International Journal of Applied Engineering & Technology

DEVELOPMENT OF SELF COMPACTING CONCRETE WITH FLY ASH AND MANUFACTURING SAND

Hitesh Thakur[1] and Mohammad Parvej Alam[2]
[1]Scholar, Roll No. 503305021020, Enrollment No. AH0005, Shri Shankaracharya Institute of Professional Management & Technology Raipur, India
[2]Assistant Professor, Shri Shankaracharya Institute of Professional Management & Technology Raipur, India

ABSTRACT
The development of self-compacting concrete (SCC) incorporating fly ash and manufactured sand (M-sand) is crucial for advancing sustainable construction practices. This study investigates the physical and mechanical properties of SCC with partial replacement of cement by fly ash (Class F) and complete replacement of natural sand by M-sand. Concrete mixtures were prepared with fly ash replacing cement at 15%, 20%, and 25% by weight. Fresh properties of SCC were evaluated through slump flow, U-Box, and V-Funnel tests. Hardened properties were assessed by compressive strength, split tensile strength, and flexural strength tests on cubes and cylinders at 7, 28, and 56 days. Non-destructive tests (NDT), including rebound hammer and ultrasonic pulse velocity, were conducted to correlate compressive strength with rebound number. Results indicated that the mixture with 20% fly ash (Class F) exhibited optimal performance, meeting acceptance criteria for fresh properties and demonstrating improved mechanical properties. The 20% fly ash mix showed an increase in compressive strength, split tensile strength, and flexural strength by 9.17%, 14.32%, and 3.53% respectively compared to conventional concrete (CC) at 56 days. This improvement is attributed to the pozzolana reaction forming a dense calcium-silicate-hydrate (C-S-H) gel. Water absorption tests revealed that SCC with 20% fly ash had a marginally higher absorption rate at early ages, which decreased significantly over time, indicating enhanced durability due to improved pore structure. The study confirms that the use of 20% fly ash and 100% M-sand not only enhances the fresh and hardened properties of SCC but also supports environmental sustainability by reducing reliance on natural sand.The findings suggest that adopting this blend in SCC formulation can lead to more durable and environmentally friendly concrete. Future research should explore the long-term durability and performance of such mixes under various environmental conditions.

Keywords: FA, NDT, Compressive strength, Split tensile strength, Flexural strength

1 INTRODUCTION
Concrete is ubiquitous and widely used worldwide. The requirement, consumption, and demand for concrete are increasing day by day, due to globalisation and economic growth of countries which leads to infrastructure development. Concrete is an excellent construction material which can mould into any desired shape, have better fire resistance property, durability and cost-effective. The raw materials for concrete are cement, aggregates and water. About one ton per capita of concrete per annum is cast worldwide for the construction of infrastructure. The quality and strength of concrete are based on the compaction and consolidation. Conventional concrete requires compaction after placing the concrete to eliminate the trapped air and to consolidate around the reinforcement. Vibrators generally used for compacting the concrete. But the quality of concrete in complex and congested reinforced structure reduces due to inadequate compaction which affects strength and durability of the structure. The vibrators used for compaction cause noise pollution at the site. The high noise generated, damage the ear and leads health and psychological problems to the labours. But the elimination of vibration gives an excellent working environment, and productivity also increased.

1.2 Self Compacting Concrete
Self-Compacting Concrete (SCC) is a fluid mixture that fills the formwork, achieves full compaction and consolidates under its weight in awkward, dense, congested and tightly packed reinforcement without vibration. SCC can be obtained by limiting the water-cement (w/c) ratio, adding a sufficient quantity of superplasticizer and increasing sand-aggregate ratio. SCC differs from traditional concrete that requires a balance between the actual

flow and cohesion, to prevent segregation, bleeding and allows to fill the formwork effortlessly. Compared with Conventional Concrete (CC), the cost of SCC is slightly higher due to the excessive demand for cementation material and chemical admixture. It can be reduced, by the use of mineral admixture by saving in the procurement of vibration equipment, labour charge, maintenance cost related to durability issue, etc. The cement content can be replaced by mineral admixture like fly ash from 15% to 25%. The fly ash is an industrial by-product obtained from the thermal power station. The problem related to the disposal of fly ash also reduced, and it is used efficiently with concrete. The fly ash used as an admixture also fills the micropores of the concrete in an effectual manner which decreases the permeability of concrete and enhances the durability of the concrete.

