Conversion of Slate Powder into Useful Chemical Product (Sodium Silicate): A Review

Hashim Khan[1] Dr.Kanjan Upadhyay[2]
[1]Student [2]Professor
[1,2]Department of Chemical Engineering
[1,2]Ujjain Engineering College, Ujjain (M.P.), India

Abstract— This paper aims to find the possible conversion of slate powder into sodium silicate. In this study, different methods of preparation of sodium silicate were studied for the analysis of physical and chemical properties of the product. The aim of this project is to convert slate waste into useful chemical product to increase the value of the economy through waste, while at the same time utilization of waste into such chemical added additional advantage for the industries.
Keywords: Sodium Silicate, Slate Powder, Slate Waste, Water Glass

I. INTRODUCTION

Sodium silicate is the common name for compounds with the formula (Na_2SiO_3) also known as water glass or liquid glass. It is a colorless compound belongs to sodium metasilicate family. The appearance of the chemical is in crystal form and it is soluble in water. Sodium silicates are produced in the form of a variety of compounds ranging from $Na_2O.4SiO_2$ to $2Na_2O.SiO_2$. Sodium silicates varying in ratio from $Na_2O.1.6.SiO_2$ to $Na_2O.4SiO_2$ are known as colloidal silicates.

Sodium silicates of certain ratios are used for application over concrete floors for hardening making dustless concrete floors and protecting pervious building materials against the effect of moisture. They are widely used in industry as sealants, binders, emulsifiers and buffers

A. Uses of Sodium Silicate -

Detergents & Soaps-Many detergent operations are performed with sodium silicates. Such operations range from metal cleaning and textile processing to washing laundry, dishes, dairy equipment, bottles, floors, and automobiles. Silicates are incorporated in synthetic detergent compositions to control corrosion and minimize alkali attack. Without silicates, many synthetic detergent compositions would be corrosive to aluminum, zinc, and certain metal alloy parts in washers. They may also attack porcelain enamel and over glaze fine china decorations.

1) Adhesives and Cements Liquid - Sodium silicates are widely used as adhesives in making fiber drums, paper tubes, and other materials.
2) Pulp & Paper - Sodium silicates are used for de-inking, sizing, coating, and bleaching of recycled paper products in the pulp and paper industry.
3) Gels and Powders - Sodium silicate is a key feedstock for the manufacture of silica gels. These products are granular, glassy materials that have a large capacity to absorb moisture and other substances.
4) Petroleum Industry - Sodium silicates are used in making silica-alumina catalysts for various operations in the petroleum industry, such as the production of high octane gasoline. Foundry Mixtures of sand and silicate offer advantages in making molds and cores in foundries by eliminating the need for drying or baking, as required with oil or resin bonded forms.
5) Soil Stabilization - Soil stabilization techniques take advantage of the gel-forming property of sodium silicate to increase load-bearing capacity, arrest settlement and lateral movement of foundations, and control the flow of water in earthwork engineering projects such as dams, mines, tunnels, and excavations.
6) Water Treatment - Activated silica colloidal solutions act as coagulants in applications for treating both raw and waste waters. Corrosion of iron in water systems may be controlled by the addition of small amounts of sodium silicate, which deposits a thin protective film of silica on the metal.
7) Coatings - Sodium silicate solutions are used in making various paints and coatings, as well as for welding rods and roofing granules.

B. Uses of slate Powder-

1) Filler material may be for roads and embankments: Being an inert material stone powder may be mixed with certain types of soil for the preparation of embankment resulting a saving of valuable soil. Mixing of stone waste with silty and sandy soils and compaction of the mix result in better strength of the base layer over which water bond, macadam can be led.
2) For manufacturing of bricks: Stone waste is used in brick manufacturing as fine aggregate using cement as filler. The physical properties of the brick are produced by this process exceeds those of normal bricks. Stone waste, cement slurry, bricks can be made by using slurry sand and cement in different proportion and moulding by vibrant compaction technique.
3) Manufacturing of Portland cement: Stone waste may be used to replace live stone in Portland cement manufacturing.
4) Manufacturing of ceramic tiles: Stone waste slurry may be used as a raw material for the production of ceramic wall tiles.
5) Manufacture of Thermo set resins: to explore the possibility of converting stone waste slurry into resin composites.
6) Manufacture of lime: Stone waste is used in place of limestone in the stabilization of soil.
7) Manufacture of activated calcium carbonate: Stone waste may be used for the production of activated calcium carbonate.
8) Hollow Blocks manufacturing: Stone waste may be used in hollow blocks for building construction.
9) Use of stone waste slurry as a substitution for limestone as follows: in synthetic agglomerated stone wastes, in manufacturing of glass, in plastic manufacture, in chemical manufacture etc.

