

Investigations on compatibility of cement-superplasticizer interaction and its influence on mortar workability incorporating copper slag as fine aggregate

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Abstract. Interaction between cement and water is a complex phenomenon to understand. Sometimes achieving the desired results is quite challenging due to the contrast spotted in the characteristics of cement, type and dosage of superplasticizers (S.P) as the behaviour is insignificant. Influence of different types of cement fineness on pastes with different superplasticizers which represents the compatibility between cement with water reducing admixture in order to obtain well-defined saturation dosage and with the partial replacement of fine aggregates (F.A) by copper slag (C.S) to study the mortar behaviour is focused in this work. A methodology based on fundamental properties of cementitious systems using marsh cone and mini-slump cone tests results to identify the suitable and compatible combinations between cement and superplasticizers for the enhancement of flow behaviour of mortar mixes.

1. Introduction

Recent advancement in the concrete technology has revolutionised the mixture of various conventional ingredients to uplift the desired properties of concrete which has renewed its definition. Today the use of chemical admixtures has been underscored in the emerging trend of concrete preparation which imparts desirable properties in both plastic and hardened state. Flow behaviour governs the concrete properties and it is controlled by dispersion of particles, as superplasticizer results in dispersion into smaller cement particles of coarse agglomerates that is predominant in the cement paste and concrete mix which increases the fluidity [1]. Reduction of both water cement (w/c) ratio improve strength and workability, addition of superplasticizers effectively decreases the capillary porosity and permeability. Thus, it helps to reduce the heat of hydration and improve concreting process in hot climates and marine structures.

The development in the chemistry with various formulations has challenged the researchers to understand the effect of rheology, hydration and effect of cement systems. Experimental Investigations are carried out to improve the rheological and mechanical properties by incorporating various fine particles like blast furnace slag, fly ash etc., where mineral admixtures have actively contributed in enhancement of workability in fresh state and to develop greater strength due to their pozzolonic reaction and latent hydraulic properties [2]. Desired rheological properties are being achieved due to the spherical



shape and the size of fly ash particles which has resulted in improvement of cement rheology at lower dose of superplasticizer.

Rheology of fresh cement paste is integrated with the evolution of microstructure in cement mortar and concrete. Considering the behaviour of blended cement on addition of mineral admixtures is crucial as it will have a direct impact on microstructure of fresh cement paste which increases yield stress and thereby decrease in plastic viscosity [3].

In this work, an attempt is carried out to understand the influence of different dosages of lingsulfonate (L.S), Sulphonated Naphthalene Formaldehyde (SNF) and Poly Carboxylate Ether (PCE) based super plasticizers on the flow behaviour of cement paste and fluidity of mortars made with Ordinary Portland cement (OPC) and Portland Pozzolona Cement (PPC) along with partial replacements of fine aggregate (FA) by copper slag. Feasible mechanism of reciprocal action is discussed

2. Materials

- 2.1 *Cements*: Ordinary Portland cement (OPC) and Portland Pozzolona Cement (PPC) of 53 Grade supplied by Ultratech were used.
- 2.2 *Superplasticizers (SP)*: Ligno Based (LB) Pozzoloth 102, Naphtha Based (NB) Rheingold 1125 and Poly Carboxylate Ether (PCE) based Glenium sky 8233 were supplied by BASF.
- 2.3 *Fine aggregate (F.A)*: Locally available river sand and Copper Slag (CS) (Fig 1) from Sterlite Industry, Tamil Nadu.

Table 1. Physical properties of different fine aggregates used

Sl no	Description	River sand	Copper slag
1	Specific gravity	2.6	3.65
2	Water absorption %	0.2	0.10
3	Fineness modulus	4.59	3.4
4	Ratio of (cement: F.A)	1 : 3	1 : 3



Figure 1. Copper Slag

3. Experimental Procedures

3.1. Marsh Cone Test

The behaviour of chemical admixtures, different type and grade of cement significantly varies from each other. Marsh cone test is reliable method to study the rheological properties of cement and mortars. Flow time of cement through marsh cone is an indicator of viscosity, depends upon cement SP compatibility to determine optimum SP dosage of a specific cement-superplasticizer combination. 1L of cement paste was prepared in mortar mixer using 2kg of OPC and PPC. Cement slurry was prepared with the w/c of 0.35 and varying admixture dosage from 0.2%-2%, in turn the saturation dosage of super plasticizer was determined.

