A review on durability properties of alkali activated composites

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Abstract: Global warming predominantly caused due to greenhouse gas emission from the cement manufacturing industry is associating climate changes. Thus, these has allured researchers towards alkali activated composite customarily known has geopolymer concrete. At this moment in time the researchers are in an unremitting process to ameliorate the durability properties of concrete. As durability of concrete chiefly sway the services viability of structural element, hence this property has a vital role. In these review paper the various durability properties of geopolymer concrete has been explored. The review of literature divulged that the production of geopolymer concrete necessitate substantial case unerring composition. The various parameters like activator to binder ratio, activator ratio, molarity, water to solid ratio, type of source materials and their proportions govern the durability property of geopolymer concrete. The various researchers in the field of GPC had concluded that geopolymer concrete had astounding property compare to cement based traditional concrete.

1. INTRODUCTION

Concrete is paramount construction material employed globally and it is second most consumed material after water [1]. 4 to 8 MJ of fossil fuel is required to produce 1 kg of Ordinary Portland Cement (OPC) [1]. 1T carbon dioxide (CO2) is liberated during production of 1T of cement [3]. Therefore, in order to eliminate the aftermath of OPC, geopolymer concrete (GPC) can be employed [4]. GPC is a cement free concrete which mainly uses source materials such as geological materials (naturally available materials) like metakaolin (MK) or the by-product of industries such as low calcium fly ash (LF), Ground granulated blast furnace (GGBS), Silica fume (SF) etc [5,6]. Along with source materials it mainly employs activators such as combination of potassium based silicate and hydroxide or sodium based silicate and hydroxide [7,8].Nevertheless, it obligatory to distinctly quantify the influence of source materials and activators on durability performance of GPC.

There is no standard mix design and code of practice for GPC, this is mainly due to inconstant idiosyncrasy of source materials [9]. The production of GPC majorly hinges on parameter such as activator to binder ratio, activator ratio, molarity, water to solid ratio, type of source materials and their proportions [4]. Consequently, it becomes necessary to optimize these parameters to achieve GPC with ameliorated property. Various investigations on mechanical properties of GPC have been carried out by various researchers. But the scrutiny on durability performance of GPC is limited. The paper centralizesthe various durability research inquiry by various researchers has been considered and discussed.
2. DURABILITY PERFORMANCE OF GPC

The various durability test conducted by various researchers are elaborated in this section. The different durability tests were conducted as per Indian Standards, American Standards, German Standards and British Standards.

2.1. ABRASION RESISTANCE TEST
The test assists to determining the ability of concrete to endure being worn away by rubbing. N Gansan et al (2015) [10] conducted test as per IS1237 [11] on GPC specimens having thickness 2.5 cm and area 50 cm^2. The test result concluded that geopolymer concrete with 1% steel fiber had better resistance to average wear. V K Nagaraj et al (2018) [4] performed the test as per IS 1237 on 70.6 X 70.6 X 40 mm self compacting geopolymer concrete (SCGC) test specimen. The Author concluded that the mix with AR= 2 and 12M had predominant resistance to abrasion. V K Nagaraj et al (2018) [3] carried out the test as per IS 1237 on 70.6 X 70.6 X 40 mm SCGC test specimen. The test result described that increase in LFlowered the abrasion resistance of SCGC.

2.2. RAPID CHLORIDE PENETRATION TEST (RCPT)
N Ganesan et al (2015) [10] carried out the test as per ASTM C 1202 [12] on 100 mm diameter and 50 mm thickness GPC samples. The result indicated that increase in steel fibers in GPC increased the RCPT results. Part Wei Ken et al (2015) [13] performed the test as per ASTM C 1202 [12] on 100 mm diameter and 50 mm thickness GPC samples. The result describes that RCPT is not suitable for GPC. V K Nagaraj et al (2018) [4] carried out the test as per ASTM C 1202 on 100 mm diameter and 50 mm thickness GPC samples. The test result describes that the test is illogical has there was increase in temperature while conducting the test which is contradictory to Ohm’s law. Thus, these test approach is not relevant to investigate Rapid Chloride Penetration of SCGC or GPC. V K Nagaraj et al (2018) [2] carried out the test as per ASTM C 1202 on 100 mm diameter and 50 mm thickness GPC samples. The test result concluded that these tests are ineffective for SCGC or GPC chiefly due to very high concentration of alkali ion’s present in pore solution. Atabey II (2017) [14] carried out the test as per ASTM C 1202 on 100 mm diameter and 50 mm thickness geopolymer mortar (GPM) samples. The RCPT results describes that increase in sodium based silicate and hydroxide improved the penetration resistance of chlorideion.

