NS-645 - Assessment of Alternative Pozzolans: Literature Search

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Resources searched: TRID, Pooledfund.org

Summary: Results are compiled from the databases named above. Links are provided for full-text, if applicable, or to the full record citation. I completed my searches using the following terminology: alternative, pozzolan. Results are categorized as most and least relevant below.

Most Relevant Results

Jafari, Khashayar; Rajabipour, Farshad. Performance of Impure Calcined Clay as a **Pozzolan** in Concrete. Transportation Research Record: Journal of the Transportation Research Board, Volume 2675, Issue 2, 2021, pp 98-107
https://trid.trb.org/view/1750022
Abstract: Supplementary cementitious materials (SCMs) are natural or industrial by-product materials which are used to improve the performance, durability, and sustainability of concrete mixtures. Motivated by the recent reports on shortage of conventional SCMs, impure calcined clays (CCs) are receiving attention as abundant **alternative pozzolan**s for concrete. In this study, a clay slurry resulting from washing aggregates in a commercial sand and gravel pit was investigated. This source clay was dried and calcined, and the properties and **pozzolan**ic performance of the resulting CC was evaluated. It was observed that despite having a large (>50%wt.) inert quartz content, the CC met all ASTM C618-19 (AASHTO M295) requirements for natural **pozzolan**. A pavement-grade concrete mixture containing 20%CC as a cement replacement (by weight) produced desired workability and fresh and hardened air content. Strength development was slightly below the control. The use of CC improved the durability of concrete with respect to chloride penetration, alkali–silica reaction, and drying shrinkage in comparison with a control (100% Portland cement) mixture. In addition, ternary limestone-calcined clay–cement and slag-calcined clay–cement mortar mixtures showed excellent strength development while replacing nearly 50% of the Portland cement.

Durability of Concrete Produced with an **Alternative** Supplementary Cementitious Material. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Aug. 2020.
https://trid.trb.org/view/1751181
Description: New Mexico contains several aggregate sources that are extremely susceptible to alkali-silica reaction (ASR). To mediate ASR, the New Mexico Department of Transportation (NMDOT) requires a minimum of 20% class F fly ash (by mass of cement) in nearly all concrete produced for their projects. However, class F fly ash has become difficult for concrete producers to procure, and future availability is uncertain. Consequently, NMDOT is considering adopting **alternative** supplementary cementitious materials (SCMs) that could be used in place of class F fly ash. The purpose of this research project is to assess one of the **alternative** SCMs being considered for potential acceptance by NMDOT. The SCM to be studied is a natural **pozzolan** mined from a pumicite deposit near Espanola, NM. Natural **pozzolan**s are a class of siliceous or siliceous and aluminous materials that possess little or no cementitious value by themselves, but can react chemically with calcium hydroxide and water at ordinary temperatures to form compounds possessing cementitious properties that can improve concrete strength and durability. NMDOT has little data for mixture proportions and durability properties of concrete produced with this material, so they are not able to confidently accept the material for use in concrete produced for NMDOT projects, even if class F fly ash is not available. This research project consists of a

comprehensive literature review to identify the most important properties and characteristics of SCMs, and especially natural **pozzolan**s, in terms of their influence on concrete durability. For the experimental work to be conducted in this study, a suite of concrete mixtures, similar to currently accepted NMDOT mixtures, will be proportioned using the natural **pozzolan** to replace different percentages of fly ash. Concrete produced from these mixtures will be tested for slump, air content, compressive strength, and flexural strength to ensure that the mixtures provide adequate workability and strength. Then, the durability of the concrete mixtures will be tested by assessing their chloride permeability, resistance to freezing and thawing, susceptibility to ASR, and their shrinkage characteristics. Results from mixtures containing the natural **pozzolan** will be compared to control mixtures produced using NMDOT concrete mixtures containing only class F fly ash. The implementation phase of the project includes documenting and disseminating the results of the research. Dissemination of the results will include the final report for the project, publication of journal papers, publication of conference papers, and presentations at conferences. The New Mexico State University (NMSU) research team is led by the PI, Professor Craig Newtson, who has over 20 years of concrete related research experience on projects totaling more than $2,300,000 in funding. The team also includes Associate Professor Brad Weldon as a Co-PI. Dr. Weldon has supervised more than $1,300,000 in funded research projects and has received national recognition for his research.