II. LITERATURE REVIEW

1) In the year 2019, Raffaele Vinai et al studied the production of sodium silicate powder from waste glass cullet for alkali activation of alternative binders. The parameters for the study include glass to NaOH ratio, temperature, duration, inclusion of water and fineness of NaOH. The experiment done by the help of glass powder, sodium hydroxide powder and water heated at temperatures of 150 to 300^{O}C. It was found that the compressive strength were similar or better than commercial available sodium silicate.
2) M.H. Ara et al (2018) studied the production of sodium silicate from rice husk ash. The experiment done by the help of rice husk ash with 30% water mixed by stirring, NaOH mixed in the mixture & heating was started for 10 min at 100^{O}C. It was found that after dilution for settling for 24 hrs and then heating at 90^{O}C. After Filtration & Evaporation sodium silicate was formed. Author findings shows that rice husk ash which was negative impact on environment can be used to produce sodium silicate. It was concluded that the production of sodium silicate by this process is economical & the process is cost effective.
3) In the year (2017) Seun Sameul et al studied the effects of extraction temperature and time on the physical properties of Soluble Sodium Silicate from Rice Husk Ash. The parameter for the study includes Viscosity, PH, Specific gravity, and Electrical conductivity. It was concluded that Sodium silicate can be extracted from rice husk ash as a silica source also sodium silicate displayed lesser viscosity & similar physical characteristics as compared to the standard sample.
4) In the year (2017) R. Mahadevi et al studied the feasibility of concrete using the waste of marble powder and dust as a partial replacement of cement. The parameter in this study includes the effect of marble powder and quarry dust on the strength and workability of concrete. It was noted that using different percentage of the replacement does not reduce the strength on the workability of concrete. This paper deals with the advanced construction technique in concrete technology replaced by different waste materials.
5) K.Nagendra Reddy et al (2017) studied the effect of Sodium Hydroxide and Sodium Silicate solution on compressive strength of metakaolin and GGBS Geopolymer. The parameters for the study includes the fixed ratio of sodium silicate to sodium hydroxide are 2.5:1 & the concentration of sodium hydroxide is taken as 10M. It was found that by mixing with Metakaolin the flexural strength increases from 50% upto 100% & by using GGBS compressive strength increases from 50% and above. It was concluded that we can replace GGBS and Metakaolin in place of cement.
6) Norhasyimi Rahmat et al (2016) Studied sodium silicate as source of silica for synthesis of mesoporous SBA-15. Test was performed to check the effect of sodium silicate (Na_2SiO_3) on SBA-15 samples. In this study, Sodium silicate (Na_2SiO_3) was investigated to synthesize mesoporous SBA-15. It was concluded that mesoporous silica SBA-15 was successfully synthesized under acidic conditions using Sodium silicate (Na_2SiO_3) as the silica source.
7) Nabil Al Joulani, (2016), studied the stabilization of stone slurry waste with addition of portland cement and soil. The parameter in this study includes cement ratio, stone powder ratio, curing times, compressive strength and tensile strength. It was noted that maximum compressive strength was attended by 20% Portland cement and 80%stone slurry after 28 days.
8) L.B. Pahhares et al studied the settling behavior of aqueous suspension of slate with citric acid in the year (2016). The parameters included were different concentrations of citric acid and varying percentage of solid in aqueous suspensions. It was observed that the settling behavior of slate powder with citric acid lowers the settling rate, better stability and compact sediment bed. The light scattering technique was used to analyze the settling rate, aggregates and sediment bed density.
9) In the year (Jun 2016) Prerit Saxena et al studied the partial replacement of cement by the use of stone dust & granite powder. The experiment was done by the preparation of Mortar mixture (5%,10%,15% & 20% replacement of cement by Stone dust & granite powder). Then sample was tested after 28days to check the compressive strength. It was found that the optimum level of replacement was upto 5% by weight by using stone dust & 10% by weight by using granite powder.
10) Palhares, LB, dos Santos, CG and Hunter, TN (2016) conducted a study on the dispersion of citric acid in resolving slate powder suspension behavior ,, The behavior of wet slide suspension with citric acid investigated using weaving techniques and culture. To determine the effectiveness of an efficient distribution agent with high solids loading, a series of 12 suspensions were prepared with a citric acid content of between 0.5 and 2.5% w / v and a solid 40, 55 and 70 percent solid. %. Light-scattering methods were used. flow curves are obtained with a rheometer. The results showed that interactions between the service particles could cause flow, high concentrations of citric acid, or improve stability, with low dispersant concentrations and pH of about 6. 1.0% citric acid. These behaviors were described on the basis of carboxyl groups of citric acid that promote higher particle distribution leading to lower levels of stability, better durability and a compacted bed.
11) B.A. Ajaji et al (2015) studied the extraction of soluble sodium silicate from corn cob ash. The parameter for the study includes temperature 600 ^{O}C & time 5hrs for burning of corn cob. Corn cob ash was mixed with 3M conc. NaOH at 80 ^{O}C for 4hrs & 90 ^{O}C for 3hrs. Test was performed for various analysis including PH value, Specific gravity, Electircal Conductivity and viscosity. It was noted that the process is feasible and dependent on temperature, amount of silica extracted from corn cob ash.
12) In the year (2015) OZKAN studied the production of sodium silicate cullet by the help of trona($Na_2CO_3.NaHCO_3.2H_2O$). The parameter for the study includes temperature 1150 & 1200 ^{O}C & Time 2hrs. It was found that trona has high Na_2O and loss of ignition content indicates the purity of the Ore. Author