3.2 Flow table test

To check the quality control the most adopted method in characterizing the pastes and grouts is the mini slump test. The gravity instigates the paste to slump down when the truncated cone is lifted vertically. This occurs when yield stress exceeds and will stop when local stress is below such yield stress [4]. The viscous forces and inertia will play a significant role in conjunction with gravitational forces at the end of slump in case of low yield stress [5].

The mortars were made for 1:3 cement sand ratio and was mixed in Horbart mixer. CS was incorporated as a partial replacement for fine aggregate at 0% and 50% replacement levels to understand the flow behaviour of copper slag in mortars. Superplasticizers of different dosages at different water cement ratio for different types of cements along with partial replacement of river sand by CS were mixed to measure the fluidity on cement sand mortars.

4. Results and Discussions:

A) *Behaviour of cement paste for OPC and PPC mixes with different chemical admixture to determine optimum dosage.*

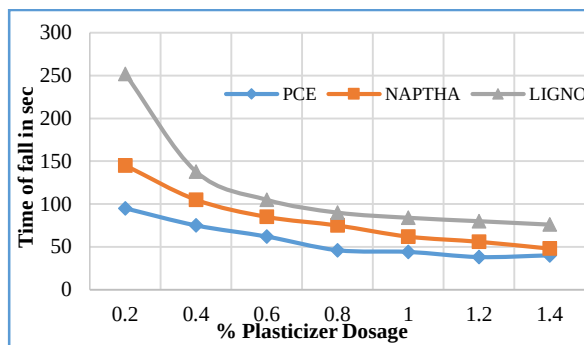


Figure 2. Marsh Cone Test for OPC

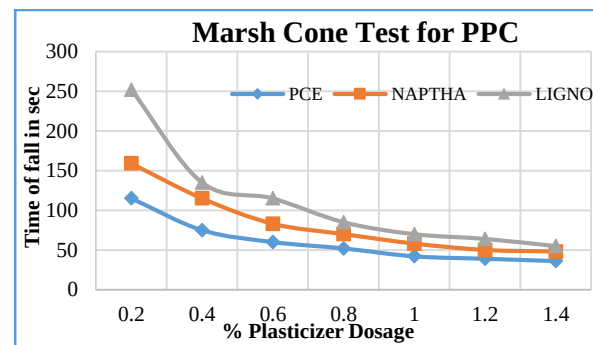


Figure 3. Marsh Cone test for PPC

From the Fig (2) and Fig (3) the optimum dosage for PCE based admixtures is 0.7 % for OPC and 0.6% for PPC from rheological point of view. For SNF based plasticizers the optimum dosage is 0.85%for OPC and 0.8% for PPC. Similarly for LS based SP for saturated dosage OPC and PPC are 0.9% and 0.85%. Flow time decreases with increase in dosage of super plasticizers and the saturation dosage varies with different types of chemical admixtures used. To achieve the steeper decline in water cement ratio by decreasing the viscosity and enhancing the workability of control mix of concrete for OPC can be modified and controlled using super plasticizers despite of unpredictable conditions based on the compatibility between choice of admixtures and type of cement. The interaction between the chemical admixtures and cement in presence of copper slag affects the rheology of the paste where addition of SP has influenced on its performance. In case of blended cement like PPC, the fineness of fly ash particles and its spherical shape enhanced the fluidity of the cement paste by reducing the porous compared to non-blended cements improved the rheological properties with lower dose of super plasticizers.

The dispersion of cement particles is associated primarily with the electrical repulsion in case of lignosulfonate and Naphthalene admixtures, attributable to the carboxylate group. The adsorption of the admixtures to cement particles are due to the presence of carboxylate groups along with ether groups, thus forms the molecular structure of Polycarboxylate superplasticizer whose dispersion mechanism can be related to steric hindrance. This has resulted in remarkable increase in the fluidity of cement mixes.

- i) Behaviour of mortar flow for OPC and PPC mixes without chemical admixtures to determine optimum w/c.