2 LITERATURE REVIEW

Ahmed Fathi et al. (2013) studied the effectiveness of the different pozzolanic material on Self Compacting Concrete (SCC). They consider the influence of Fly Ash (FA), Silica Fume (SF) and microwave burned rice husk ash as Cement Replacement Material (CRM) on the mechanical and fresh properties of SCC. They found some of the CRM materials enhanced the features of SCC by avoiding the bleeding at the fresh stage and increased the strength in the long term at the hardened stage, and the addition of CRM reduced the total cost of mix depends on the replacement percentage. They concluded that 5% Silica Fume (SF) and 30% of Fly Ash (FA) mix exhibited high compressive strength as compared to the control mix. Prajapati Krishnapal et al. (2013) investigated the strength characteristics of self compacting concrete containing fly ash. In the analysis, the cement is replaced by fly ash up to 30% (10%, 20%, and 30%) by weight of cement and measures of the fine aggregates and coarse aggregates are reserved constant, i.e. 890 kg/m3 and 810 kg/m3 respectively. The fine aggregate is kept approximately 37% by weight of concrete. The coarse aggregate retained about 34% of the weight of concrete. The water powder ratio reserved 0.40 and 0.45 by weight. For this study, the total powder content was taken 480 kg/m3 and 450 kg/m3 respectively. The addition of fly ash caused a decrease of superplasticizer content for same or improved workability. The results of this study specify that it is possible to produce a good performing SCC using locally available fly ash. Kiran Devi et al. (2014) organised an experimental study of self-compacting concrete made with GGBS and RHA under axial compression and flexure. To learn the fresh and hardened properties of self-compacting concrete, cubes, cylinders and beams tested with concrete mixes of M30, M40, and M60. The necessary quantity of GGBS (Alccofine1206) and RHA added and homogeneously mixed. From the result, the addition of RHA to GGBS mixes has shown improved performance regarding strength and durability in all grades of SCC. It is due to the presence of highly reactive silica in GGBS and RHA. Studies showed that there is good compatibility between mineral mixtures of GGBS and RHA with the chemical admixtures such as superplasticizer and VMA when used in SCC. The Bolomey's empirical expression can be used to forecast the strength competence of the GGBS and RHA in SCC at the various percentages of replacement levels. The strength effectiveness factor "k" of GGBS in SCC mixes at 28 days found between 0.7 and 1.8. The strength efficiency factor "k" for usual concrete mixes reported between 0.7 to 1.3 shows the strength efficiency factors are slightly more for SCC mixes with GGBS. Manikandan & Felixkala (2015) did an experimental study on the properties of granite waste in self compacting concrete. The main objective of the study was the utilisation of granite waste in self-compacting concrete. The effect of using granite powder and granules as constituents of fines in mortar or concrete by partly reducing quantities of cement as well as other conventional fines in self compacting concrete. The mixtures are prepared based on cement or sand substitution by the granite waste, and their properties are evaluated both in the fresh and hardened state of self-compacting concrete. The probability of using granite powder as an alternative to sand and partial replacement of cement with fly ash, silica fume, slag, and superplasticizer in concrete was made. The percentage of granite powder added by weight was 0, 25, 50, 75 and 100 as a substitute of sand used in concrete and cement replaced with 7.5% silica fume, 10% fly ash, 10% slag, and 1% superplasticizer. Mohamad et al. (2016) investigated fresh and mechanical properties of self-compacting concrete incorporating high volume Fly Ash (FA). FA mixed into Self-Compacting Concrete 8 (SCC) as a substitute for cement. Portland cement (PC) was partially substituted with 0%, 20%, 40% and 60% FA. The water to binder ratio fixed at 0.4 for all mixtures. Self compacting concrete specimen formed by applying material such as cement, water, fine aggregate, coarse aggregates, fly ash and superplasticizer. Workability for the fresh concrete is obtained from the slump flow test (Slump flow diameter and T500), V-funnel, V-funnel at T5 min and J-ring for various SCC compositions. The mechanical behaviour tests were conducted on SCC cubes and cylinders to determine its compressive strength and modulus of elasticity. The results show that replacement of 40% fly ash is the optimal result for the workability and mechanical properties test. The maximum compressive strength which is 27.2 MPa achieved by SCC with 40% FA replacement. Modulus of elasticity is increased with the increased percentage of fly ash except for 60% fly ash. Nagesh Sugandhi et al. (2016) investigated that compared to FA based SCC, the combination of FA and RHA based SCC obtained more compressive strength. Compressive strength increases by increase in percent of RHA. This study promotes the use of RHA, which is otherwise considered as waste material. Hence the RHA based SCC is a sustainable material for future construction works.