Evaluation of **Alternative** Sources of Supplementary Cementitious Materials (SCMs) for Concrete Materials in Transportation Infrastructure. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Aug. 2020.
https://trid.trb.org/view/1751123
Description: Concrete materials are present in almost all types of transportation infrastructure including roads, bridges, and airports. As such, concrete is an essential component of the transportation infrastructure. Supplementary cementitious materials (SCMs) are a key ingredient of modern concrete. SCMs improves the durability (e.g., decreases permeability and help mitigate deleterious reactions) and mechanical properties of concrete and significantly reduces its carbon footprint by reducing the utilization of clinker. In recent years, the decline in coal-fired power generation in the U.S. jeopardizes the wide availability of fly ash for concrete production. Since fly ash is vastly the most utilized supplementary cementitious material (SCM) in the U.S., there is an urgent need to find **alternative** sources of SCMs that can provide with a portfolio of **alternative**s. As a response to the expected shortage of fly ash, the objective of this project is to evaluate the much-needed **alternative** sources of SCMs which can include unconventional sources of fly ash (i.e., landfilled and impounded fly ash), natural **pozzolan**s, and calcined clays to provide with high-quality, cost-effective, and readily-available SCM **alternative**s for the future of concrete production in Region 6.

Rajabipour, Farshad; Jafari, Khashayar; Zahedi, Mona. Evaluation, Beneficiation, and Implementation of **Alternative** Concrete **Pozzolan**s for Transportation Infrastructure. Pennsylvania State University, University Park; Center for Integrated Asset Management for Multimodal Transportation Infrastructure Systems (CIAMTIS); Office of the Assistant Secretary for Research and Technology, 2020, 51p
https://trid.trb.org/view/1741691
Abstract: The supply of conventional supplementary cementitious materials (SCMs such as coal fly ash and ground granulated blast furnace slag) continues to fall further behind the concrete industry's demand to produce durable and sustainable concretes. As an **alternative**, interest in nontraditional **pozzolan**ic materials continues to grow. This study evaluated two such **alternative**s: fluidized bed combustion (FBC) fly ash and impure calcined clay. Four compositionally different FBC fly ashes and one low-purity kaolinite clay deposit, all from the Mid-Atlantic region of the United States, were evaluated. These **pozzolan**s were characterized according to the requirements of ASTM C618 (equivalent with AASHTO M 295), "Standard Specification for Coal Fly Ash and Raw or Calcined Natural **Pozzolan** for Use in Concrete." Additionally, these **pozzolan**s were used at 20% mass replacement of portland cement in a pavement-grade concrete mixture and their effects on the fresh, hardened, and durability properties of the concrete were evaluated. It was observed that desirable slump, air content, air-voids structure, and strength development can be achieved in concrete

with FBC fly ashes and calcined clays. In addition, the use of these **pozzolan**s improved the durability of concrete with respect to chloride penetration, alkali-silica reaction, and drying shrinkage in comparison with a control (100% portland cement) mixture. A preliminary cost analysis and suggestions for modifying ASTM C618 to better regulate these **pozzolan**s are offered.

Yagüe García, Santiago; González Gaya, Cristina. Durability analysis of **pozzolan**ic cements containing recycled track ballast: Sustainability under extreme environmental conditions. Construction and Building Materials, Volume 242, Issue 0, 2020
https://trid.trb.org/view/1684634
Abstract: Since the ratification of the Kyoto protocol by the EU in 2002, Members States have committed themselves both to reducing their greenhouse gas emissions and to environmental sustainability, inter allia by using cements with **alternative** additions that incorporate industrial waste. In this paper, ionic mobility through a **pozzolan**ic cement is studied. The cement contains substitutions of 10% and 20% rejected ballast waste and is prepared for railway infrastructure (slab or ballast less track) that is exposed to extreme climatic conditions (high thermal amplitudes and saline environments). Studied with CT-Scanning, ionic mobility can be observed along the cement pores. The cement with 10% substitutions of ballast waste was considered ideal to minimize ionic penetration and cement deterioration.