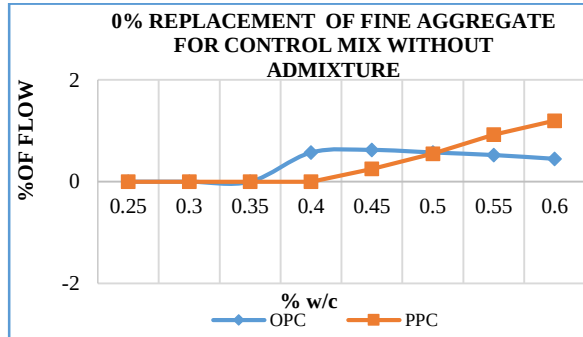


Figure 4. 0% replacement of F.A

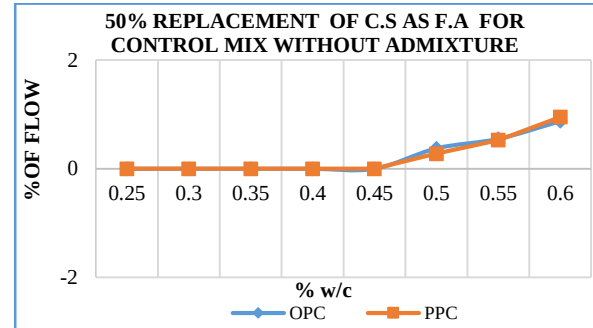


Figure 5. 50% replacement of C.S for F.A

The optimum w/c for OPC and PPC control mixes without admixtures is 0.5% and 0.45% respectively as observed from Fig 2. From Fig 3, the w/c for OPC and PPC mixes for 50% replacement of fine aggregate without admixture obtained is 0.55% and 0.5% respectively.

- B) Behaviour of mortar flow with partial replacement of Copper slag for Fine aggregate

- i) Partial replacement of F.A by C.S considering 0.4% w/c for OPC and PPC mixes for various dosage of SP respectively.

