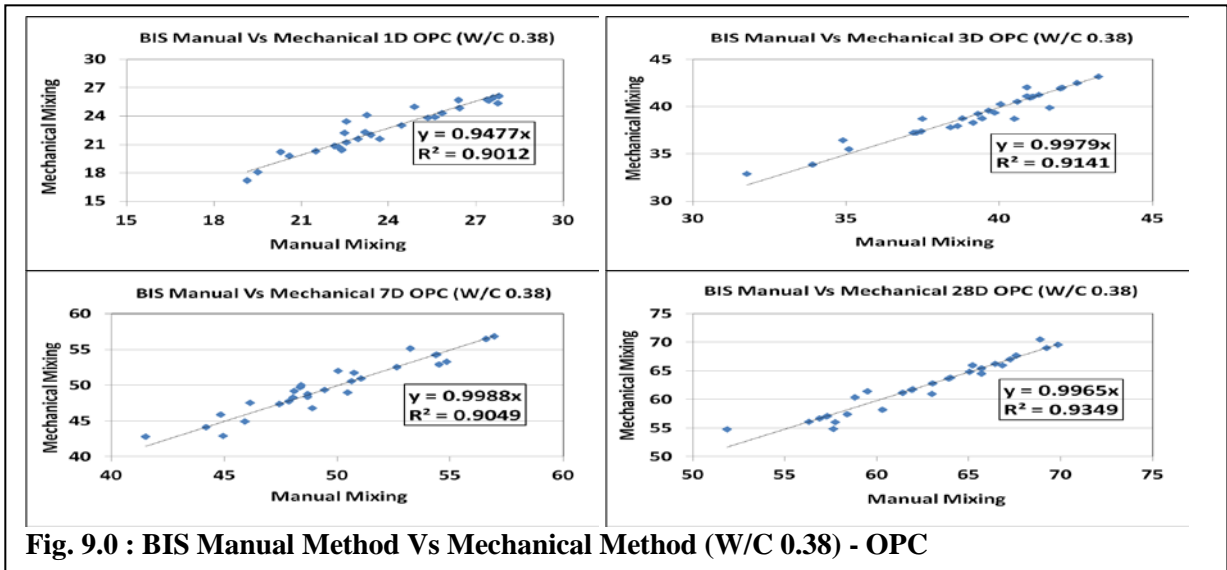
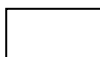
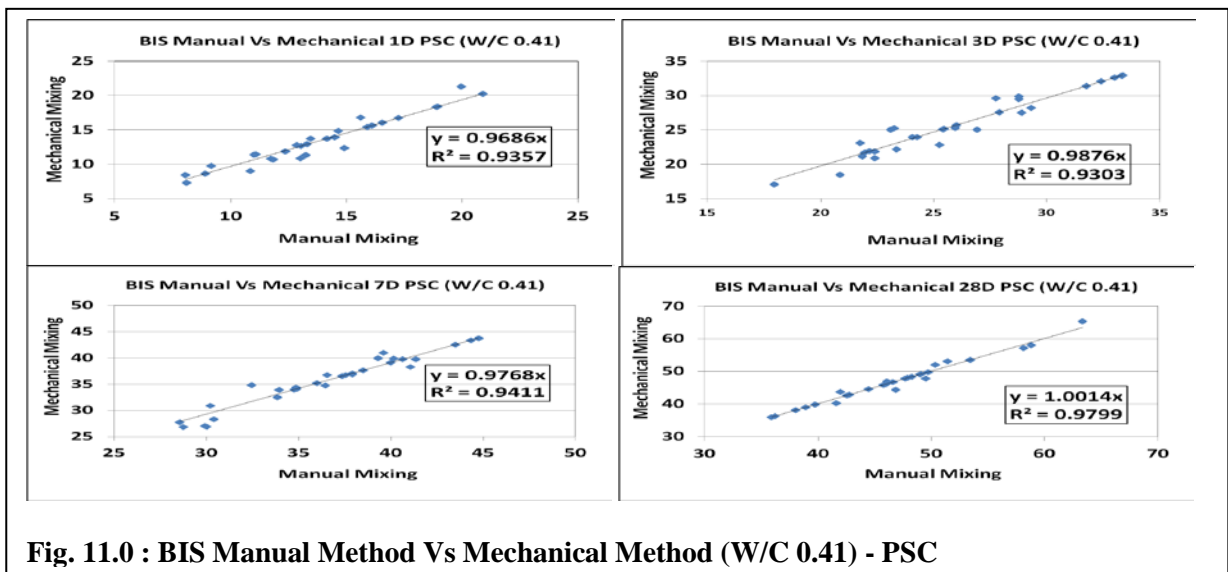
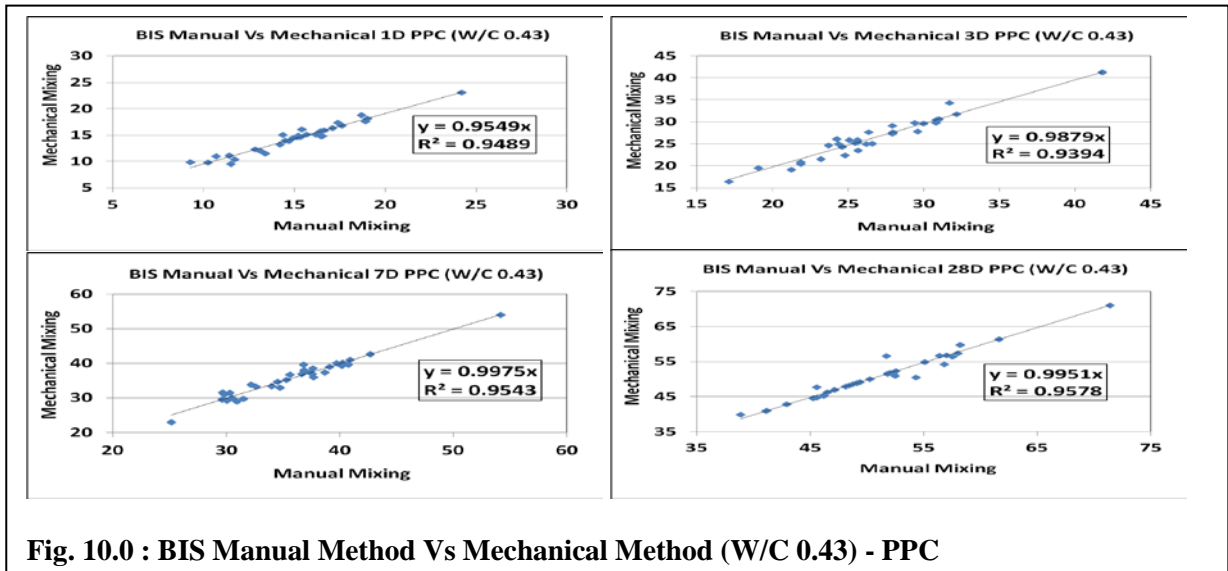