Al-Shmaisani, Saif; Juenger, Maria. What Does the Changing Face of Electricity Production Mean for Concrete?. Public Roads, Volume 83, Issue 4, 2020
https://trid.trb.org/view/1682034
Abstract: Recent environmental regulations that require emissions-control systems and the abundance of natural gas as an **alternative** fuel to coal have led to a decline in coal-fired power plants—a trend that is likely to continue. The U.S. Energy Information Administration (EIA) forecasts that 42 percent of existing coal-fired generation capacity will retire by 2050. As fly ash becomes less and less available, State departments of transportation and their contractors will need to seek **alternative**s. Many are already considering other options, such as natural **pozzolan**s. This article describes some of the research being conducted to address this situation, as well as some of the materials that are being considered as **alternative**s to fly ash.

AlArab, Amir; Chehab, Ghassan; Hamad, Bilal. **Pozzolan**ic Activity of Concrete Incorporated Sustainable Materials for Rigid Pavements. International Airfield and Highway Pavements Conference 2019, American Society of Civil Engineers, 2019, pp 460-469
https://trid.trb.org/view/1638970
Abstract: Many scholars worked on utilizing byproducts materials in rigid pavements because of the increasing demand for incorporating sustainable pavement materials in construction. Ceramic is one of the materials integrated to the concrete mix as a cement **alternative**. Recently, it has been witnessing a debate on whether it is considered **pozzolan**ic. In line with this trend, this study aims at first in assessing the **pozzolan**ic activity of ceramic powder and the hybrid powder composed of ceramic and slag cement as well as assessing the flexural capacity of concrete. The adopted research program made on pastes is achieved through Frattini test (direct method) and strength activity index (indirect method) along with SEM and X-ray diffraction tests to characterize the studied pastes. Four types of pastes are considered in the experimental plan: cement paste, slag cement paste, ceramic cement paste, and a hybrid paste which consists of ceramic, slag, and cement. Lastly, the flexural capacity is made through the four combinations. The accomplished laboratory-testing program is presented, and the results will be further analyzed and discussed.

Evaluation, Beneficiation, and Implementation of **Alternative** Concrete **Pozzolan**s for Transportation Infrastructure. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 11 Mar. 2019.

https://trid.trb.org/view/1595400
Description: This study will evaluate, improve, and facilitate the use and field implementation of two new, low-cost, and locally available supplementary cementitious material (SCM) sources that can be used for producing high-performance concrete. First is the fluidized bed combustion (FBC) fly ash that is widely produced (3+ million tons/year) in Pennsylvania and West Virginia as a result of environmental cleanup of waste coal piles in the region by FBC electric power utilities. Second is the low purity kaolinite clay that is intermixed with glacial deposits of sand and gravel within the region (PA, MD, VA). Aggregate producers need to wash off this clay, which can be retrieved, calcined, and used as a quality SCM for concrete. While they are cheap and locally abundant, these SCM resources have not been previously used in concrete, their properties and performance are largely unknown, and as such, they are not included in DOT specifications in the region. This study will address these gaps by providing reliable data on the performance of these materials, developing guidelines and
draft specifications, and educating and connecting practitioners and stakeholders on proper testing and utilization of these valuable concrete **pozzolan**s.

