was reported at 80% steel slag, which was added in combination with 20% milled glass. The compressive strength obtained for this combination was 14% more than the normal concrete. Therefore, the 80% steel slag and 20% milled glass may be considered as the optimum dosage in the concrete mixture.

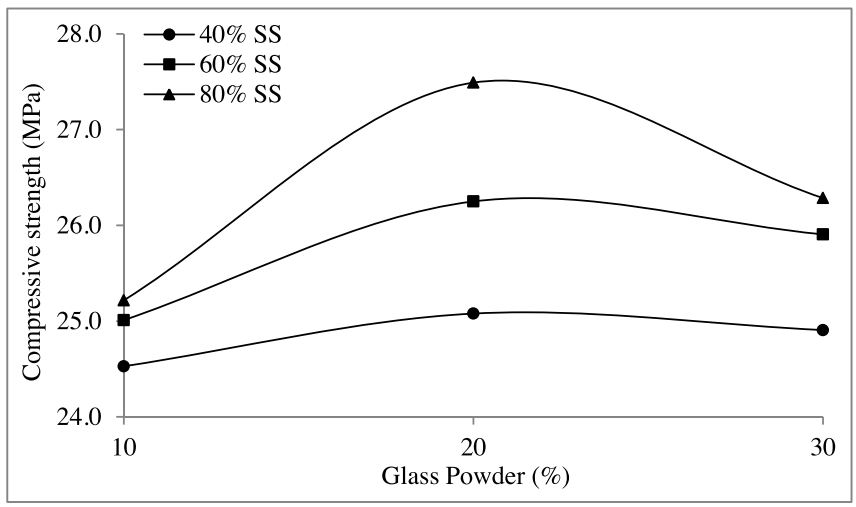

Figure 4. Effect of milled glass on compressive strength of steel slag incorporated concrete.

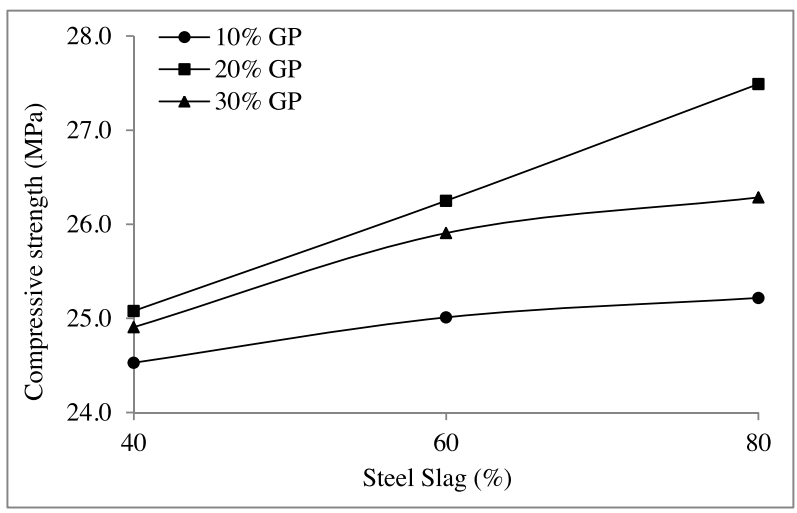

Figure 5. Effect of steel slag on compressive strength of milled glass incorporated concrete.

Splitting tensile strength

Influence of milled glass on splitting tensile strength of concrete is graphically represented in Figure 6. The results show development splitting tensile strength at 10% and 20% milled glass level in the mix. At 30% milled glass content, no more improvement was observed in the splitting tensile strength of concrete. The influence of steel slag on splitting tensile strength of concrete at constant milled glass content is represented in Figure 7. The splitting tensile strength increased as the steel slag quantity was increased in the concrete mix. The highest improvement in the splitting tensile strength was reported for 80% steel slag and 20% milled glass level in the mix, which was 42% more than the normal concrete.