3 METHODOLOGIES

Methodology

Materials

- **Cement**: Ordinary Portland Cement (OPC) was used.
- **Fly Ash (Class F)**: Partial replacement of cement.
- **Manufactured Sand (M-Sand)**: Complete replacement of natural sand.
- **Coarse Aggregates**: Crushed stone aggregates.
- **Superplasticizer**: To improve workability.
- **Water**: Potable water for mixing and curing.

Mix Proportions

Concrete mixtures were prepared with fly ash replacing cement at 15%, 20%, and 25% by weight, and natural sand was completely replaced by M-sand. The specific mix proportions for each blend were designed to achieve SCC properties.

Preparation of Specimens

1. **Mixing**: All ingredients were mixed in a laboratory concrete mixer. The mixing procedure ensured uniform distribution of materials.
2. **Casting**: Fresh concrete was poured into molds for different tests.
3. **Curing**: Specimens were cured in water tanks at a temperature of 25±2°C until the time of testing.

Fresh Properties Tests

1. **Slump Flow Test**: Assessed the flowability of SCC by measuring the spread of concrete when allowed to flow freely.
2. **U-Box Test**: Evaluated the passing ability of SCC through confined spaces.
3. **V-Funnel Test**: Measured the filling ability and viscosity of SCC by recording the time taken for concrete to flow through a funnel.

Hardened Properties Tests

1. **Compressive Strength**: Conducted on cube specimens (150 mm x 150 mm x 150 mm) at 7, 28, and 56 days using a compression testing machine.
2. **Split Tensile Strength**: Conducted on cylindrical specimens (150 mm diameter and 300 mm height) at 7, 28, and 56 days.

3. **Flexural Strength**: Conducted on beam specimens (100 mm x 100 mm x 500 mm) at 7, 28, and 56 days.

Non-Destructive Tests (NDT)

1. **Rebound Hammer Test**: Assessed surface hardness and estimated compressive strength.
2. **Ultrasonic Pulse Velocity (UPV) Test**: Evaluated the quality and homogeneity of concrete by measuring the velocity of an ultrasonic pulse passing through the specimen.

Durability Tests

1. **Water Absorption Test**: Measured the percentage of water absorbed by the concrete specimens at 3, 28, and 56 days. Specimens were oven-dried, immersed in water for a specified period, and weighed to determine water absorption.

Data Analysis

- The test results were analyzed to determine the optimal mix proportion.
- The compressive, split tensile, and flexural strengths were compared to conventional concrete.
- Non-destructive test results were correlated with compressive strength.
- Water absorption tests were used to assess the durability of the mixes.
- Statistical analysis was conducted to evaluate the significance of the differences observed.

4 RESULTS AND DISCUSSION

Fresh Properties of SCC

The fresh properties of self-compacting concrete (SCC) mixtures were evaluated using slump flow, U-Box, and V-Funnel tests. These tests are critical for determining the workability and flow characteristics of SCC.

