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Background Study for Fly Ash Free One Part Geopolymer Cement

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ABSTRACT: Infrastructure sector is growing very rapidly due to which availability of construction materials plays a vital role. Also, the amount of pollution created while manufacturing of such materials has to be considered. Production of 1 MT of Fly Ash (FA) emits 33 MT of CO_2. Conventional cement is produced normally blended with 50% of FA which indirectly emits 16.50 MT of CO_2 per MT of cement. Based on numerous researches, Geopolymer Concrete (GPC) was invented using various silica rich precursor and alkali activator solutions. In GPC, FA was used owing to the existence of intense silica content which is also leads same amount of CO_2 emission. Also, due to the planned retirement of coal – fired thermal stations & promotion of green energy, conventional cement blended with FA will be no longer available. Hence, a FA free cement has to be developed. This paper reviews GPC made with various precursor materials and its compressive strength which will help for invention of new FA free cement using sustainable source

KEYWORDS*: One-part Geo polymer, High Calcium FA, Cement Kiln Dust, Red Mud, Mine tailings, Wood Biomass Ash.*

I. INTRODUCTION

The demand for cement has enlarged due to rapid infrastructure development. Even though Portland cement (PC) industries have full-fledged technologies, the CO_2 emission is inevitable, which results global warming& affects environment and human health, adversely.

Earlier, the necessity for coal in power plants were increasing worldwide and consequently generates more&more FA. Coal fired thermal power stations were lobbying the cement and building materials industry with so-called low- carbon FA-based cements. The point of producing FA based construction supplies is an excuse to elevate utilization of coal. Hence, any activity promoting use of FA based cement accelerates firing of coal which leads to added CO_2 emission.[12]

But, now due to rapid development of green energy and early retirement of coal-fired Thermal Stations through the world [11],[13] the FA will be no longer available and therefore, producing FA-based cement doesn't tend to be along-lastingsolution.

To overcome the above issues, Mr. Joseph Davidovits has developed cement less Geopolymer which are inorganic, polymeric, amorphous alumino silicate binding material. Geopolymer exhibits the specific properties of rock forming minerals. An alkaline solution was proposed to react with a precursor having silicon and aluminum in it.

Now, to enhance the commercial viability and to make user friendly, instead of using alkaline activator solutions, powder formed solid activators has been proposed and named as one-part geopolymer cement (GP), alike the well-established Portland cement. This Paper summarizes the previous researches made with different precursors and different alkaline compositions as one-part geopolymer and their Pros & cons.

II. WHY FLYASH MUST BE AVOIDED

Fly Ash is a major threat to Human and also to the environment. It causes various health impacts by which the human organs including Brain, Heart, Lungs are all affected and further impacts may even lead to mortality. This is due to presence of arsenic, mercury, lead and Chromium in FA.

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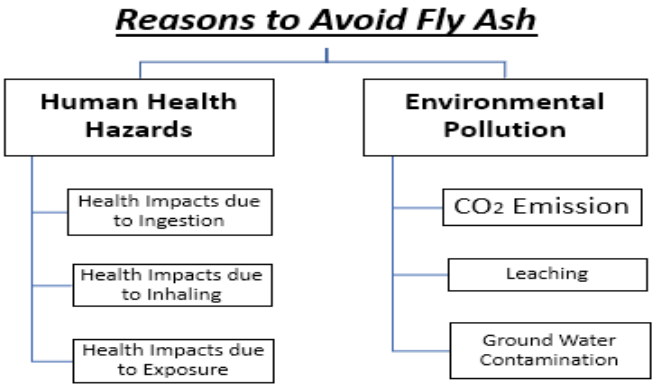

Figure 1 – Reasons to avoid FA.

FA contaminates groundwater in the following way. Water from FA slurry dissolves heavy metals, while percolates through soil and reaches groundwater making it contaminate which results the groundwater unfit for domestic and other purposes.