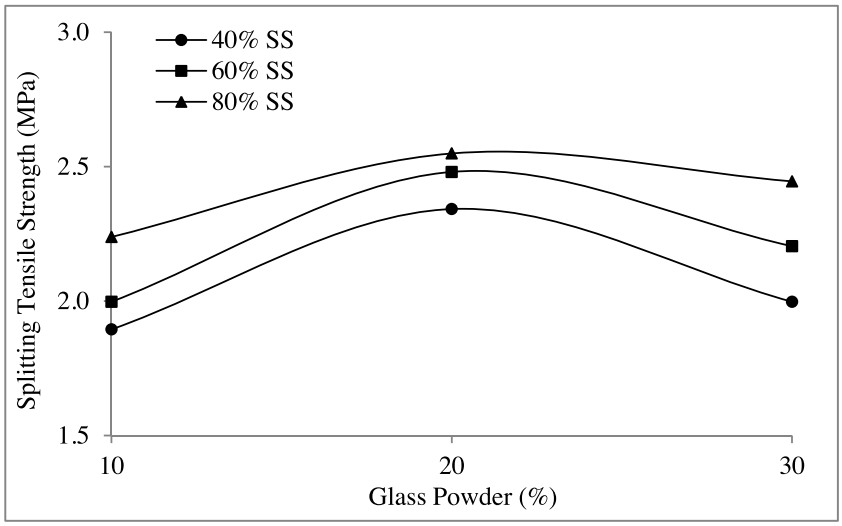

Figure 6. Effect of milled glass on split tensile strength of steel slag incorporated concrete.

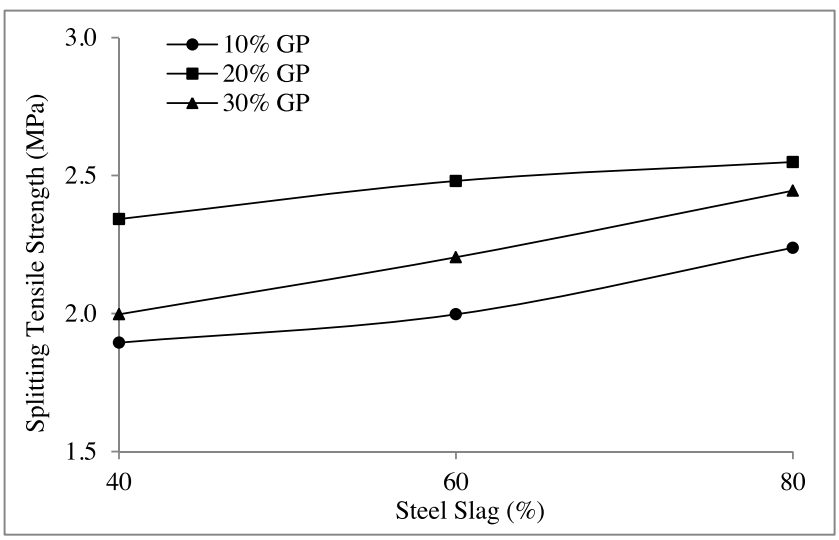

Figure 7. Effect of steel slag on split tensile strength of milled glass incorporated concrete.

Flexural strength

Flexural strength test results of milled glass incorporated concrete are displayed in Figure 8. Improvement occurred in the flexural strength for 10% and 20% substitution of milled glass in the mixture as reported by Tho-In *et al.* (2018) but decreased as 30% milled glass was substituted in the concrete mix. The effect of steel slag on flexural strength is represented in Figure 9. The increasing quantity of steel slag in the concrete mixture also increased the flexural strength. The highest increase in the flexural strength is reported for 80% steel slag and 20% milled glass incorporation in the mixture. This increase was 16% more than the normal concrete.