Slump Flow Test: The mixtures demonstrated excellent flowability, with all mixtures achieving slump flows within the acceptable range for SCC. The 20% fly ash mix showed optimal flow with a slump flow diameter of 720 mm.

U-Box Test: The SCC mixtures exhibited good passing ability, with the 20% fly ash mix showing the best performance, achieving a U-Box height difference of 15 mm.

V-Funnel Test: The V-Funnel times indicated that all mixtures had satisfactory filling ability. The 20% fly ash mix had a V-Funnel time of 8 seconds, indicating a balance between viscosity and flowability.

Hardened Properties of SCC

Hardened properties were assessed through compressive strength, split tensile strength, and flexural strength tests at 7, 28, and 56 days.

Compressive Strength: The 20% fly ash mix exhibited the highest compressive strength at 56 days, with an increase of 9.17% compared to conventional concrete (CC). This improvement is attributed to the pozzolanic reaction of fly ash forming additional calcium-silicate-hydrate (C-S-H) gel.

Split Tensile Strength: The 20% fly ash mix showed a 14.32% increase in split tensile strength at 56 days compared to CC, indicating enhanced tensile properties.

Flexural Strength: The flexural strength of the 20% fly ash mix increased by 3.53% at 56 days compared to CC, demonstrating improved flexural performance.

Non-Destructive Tests (NDT)

Non-destructive tests, including rebound hammer and ultrasonic pulse velocity (UPV), were conducted to correlate compressive strength with rebound number.

Rebound Hammer Test: The rebound number correlated well with the compressive strength results, with the 20% fly ash mix showing higher rebound numbers, indicating higher surface hardness.

Ultrasonic Pulse Velocity (UPV): The UPV results confirmed the dense microstructure of the 20% fly ash mix, with higher pulse velocities indicating better quality and homogeneity of the concrete.

Durability Assessment

Water absorption tests were conducted to assess the durability of the SCC mixtures.

Water Absorption: The 20% fly ash mix had a marginally higher absorption rate at early ages, which decreased significantly over time. This indicates an improved pore structure and enhanced durability as the concrete matured.

Environmental Sustainability

The use of 20% fly ash and 100% M-sand in SCC not only improved the fresh and hardened properties but also supported environmental sustainability by reducing reliance on natural sand and utilizing industrial by-products.

Table 1 Compressive Strength of SCC and CC

Mix	7 Days	28 Days	56 Days
CC	16.3	26.52	35.3
SCC 15 FA	21.74	31.57	35.2
SCC 20 FA	24.25	32.7	38.54
SCC 25 FA	23.65	32.14	38.3