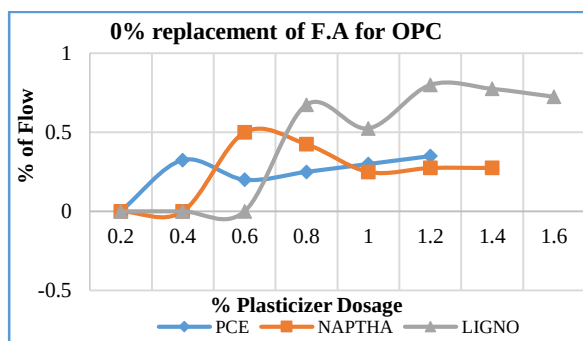


Figure 6. 0% replacement of F.A for OPC

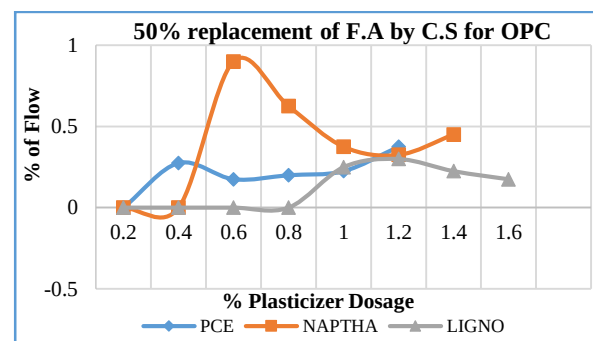


Figure 7. 50% replacement of F.A by C.S for OPC

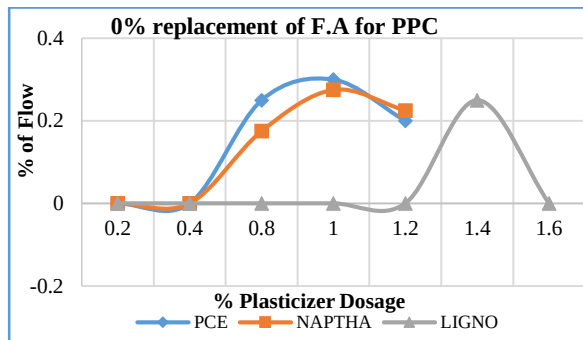


Figure 8. 0% replacement of F.A for PPC

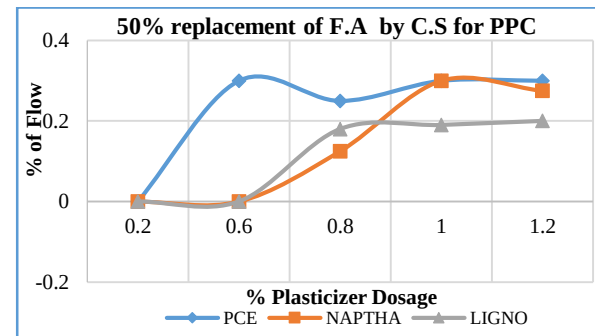


Figure 9. 50% replacement of F.A by C.S for PPC

From the Fig 6 and Fig 8, the optimum dosages obtained for PCE based admixtures for OPC and PPC mixes are 0.7% and 0.6% for 0% replacement of fine aggregate. From Fig 7 and Fig 9, for 50% replacement the saturated dosage observed are 0.8% and 0.85% for OPC and PPC mixes. In case of Naptha based admixture at 1.0% of dosage reliable flow was achieved for OPC mix and at 0.95% of dosage for PPC mix for 0% replacement and 1.0% of dosage reliable flow was achieved for OPC mix and at 0.98% of dosage for PPC mix for 50% replacement. In case of Ligno based admixture at 1.3% of dosage reliable flow is achieved for OPC mix and at 1.1% of dosage for PPC mix for 0% replacement. The saturated dosage of 1.1% of dosage the reliable flow is achieved for OPC mix and at 1.0% of dosage for PPC mix for 50% replacement of fine aggregate.

- ii) *Partial replacement of F.A by C.S considering 0.45% w/c for OPC and PPC mixes for various dosage of superplasticizers respectively.*

