INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 7, ISSUE 6, JUNE-2016
ISSN 2229-5518

PERFORMANCE AND ECONOMIC FEASIBILITY OF SELF COMPACTING CONCRETE

Eskinder Desta Shumuye[1], Tariku Niguse Keneni[2] and Mikias Wondimu Hundie[3]

[1, 3]school of Water Resources Engineering, School Of Civil Engineering, Hawassa University, Institute of Technology[2], (Ethiopia)

Abstract

Self-Compacting Concrete as the name refers is the concrete requiring a very little or no vibration to fill the form homogeneously. Self-Compacting Concrete (SCC) is defined by two primary properties: Ability to flow or deform under its own weight (with or without obstructions) and the ability to remain Homogeneous while doing so. Flowability is achieved by utilizing high range water reducing admixtures. And segregation resistance is ensured by introducing a chemical viscosity modifying admixture (VMA) or increasing the amount of fines in the concrete. The study explores the use of Rice Husk Ash (RHA) to Increase the amount of fines and hence achieve self-compatibility in an economical way, suitable for Ethiopian construction industry.

The study focuses on comparison of fresh properties of SCC containing varying amounts of RHA with that containing commercially available viscosity modifying admixture. The comparison is done at different dosages of superplasticizer keeping others constant. Test results substantiate the feasibility to develop low cost SCC using RHA. Cost analysis showed that the cost of ingredients of specific SCC mix is 16.25 percent less than that of control concrete. To decrease the cost of SCC, the researchers have applied a 15% replacement of cement with rice husk powder.

Key Words: Admixture, Flowability, Rice Husk Ash, Self-Compacting Concrete

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1. Introduction

Nowadays Ethiopia has become one of the fastest growing countries in Africa, especially the construction industry. Large number of buildings, highways and dams are being constructed. These constructions use conventional concrete which is difficult to compact in congested reinforcement and thin sections such as beam -column intersections.

Furthermore, conventional concrete requires vibration, which results escalating the running cost. These problems led to adapt self -compacting concrete. Self-compacting concrete (SCC) is a highly flowable and non-segregating concrete that can flow in to place, fill the form work and achieve full compaction without vibration even in the presence of congested reinforcement (Okamura H. June 25, 1995). The elimination of vibrating equipment protects the environment especially near construction site where concrete is being placed.

Self-compacting concrete has economic, social, and environmental benefits over conventionally vibrated concrete. SCC technology has been rapidly progressing over the last 20 years. As a result, SCC is viewed as a solution to many constructability challenges, such as beam-column and congested reinforcement (Nan Su March 31, 2001).

The need to reduce the high cost of Pozzolana Portland Cement in order to provide accommodation for the populace as intensified research into the use of some locally available materials that could be used as partial replacement for Pozzolana Portland Cement (PPC) in Civil Engineering and Building Works.

Supplementary cementitous materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cements are now used in many parts of the world (Bakar, Putrajaya, and Abdulaziz, 2010).

Rice Husk Ash (RHA), which is an agricultural by-product, has been reported to be a good Pozzolana by numerous researchers. Mehta and Pirth (2000) investigated the use of RHA to reduce temperature in high strength mass concrete and got result showing that RHA is very effective in reducing the temperature of mass concrete compared to PPC concrete.

The introduction of SCC in construction industry will improve the durability of concrete. Self-compacting concrete can be used in congested reinforcement and thin sections. It can also be applied in dam and beam-column joints .To make this product economical, Rise husk powder can be used as partial replacement of cement in the application of a dam or in the need of mass concrete construction. As a result, it will helps us to save money and time during the whole construction period.

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ISSN 2229-5518

There are a lot of constructions being developed on many parts of the country especially in the fast growing cities like Hawassa, Bahir Dar, Gondar, Adama, Addis Ababa and other developing cities. Keeping in mind what is mentioned above, self-compacting concrete should be employed in practical structure in order to shorten the construction period at large, by employing self-compacting concrete the cost for vibrating compaction can be saved and the compaction of the concrete into the structure can be assured.

Nevertheless, the advantage of advance technology like SCC has not been recognized in Ethiopia industry. This might be due to lack of knowledge and unavailability standardized manual for the production of SCC (et.al. June 2011).