III. SCARCITY OF FLYASH

Scarcity of FA is arising in a smaller scale now. But in near future there are chances of Zero production of FA. This is because two major reasons as follows:

I. Retirement and Decommissioning of coal Fired Thermal Power Plants.

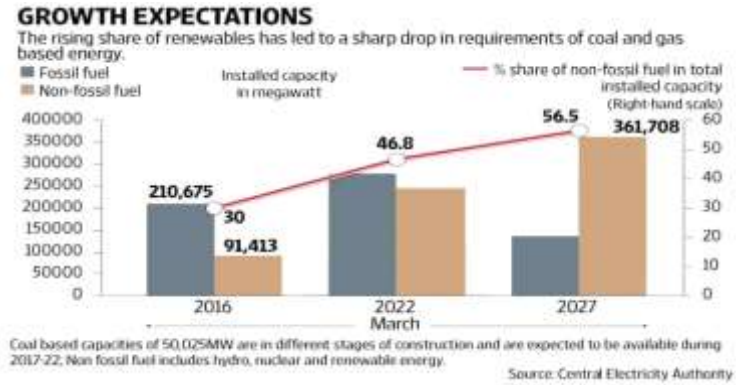

Figure 1 Growth Expectations of Renewable energy sources

Power Plants are being shutdown across the globe due to various reasons but the key reason is to reduce the carbon footprint which is raising day by day.

Table 1 Coal Plant Retirement Year wise Data

Retired Coal Plants by Year, 2006-2019 (MW)

Global Coal Plant Tracker, January 2020

Global Energy Monitor

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Undated	Dated 2006-2019	All retired (includes dated and undated)
World Total	2,207	11,846	10,513	11,478	16,968	12,522	23,479	23,203	22,600	37,458	32,732	38,328	34,856	34,233	11,532	303,623	315,155
Outside India and China	1,645	1,569	1,446	1,451	7,664	8,658	19,680	20,243	13,847	31,599	27,647	21,988	24,057	27,203	5,816	208,697	214,513
India and China	562	9,477	9,067	10,027	9,304	3,864	3,799	2,960	8,753	5,859	5,085	8,340	10,799	7,030	5,716	94,926	100,642

ISSN- 2394-5125 VOL 7, ISSUE 04, 2020

IV. Promotion of Green Energy

Nowadays, the sustainable energies such as Wind, Hydro &Solar areused mainly for electricity generation.India is moving towards a holistic stratagem for renewable energy for ecologicaldevelopment, including local air and water quality.

So this promotion of green energy will thereby directly impact on the Thermal Power plants which are major source of FA and may lead to the scarcity of FA.

V. ONE-PART GEOPOLYMER USING FLYASH

Bashar S. et. al.(2019)[1] have conducted a study onGP Cement by incorporating High Calcium FA (HCFA) which is a part of one-part alkali-activated binders. It is evident that on increasing the HCFA content, increases the resistance of OPG Paste & decreases its setting time. The optimum dosage is arrived as 12% (i.e. 6% Na_2O). A maximum of 50 MPa compressive strength was recorded. Based on the above workings, it is clear that the strength evolution in one-part GPC is similar to that of the Portland cement.

Moreover, FA is utilized as precursor / binder, which can be obtained mainly from Thermal Power stations. In recent days, due to the planned retirement of Coal-fired thermal stations, worldwide and due to the rapid development of Green Energy, production of FA will be stagnated.

VI. PROPERTY OF OPG WHEN FLYASH IS REPLACED

Yazan Alrefaei, et. al. [2] examined the ductilecapacity of one-part engineered geopolymer composites (EGC) with polyethylene (PE) &steel (ST) fibers. Also, the compressive strength at 28^{th} day was found to be 58 & 60 M Pa respectively and regarding tensile response, GGBS based EGCs displayed a comparatively healthier value.