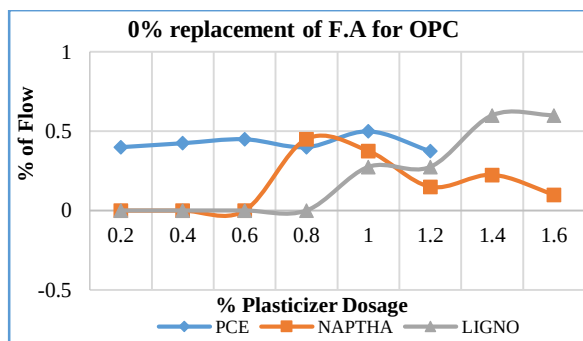


Figure 10. 0% replacement of F.A for OPC

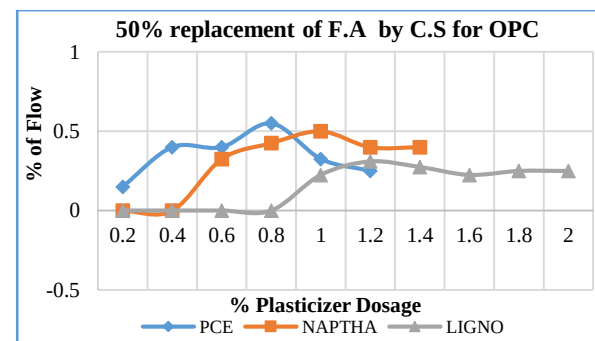


Figure 11. 50% replacement of F.A by C.S for OPC

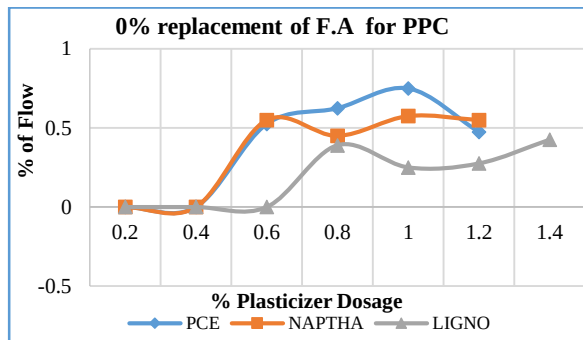


Figure 12. 0% replacement of F.A for PPC

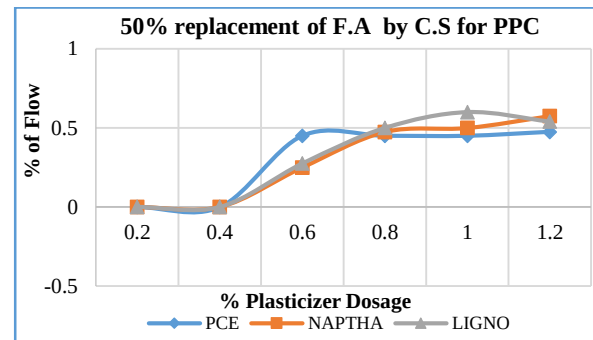


Figure 13. 50% replacement of F.A by C.S for PPC

From the above figures, the optimum dosages obtained for PCE based admixtures for OPC and PPC is 0.8% and 0.75% for 0% replacement. It is observed that the optimum dosage obtained are 1% and 0.8% for 50% replacement of Fine aggregate. The optimum dosage for Naptha based admixture obtained is 1.25% for OPC and 0.85% for PPC for 0% replacement. For 50% replacement the saturated dosage is 0.85% for OPC and 0.8% for PPC. The saturation dosage of 1.4% and 1.2% for 0% replacement of OPC and PPC mixes. Optimum Dosages for 50% replacement obtained is 1.1% for OPC and 0.9% for PPC for Ligno based super plasticizers.

- iii) *Partial replacement of F.A by C.S considering 0.5% w/c for OPC and PPC mixes for various dosage of supe rplasticizers respectively.*

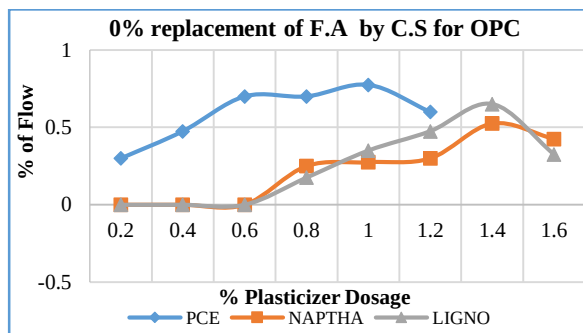


Figure 14. 0% replacement of F.A for OPC

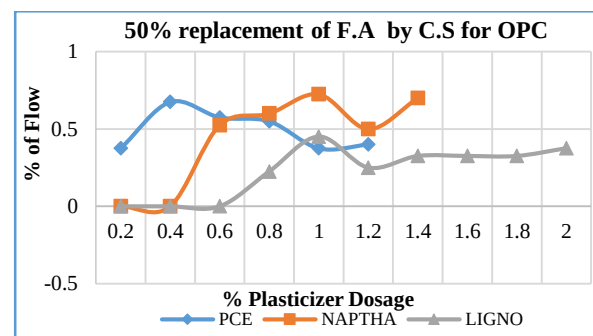


Figure 15. 50% replacement of F.A by C.S for OPC

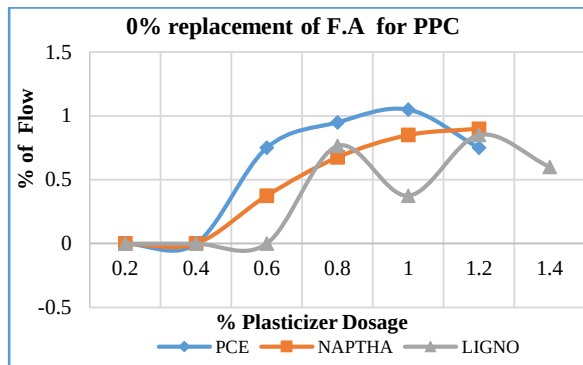


Figure 16. 0% replacement of F.A for PPC

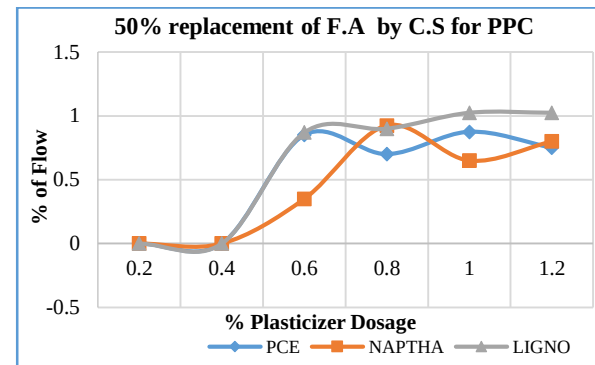


Figure 17. 50% replacement of F.A by C.S for PPC

From the above figures, the optimum dosages obtained for PCE based admixtures for OPC and PPC is 1.1% and 1% for 0% replacement. 0.9% and 0.7% for 50% replacement of fine aggregate. The optimum dosage for Naptha based admixture for OPC and PPC obtained is 1.25% and 1.0% for 0% replacement. Optimum dosage of 1.3% and 1.1% for 50% replacement of fine aggregate. The saturation dosage of 1.4% and 1.2% for 0% replacement. Saturated dosage of 1.3% and 1.1% for 50% replacement is obtained for Lingo based super plasticizers for OPC and PPC mixes.