The aim of this research is to find economical SCC by applying natural mineral admixture, i.e. Rice husk powder obtained as end product of Rice processing factories. It is believed that using this mineral admixture in construction industry will reduce the cost of the cementitous materials and its pollutant nature.

2. Methodology and Materials

This research emphasizes on self-compacting concrete. The methodology followed during the research is reviewing past literature on related documents, discussed with professionals and experimentation for further understanding on material used, mix proportion, and application of SCC.

The primary data for the research work is obtained from experiment, which is carried out in Hawassa University, Institute of Technology: Construction Material Laboratory.

2.1 Portland Pozzolana cement (PPC)

PPC may take a longer time to settle than OPC, but it will eventually produce similar results in a given time, in addition in Ethiopia it is challenging to get OPC for private construction activities this is because OPC is currently sold up on the government request.

2.2 Rice Husk Powder

Presently large amounts of rice husk are generated in natural rice processing plants with an important impact on environment and humans as leaving the waste materials to the environment directly can cause environmental problems. The main concern of using pozzolanic wastes was not only the cost effectiveness but also to improve the properties of concrete, especially durability. The color of RHA may be blue black, gray, or pinkish-white, depending on the combustion process. The darker the ash, the higher the percentage of unburnt carbon. Higher temperatures and longer durations of controlled burning produce RHA with higher pozzolanic properties.
This research describes the application of the rice husk powder in concrete production as partial replacement of cement.

2.3 Coarse Aggregate

Self-compacting Concrete mixtures require special attention to the total gradation of the combined aggregates. The course aggregate used for this research was crushed natural aggregate (maximum size 25 mm) and it was gathered from available quarry sites around Hawassa Area. The nominal maximum size of the coarse aggregate must be chosen with respect to obtaining the desired passing ability and stability of the plastic concrete.

Although typical nominal maximum size of aggregate used in SCC is 19 mm, aggregates as large as 25 mm were presented in the gathered sample. However, since aggregates with a nominal maximum size larger than 25 mm are not recommended for use in SCC, we had to sieve the whole sample to get the suitable nominal maximum size i.e. 19 mm.

Table 1: Test results of Course Aggregate

Test	Result
Unit Weight	1465 kg/m^3
Specific Gravity	2.65
Absorption Capacity	1.62%
Moisture Content	2.25%

2.4 Fine Aggregate

The sand was collected from "Langano" areas, which is around 70 Km far from the study area. We have carried out the appropriate quality tests in order to determine if it is suitable to be applied in the proposed work according to ASTM test standards.

Quality test for silt content of sand was first carried out. The silt content was found to be much greater than the allowable limit i.e. 6% by weight. Therefore, the sand was washed and dried in the exposed sun until it reaches the SSD (Saturated Surface Dry) state. Then the silt content of the washed sand was again carried out. But this time, the silt content was within the allowable value.

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INTERNATIONAL JOURNAL OF SCIENTIFIC & ENGINEERING RESEARCH, VOLUME 7, ISSUE 6, JUNE-2016
ISSN 2229-5518

Figure 1: Sand washed and tested for silt content

Table 2: Test results of fine aggregate

Tests	Results
Silt Content	1.67%
Bulking of Sand	19.4%
Unit Weight	1225Kg/m^3
Specific Gravity	2.44
Absorption Capacity	1.6%
Moisture Content	7.3%

2.5 Water

Impurities in mixing water may affect the cement's setting time, the concrete's strength, corrosion of reinforcement etc. For this research, tap water is used.

2.6 Admixture

Super plasticizer / High range water reducing admixture (HRWR) was used for this research. We applied an admixture named "Mape fluid N300" that is designed to be used for SCC mixtures containing cementitous materials. This admixture conforms to the specification of ASTM C-494 standard.

Figure 2: Superplasticizer used for the SCC mix

3. SCC Mix Proportion

The three primary components of SCC include a properly proportioned mixture designed for the application, an appropriate high-range water reducer (HRWR), and sometimes a viscosity-modifying admixture (VMA). These components can be varied to achieve a wide range of results.

