EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF AIR-CURATED ACTIVATED CONCRETE FOR RURAL PAVEMENTS

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Abstract:

In the present study, the probabilistic use of alkaline binders in rigid pavements is examined. The performance of Conventional concrete (CC) and Alkali Activated slag concrete (AASC) along with Polypropylene fiber (PPF) inclusion is discussed. Complete cement replacement was done with Ground granulated blast furnace slag and a mix of M20 grade concrete is prepared as per IS 456 and IS 10262. Trial mixes are carried out for the selection of optimum Activator modulus (Ms) and also the percentage of Polypropylene fiber results are plotted. A combination of 14M Potassium hydroxide (KOH) and Potassium silicate solution along with Ms of 1.25 and 5 percentage Potassium oxide dosage is considered to be the best for slag mix. Mechanical properties are studied for both concrete mixes and it is noticed that the AASC +1%PPF performance is slightly better than another mix. The utilization of activated binder covers will limit the natural perils happening from increased OPC creation, alongside compelling usage of modern waste materials and protection of regular assets. It is more suitable for Rural Rigid pavements where the load-carrying capacity is low and it also helps in ecological and economical aspects.

Keywords: Activator modulus, Fiber, AASC, KOH, Potassium silicate solution, Strength.

Introduction:

It is an established fact that the utilization of concrete is next to water, which in turn increases the demand for cement. Due to the manufacturing of cement a lot of carbon dioxide is emitting into the atmosphere, creating ecological imbalances. So as an urgent need a replacement for cement is to be considered and one among them is GGBS (Ground granulated blast furnace slag) which is an industrial waste by product obtained from iron and steel industry. Complete replacement is considered for cement with GGBS but it doesn't fetch desirable results for mechanical properties. So an alkali activator solution is taken in consideration. A combination of potassium hydroxide and potassium silicate solution added at required proportions observed to achieve better strengths. To a great extent the rigid pavements are maintained for highways but not considerably for rural areas. Based on the available literature the AASC concrete is highly resistant towards high temperatures. AASC specimens exhibits better properties compared to conventional concrete in strength and durability parameters, but when considered in proper equations. In general for rural pavements where the vehicular load is less an M20

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grade concrete is considered which is weak towards durability characteristics as well as high maintenance cost is required. So a special concrete named AASC with the addition of polypropylene fiber shows excellent results in all aspects with low cost and also helps in ecological balance by reducing the carbon emissions into the atmosphere. But detailed investigation is needed in deciding the amount of alkaline solution to be considered and percentage of activators and also potassium oxide dosage contents are to be trailed and the optimum mix is engaged for further mix design. Rigid pavements have high impact towards flexural loads. The inclusion of percentage of polypropylene fiber is considered based on the available literature review which indicates the increment of flexural strength to a higher extent which is a feasible option for rigid pavements. Nitendra Palankar et al [1] considered various preliminary blends to distinguish the ideal Activator Modulus (Ms) for every mix of GGBFS and FA. The blending plan for the perfect activator modulus is upgraded to accomplish adequate strength for Asphalt Quality Cement and the new and mechanical properties are concentrated exhaustively. The outcomes demonstrate the properties of AASC and AASFC are comparative or somewhat better than customary OPC and fulfil the base strength prerequisites for substantial asphalts. Nibha Singh Banafer [2] stated that the advantages of geopolymer concrete are its Durability, rapid strength gain, ecofriendly, cheap and elimination of water curing. Precast concrete products such as railway sleepers, sewer pipes, rigid pavements are some of the applications of geopolymer. M M Abdelmoamen et al. [3] reported that the workability of Geopolymer (GP) is influenced by the alkaline activator. When one of the variable compounds changes, the GP density does not change much. Miral H. Mostafa [4] observed that the compressive strength of 28 days of traditional concrete was nearly achieved by Geopolymer concrete in 7 days. N Sai Ketana et al [5] concluded that GPC manufactured with K2SiO3/KOH performs better than GPC created with Na2SiO3/NaOH when precisely constructed. Otherwise, both alkaline activator solutions achieve the desired strengths at their respective concentrations. Chen Yang [6] presumed that the compressive strength improves with rising hydroxide fixation and bringing silicate down to hydroxide proportion. Rather than utilizing a sodium-based activator, this study embraces a potassium-based activator that comprises hydroxide and silicate, because of its better commitment to functionality and strength. D Sabitha [7] reported comparative investigation on the usefulness of lower concentrations of sodium and potassium hydroxides and alkali silicates at room temperature is reported in this communication. The study found that geopolymers containing potassium activators have decreased liquid consumption. The ongoing examination centers around the appropriateness of soluble base initiated concrete as an option in contrast to OPCC for substantial asphalts. Poloju et al [8] studied characteristics of geopolymer concrete with different replacements of GGBS to flyash and found the increase of GGBS content improved strength and decreased workability. Alkali activated binders are created by combining GGBS in various Modular ratios and with changing percentages of oxide content. The mix proportions of Alkali activated binder and also the compressive strength, Splitting tensile, and Flexural strength of CC+1%PPF and AASC+1%PPF blends will be examined. This study helps in finding a solution to achieve a low cost ecological concrete for rural rigid pavements.