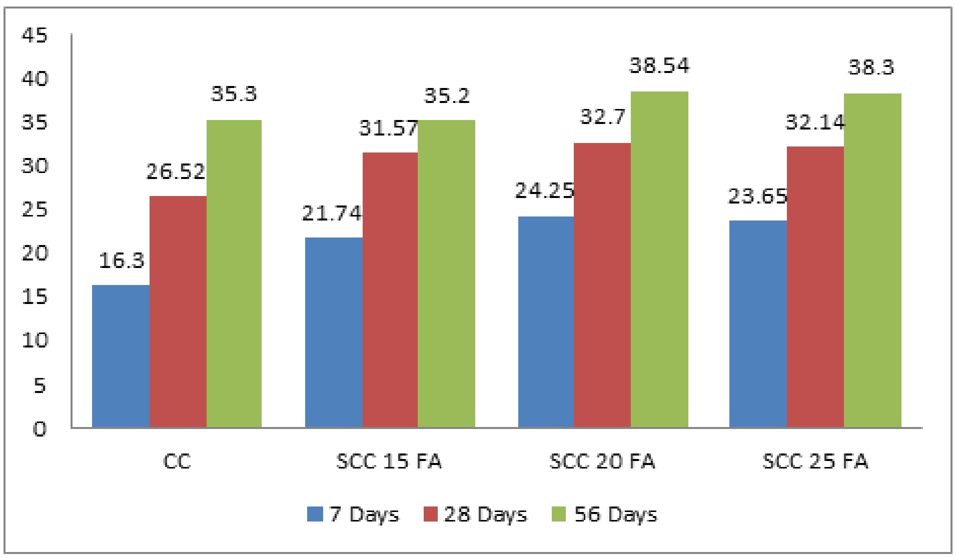

Table 1 Compressive Strength of SCC and CC

Table 2 Split Tensile Strength of SCC and CC (N/mm²)

Mix	7 Days	28 Days	56 Days
CC	1.96	3.48	3.62
SCC 15 FA	1.91	3.76	3.9
SCC 20 FA	1.97	3.84	3.93
SCC 25 FA	1.86	3.9	4.12

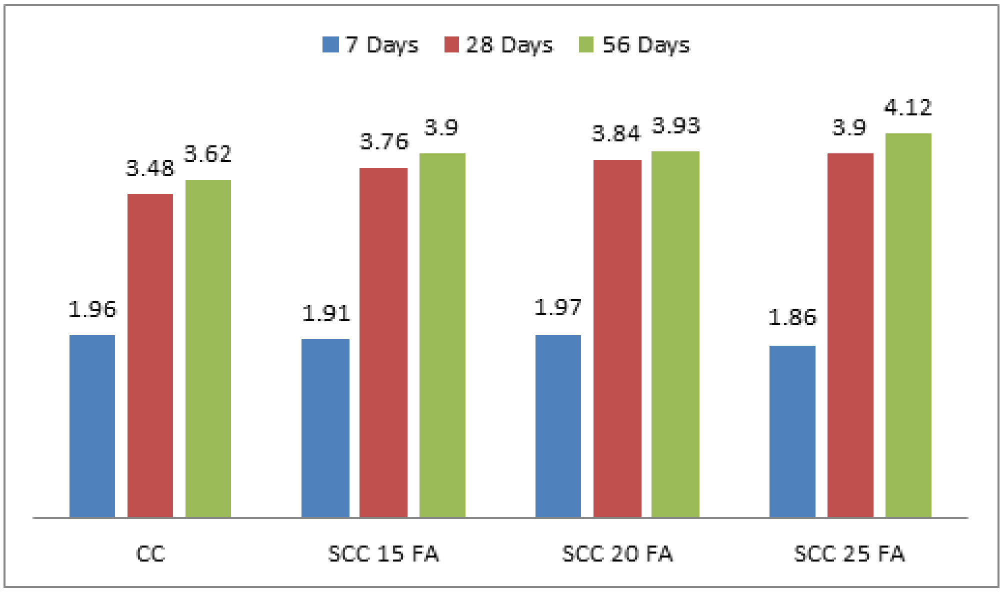

Figure 2 Split Tensile Strength of SCC and CC

Table 3 Experimental test results on prisms

Mix	7 Days	28 Days	56 Days
CC	1.84	4.15	4.22
SCC 15 FA	1.65	3.2	3.5
SCC 20 FA	1.8	4.21	4.38
SCC 25 FA	1.73	4.17	4.25