findings shows that trona can be used instead of soda ash to produce sodium silicate cullets.

13) Ifrah Habib Lone et al (2015) studied the effect of sodium silicate (Na_2SiO_3) on properties of concrete. The experiment done with M20 (1:1.5:3) with water to cement ratio of 0.5. Total Four castings were done at 1.2 ^{O}C,1.6 ^{O}C.1.2 ^{O}C & -1 ^{O}C with the percentage ratio of sodium silicate by weight of cement 1%,1.4%,1.8% & 2.2%. Test was performed to study the rate of variation of strength with respect to the sodium silicate percentage. It was found that sodium silicate does not contribute to an increase in strength of concrete but it increase compacting factor & enhance the workability of concrete.
14) Pramod Kilabanur et al (Jun 2015) studied soil stabilization by using envirobase & sodium silicate with lime. Test was performed thru chemical stabilization method where the chemicals used are envirobase & sodium silicate with lime. The experiment was carried out by adding 1%, 2% & 3% of envirobase with dry weight of soil. It was found that sodium silicate with lime reduces the plasticity index & holds good in consistency limits. Also sodium silicate with lime can be used as local stabilizer in small construction work due to cheap & easily available.
15) Manju Pawar et al (2014) A study conducted in periodic research, The Importance of Partial Recovery of Cement with Waste Slate Powder. They found that the effect of using slate powder as a particle with mortar or concrete by reducing a portion of the cement was studied in terms of stronger, greater strength and flexibility.
16) In the year 2013, Longsheg Zhang et al studied the effect of slate powder on fly ash in suppressing alkali activity of slate aggregate. In this experiment the raw materials are cement, fly ash, sand & slate powder. The test were preformed in 19 groups in which fly ash having 10%,20%&30% in three groups and 0%,5%,10%,15%,20% & 30% six dosage of slate powder. It was found that when slate powder is less than 15%, it has no adverse effect on fly ash & when slate powder is greater than 15%, it can increase the effect of suppression.
17) In the year (2013) M. Keawthun et al studied the possible conversion of waste glass into sodium silicate solution. The parameters for the study includes 650^{O}C temperature, NaOH reacted with waste bottle glass for 60 Min (Test were performed : $NaOH/SiO_2$ Molar ratio (1,2,3 & 4), H_2O/SiO_2 Molar ratio (11,15,19 & 23), reaction time (varing of 20 to 100 min) further conversing silica into silicate by hydrothermal and fusion method. It was noted that the conversion is feasible with small amount of impurity of Iron & Sulphate.
18) In the year (2013) X. Peng et al studied the effect of slate powder on the alkali activity of slate aggregate. The parameter in this study includes particle size and percentage of slate powder in the expansion of aggregate. It was found that up to 20% of content of powder in slate aggregate it does not suppress the alkali aggregate reaction ,but it affects the particle size and reduced the expansion of specimen and when the content is less than 10% it does not have an adverse effect on the expansion of specimen.