H.A. Abdel-Gawwad, et. al. [3] have conducted a study over (OPG) cement with thermally activated Cement Kiln Dust (CKD) and Feld-Spar (FS), at 60/40 weight ratio, subjected to higher temperature with Na_2CO_3 (soda ash), produces molten glassy material and the same was cooled, grounded to produce OPG - powder. in the existence of Na_2CO_3 Heat Treatment results in formation of a glassy material, which gives a 52 MPa strength on reaction with water.

Nan Ye, et. al. [4] have analyzed OPG with red mud (RM) and silica composition. However, the strength of the binder exclusively with RM was meagre due to the unbalanced polymerization. On addition of 25% of SF, the 28^{th} day comp. strength of GP with SiO_2/Al_2O_3 molar ratio of 3.45 reached 31.5 M Pa at 0.45 water/solid ratio.

VII. OTHER ALTERNATIVE MATERIALS

Priyadharshini Perumal, et. al. [5] Experimented on GPC with Mine tailings. This study exhibits the effectiveness of thermal treatment over crystalline structure and solubility of an Alumino Silicate material mainly based on its mineral structure & treatment temperature. An attempt was made to correlate the strength acquired by alkali activation of mine tailings against its solubility. However, in spite of the higher solubility presented by phosphate tailings, impure kaolinite, due to the presence of Calcium compounds, it gives the maximum strength development up to 62%. Compressive strength of 15 MPa at 7^{th} day has been achieved from the specimen with 750^0 treated temperature.

VIII. GUIDANCE FOR OPG PRODUCTION

C Ma et. al. [6] havestated that Na_2SiO_3-anhydrous the CO_2 release and Basicity is enormous. In this research, Na_2CO_3 is utilized to substitute a portion of Sodium Metasilicate and the properties of OPGP with composite activators was examined. Replacement of Na_2CO_3 slight impacts over the fluidity and increases the ultimate setting time. the compressive strength decreases on increasing Na_2CO_3 content. The compressive strength has been achieved up to 75 M Pa at 28 th day.

IX. APPLICATIONS

Biranchi Panda, et. al. [7]has invented GPCwhich is suitable to be used in 3D concrete printing. Due its high viscosity, it gives bothersome in 3D concrete printing. In this study, a printable OPG mix was developed, and their viscosity & thixotropic behavior of the developed geopolymer were assessed. Printed specimen were found better when compared to the samples which are casted using moulds.

Yun-Ming Liew, et. al. [8] experimented on Geopolymer powder Produced by crushing exhibited greater latent to produce not only OPG but also High Flexural Strength GP ceramics (HFSGPCer). OPG attained a compressive strength of 10 MPa after 28 days with development of geopolymer precipitates. Despite of their lesser Compressive strength, can remain stable and did not disintegrates while dipped in water. While the HFSGPCer revealed a Extra-High flexural strength (90 M Pa) post sintering at 1200°C resulting in nepheline formation.

Hassan Soltan Hassan, et. al. [9] have conducted investigation to utilize Wood Biomass Ash (WBA) generated while making bricks for preparation of OP-WGPC (white GPC) with diatomite as an ingredient. The optimum content of WBA is 21.5 wt.% added to diatomite to produce OPWGPC havingoptimumcompressive strength 48 M.Pa on 28th day and reasonably better whiteness (85%). This concludes that WGPC can be used instead of White Portland Cement in ornamental works & prestigious construction assignments.

X. CONCLUSION

Based on this study, it is concluded that in place of FA, materials such as Cement Kiln Dust, Red Mud, Mine tailings, Wood Biomass Ash and industrial products like GGBS, Micro silica etc.,are used extensivelyby adoptingdifferent methodologies such as Heat treatment, various curing methods etc. It helps to reduce the Carbon foot-print produced during generation of fly ash.

Hence hereby we could conclude that a suitable material with proper methodology can easily eliminate the use of FA thereby resulting in a comparably greener environment.

Also, to eliminate the constraints of using alkaline solutions, the OPGPC (without FA) will be user friendly, commercially viable as that of conventional cement but without emission of CO_2

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ISSN- 2394-5125 VOL 7, ISSUE 04, 2020

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