Materials:

Concrete: As a fundamental constituent in the substantial blend, OPC 53 grade concrete was utilized whose particular gravity is 3.11.

GGBS: It is gotten from a neighbourhood seller which involves physical and synthetic properties inside the cut-off points according to BS: 6699:1992.

Fine total: Zone 3 total is thought of, whose particular gravity is 2.5 and a fineness modulus of 2.

Coarse total: Totals of 20 and 10 mm are considered with a relative thickness of 2.7 and fineness modulus of 7.1.

Salt activator: Potassium hydroxide and potassium silicate arrangements got from the seller. The potassium silicate arrangement contains a 42.4% vital substance with a general thickness of 1.26.

Polypropylene fiber: Strands with a general thickness of 0.9 and in the middle of between 6 and 6.5 mm are utilized.

Experimental program:

Table.1 Mix proportions of 0.75 MS alkaline activator solution

MS =0.75					
Oxide %	4	4.5	5	5.5	6
K_2O Required	12.67	14.25	15.84	17.42	19
SiO_2 Required	9.5	10.68g	11.88	13.06	14.25
K_2SiO_3 Solution	35.33	39.73	44.16	48.57	52.97
KOH	8.58	9.65	10.72	11.8	12.86

Table.2 Mix proportions of 1 MS alkaline activator solution

MS =1					
Oxide %	4	4.5	5	5.5	6
K_2O Required	12.67	14.25	15.84	17.42	19
SiO_2 Required	12.67	14.25	15.84	17.42	19
K_2SiO_3Solution	47.1	52.9	58.88	64.75	70.63
KOH	6.4	7.22	8	8.8	9.59

Table.3 Mix proportions of 1.25 MS alkaline activator solution

MS =1.25					
Oxide %	4	4.5	5	5.5	6
K_2O Required	12.67	14.25	15.84	17.42	19
SiO_2 Required	15.83	17.82	19.8	21.77	23.75
K_2SiO_3 Solution	58.84	66.24	73.6	80.94	88.28
KOH	4.23	4.75	5.29	5.8	6.33

Table.4 Mix proportions of 1.5 MS alkaline activator solution

MS =1.5					
Oxide %	4	4.5	5	5.5	6
K_2O Required	12.67	14.25	15.84	17.42	19
SiO_2 Required	19	21.37	23.76	26.13	28.5
K_2SiO_3 Solution	70.65	79.4	88.32	97.13	105.9
KOH	2.05	2.31	2.56	2.81	3.07

Table.5 Mix proportions of 1.75 MS alkaline activator solution

MS =1.75					
Oxide %	4	4.5	5	5.5	6
K_2O Required	12.67	14.25	15.84	17.42	19
SiO_2 Required	22.17	24.93	27.72	30.48	33.25
K_2SiO_3 Solution	82.42	92.7	103.04	113.32	123.6
KOH	-	-	-	-	-

The consideration of KOH for MS 1.75 is preposterous because of the expansion in Silica dioxide expected for the blend. Because of this, the blend is disposed of from trail blends for strength boundary thought, as it can't frame a basic arrangement without KOH. So four blends of MS proportion are thought of and were tested for 5 different percentages based on previous literature. The oxide content assumes a significant part so beginning from 4 and thought about till 6 rates.

Procedure:

A soluble base activator mix is created through caustic potash and potassium silicate arrangements. caustic potash chips are blended at 14M then be present ready by accumulation of adequate H_2O a day before the arrangement of examples. In advance 60 minutes of the projecting system, the potassium silicate arrangement is added to the recently pre-arranged potassium hydroxide arrangement and appropriately blended. After the option of all totals and GGBS, the arrangement is arbitrarily included with the existing blend alongside the overabundance of water which is stayed after derivation from water accessible in silicate arrangement and water utilized for the readiness of potassium hydroxide arrangement. A proportion of 1.25 activator modulus (sio_2/k_2o) and 5% dose of potassium oxide is thought of. No plasticizers or superplasticizers are included. When after the substantial combination readiness, samples of various sizes are shaped and left till age and are exposed to testing.