19) UM. SahulHameed et.al, (2012), has shown that it can be achieved to use individual slate sludge powder (MSP) and broken garbage (CRD) within the production of self-compacting concrete (SCC). This use of waste improves physical and mechanical properties. Reusing and reusing waste to produce SCC may be the most effective decision to fund the future economy. it is proposed to replace natural sand with 85% CRD (Crus Crosed Rock Dust) and 15% slate sludge powder (MSP), instead of SCC.
20) In the year 2010, Sina K et al studied the effect of cement, sodium silicate, kaolinite and water on the viscosity of the grout. This study was carried out to investigate the effect of the components of the cement-sodium silicate grout and kaolinite on the viscosity of the grout. It was found that the effect of cement and sodium silicate on viscosity of grout showed that by increasing the ratio of cement and sodium silicate on the samples then the viscosity increased.
21) Corinaldesi V et al (2010) Slate as a building material especially in palaces and monuments has been used for years. However, use is limited to stone bricks in walls or rooms or as wall cracks in walls, ceilings or floors, leaving its spill in marks or in the size industry can often be considered for use in the construction industry itself as a filler or plasticizer in mud or concrete. The result is that a large 40% of the total rock masses have already acquired a large amount of space. This magnificent era of rock formations that can be formulated with the finest pollutants these days is one of the biggest environmental problems in the world.
22) Dr. Suji D, et al found that slate powder in place of cement is replaced by various percentages (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%). and presented his paper the results of research conducted to investigate the possibility of using dust and dumping slate powder in concrete. It has been found that concrete studies made of starry rock dust and slate powder increase by 12.5%. The flexible beams gradually increased to 10% with the inclusion of slate powder and starry dust and continued with the addition of similar products simultaneously with reduced strength. Therefore, it is concluded that the replacement of natural sand with stone dust, such as replacement of concrete and the return of concrete with slate powder is possible and economical compared to conventional concrete.
23) Zoran Grdić, et.al (2008), found that the addition of fly ash to the component containing hydraulic lime is very useful, bringing about a positive moral improvement of SCCFAHL (SCC by mixing concrete with hydraulic lime). Also, this mixture has less filling and water flow capacity than different mixtures. Silica fume, an additional cost, incorporates into the SCC the same performance as that of conventional concrete mixed with vibration. it is caused by a mismatch between silica fume and a super-plasticizer that requires an increase in water balance in order for concrete to work consistently.
24) Uzma K H Bangi et al (2008) studied the preparation of sodium silicate based hydrophobic silica aerogels via ambient pressure drying. The experiment done by the

help of using sodium silicate, tartaric acid as a catalyst and reactant trimethylchlorosilance as a surface modifier and methanol & hexane as solvents. It was found that low density and semitransparent silica aerogels were obtained by using sodium silicate. It was observed that for a large number of gel washings, the optical transmission of the aerogel improved.

