# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

A research study on the development and mechanical behaviour of SCGC was carried out. The study produced encouraging results and confirmed the production of satisfactory SCGC with acceptable physical and mechanical properties. Based on the results reported in this study, the following conclusions are drawn:

1. **Effect of salient synthesis parameters on fresh properties and compressive strength of SCGC**

    - The workability of freshly prepared SCGC was dependent on the amount of extra water and dosage of superplasticizer and found to have least effect on the concentration variation of sodium hydroxide. With the increase in the contents of extra water (from 10% to 20%) and superplasticizer (from 3% to 7%), the fresh properties of fly ash-based SCGC were improved; however, the workability of SCGC was slightly decreased as the sodium hydroxide concentration was increased from 8M to 14M.

    - Extra water, superplasticizer, concentration of sodium hydroxide, and curing time and temperature played an important role in the geopolymer synthesis and significantly affected the compressive strength of fly ash-based SCGC. The compressive strength of SCGC increased with the increase in superplasticizer content and time of curing. However, it decreased substantially as the amount of extra water in the mix increased. On the other hand, the compressive strength of SCGC was increased as the sodium hydroxide concentration increased from 8M to 12M and concrete specimens were cured at temperatures from 60°C to 70°C. Further increase in sodium

hydroxide concentration and curing temperature however resulted in decrease in the compressive strength of SCGC.

## 2. Physical and Mechanical properties of SCGC

- The density values of SCGC were comparable to that of OPC-based mix, indicating good self-compaction of SCGC. On average, the density of SCGC was 2332 kg/m$^3$, which was close to the value of 2365 kg/m$^3$ exhibited by OPC mix and well within the range of 2240-2400 kg/m$^3$, prescribed for normal strength Portland cement concrete.

- SCGC mix specimens displayed better performance with regard to water absorption and produced low water absorption values than OPC-based mix. On average, the water absorption of SCGC was 2.84%, which was relatively lower than the value of 4.41%, achieved by OPC mix and the limit of 3% specified for good concretes.

- SCGC mix specimens produced higher compressive strengths at 3 and 7 days, but lower at 90 and 180 days while at 28 days, SCGC mix developed almost similar strength to the control OPC mix. The splitting tensile strength of fly ash-based SCGC was only a fraction of its compressive strength, as in the case of conventional cement concrete. On average, the splitting tensile strength of SCGC was about 8.11% of its compressive strength, which is in good agreement with the range reported for normal strength Portland cement concrete. However, the flexural strength of SCGC was about 8% of its compressive strength, which is slightly lower than the range of 10-20% assigned for conventional cement concretes.

- SCGC mixes generally exhibited lower values of static modulus of elasticity than the OPC concrete mix. After 28 days, the modulus of elasticity of SCGC mixes were 21.40 and 22.34 GPa, respectively compared to OPC mix, which displayed 28.26 GPa. These values were around 20% to 25% lower than the associated OPC mix. The values of Poisson's ratio for all of the SCGC samples fallen between 0.109 and 0.155, which were close to the range of 0.15 to 0.22 assigned for normal strength Portland cement concrete.

- Heat-cured fly ash-based SCGC displayed very low creep and drying shrinkage compared to water-cured OPC-based concrete. After one year of loading, the creep coefficient of SCGC was around 0.68 to 0.70, while the specific creep was about 33.80 to 35.07 με/MPa. These values were about 50-60% of those experienced by OPC control concrete. On the other hand, after one year of exposure, the drying shrinkage strains of SCGC mix ranged between 141 and 159 microstrains compared to the value of 466 microstrains, experienced by control OPC mix. These values were about 65-70% lower than that of OPC concrete.

**3. Development of SCGC**

- In conclusion, the objective of producing SCGC with the incorporation of Fly ash has been achieved. The 28-days compressive strength targeted (> 40 MPa) was also obtained in this research.

## 5.2 Recommendations for Future work

SCGC represents an opportunity to simultaneously improve both environmental and engineering performance compared to traditional Portland cement concrete. Although the present research has manifested the high potential of this new binding material that could be used in the near future, yet before implementing SCGC into the construction industry, much research needs to be conducted. Some of the potential areas for the future research are as follows:

1. The findings of this research indicated that the flexural strength and elastic modulus of SCGC were lower than those of conventional OPC-based concrete. A more elaborate study on elastic behaviour of SCGC could be performed by incorporating different types and contents of coarse aggregate. This would be beneficial in determining the precise elastic characteristics of SCGC as a composite material.
2. SCGC was produced in a way suitable for pre-cast applications by using oven curing, but the research can be extended to make this potential construction material for cast-insitu applications.

3. An examination into the use of different other Al-Si rich source materials (such as Metakaolin, GGBFS) and/or the use of a ‘cocktail’ of these materials into the mechanical behaviour of SCGC would be interesting for the future studies.
4. To use the advantages of SCGC efficiently, an in-depth analysis into the durability of SCGC, which may include examining the attacks by external chemical agents, corrosion of reinforcement embedded in SCGC and potential issues regarding expansion due to alkali-aggregate reaction, should be performed.
5. To fully commercialize the concrete, future research studies regarding the structural behaviour of SCGC are required to be done.