SAILLIO, Mickael; ANDRADE, Lucie; MEJDI, Mehdi; CHAUSSADENT, Thierry; TAGNIT-HAMOU, Arezki. Properties of cementitious materials with sewage sludge ashes.. Proceedings of the International Conference on Sustainable Materials, Systems and Structures (SMSS2019) : New Generation of Construction Materials, 2019, pp. 156-163
https://trid.trb.org/view/1681523
Abstract: Numerous industrial by-products have potential for use as **alternative** supplementary cementitious materials (ASCMs) in concrete. The objective of the present study is to better understand the reactivity and the impact on durability and on hydration of one ASCMs: calcined sewage sludge ashes (SSA). Some tests are directly performed on SSA such as the **Pozzolan**ic test. In addition, cement pastes and mortars with SSA are mixed with the same W/B ratio. Seven binders are studied: a reference OPC and 6 mixes with OPC substituted by SSA from 5 to 30%. In order to study the hydration, setting time test, XRD, TGA/DTA are performed on cement paste and the durability tests are also performed on mortars such as water porosity, rapid chloride test and resistivity test. Various water curing time (from 7 to 365 days) are chosen in order to take into account the evolution of the materials. The first results, based on chemical tests have highlighted the behaviour of this ASCMs and led to the design of materials which exhibit good durability properties at long age. In particular, chloride diffusion apparent coefficient is significantly reduced for material with SSA. Some properties (such as a potential **pozzolan**ic activity) appear to be quite similar to standard fly ash or metakaolin.

Use of Bagasse Ash as a Concrete Additive for Road Pavement Applications. [Project]. Department of Transportation, Office of the Assistant Secretary for Research and Technology. Start date: 15 Mar. 2018.
https://trid.trb.org/view/1505361
Description: This research will investigate potential uses of sugarcane bagasse ash to reduce the cost and carbon footprint of concrete materials for road pavement construction and maintenance. Bagasse is the fibrous by-product of sugarcane stalks after they are crushed to extract their juice. Fortunately, bagasse ash has also been found to be a suitable supplementary cementitious material (SCM) due to its **pozzolan**ic behavior. Hence, it can be used as an **alternative** to reduce cement consumption, similar to the current use of fly ash. **Pozzolan**ic additives such as bagasse ash present several benefits, such as lower costs, lower environmental impacts, higher long-term compressive strength at the expense of a small reduction of the 28-day compressive strength, and improved durability. This study's goal is to develop new uses for bagasse ash as an SCM for concrete. In particular, the use of bagasse ash as a partial substitute for cement and fly ash will be investigated. An efficient production method to maximize the **pozzolan**ic activity of bagasse ash will be developed, and the optimal amounts of bagasse ash to obtain desired concrete properties will be identified. The economic feasibility of bagasse ash used as an SCM will be explored through a preliminary life-cycle cost analysis.

Al-Shmaisani, Saif; Kalina, Ryan; Rung, Michael; Ferron, Raissa; Juenger, Maria. Implementation of a Testing Protocol for Approving **Alternative** Supplementary Cementitious Materials (SCMs): Natural Minerals and Reclaimed and Remediated Fly Ashes. University of Texas, Austin; Texas Department of Transportation; Federal Highway Administration, 2018, 138p
https://trid.trb.org/view/1502729
Abstract: Supplementary cementitious materials (SCMs) provide many benefits to concrete mixtures in terms of cost, -strength, and durability. Class F fly ash is the most widely used SCM in Texas, but its availability is dwindling while demand is increasing. Given the importance of Class F fly ash as a means to improve concrete durability, it is important to find **alternative** materials that can maintain the high quality and durability of concrete required in Texas. TxDOT Project 0-6717: Investigation of **Alternative** Supplementary Cementing Materials (SCMs), completed in August 2014, identified sources of Class F fly ash **alternative**s that can be used in Texas concrete and developed best practices for testing these materials. Lower cost sources of materials have been identified since the completion of that project and may present better opportunities for Class F fly ash replacement than those initially tested. These materials include natural mineral byproducts of other industries, reclaimed fly ashes, and remediated fly ashes. The experimental protocols developed in Project 0-6717 were performed on these new sources of materials to determine their suitability for use in Texas concrete. The materials were chemically and physically characterized, and their performance in cement paste, mortar, and concrete mixtures was tested. It was determined that some of the natural minerals were inert; thus, they are not recommended for use in concrete. Natural pumicite performed well as an SCM, including a pumicite that is quarry overburden and could be procured at a relatively low cost. This overburden pumice, however, did not perform as well as expected in testing for sulfate resistance and merits further investigation. It is possible that the overburden pumicite would perform better if used as at a higher replacement level of cement. The reclaimed and remediated fly ashes performed very well, proving their ability to be used as substitutes for “production” Class F fly ash based on the criteria established in this project. In the cases where reduced performance was seen in fly ashes, the problems should be easily managed through the addition of chemical admixtures.