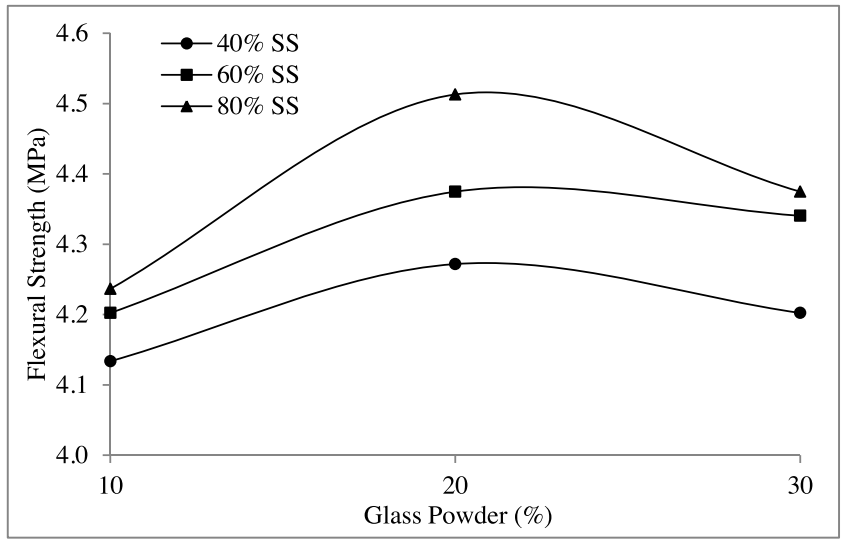

Figure 8. Effect of milled glass on flexural strength of steel slag incorporated concrete.

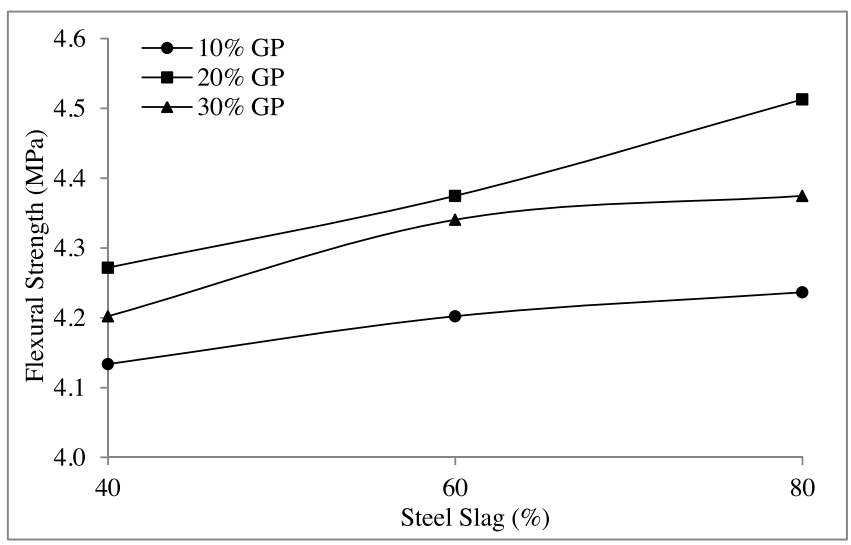

Figure 9. Effect of steel slag on flexural strength of milled glass incorporated concrete.

Modulus of elasticity`

The effect of milled glass on the modulus of elasticity is shown in Figure 10, while the influence of steel slag on the modulus of elasticity of concrete is presented in Figure 11. Like other properties, the modulus of elasticity increased for 10% and 20% milled glass content, while there was no more development reported at 30% milled glass content. Similarly, the increasing quantity of steel slag enhanced the modulus of elasticity of concrete. The highest modulus of elasticity is reported when 80% steel slag and 20% milled glass were added in the mixture. This increase in the modulus of elasticity was 16% higher than the reference concrete. This increase is due to the reduction of porosity and better pore refinement because of additional CSH production as reported by Heriyanto *et al.* (2018).

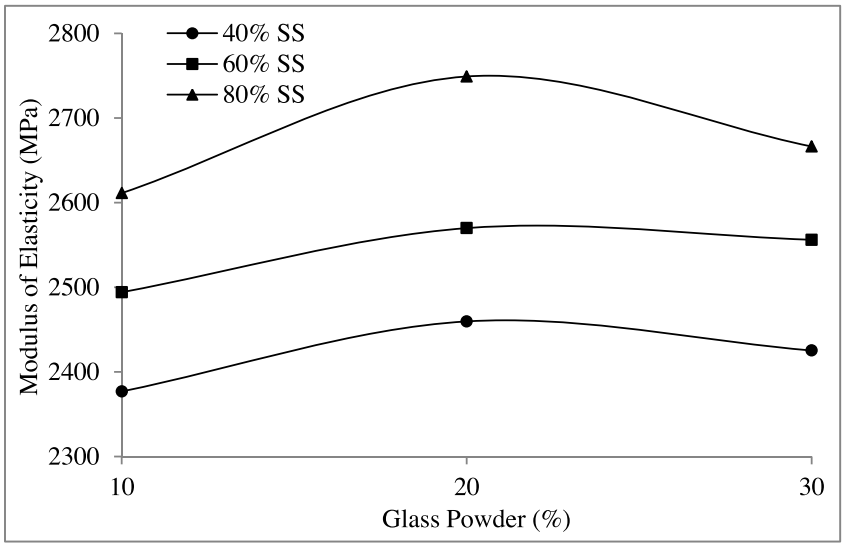

Figure 10. Effect of milled glass on modulus of elasticity of steel slag incorporated concrete.