The following mix design approaches were done for designing the SCC mix used in this work. The desired air content was assumed to be 4 % (Moderate weather condition)

- ✓ The w/c ratio was adapted from ACI code for mixing design of SCC i.e. (0.25-0.32)
- ✓ The coarse aggregate volume was selected from (27 –30 % of Concrete)
- ✓ The sand volume was determined to be 43 % of Volume of Paste
- ✓ The maximum amount of cement was taken as 550 Kg/m^3 as per standard of EBCS 2, 1995, 92
- ✓ Amount of SP. was selected from the suggested dosage on the container i.e. (0.5 - 2.0 % of total cementitous material)

Table 3: Trial mix proportion for SCC

Materials	Amount
Cement	630.99
Coarse Aggregate	795
Fine Aggregate	644.64
Water	195
Superplasticizer	1.2%
Air	4%
W/C Ratio	0.31

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Table 4: Trial mix proportion for SCC with Rise Husk Powder

Materials	Amount
Cement	475.82
Rice Husk	68.8
Fine Aggregate	644.39
Coarse Aggregate	795
Water	218.31
Superplasticizer	1.5%
Air	4%
W/C Ratio	0.39

Mix proportions for SCC made with 15% of Rice Husk Powder replacement were also done using the normal SCC mix principles and approaches. But, it has been discovered that the w/c ratio used for normal mix of SCC is not suitable for this mix as the rice husk powder consumes more water than the cement used in normal SCC mix. Since the water amount was not sufficient, the

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ISSN 2229-5518

workability and flow ability of the mix decreased. Therefore, we have increased the w/c ratio to 0.39 and the admixture to 1.5 in order to get the required workability and flow ability of the SC C mix containing rice husk powder.

3.1 Mixing

The type of mixer available in the laboratory was Pan Mixer. We have used this motorized mixer for all of the mixes in this work.

The constituent materials were tested and prepared for the mix before the proposed date of mixing. On the day of mixing, we have made some calculations to correct the moisture content and water absorption value by adding the suitable value of water on the mix as a result of the evaporation that maybe caused due to the surrounding environment impact.

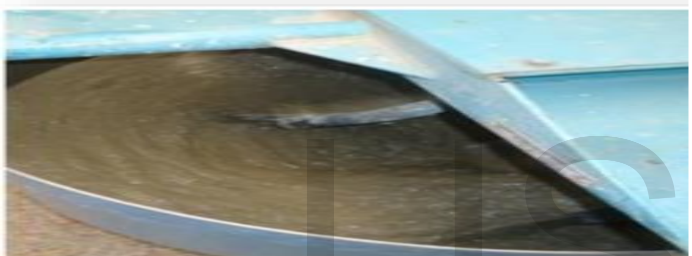

Figure 3: Mixing carried out in a Pan Mixer

3.2 Tests on Fresh SCC

3.2.1 Slump Flow

The slump-flow and T 50cm time is a test used to assess the flow ability and the flow rate of self-compacting concrete in the absence of obstructions. Segregated coarse aggregate was not observed in the central area. Since segregation has not occurred, the test was therefore satisfactory.

Figure 4: Cone apparatus prepared for slump flow test

3.2.2 V-Funnel Test

The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Shorter flow time indicate greater flowability.

Figure 5*:* Test carried out in V-Funnel

3.2.3 L-Box Test

A measured volume of fresh concrete is allowed to flow horizontally through the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured.

Figure 6*:* Test carried out in L-Box

3.3 Tests on Hardened SCC

Compressive tests were done on hardened 15 cm ^{3} samples of SCC cubes using a compression machine that is available in the material lab. The test was done according to ASTM C39.

4. Results and Discussions

4.1 Producing Conventional Concrete

The mix design for the conventional concrete was done using DOE mix design. The format of DOE mix design.

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ISSN 2229-5518

4.1.1 Mix Proportion

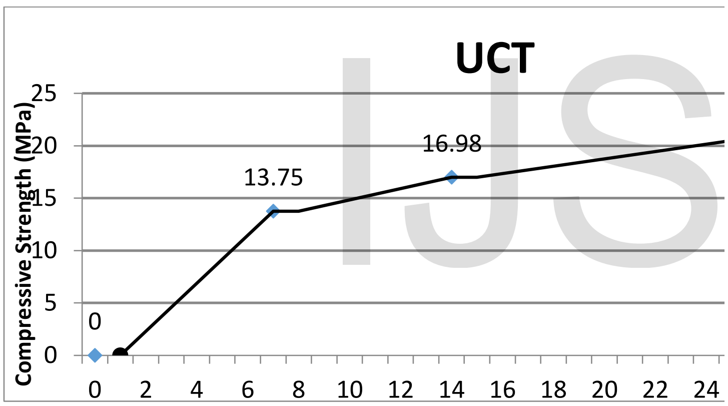
Table 5: Mix proportion of conventional concrete.