Results and Discussions:

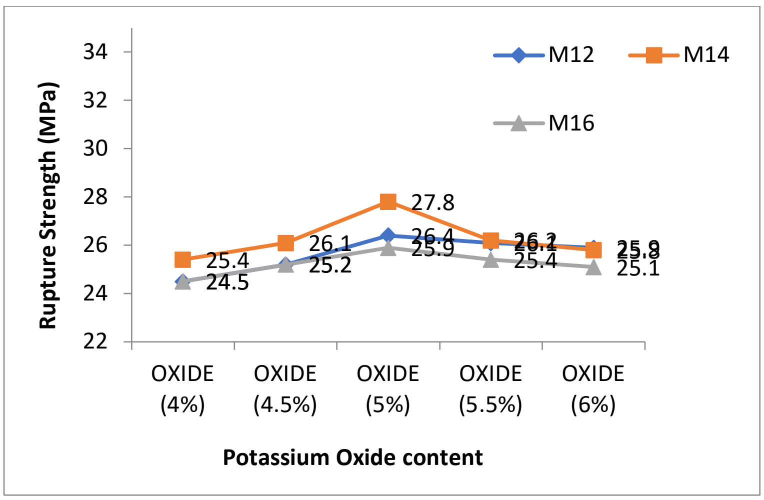

Figure.1 Strength versus Oxide content for 0.75 Modular Ratio

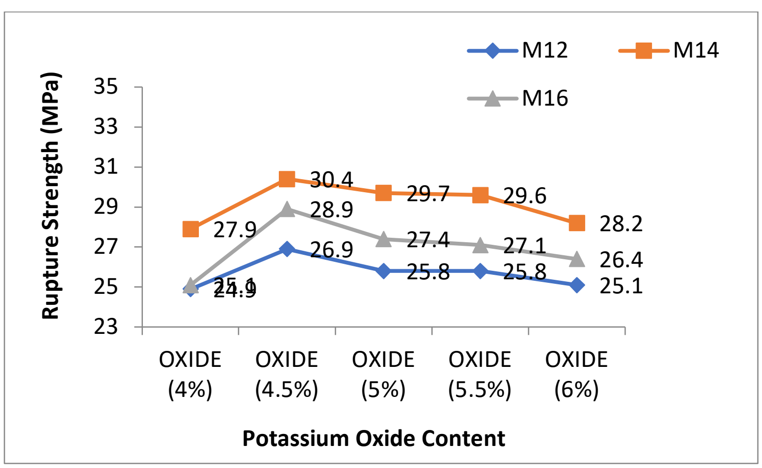

Figure.2 Strength versus Oxide content for 1 Modular Ratio

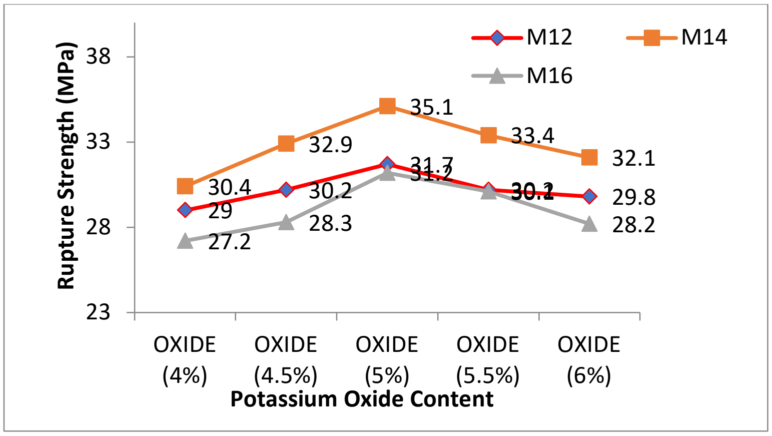

Figure.3 Strength versus Oxide content for 1.25 Modular Ratio

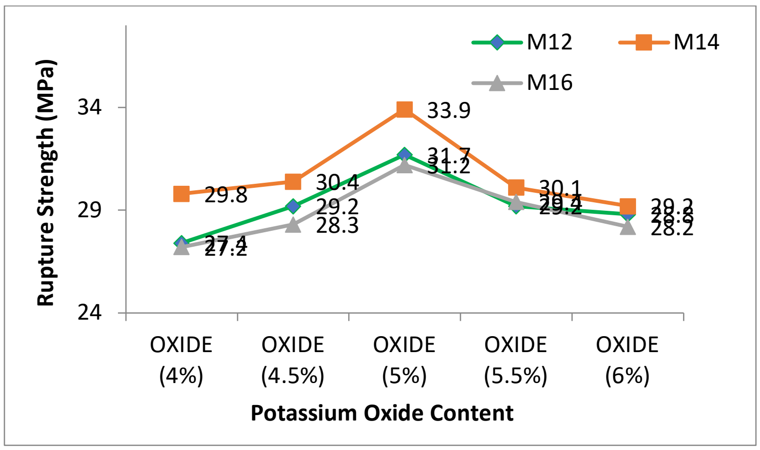

Figure.4 Strength versus Oxide content for 1.5 Modular Ratio

M represents Molarity
CC+F = Conventional Concrete with 1%PPF
AASC+F = Alkali Activated Slag Concrete with 1%PPF

The Modular Ratio and potassium oxide content have a great influence on the compressive strength of the alkali-activated mixes. Modular Ratios are considered from 0.75-1.75 and are tested with varied oxide dosages with different molarities. As it is necessary to find the optimum activator ratio based on the strength parameters from Fig.1-4, a mix with a 14M solution of 1.25 Ratio and 5% oxide dosage is considered the best among all other mixes.