Azarijafari, Hessam; Tajadini, Azim; Rahimi, Motahareh; Berenjian, Javad. Variation in the Test Results of Self-Consolidating Lightweight Concrete Containing Ternary Blended Cement. Transportation Research Board 97th Annual Meeting, 2018, 15p
https://trid.trb.org/view/1494933
Abstract: Portland limestone cement can be considered as a suitable **alternative** for portland cement in self-consolidating lightweight concrete (SCLWC) mixtures. However, certain inconsistencies were reported in terms of strength development and durability properties of the portland limestone cement concrete. In addition, fresh SCLWC mixtures are more likely to encounter test results variation than ordinary concrete. This paper experimentally investigates the performance of SCLWC incorporating ternary blended cements containing portland limestone cement and silica fume, fly ash, natural zeolite or metakaolin. The results show that the **pozzolan**ic materials mixtures have greater but less variable results of flowability compared to the portland limestone mixture. The coefficient of variation in results of slump flow test is varied 0.8-2.9%. It was also observed there is a reduction in variation of the V-funnel results as the mean value increased. The obtained coefficient of variation was as low as 7% for zeolite ternary mixtures and the highest variation belonged to the binary mixture by 19.2%. The result of rapid chloride migration test (RCMT) and electrical resistance test indicated that there is a strong correlation between these two variables. Comparing the results to other studies, we recognized that the correlation seems to be unique for each case study.

Evaluation of Silica-Based Materials for Use in Portland Cement Concrete. [Project]. Florida Department of Transportation. Start date: 7 Jun. 2017.
https://trid.trb.org/view/1470272
Description: This research will investigate the use of new sources of **pozzolan**ic materials, which will be used to implement recommendations for revisions to the Florida Department of Transportation (FDOT) Standard Specification for road and bridge construction, particularly section 929, **Pozzolan**s and Slag. The research will investigate the plastic,

rheological, heat generating, chemical, physical, and durability properties of the **alternative** materials and their suitability for use in concrete.

Use of Rice Hull Ash (RHA) as a Sustainable Source of Construction Material. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 8 May. 2017.
https://trid.trb.org/view/1466418
Description: Rice hull ash (RHA) is a cementitious material, which may contain about 75% silica in an amorphous form and has an extremely high surface area. RHA is also economically beneficial, but its performance as a construction material has been investigated very little. High silica content makes it a probable **pozzolan**ic material for concrete by following the Roman Concrete technology.
The main objective of the proposed study is to assess the usage of rice hull ash (RHA) as a construction material. Specific objectives are given as: (i) evaluate chemical, physical and strength and expansion properties of RHA-modified concrete based on curing time and environmental conditions; and (ii) assess the feasibility of using RHA as an **alternative** modifier to enhance performance properties of soft asphalt binders. These objectives will be accomplished by testing RHA-modified samples in laboratories. Strength properties (compressive, tensile, elastic modulus, etc.) and alkali-silica reactivity (ASR) properties of RHA-modified concrete at different curing time will be evaluated. Rheological properties of RHA-modified asphalt binders will be determined by following the routine and Superpave test protocols. The benefits of the proposed study are (a) reuse of waste materials in transportation construction projects, (b) enhance training opportunity for students in the Mississippi Delta region, (c) help local farmers and asphalt industries to be economically sustainable, and (d) build a future workforce.