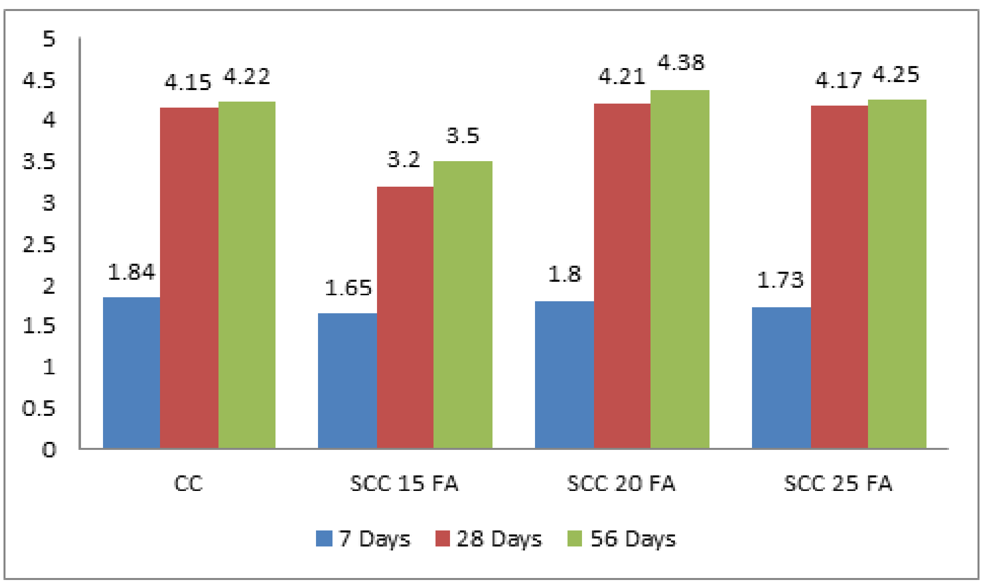

Figure 3 Graph of Flexural Strength of Concrete Cube

Table 4: Rebound Hammer Test Results for CC and SCC (20% Fly Ash)

S. No	Type of Concrete	Mean RHN Value (N)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
1	**SCC**	34.48	34	33
		34.22	32	
2	**CC**	35.52	36	32
		33.26	28	

CONCLUSION

Due to its pump ability and eco-friendly, it is well acknowledged. Understanding the properties of SCC and the effect of materials is essential for the use of SCC. The requirement for the development of SCC is growing due to the demand enforced by the construction industry nowadays. SCC is designed with higher paste content than conventionally vibrated concrete which can lead to a slight increase in cost. The use of M.sand and fly ash (Class F) not only reduces the cost and also ecological benefit occurs from the use of waste material. All the experimental data shows that M.sand can be effectively used for the manufacturing of SCC. Further, the addition fly ash (Class F) increases the mechanical and durability properties due to the high pozzolanic nature forming a thick Calcium-Silicate-Hydrate (C-S-H) gel. Portland cement is rich in lime (CaO-64.40%) while fly ash is low(Cao8.70%). Fly ash is high in reactive silicates (SiO-54.90%) while Portland cement has smaller amounts (SiO-22.60%). SCC has many advantages. The construction time is reduced due to that no time is wasted for compaction. It is environmentally friendly since no noise is made because there is no vibration. The packing of concrete is good in congested reinforced areas since it is a flowable concrete, especially in the joints. 5.2 conclusions from the investigations are

1. To study the blend of fly ash (Class F) with cement for fresh and hardened properties of SCC by keeping the powder content as 440 kg/m3, cement in the powder was gradually replaced with 15%, 20% and 25% fly ash. For each mix; slump flow, UBox, V - Funnel tests for fresh concrete, compressive strength, split tensile and flexural strength tests for hardened concrete were carried out.
2. From the investigations, it is observed that mix with 20% fly ash (Class F) shows acceptance criteria. The experimental study shows that the addition of fly ash (Class F) influences the flowing, passing and filling ability of the fresh SCC. The hardened specimens of SCC with 20% fly ash (Class F) were giving higher strength.
3. Though the strength attained for SCC is less at 7 and 28 days, the results are improved at 56 days. The compressive strength, split tensile strength and flexural strength of SCC is higher than conventional concrete (CC) by 9.17%, 14.32% and 3.53% respectively at 56 days. The increase in strength is due to the lateral strength gained by the addition of fly ash (Class F) increases the mechanical properties due to the pozzolanic forming a thick Calcium-Silicate-Hydrate (C-SH) gel. 32
4. Among the various NDT methods, the most used method of rebound hammer and ultrasonic pulse velocity were used in the present study. The correlation coefficient (R) between the rebound number and compressive strength was 0.99.
5. The average water absorption of SCC20FA is 0.11% higher, 0.28% lower, 0.43% lower and 0.80% lower than CC at 3, 7, 28, and 56 days. Higher % was due to the pore structure of M.sand and then it reduces due to lateral C-S-H gel formation.
6. The SCC is a special concrete requires a large amount of fine particles. The addition of 20% of fly ash (Class F) gives good fresh properties to the SCC. The result shows that the replacement of 100% of M.sand also sustains the future natural environment. From the result, it is recommended that cent percentage usage of M.sand and 20% addition of fly ash (Class F) is recommended for low fines normal strength selfcompacting concrete