25) In the year 2007, ZHU chun studied the recent advantages in waterglass sand technologies. The experiment done to check the binding strength of the waterglass by several modifications such as physical, chemical, cation & anion, organic and polymer modification to obtained the latest advances of waterglass sand. Authors finding shows that waterglass modification has a significant potential for future developments.
26) In the year (2006) Edson Luiz Foletto et al studied the feasibility of manufacture of soluble sodium silicate using rice hull ash. The parameters for the study includes time of reaction (varying from 0 to 80 minutes), molar ratio $NaOH/SiO_2$ (1,2,3&4), Molar ratio H_2O/SiO_2 (11&12) and reaction temperature (100,110,120,150 & 200 ^OC). Test were performed to check yield, quality of product manufactured. It was noted that the process is feasible and dependent on temperature, molar ratio & reaction time. Author findings shows that RHA contain large amount of silica & small amount of other impurities.
27) W. Labib et al (2005) reviewed that using of slate waste as an alternative aggregate in concrete. The parameter includes the impact of particle shape, size grading, surface texture on workability, strength and durability of concrete. It was found that the flaky particle shape of slate powder waste may be used as an aggregate in concrete. The use of industrial wastes such as slate waste, fly ash, marble waste powder etc in concrete and form an aggregate. This conserves natural resources and reduces the space needed for landfill disposal.
28) F.M .Barrior et al, (2005), worked on the rheological characteristics of ceramic binder in the injection moulding process. The parameter includes in this study were flexural strength, shrinkage porosity and slate waste content. It was noted that 60% ceramic and 40% binder ratio with injection moulding increases the strength of cement and recovered the slate waste.
29) Wafa Labib et al studied the use of slate waste aggregate in concrete. The experimental investigations show that the workability of slate waste aggregate concrete improved by using a crushing process to improve the shape of the slate particles. Authors findings shows that before mixing slate waste, slate composition must be checked.
30) Prassianakis and Prassianakis (2004) and Prassianakis et al (2000) It was noted that slate is a metamorphosed product for the incorporation of limestone subjected to heat and pressure and is chemically sensitive.
31) F.M. Barreiros et al (2002) studied the Powder injection moulding to recover slate wastes. In this study, a method for feedstocks preparation based on slate was optimized, and the influence of thickness of moulded parallel piped bars on debinding cycle studied. It was concluded that best mixture (ceramic /binder ratio 60/40 vol%) was obtained from the continuous mixer while maintaining the mechanical properties thickness around 5mm.
32) Vuk et al (2001), describes slide dust as pozzolan. He also pointed out that calcium carbonate (CaCO3) in slate dust combines with trical calcium aluminate (C3A) cement, which is present in large quantities. This reaction increases the speed of hydration and the compressive strength of the cement.
33) In the year (1996) Dr. A. K. Soni viewed a case study for utilization of slate mine waste into value added products (bricks). The parameter includes compressive strength, tensile strength, flexural strength, porosity etc. It was found that manufacture of bricks using slate mine waste can be utilized in building construction, especially in hilly areas where conventional bricks are not readily available.
34) In the year (1992) Eric Goulden studied the feasibility of use of slate waste aggregate in road construction. The parameter in this study includes the effect of particle size on water permeability, moisture-density relationship and frost susceptibility. It was noted that the mechanical and chemical properties of the slate aggregates from different sources are consistent and can be used as an unbound granular layer in the road woks.
35) Lutz Jeromin et al (1987) studied the continous production of sodium silicate solutions. The experiment done by the help of SiO_2:Na_2O weight ratio of 1-2.8:1 by fusing sand in aqueous sodium hydroxide. The objective of the process is to obtain high volume/time in the reaction of quartz sand with the sodium hydroxide solution. It was found that the process is feasible & depends on temperature, pressure & SiO_2:Na_2O weight ratio.
36) Hans-Peter Rieck et al (1986) studied the process for the preparation of crystalline sodium silicates. The experiment done by usssing SiO_2/Na_2O molar ratio of 1.9:1 to 3.5:1, water content of 5 to 95% by weight & temperature of dehydration kept at 450^OC. It was found that the process is feasible and depends on the molar ratio of SiO_2/Na_2O and dehydration temperature.
37) Jean Deabriges et al (1982) studied the process for the manufacture of sodium silicates. It stated that sodium silicate manufactured from quartz by heating in the autoclave with caustic soda at a temperature from 225^OC to 245^OC with the pressure from 27 to 32 bars and the reaction time from 20 to 35 minutes. It was found that thes process is feasible & cost effective.