Materials	Type	Conventional (kg/m^3)
Cement	PPC	303.52
Fine Aggregate	Uncrushed	736.85
Coarse Aggregate	Crushed	1035.52
Water		170
W/C Ratio		0.56

4.1.2 Test Results for Hardened Concrete

Table 6*:* Compressive strength of conventional concrete

Test Day	Max Fracture Load (KN)	Failure Stress(MPa)
7th	309.37	13.75
14th	375	16.98
28th	484.97	21.56



As shown in the above table, the compressive strength at 28th day decreased from the ordinary C-25 concrete grade. This is because of the poor quality of the material as mentioned above.

4.2 Producing SCC Using PPC

4.2.1 Test Results for Fresh Concrete

Trial mix 2: W/C ratio of 0.31 and SP. 1.2%.

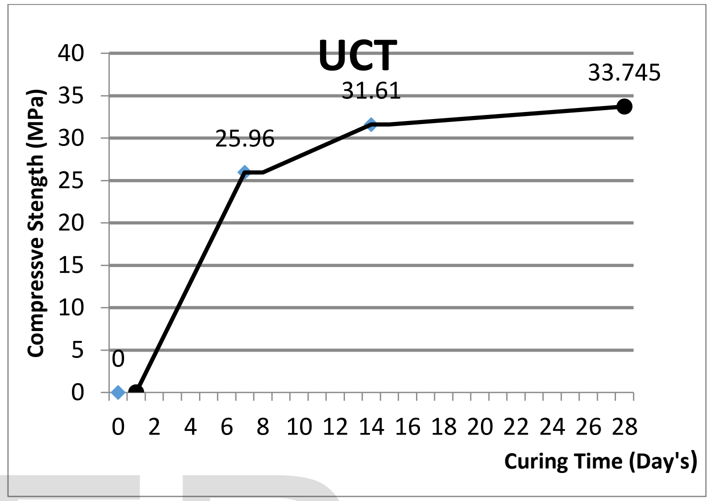
Table 7: Test results for fresh SCC trial mix 2

Test Day	Max Fracture Load (KN)
Slump	675 mm
T_{50}cm	3.5 sec
V-Funnel	10 sec
L-Box	0.83

Compressive Strength for Trial Mix 2

Table 8: Compressive strength of SCC

Test Day	Max Fracture Load (KN)	Failure Stress (MPa)
7^{th}	584.05	25.96
14^{th}	711.15	31.61
28^{th}	751.25	33.745



The SCC mixed with PPC in the first trial did not achieve the fresh property i.e. the pass ability requirement of L-Box. This was due to the lack of workability of the mix. To combat this problem, we designed another mix by increasing the W/C ratio 0.29 to 0.31.

We have also experienced a problem of segregation in the previous mix. There was an accumulation of aggregates around the center of the slump diameter. This was due to dosage of super plasticizer beyond the optimum limit. To overcome this problem, we have reduced the percentage of super plasticizer from 1.3 to 1.2. Trial mix 2 is preferably a suitable mix because it satisfies the fresh properties of SCC.

4.3 Producing SCC Using PPC and Rice Husk Powder

Trial mix 3: W/C ratio of 0.39 and SP. 15%

Table 9: Test results for fresh SCC with Rice husk: trial mix 3

Test Day	Failure Stress (MPa)
Slump	635 mm
T_{50}cm	3.5 sec
V-Funnel	10 sec
L-Box	0.96

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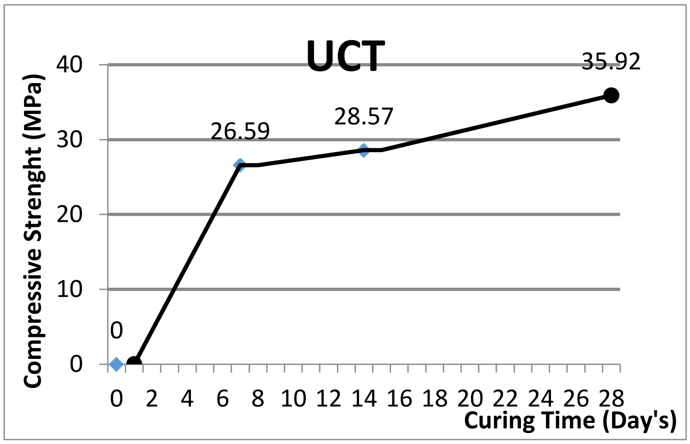
ISSN 2229-5518