Mix design is carried out for the AASC+1%PPF mix to achieve desired strength requirement and slump. This slag mix is prepared with a binder content of 320 kg/m3 with water to cement ratio of 0.5. In the AASC mix, ggbs replaced cement completely. Cube specimens of 100mm were cast and tested for strength after 28 days of ambient curing. The workability test has conducted the determination of the slump. Almost all mixes follow a similar trend toward oxide dosage and modular ratios. It is noticed that as molarity increases beyond 14 strengths started

decreasing. The compressive strength increases with an increase in activator modulus and after reaching an optimal point started a downtrend. The mix design for conventional concrete (cc) is based on IS 10262. The cement is 320kgs/m3 and water cement ratio of 0.5 and coarse, fine aggregates of 1222 and 694 kg/m^3 are adopted.

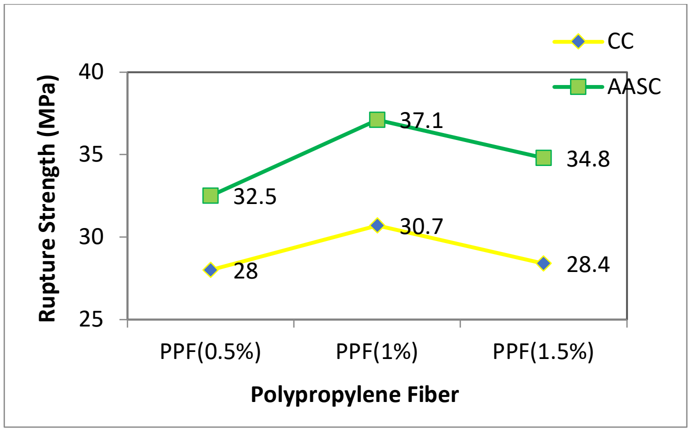

Figure.5 28-day Rupture Strength of mixes with addition of PPF

So from the above figure 5, it is clear that the replacement of cement with 1% polypropylene fiber is found to be effective for the improvement of mechanical properties. The above figure represents the 28-day compressive strength of both CC and AASC mixes.