Fig 10.0 & Fig 11.0 illustrates the correlation for PPC & PSC respectively at 1, 3, 7 & 28 day.



Cement Type	1D	3D	7D	28D
OPC	1.2	1.2	1.4	1.3
PPC	0.9	1.2	1.4	1.3
PSC	1.0	1.3	1.5	1.2

Fig. 12.0 : Average difference between Compressive Strengths of manual mixing & mechanical mixing with fixed W/C ratio

The above studies indicate that the mortar strengths results by BIS method (IS: 4031) & by mechanical mixing with fixed W/C ratio (0.38, 0.43 & 0.41 for OPC, PPC & PSC respectively) are similar for all the three types of cements. The values of R^2 (> 0.9) in all cases also indicate that there is a good co-relation between the manual mixing & mechanical mixing (with fixed W/C ratio) methods of testing mortars. The average difference in compressive strengths is within limits of variability of any mortar testing.

4.0 Conclusion

- The test data on mortar tests experiments of Manual mixing v/s Mechanical mixing at manually determined %N. C. based W/C ratio discussed in the paper indicates *that the manual mixing can be replaced by mechanical mixing for all three types of cements OPC, PPC & PSC using W/C ratio based on manually determined %NC*. This would help improve reproducibility and repeatability of test results, & would reduce the dependability of test results on manual efforts from Gaugers and even a semi-skilled operator could carry out Gauging with minimum errors & with efficiency.
- Using a fixed EN based 0.5 W/C ratio, with BIS moulds and with compaction using vibrating machine results in bleeding and so not feasible.
- As discussed in the paper instead of a universal W/C ratio of 0.5 if individually for OPC, PPC and PSC are tested using fixed W/C ratio of 0.38, 0.43 & 0.41 respectively as per types of cements followed by mechanical mixing can further reduce the complexity of mortar testing of basing the W/C ratio on manually determined %NC. This would also maintain the effects of the difference in water demand due to the effect of cement type on mortar test results.
- The general mortar test results of the above modified methodology were observed to be similar to the present mortar results for any type of cements viz: OPC, PPC, PSC, thus even if the above options are adopted by BIS it would not have any impact on the present definitions of compressive strengths of 33 G, 43G and 53G of cements.
- Such adoption of the above methodology would assist in improving the reproducibility and repeatability of test results, making the results independent of operator's skill/experience of manual gauging of cement mortars. This would be a step towards alignment of BIS standards with EN/International Standards.