III. CONCLUSION

In this paper, characteristics of slate powder and its usage in the production of cement, concrete, tiles, bricks, lime and other useful chemical products were studied. From the research work it appears that slate powder can be used as filler for a variety of products where fillers are applied to produce desirable properties and it contain sufficient amount of silica. It was concluded that slate powder contain large amount of silica so that it can be used in the production of sodium silicate by which the additional cost of adding silica will be minimized and slate waste can be utilized.

ACKNOWLEDGEMENTS

The Authors thankfully acknowledge to Dr. Umesh Pendharkar, Principal, Dr. Anjani Kumar Diwedi, HOD, Dr. Kanjan Upadhyay, Professor, Ujjain Engineering College, Ujjain, India for their motivations and infra structural support to carry out this research.

REFERENCES

[1] Raffaele Vinai, Marious Soutsos, Production of sodium silicate powder from waste glass cullet for alkali activation of alternative binders, College of Engineering, Mathematics and Physical Sciences, University of Exeter, Harrison Building, EX4 4QF, United Kingdom, Volume 116, February 2019.

[2] M. H. Ara Begum, M. M. Hossain, R. Islam, S. Aziz, PILOT PLANT STUDY ON PRODUCTION OF SODIUM SILICATE FROM RICE HUSK ASH, Vol. 4, Issue, 2, pp.38-42, February, 2018.

[3] Seun Samuel Owoeye , Olanireti Esther Isinkaye, Effects of Extraction Temperature and Time on the Physical Properties of Soluble Sodium Silicate from Rice Husk Ash, Department of Glass and Ceramic Technology, Federal Polytechnic, Ado-Ekiti, Nigeria, Science Journal of Chemistry 2017; 5(1): 8-11.

[4] R. Mahadevi, B.M. Sam, Ilavarsan .K, Mohan Kumar. P ,M .Ramchandran, Experimental investigation on Partial Replacement of Cement by Marble Powder and Quarry Dust, International Research Journal of Engineering and Technology (IRJET) - Volume 4(4)(2017),e- ISSN: 2395-0056, p- ISSN: 2395-0072

[5] K.Nagendra Reddy, K.Surya Narayana and J.Damodhar Reddy, Effect of Sodium Hydroxide and Sodium Silicate solution on compressive strength of metakaolin and GGBS Geopolymer, Department of Civil Engineering K L University, Andhra Pradesh India.

[6] Norhasyimi Rahmat et al (2016), Sodium Silicate as source of Silica for synthesis of mesoporous SBA-15,IOP Conference Series : Materials Science and Engineering.

[7] Nabil Al-Joulani, Stabilization of stone Slurry Waste with Cement and Cohesive Soils, International Journal of Applied Engineering Research, Volume 11 Issue 9 Pages 6236-6243(2016).

[8] Palhares, LB, dos Santos, CG and Hunter, TN (2016) Study of citric acid dispersant in the settling behavior of slate powder suspensions. International Journal of Mineral Processing, 150. pp. 39-46. ISSN 0301-7516.

[9] Prerit Saxena, Rishabh Pratap Singh, Sumit, Neelesh, Use of Stone Dust & Granite Powder as a Partial Replacement of Cement, Int. Journal of Engineering Research and Application ISSN:2248-9622,vol-6 Issue 6 June 2016.

[10] B.A.Ajayi, S.S. Owoeye, Extraction of Soluble Sodium Silicate using Corn Cob ash as a Silica Source, Department of Glass & Ceramic Technology, e-ISSN:2320-0847 p-ISSN:2320-0936, Vol-4,Issue-9.

[11] OZKAN, The production of sodium silicate cullet by using trona. Vol. 129 (2016).

[12] Ifrah Habib Lone, Abdul Muneeb, Javid Ahmed, Syed, Experimental study of the effect of sodium silicate (Na_2SiO_3) on properties of concrete, IJCIET Vol-6 Issue 12 , Dec 2015.

[13] Pramod Kilabanur et al , Stabilization of Black Cotton Soil Using Envirobase And Sodium Silicate With Lime, Internation Journal of Science & Technology Research Vol 4 Issue 06, June 2015.