Table.6 Variation of compressive strengths with age under ambient curing

Age in days	7	28	56	91
CC+F	25.2	30.7	32.9	33.6
AASC+F	33.8	37.1	39	40.8

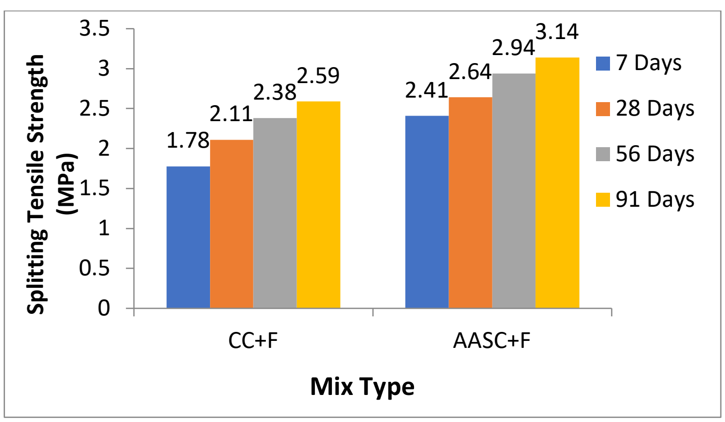

Figure.6 Variation of splitting tensile strength with age under ambient curing

Table.7 Variation of flexural strengths with age under ambient curing

Age in days	7	28	56	91
CC+F	3.42	3.87	3.95	4.02

AASC+F	3.9	4.31	4.7	4.81

From Table 6 it is apparent that there is an increment of 20.84% in compressive strength for AASC+F blends contrasted with CC+F blend at 28 days of relieving. The consideration of PPF in concrete further develops strength however when taken at 1% of concrete substitution. An augmentation of 42% is seen in slag blends at 7 days of relieving than in CC blends.
From Fig.6 the parting rigidity of AASC+F blends shows higher qualities contrasted with CC+F blends at all times of the relieving time frame. An augmentation of 25.1% is seen in CC+F blends at 28 days old enough relieving. The most noteworthy augmentation is seen as 35.4% at 7 days of the relieving time frame.
From Table 7 the flexural strength of AASC+F blends displays an 11.3% increment to CC+F blend at 28 days of relieving. The most elevated addition of 19.15% is seen at 91 days restoring period for slag blends.
Taking into account every one of the mechanical properties all the strength boundaries are expanding yet the level of augmentation of solidarity is lessening continuously with an expansion in the period of examples for both the blends.

Conclusions:

- The compressive strengths of the AASC+F mix exhibit higher values than CC+F mixes at all ages. The splitting tensile strengths of the AASC+F mix exhibit higher values than CC+F mixes at all ages. The flexural strengths of the AASC+F mix exhibit higher values than CC+F mixes at all ages. The inclusion of polypropylene fiber helps in strength improvements.
- Due to the use of complete ggbs replacement to cement the amount of carbon dioxide that enters into the atmosphere can be reduced to a great extent.
- The cost analysis also proved that the slag mixes are more economical than CC mixes as the water (curing) costs will reduce and also due to the proportions of the alkaline activation solution considered.
- Due to their improved mechanical properties, conventional concrete slag mixes are suggestible for rigid pavements. The slag mixes can compete with high grades of concrete.
- As alkali-activated slag concrete is not suitable for structures so it can be used for the construction of rural rigid pavements, where the traffic volume is minimal.
- Labour Cost for curing gets reduced in the slag mix compared to the conventional concrete mix.

References:

1. Nitendra Palankar, A.U. Ravishankar and B.M. Mithun, (2015). “Air-cured alkali-activated binders for concrete pavements”, International Journal of Pavement Research and Technology, Chinese Society of Pavement Engineering, 8 (4), 289-294.
2. Nibha Singh Banfer, (2017). “Experimental Study of Geopolymer Concrete in

Construction of Rigid Pavement", Trends in Transportation Engineering and Applications, Vol 4, No 2, pp.24-29, DOI: https://doi.org/10.3759/ttea.v4i2.2876.

3. M M Abdelmoamen, E Abdelsalam, M Y Elsheik, (2020). "Effect of Potassium Hydroxide and Sodium silicate as an alkaline Activator on the Properties of GPC", Al-Azhar University Civil Engineering Research Magazine, Vol. (42) No. (2), Pages 1-13, April 2020.
4. Miral H. Mostafa, Anwar M. Mohammed, Mohammed H. Agamy, Shady N. Mohammed and Sherif F.M. Abd El Naby, (2020). "An Experimental Study on Slag Based Geopolymer Concrete", Al-Azhar University Civil Engineering Research Magazine, Vol. (42) No. (2), Pages 265-273, April 2020.
5. Nutakki Sai Ketana, Srinivasa Reddy , M V Seshagiri Rao, and S Shrihari, (2021). "Effect of various parameters on the workability and strength properties of geopolymer concrete", E3S Web of Conferences 309, 01102 (2021) ICMED 2021.
6. Chen Yang, (2017). "Prediction of the Compressive Strength from Resonant Frequency for Low-Calcium Fly Ash-Based Geopolymer Concrete", MEng, University of Victoria, 2017.
7. Sabitha, D., Dattatreya, J.K., Sakthivel, N. et al. (2020). "Assessment of reactivity of energy efficient high volume fly ash based geopolymers through various approaches", Sadhana 45, 178. https://doi.org/10.1007/s12046-020-01417-y.
8. POLOJU K. K., Sinivasu. K., (2021). "Influence of GGBS and Alkaline Ratio on Compression Strength of Geopolymer Concrete", The Electrochemical Society, Vol. 1 No. 01, pp.8897-8904, http://dx.doi.org/10.1149/10701.8897ecst.