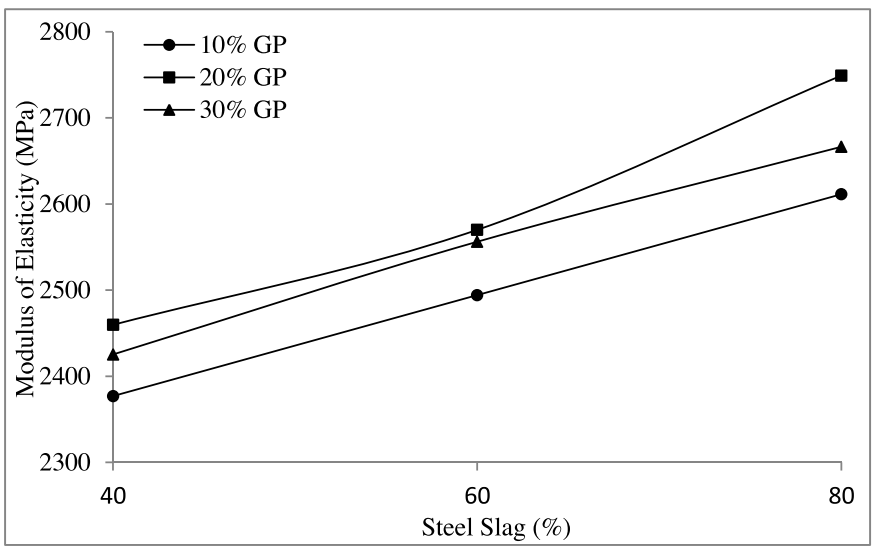

Figure 11. Effect of steel slag on modulus of elasticity of milled glass incorporated concrete.

Microstructure analysis

To study the microstructure of concrete specimens, scanning electron microscopy (SEM) was performed on test specimens after performing compressive strength test at 28 days of age. The SEM analysis for all the concrete specimens is shown in Figure 12. The results showed that milled glass enhanced the formation of secondary CH and CSH. It also improves the pore structure of the concrete, which is the result of secondary CSH production due to pozzolanic reaction (Rodier and Savastano 2018). This can be seen in Fig. 12(C1), Fig. 12(C4), and Fig. 12(C7), which contains 10%, 20%, and 30% milled glass at 40% steel slag content, respectively. Similarly, the increase in the amount of steel slag caused a reduction in the volume of voids and pores. This can be seen in Fig. 12(C4), Fig. 12(C5), and Fig. 12(C6), which contains 40%, 60%, and 80% steel slag at 20% milled glass content, respectively. The strength parameters of concrete depend on the microstructure of concrete. The results for mechanical properties for concrete mixture C6 are

higher than other mixtures of concrete. The mixture C6 has a more compact structure than other mixtures studied in this research as indicated by SEM analysis. Although the substitution of steel slag makes the concrete porous, but in this study, the addition of steel slag made the structure more compact. This may be due to the presence of milled glass, which resulted in a reduction in the pore formation. Also, some fine particles were also present in the steel slag, which may also have contributed to gel formation, thus resulting in a more compact structure.