4.3.1 Test Results for Hardened Concrete
Compressive Strength for Trial Mix 3

Table 10: Compressive strength of SCC with Rice Husk

Test Day	Failure Stress (MPa)
7th	26.59
14th	28.57
28th	35.92



The mixture of SCC that contains rice husk powder was designed according to the second trial mix of SCC i.e. using a water cement ratio of 0.31 but when we mixed the constituent materials, the mix did not have an SCC texture. Therefore, we have designed the mixture by increasing the W/C ratio to 0.36 and the super plasticizer percentage to 1.3.

The test carried out to determine the compressive strength of the third trial mix i.e. rice husk powder blended concrete after 7th, 14th and 28th days of curing results increased when we compared with that of SCC Mix without Rice husk. This is of course due to the presence of Super plasticizer or High range water reducer and rice husk powder in the mix.

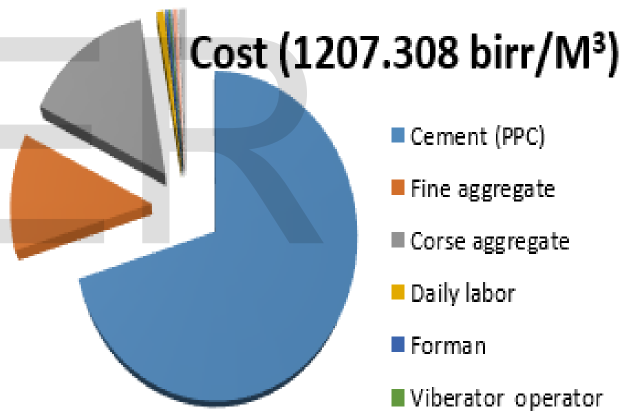
According to James E. O. Overi and Overi P, the self-compacting concrete without introducing rice husk developed compressive strengths ranging from 16.93 to 18.89 MPa at 7 to 28 days with no extra charge. In addition to this B.H.Venkataran and Philips George produced, a self-compacting concrete with addition of 8.65 % rice husk and having a 0.5 W/C developed a compressive strengths ranging from 21.23 to 30.52 MPa at 7 to 28 days.

5. Possible Methods of Cost Minimization

Cost analysis of the materials used, has been analyzed as per the purchased price from the market (as of September 2015 of Ethiopia Currency (Birr)). The mixes selected for calculation and analysis were those, which could pass maximum properties of freshly mixed concrete.

Table 11: Cost estimation for conventional concrete

Ingredient per (m³)	Unit	Quantity	Cost (birr)
Cement (PPC)	Kg/m³	303.52	849.85
Fine Aggregate	Kg/m³	736.85	140.42
Corse Aggregate	Kg/m³	1035.52	181.7
Daily labor	Per Person	10	10.5
Forman	Per Person	01	04
Viberator Operator	Per Person	01	2.084
Mixer Operator	Per person	01	2.084
Viberator	Per day	01	6.25
Mixer	Per day	01	10.42
Sum			1207.308



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ISSN 2229-5518

Table 12: Cost estimation for Self-compacting concrete

Ingredient per (m³)	**Unit**	**Quality (kg/m³)**	**Cost (birr)**
Cement (PPC)	Kg/m³	630.99	1766.77
Fine aggregate	Kg/m³	644.32	122.79
Corse aggregate	Kg/m³	795	139.5
SP	Per liter	7.57	355.8
Daily labor	Per person	8	4.2
Forman	Per person	01	02
Mixer operator	Per person	01	1.042
Mixer	Per day	01	5.21
Sum			2397.312