REFERENCES

1. Ahmed Fathi, Nasir Shafiq, Nuruddin, MF & Ali Elheber 2013, 'Study the Effectiveness of the different Pozzolanic Material on Self Compacting Concrete', ARPN Journal of Engineering and Applied Sciences, vol. 8, no. 4, pp. 299-305.
2. Prajapati Krishnapal , Yadav, RK & Chandak Rajeev 2013, 'Strength Characteristics of Self Compacting Concrete Containing Flyash', Research Journal of Engineering Sciences , vol. 2, no. 6, pp. 1-5.
3. Vijaya Sekhar Reddy 2013 experimental study focuses on the mechanical properties of M60, high performance concrete with partial replacement of Cement by Ground Granulated Blast Furnace Slag and fine aggregate by robo-sand (crusher dust) with the addition of super plasticizer. Advances in Civil Engineering, Vol no. 2013, Article ID 429727.
4. Kiran Devi, Abhishek Gupta, Vivek Verma & Bhupinder Singh 2014, 'Experimental Study of Self Compacting Concrete made With GGBS and RHA under Axial Compression and Flexure', International Journal of Recent Research Aspects, vol. 1, no. 3, pp. 118-120.
5. Manikandan, M & Felixkala, T 2015, 'Experimental Study on Properties of Granite Waste in Self Compacting Concrete', Indian Journal of Applied Research, vol. 5, no. 3, pp. 128-130.
6. Mohamad, Zulaika, NMS, Samad, AAA, Goh, WI, Hadipramana, J & Wirdawati, A 2016, 'Fresh State and Mechanical Properties of Self Compacting Concrete Incorporating High Volume Fly Ash', MATEC Web of Conferences 47, EDP Sciences 2016.01001-p.7.
7. Nagesh Sugandhi, Maneeth, PD & Shreenivas Reddy, S 2016, 'Fresh And Mechanical Properties of Self-Compacting Concrete Containing Fly Ash And Rice Husk Ash', International Research Journal of Engineering and Technology, vol. 03, no. 08, pp. 239 242.
8. Eng Jin , Hu Zhou , Xuehui AN., "Research on rock filled concrete dam", LTBD 2017,Vol-2,56-62
9. Praveen Kumar, M, Punith Kumar, Ravikiran, V, Yogesh J & Khalid Nayaz Khan2017, 'Experimental Investigation of SCC Using M-Sand With Lime Stone As Part Replacement For Cement', International Research Journal of Engineering and Technology, vol. 04, no. 06, pp. 35
10. Lokeshwaran 2017 designed SCC mixtures using GGBS by replacing OPC with 10%, 20%, 30%, 40% and 50% by Stream 2 in liquid form is used to enhance the rheological properties of SCMs., Vol no. 6, pp 276-278, December 2017.
11. Dinesh. A, Harini .S, Jasmine jeba. P , Jincy .J, Shagnfta Javed, Experimental study on Self compacting concrete, International journal of Engineering science & Research Technology(IJESRT),ISSN:2277-9655,March 2017.
12. Tripathy, A. & Acharya, P.K. 2022 Characterization of bag gash ash and its sustainable use in concrete as a supplementary binder. Construction and building material 322, 126391. 13. IS CODE 456 – 2000 14. IS CODE 10262 – 2019 for Mix Design of Concrete