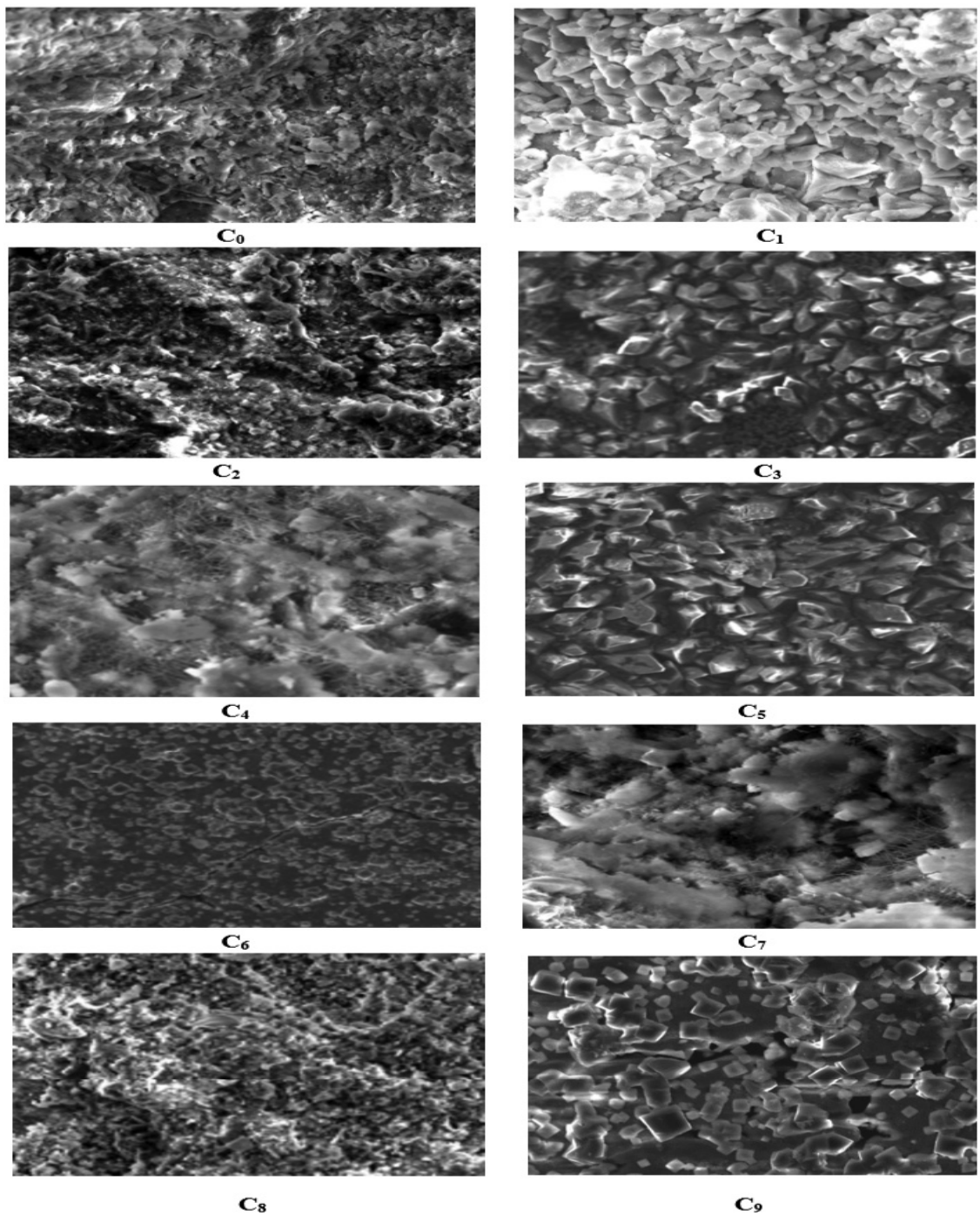

Figure 12. SEM for concrete specimens after 28 days of hydration at 20 μm.

CONCLUSIONS AND RECOMMENDATIONS

It is possible to develop a workable concrete and improve mechanical properties at a high content of steel slag. Thus, it is useful to use steel slag in combination with milled glass to achieve high workable concrete with good mechanical properties. The workability is influenced by the elevated amount of steel slag in the presence of 20% milled glass or above.

The maximum dosage for milled glass content in the mixture is 20%. However, when steel slag was added, even higher flexural strength, splitting tensile strength, modulus of elasticity, and compressive strength were obtained at the higher quantity of milled glass. This increase could be the reason for more compact structure when these materials are added to concrete as concluded in the microstructure analysis. This also encourages the study of durability of steel slag and milled glass added concrete. Thus, it may be inferred that steel slag and milled glass can be used in the concrete taking the assistance of good workability and high mechanical properties.

Researchers are recommended to carry out further study on the durability of steel slag and milled glass added to concrete. The bond strength of concrete with rebar shall also be investigated. The concrete industry is recommended to use milled glass in combination with steel slag in concrete.

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