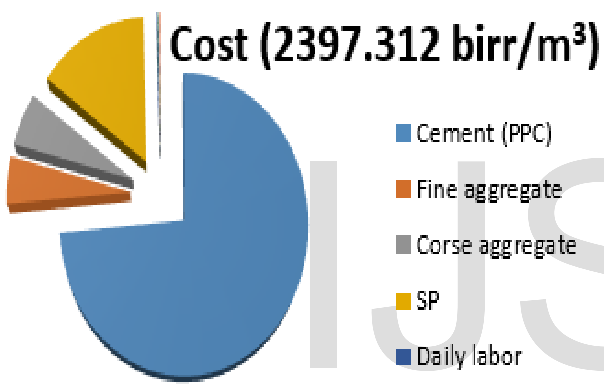

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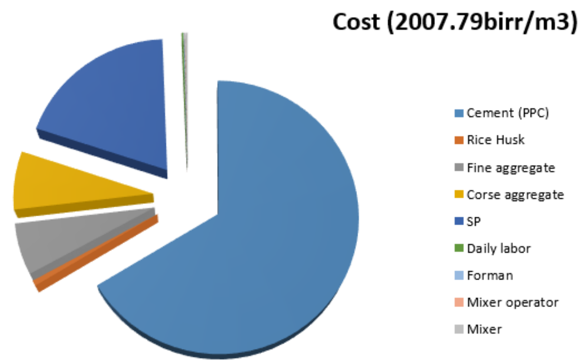
Table 13: Cost estimation for Self-Compacting concrete with mineral admixture.

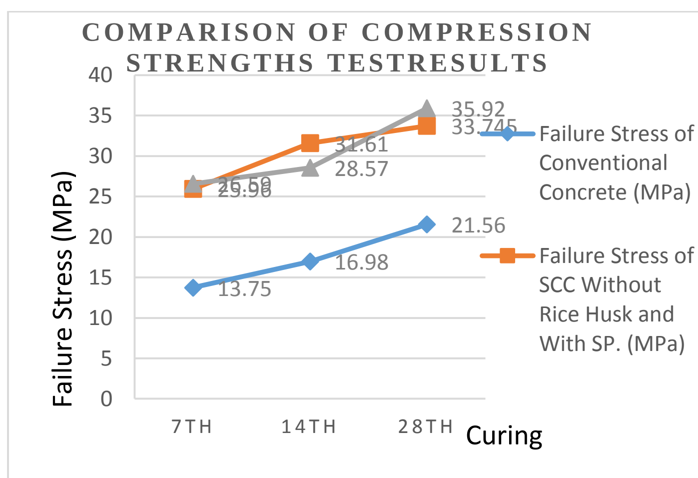
Ingredient per (m³)	Unit	Quality (kg/m³)	Cost (birr)
Cement (PPC)	Kg/m³	475.82	1332.296
Rice Husk	Kg/m³	68.5	13
Fine aggregate	Kg/m³	644.39	122.80
Corse aggregate	Kg/m³	795	139.5
SP	Per liter	8.165	387.75
Daily labor	Per person	08	4.2
Forman	Per person	01	02
Mixer operator	Per person	01	1.042
Mixer	Per day	01	5.21
Sum			2007.79



From the above table it is shows that the conventional concrete cost is almost half the cost of the SCC. This is due to the consumption of cement in SCC is higher than that of the conventional concrete. In order to develop SCC it is necessary to use SP. This leads to an increase in cost from the conventional concrete. Hence, the price of Admixture are very expensive in Ethiopia when we compare to other countries.

The extra cost of the SCC mixture is compensated by production cost efficiencies such as reduction in placing time, vibrator use and maintenance, form maintenance, and improvement worker safety. Placing time is the time it takes to transfer the concrete from the transportation unit to the form and consolidate it. Improved productivity by reducing time, labor, or equipment may easily compensate for additional material costs.

As the result shows the cost of SCC with mineral admixture is less than that of SCC without mineral admixture. This is due to the partial replacement of cement (15 %) with rice husk powder.



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ISSN 2229-5518

6. Conclusion

Taking into account the finding from this study, the following conclusions can be drawn. By using the slump flow and V-funnel tests, that self-compacting concrete (SCC) achieved consistency and self-compactability under its own weight, without any external vibration or compaction.