2.3. PERMEABILITY TEST
Kolli Ramajee (2014) [15] conducted the test as per IS 3085 [16] on split moulds of size 100 X 100 mm, the test results indicated low co-efficient of permeability for GPC mix having higher molarity. V K Nagaraj et al (2018) [3] performed test as per DIN 1048 [17] on 150 X 150 X 150 mm SCGC cube specimens. The test results indicated that the mix with higher percentage of GGBS had very low permeability. V K Nagaraj et al (2018) [4] performed the test as per DIN 1048 [17] on 150 X 150 X 150 mm SCGC cube specimens. The test result suggested that the use of AR=2 and 12M had lower depth of water penetration. VK Nagaraj et. al(2018) [2] performed test as per DIN1048 [17] on 150 X 150 X 150 mm SCGC cube specimens. The test results indicated that the mix with lowerA/B and higher GGBS reduced the depth of penetration. Chamila Gunasekaraetal(2018) [18] conducted test as per DIN 1048 [17]. The test concluded that GPC had lower permeability with age, this is predominantly due to ongoing geopolymerization.

2.4. SORPTIVITY TEST
R PrasannaVenkatesan et al (2015) [19] conducted the test on as per ASTM C 1585 [20] on 50 mm height and 100 mm diameter GPC specimen. The results concluded that partial replacement of rice husk ash (RHA) in GGBS lowered the cumulated absorption in geopolymer specimen. R Premkumar et al (2019) [21] conducted the test on as per ASTM C 1585 [20] on 50 mm height and 100 mm diameter GPC specimen. The test results concluded that increase in steatite in GPC mix increase the water absorption. VK Nagaraj et. al(2018) [2] performed test as per ASTM C1585.[20] on 50 mm height
and 100mm diameter SCGC specimen. The test concluded that the SCGC specimen with 100% GGBS and A/B = 0.1 had lower initial and secondary absorption. V K Nagaraj et al (2018) [2] performed test as per ASTM C 1585 [20] on 50 mm height and 100 mm diameter SCGC specimen. The test on SCGC result concluded that SCGC mix with 12M and AR=2 had minimal initial and secondary absorption. N Ganesan et al (2015) [10] carried out the test as per ASTM C 1585 [20] on 50 mm height and 100 mm diameter GPC specimen. The test results indicated that the geopolymer concrete mix with high steel fiber had lower absorption and whereas OPC conventional concrete had greater absorption. Table 1 indicates the different durability tests conducted by various authors on alkali activated composites (Geopolymer Concrete).

| Durability tests                  | Author               | Year  | Tested result                                                                 | Ref. |
|----------------------------------|----------------------|-------|-------------------------------------------------------------------------------|------|
| Abrasion resistance test         | V K Nagaraj et al    | 2018  | The mix with 100% GGBS had a better resistance to abrasion with minimal wear 2.05 mm | [3]  |
|                                  | V K Nagaraj et al    | 2018  | SCGC mix with AR= 2 and 12M had minimal wear of 2.15 mm                      | [4]  |
|                                  | N Ganesan et al      | 2015  | GPC specimen had 27% less average wear compare to PPC concrete               | [10] |
| Rapid chloride penetration test   | V K Nagaraj et al    | 2018  | Not suitable test                                                             | [4]  |
|                                  | V K Nagaraj et al    | 2018  | Not suitable test                                                             | [2]  |
| Permeability test                | Atabey et al         | 2015  | Increase in AR and molarity of sodium hydroxide solution improved resistance to chloride ion penetration | [14] |
|                                  | N Ganesan et al      | 2015  | GPC mix without steel fibers had charged passed of 1321C which is described as low chloride ion permeability as per ASTM C 1202 | [10] |
|                                  | V K Nagaraj et al    | 2018  | SCGC mix with A/B= 0.1 and 100% GGBS had a low depth of penetration of 10.5 mm | [2]  |
|                                  | V K Nagaraj et al    | 2018  | The mix with 100% GGBS had low depth of penetration of 10 mm                  | [3]  |
|                                  | V K Nagaraj et al    | 2018  | The mix with AR= 2 and 12M had minimal depth of penetration of 11.5 mm       | [4]  |
|                                  | Chamila Gunsekara et al | 2017 | Increase in age of GPC reduced depth of water penetration                   | [17] |
|                                  | KolliRamajee et al   | 2014  | The mix with 16M, mix proportion of 1:1.35:3.16 and W/S = 0.35 had low coefficient permeability of 0.18x10^{-9} m/s | [15] |
| Sorptivity test                  | R Premkuma et al     | 2019  | The GPC mix with 100% LF had sorptivity of 1 mm/min^{1/2}                    | [21] |
|                                  | V K Nagaraj et al    | 2018  | SCGC specimen with 100% GGBS and A/B=0.1 had initial absorption of 0.0015 mm/sec^{1/2} and secondary absorption of 0.0002 mm/sec^{1/2} | [2]  |
|                                  | V K Nagaraj et al    | 2018  | SCGC specimen with 12M and AR= 2 had initial absorption of 0.0012 mm/sec^{1/2} and secondary absorption of 0.0002 mm/sec^{1/2} | [4]  |
3. CONCLUSION

