# Enhanced Effect of Multi-Walled Carbon Nanotubes and Silica Fume on Workability and Compressive Strength of Concrete Composites


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## ABSTRACT


The workability and compressive strength of concrete mixes with the same proportion of cement, sand, gravel and water but with different amounts of silica fume (SF) and MWCNT were examined. SF content of 0%, 5% and 10% by weight of cement, in combination with MWCNT at 0.0% , 0.01% , 0.02%, 0.03%, 0.04% and 0.05% by weight of cement, were added into the concrete mix. Dispersion of MWCNTs was facilitated by utilizing very fine particles of silica fume which helped improved the interfacial bond between MWCNTs and the concrete mixes. Tests demonstrate that there is an optimum combination of MWCNT and silica fume for maximum gain in concrete compressive strength of the concrete mix.


## METHODOLOGY

**Component materials and mix proportions** Type 1 Ordinary Portland cement (OPC), MWCNTs and highly densified silica fume were used. Washed sand of the particle size distribution within a range of 0.15–4.75 mm was obtained by sieving. The specific gravity and water absorption of the washed sands with the saturated surface dry condition was 2.63 and 3.91%, respectively. Maximum size of coarse aggregates is 10 mm. The polycarboxylate based super-plasticizer is used to enhance the flow and dispersion of the MWCNTs in the concrete mix.

A total of eighteen mixes were prepared and examined. Five different quantities of MWCNTs, 0; 0.01; 0.02; 0.03; 0.04 and 0.05% by weight of cement were added. Silica fume was added in an amount of 0,5 and 10% by weight of cement in each mixture. The amount of water added to all the mixtures was kept constant at 20% by weight of binder. The amount of super-plasticizer was kept constant at 0.01% by weight of the binder.

**Laboratory Tests.** Workability of concrete was determined by taking samples for slump test following ASTM C143/143M. The 28-day compressive strength of each concrete mix was determined by testing standard 150mm diameter and 300mm height cylinder samples following ASTM C39.

## CONCLUSIONS

The study proves the enhanced effect of concrete utilizing together MWCNT and silica fume as admixtures. It shows that there is an optimum combination of MWCNT and silica fume for maximum compressive strength of the concrete mix added with the admixtures. The combination of about 0.02% MWCNT and 10% silica fume produces maximum compressive strength of concrete.

## INTRODUCTION

Some structures in the Philippines like single span bridges usually encountered problems in the bridge approach, abutment and slope protection due to poor engineering designs (SunStar Philippines, 2016). One possible solution to improve the strength of concrete is to use admixture. Among the concrete admixtures gaining popularity are the Multi-walled carbon nanotubes (MWCNTs) and silica fume. MWCNTs provide excellent performance in concrete since the theoretical strength of these nanofilaments is 100 times that of steel, at only 1/6$^{th}$ the specific gravity (Xu et al., 2015). Conversely, silica fumes enhance the interfacial interaction between CNTs and the hydration products (Khan et al., 2011). Silica fumes helps the production of C–S–H bonds which could effectively anchor CNTs improving interaction with the matrix (Alrekabi, 2016).The combined addition of the two additives in a concrete mix, however, is less explored. This study aims to provide valuable information on the enhance effect of the additives in the concrete mix. Specifically, it aims: (1) to evaluate the workability of MWCNT and Silica Fume in the concrete mix; and (2) to determine the combined amount of MWCNT and silica fume that would result in optimal gain in concrete compressive strength.

## RESULTS AND DISCUSSIONS

**Workability of concrete mixes.** For a given dosage of silica fumes, Fig. 1 shows the variation of slump with varying dosage of MWCNTs. The increase in dosage of MWCNT reduces the workability due to MWCNTs interaction with water which reduces the free water available and increasing the shear stresses induced (Xu et al., 2015). Different types of mixes vary from medium to high workability, which shows that the proposed mixes can be used for construction purposes.

**Compressive Strength.** For a given dosage of silica fumes, Fig. 2 shows the graph of the 28–day compressive strength with varying dosage of MWCNTs. Different contents of silica fume (SF) attain their optimum strengths at 0.02% MWCNT, with 5% SF content being the highest. Beyond 0.02% MWCNT, all graphs start to go down. The reduction in compressive strength at a higher concentration of CNTs is caused by the agglomerations of MWCNTs within the hardened structure raise the local stress and thus weaken the strength.

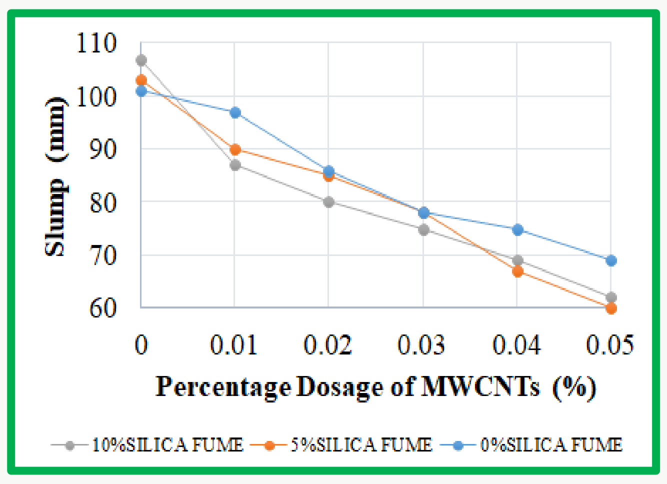


**Fig. 1** Slump test of concrete samples with varying amounts of MWCNTs and silica fume

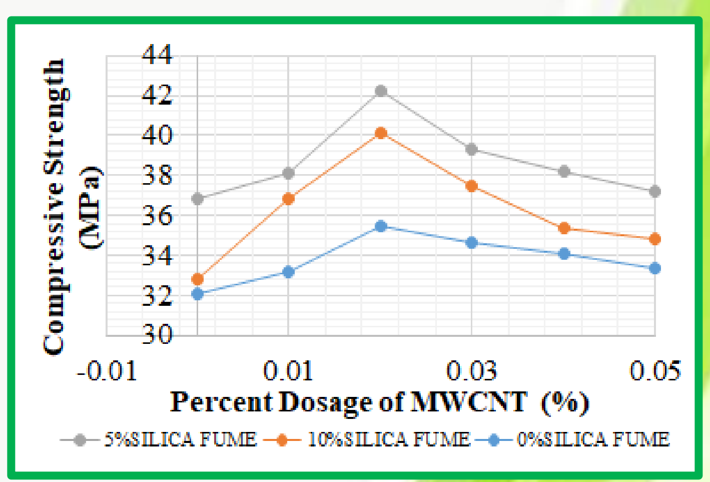


**Fig. 2** Compressive strength of concrete with varying amounts of MWCNTs and silica fume