- iv) *Behaviour of mortar flow for 0% and 50% replacement of F.A by C.S for OPC and PPC mixes for the optimum dosage of PCE to find Optimum w/c.*

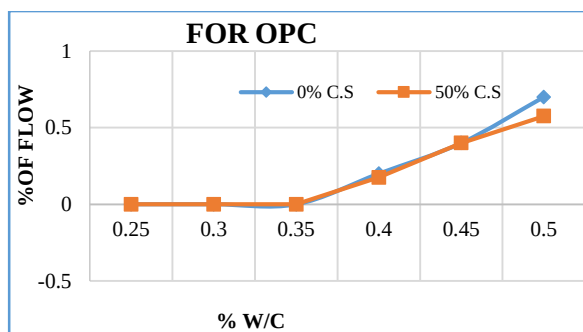


Figure 18. w/c ratio for optimum dosage of PCE for OPC mixes

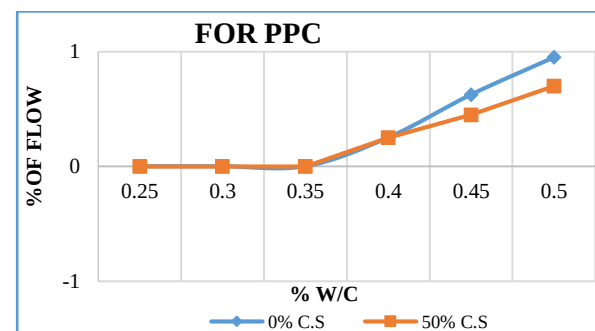


Figure 19. w/c ratio for optimum dosages of PCE for PPC mixes

The optimum w/c for OPC mixes with 0% replacement of fine aggregate by copper slag for optimum dosage of PCE based admixture of 0.7% is 0.40. It is observed that for 50% replacement of fine aggregate with 0.8% saturated dosage of PCE, the w/c from the Fig 18 obtained is 0.4. Comparatively for PPC mixes, the most favourable w/c for both 0% and 50% replacement of fine aggregates for optimum dosage of super plasticizer of 0.7% and 0.8% is 0.45 respectively as obtained from Fig 19.

5. Conclusion

The behaviour trend of admixtures is similar with respect to dosage for both OPC and PPC. The optimum dosage was carried forward to do behaviour study of mortar matrix using optimum dosage of admixture. The flow of mortar using mini slump cone was observed and documented .

1. For mortar mixes without admixtures the results obtained were fairly consistent as there was no significant behavior in flow pattern for standard mix and mix with partial replacement of fine aggregate.
2. The optimum dosage of any admixture for cement paste and mortar may not be same. However, this point at which the mortar begins to exhibit movement on a flow table test is considered as starting point for our studies.
3. It is observed that minimum of 0.35 w/c was required for both standard and partial replacement mix to exhibit the reliable flow, which was considered for the initial point for further investigation.
4. Various trials carried out for a fixed w/c, exercising various chemical admixture levels for paste and mortar with 50% replacement of copper slag for fine aggregate in both OPC and PPC. In terms of flow for admixtures the peak behaviour is observed at optimum dosage of 0.6% beyond which there is significant reduction. With the increase in water content PCE requirement also increased. However optimum dosage was between 0.6% - 0.8%.
5. But lingo-based SP displayed higher flow compared to other SP which cannot be considered as better performances since it is well established that lingo will show better fresh properties but will have drastic effect in terms of setting time, gain of strength and sometimes not set at all. Similar behaviour has been noticed when the w/c has gone to 0.5%.
6. In all the three w/c we observe that the mix tends to be more cohesive in the case of samples with fine aggregate replaced by copper slag and there is a significant variation of its percentage flow with 0% replacement.
7. The performance is more consistent in case of PPC as the particles size distribution is better and no spikes are observed. The performance is better probably because of higher specific gravity.

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Acknowledgement

The authors acknowledge the support of National Institute of Technology Karnataka, India and BASF Bangalore, India.