[14] F.M. Barreiros, M.T. Vieira, Powder Injection Moulding to Recover Slate Wastes, Key Engineering Materials Vols. 230-232 (2002) pp. 247-250.

[15] Jean Deabriges, Aix-en-Provence,France, Process For The Manufacture Of Sodium Silicate, United States Patent, 4336235, Jun 22, 1982.

[16] Lutz Jeromin, Hilden; Heinrich Krings,Erkrath; Dieter Legel,Haan; Rudolf Novotny, Duesseldorf; Harald Skrobek, Langenfeld, Continous Production Of Sodium Silicate Solutions, United States Patent 4676953, Jun 30, 1987.

[17] Santosh Dhakar, S. K. Jain, Stabilization of Soil: A Review, International Journal of Science and Research(IJSR) ,Vol 5, Issue 6, June (2016), ISSN(Online): 2319-7064, Index Copernicus Value (2013), Impact Factor (2015):6.391

[18] X.Peng, G.Li, W. Huang, F.Li, X.He, Effect of Slate Powder on Alkali Activity of Slate Aggregate, Applied Mechanics and Materials, ISSN: 1662-7482, Volume 275-277, pp 2124-2130(2013)

[19] Dr.A.k.Soni, Utilization of Slate mine Waste: A Study, Scientist Central Mining research Institute(CMRI)

[20] W.Labib, N.Eden, An Investigation Into the Use of Slate Waste Aggregate in Concrete, Built of Environment, Liverpool John Moores University, Liverpool, L33AF, UK

[21] T.subramani, C.Suamathi, Experimental investigation on Partial Replacement of Cement with Fly ash and Sand with Bottom Ash and Glass Used in Concrete, International Journal of Application or Innovation in Engineering & Management (IJAIEM) - Volume 4(5)(2015), ISSN: 2319-4847

[22] Prof. P.A.Shirule, A. Rahman, R.D.Gupta, Partial Replacement of Cement with marble Dust Powder, International Journal of Advance Engineering Research & Studies, E-ISSN: 2249-8974

[23] F.M.Barrieors, M.T.Vieira, Powder Injection Moulding to Recover Slate Wastes, Key Engineering Materials - Volume 230-232(2002), pp 247-250.

[24] R. Lakahani, R.Kumar, P.Tomar, Utilization of stone waste in the development of value added product: A state of the art review, CSIR, Journal of Engineering Science and Technology Review, (2014)

[25] Dinesh A, Gokilavani.S, Ramya.G, Stabilization of soil by using solid waste: A Review, International Journal of Engineering Development and Research(IJEDR) , Vol 5, (2017), ISSN: 2321-9939, Issue-3

[26] Sina Kazemian, Arun Prasad, Bujang B.K et al, Effect of cement, sodium silicate, kaolinite and water on the viscosity of the grout, Scientific Research and Essays Vol. 5(22), pp. 3434-3442, 18 Nov 2010.

[27] L. S. Zhang et al., "The Effect of Slate Powder on Fly Ash in Suppressing Alkali Activity of Slate Aggregate",

Applied Mechanics and Materials, Vols. 357-360, pp. 1450-1454, 2013

[28] Vuk, Tomaž & Tinta, V. & Gabrovšek, R. & Kaučič, Venčeslav. (2001). The Effects of Limestone Addition, Clinker Type and Fineness on Properties of Portland Cement. Cement and Concrete Research. 31. 135-139. 10.1016/S0008-8846(00)00427-0.

[29] M. Campos, F. Velasco, M.A. Martínez, J.M. Torralba, Recovered slate waste as raw material for manufacturing sintered structural tiles, Journal of the European Ceramic Society, Volume 24, Issue 5, 2004, Pages 811-819

[30] Palhares, LB, dos Santos, CG and Hunter, TN (2016) Study of citric acid dispersant in the settling behavior of slate powder suspensions. International Journal of Mineral Processing, 150. pp. 39-46. ISSN 0301-7516.