- The self-compacting concrete with 15% of rice husk developed compressive strengths ranging from 26.59 to 35.92 MPa at 7 to 28 days with no extra cost. The present investigation has shown that it is possible to design a self-compacting concrete incorporating 15% of rice husk.
- The utilization of rice husk in SCC solves the problem of its high cost thus keeping the construction running cost minimum.
- Its advantages related to the SCC does not require compaction, it can be considered environmentally friendly, because of no vibration is applied no noise is made.
- It has been shown that the compressive of the concrete increases with age.
- It could be concluded that inexpensive concrete could be produced using RHA as partial replacement for cement which is the most expensive component for concrete.
- It was observed that total replacement of RHA specimen did not set and with this fact, the use of RHA alone in concrete production is not feasible.
- The rice husk can be properly managed when it is used as a partial replacement in the production of concrete.

7. Acknowledgment

We would like to thank the Czech University of life science progue for their financial support and for having given us the opportunity to finalize this paper. We express our deepest gratitude to our principal supervisors' prof. Ing. David, (PhD) for his enthusiasm, support, guidance and expertise in helping to conduct the study. We also give special thanks to Ing. Hidare D., for her extensive follow-up, support and guidance. We are truly grateful to Addis Ababa University Institute of Technology and Hawassa University Institute of Technology for their assistance and cooperation.

8. References

1. A.M.Neville. Properties of concrete: longman scientific and technical series. London, 1986.
2. Association, NRMCA (Natural Ready Mixed Concrete) NRMCA. n.d. www.nrmca.org.
3. Dinku, Abebe. Construction Materials Laboratory Manual. Addis Ababa: Addis Ababa University Press, June 2002.
4. Druta, Cristian. Tensile Strength and Boarding Characteristics of Self-compacting Concrete . Augest 2003.
5. et.al., B. Research paper on Development of an Economical Self Compacting Concrete in Ethiopia. June 2011.
6. et.al., Belen. Research paper on Development of an Economical Self Compacting Concrete in Ethiopia. June 2011.
7. http//www.crcnetbase.com/doi/abs/10.4324/ 9780203017241.ch2. n.d.
8. Liu, Miao. Wider Application of Additives in Self Compacting Concrete. July, 2009.
9. Misha, Gopal. The Constructor, Self-compacting Concrete with Tests. May, 2012.
10. Nan Su, K.-C. H.-W. A simple mix design method for self-compacting concrete. Cement and Concrete Research, March 31, 2001.
11. Nan Su, Kung-Chung Hsu, His-Wen Chai. A simple mix design method for self-compacting concrete. Cement and Concrete Research, March 31, 2001.
12. Noha M.Soloman. "Journal of Effect of Using Marble Powder in Concrete Mixes on the Behavior and Strength of R.C Slab." Vol. 3 (December 2013): p. 1863-1870.
13. NRMCA, Natural Ready Mixed Concrete Association. Promotion Brochure Self-consolidating Concrete. July 2004.
14. Okamura H., O. K. Mix Design for Self-Compacting Concrete. Japanese: Concrete Library of Japanese Society of Civil Engineers, June 25, 1995.
15. Okamura H., Ozawa K. Mix Design for Self-Compacting Concrete . Concrete Library of Japanese Society of Civil Engineers, June 25, 1995.
16. Shirulea, Prof. P.A. Research Paper on PARTIAL REPLACEMENT OF CEMENT WITH MARBLE DUST POWDER. Bambhori, Jalgaon, Maharashtra: Dept. Of Civil Engineering, SSBT's COET, 2013.
17. Vasović, Ruža Okrajnov-Bajić and Dejan. Self-compacting concrete and its application in contemporary architectural practise. Belgrade,

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ISSN 2229-5518

Serbia : University of Belgrade, Faculty of Architecture, September 2009.

18. IS: 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete. New Delhi, India: Bureau of Indian Standards. EFNARC, Specification and guidelines for Self Compacting Concrete, 2002, website: http://www.efnarc.org.
19. A. Juma, E. Rama Sai, "A Review on Experimental Behavior of Self Compaction Concrete Incorporated with Rice Husk Ash", International Journal of Science and Advanced Technology, 2(3), 2012,pp: 75-80.
20. B. H. Venkataram Pai, Maitreyee Nandy, A. Krishnamoorthy, Pradip Kumar Sarkar, C. Pramukh Ganapathy, Philip George. Developmentv of Self Compacting Concrete with Various Mineral Admixtures. American Journal of Civil Engineering. Vol. 2, No. 3, 2014, pp. 96-101. doi: 10.11648/j.ajce.20140203.

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