- With absolute elimination of OPC, the CO2 emission by cement industries can be completely terminated.
- The geological materials and by-product of industries can be constructively employed to produce GPC.
- The various parameters like activator to binder ratio, activator ratio, molarity, water to solid ratio, type of source materials and their proportions govern the durability property of geopolymer concrete.
- From the literature it is clearly observed that the tested results indicated that GPC had better durability performance compared to OPC concrete.
- It can be concluded that GPC has a promising feature.

REFERENCES

[1] Nuruddin M F, A B Malkawi, A Fauzi, Mohammed B S and Almattarneh H M, 2016 IOP Conference Series: Materials Science and Engineering133 012021.
[2] Nagaraj V K and VenkateshBabu D L, 2018 Asian Journal of Civil Engineering191021– 1036.
[3] Nagaraj V K and VenkateshBabu D L, 2018 AIP Conference Proceedings 2039 020064.
[4] Nagaraj V K and VenkateshBabu D L, 2018 Journal of Building Engineering20137-155.
[5] Santa R A A B, Soares C and Riella H G 2016, Journal of Hazardous Materials318145-153.
[6] Nematollahi B, Sanjayan J and Shaikh F U A, 2015 Ceramics International 5696-5704.
[7] Nematollahi B, Ranade R, Sanjayan S and Ramakrishnan, 2017 Archives of Civil and Mechanical Engineering 17 55-64.
[8] Phummiphan I, Horpibulsuk S, Rachan R, Arulrajah A, Shen S L and Chindaprasirt P, 2018 Journal of Hazardous Materials341 257-267.
[9] Park Y M, Yang T Y and Yoon S Y, 2007 Materials Science and Engineering A454 518-522.
[10] Ganesan N, Ruby Abraham and Deepa Raj S, 2015 Construction and Building Materials 93 471-476.
[11] IS 1237:1980, Indian standard, Specification for cement concrete flooring tiles.
[12] ASTM: C 1202-97, Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration.
[13] Part, Wei Ken, Mayyuddin Ramli, Cheah, Chee Ban, 2015 Construction and Building Materials77 370-395.
[14] Atabey II, 2017 Dissertation, Erciyes University.
[15] KolliRamujee, 2014 Indian Concrete Journal88 34-43.
[16] IS 3085:1965, Indian standard, Method of test for permeability of cement concrete mortar and concrete.
[17] DIN 1048:1991, Testing concreter, testing of hardened concrete (specimens prepared in mould).
[18] Chamila Gunasekara, Sujeeva Setunge, David W. Law and Nick Wills, 2018 Journal of Materials in Civil Engineering 30 04018299.
[19] PrasannaVenkatesan R and Pazhani K C, 2015 KSCE Journal of Civil Engineering20 pp2384–2391.
[20] ASTM: C 1585-13, Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes.
[21] Premkumar R, Ramesh Babu Chokkalingam, M Shanmugasundaram, 2019 IOP Conference Series: Materials Science and Engineering561 012055.