[31] Prassianakis, I.N., Prassianakis, N.I., 2004. Ultrasonic testing of non-metallic materials: concrete and marble. Theor. Appl. Fract. Mech. 42 (2), 191e198. http://dx.doi.org/10.1016/j.tafmec.2004.08.007. Rai, B., Khan, N.H., Abhishek, Kr, Tabin, R.S., Duggal, S.K., 2011a. Influence of Marble powder/granules in concrete mix. Int. J. Civ. Struct. Eng. ISSN: 0976-4399 1(4) 827e834., 83e89

[32] Omar, M., Abd Elhameed, G. D., Elhameed, A., Sherif, M. A. and Mohamadien, H.A.(2012) Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties. HBRC Journal 8: pp.193–203.

[33] Uzma K H Bangi, A Venkateswara Rao and A Parvathy Rao, A new route for preparation of sodium silicate based hydrophobic silica aerogels via ambient-pressure drying, Sci. Techno. Adv. Mater. 9(2008) 035006(10pp).

[34] Introduction of sodium silicate, Product code: 31337, March 2003, Small Industries Service Institute Bangalore – 560044.

[35] Oxyoccidental Chemical Corporation – A subsidiary of Occidental Petroleum Corporation, Product Stewardship Summary Liquid Sodium Silicate.

[36] M. Poojidha, K Nirmalkumar, Review Paper on Reaction of Alkaline Solution in Geo-polymer Concrete, Internation Journal of Recent & Innovation Trends in Computing and Communication Vol 4 Issue 10.

[37] ZHU Chun, Recent advantages in waterglass sand technologies, School of Material Science & Engineering, Feb 2007.

[38] Sang-wook Ui, In-seok Choi, Synthesis of High Surface Area Mesoporous Silica Powder Using Anionic Surfactant, Volume 2014, Article ID 834629.

[39] M.Keawthun, S.Krachodnok, A.Chaisena, Conversion of waste glasses into Sodium Silicate solutions, Department of Chemical Enginnering, 12(1) 2014.

[40] Soluble Sodium Silicate Manufacturem I-Chemicals-G-Sodium Silicate-I, Written by Craig Turner (IChem Ltd.) with summary box by Heather Wansbrough.

[41] M. Kermani, F.P Hassani, Evaluation of the effect of sodium silicate addition to mine backfill, Gelfill,Part 2:Effect of mixing time & Cuing temperature, Journal of Rock Mechanics And Geotechnical Engineering, (2015) 668-673.

[42] T.Subramani, T. Senthilkumar, J. Jayalakshmi, Analysis of admixtures and Their Effects of Silica Fumes, Metakaolin,and PFA on the Air Content, International Journal of Modern Engineering Research (IJMER) (2014)

[43] T.subramani, C.Suamathi, Experimental investigation on Partial Replacement of Cement with Fly ash and Sand with Bottom Ash and Glass Used in Concrete, International Journal of Application or Innovation in Engineering & Management (IJAIEM) - Volume 4(5)(2015), ISSN: 2319-4847

[44] T. Subramani, S. Kumaran, Experimental investigation of Using Concrete waste and Brick Waste as A Coarse Aggregate, International Journal of Application or Innovation in Engineering & Management (IJAIEM) - Volume 4(5)(2015), ISSN: 2319-4847

[45] A. Ram Prasanth, J.R. Murugadoss, K.Saranya, An Experimental Study of Concrete by Partial Replacement of Cement by Bagasse Ash and Coarse Aggregate by Recycled Aggregate, International Journal of Chem. Tech Research s(IJCRGG) - Volume 10, No. 11, pp 911-94,(2017), ISSN: 0974-4290

[46] Theunissen, Joseph Pierre Huhert Verdistraat, Preparation of Sodium Silicate, EUROPEAN PATENT APPLICATION 0 363 197, 05.10.89.

[47] Ellis, Harold Bernord, Stabilization of Soils with lime & Sodium Silicate, Hectographed Special Bulletin, Philadelphia Author.

[48] Ankit Singh Parihar et al, Application of Slate Powder Waste in the Manufacturing of Tiles and Pavers: A Review, IJSRD - International Journal for Scientific Research & Development| Vol. 8, Issue 6, 2020 | ISSN (online): 2321-0613.

[49] Megha Kasliwal et al, Utilization of slate powder into value added product: A Review, International Journal of Current Research Vol. 10, Issue, 08, pp.72653-72660, August, 2018.