Use of Nevada's Natural **Pozzolan** to Mitigate Alkali-silicate Reactivity. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Feb. 2017.
https://trid.trb.org/view/1464479
Description: In 2009, the International Energy Agency and World Business Council for Sustainable Development prescribed four strategies the cement industry can utilize in order to reduce CO_2 emissions: (1) thermal and electric efficiency; (2) **alternative** fuel; (3) cement substitution; and (4) installation of carbon capture and storage devices. While cement manufacturing technology is reaching its efficiency limit, and **alternative** fuel and carbon capture technologies are still at infancy; cement partial substitution with Secondary Cementitious Materials (SCMs) has received the most attention with positive results, reducing demand for Portland cement by 20-25%. However, with on-going closure of coal-fired power generating plants and ash ponds across the United States (US), as well as recent changes in the Environmental Protection Agency's regulations, the production of available fly ash that is acceptable for use in concrete will be more limited in future. This supply-demand problem adversely impacts cement substitution strategy, forcing concrete industry into finding and evaluating **alternative** sources of SCMs. One overlooked **alternative** to alleviate the

rapidly declining sources of SCMs in the US is natural **Pozzolan** as a key part of the solution to reduce environmental burden of the cement industry.

The overall objective of this study is to assess effectiveness of Nevada's natural **pozzolan**s as SCMs on mitigation of alkali-silicate reactivity. This project will:
(1) Assess the effectiveness of different natural **Pozzolan**s as SCMs on resistance to alkali silica reactions (ASR) of Portland cement pastes, mortars and concretes prepared with four known Nevada's reactive aggregate sources.
(2) Find minimum and maximum dosages of natural **Pozzolan**s as cement replacements based on resistance to ASR, as well as strength properties, for the selected reactive aggregate sources.
(3) Compare effects of Class F fly ash and natural **Pozzolan**s on ASR resistance of Portland cement mortars and concretes.

SAILLIO, Mickael; FROHARD, Fabien; CHAUSSADENT, Thierry; DIVET, Loïc; TAGNIT-HAMOU, Arezki. Durability of concrete with **alternative** supplementary cementitious materials. 10th ACI/RILEM International Conference on Cementitious Materials and **Alternative** Binders for Sustainable Concrete, 2017, 19 p.
https://trid.trb.org/view/1491657
Abstract: Numerous industrial by-products have potential for use as **alternative** supplementary cementitious materials (ASCMs) in concrete. The objective of the present study is to define the reactivity and the impact on reinforcement corrosion of three ASCMs: glass powder, biomass fly ashes, and calcined sewage sludge. The first results, based on chemical tests and thermodynamic analysis have highlighted the behavior of these ASCMs and led to the design of concretes which exhibit good mechanical properties with a replacement of Portland cement of 15 or 20%. It can be highlighted that the main parameter considering the mechanical properties is the water to binder ratio; here 0.40 and 0.55 ratios are studied. The second part of the study deals with concrete durability properties such as chloride and carbon dioxide transfer properties. Due to its **pozzolan**ic reactivity, glass powder significantly increases carbonation process but limits chloride penetration in concrete.

Calcined marl as supplementary cementitious material (SCM)
http://www.tsus.sk/sluzby/dokumenty/brochure_%20workshop_novacem_consents.pdf#page=8

Influence of aging conditions upon the properties of calcined clay and its performance as supplementary cementitious material
https://www.sciencedirect.com/science/article/abs/pii/S095894651630186X

DURABILITY OF TERNARY BLENDED CEMENT CONCRETE CONTAININING BAMBOO LEAF ASH AND PULVERIZED BURNT CLAY
https://www.researchgate.net/profile/John_Kolawole/publication/319964232_DURABILITY_OF_TERNARY_BLENDED_CEMENT_CONCRETE_CONTAINING_BAMBOO_LEAF_ASH_AND_PULVERIZED_BURNT_CLAY/links/59c3cab6a6fdcc8ff7910a6b/DURABILITY-OF-TERNARY-BLENDED-CEMENT-CONCRETE-CONTAINING-BAMBOO-LEAF-ASH-AND-PULVERIZED-BURNT-CLAY.pdf

Least Relevant Results

Evaluation of Sustainable and Environmentally Friendly Stabilization of Cohesionless Sandy Soil for Transportation Infrastructure. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Aug. 2020.
https://trid.trb.org/view/1751144
Description: The stabilization of cohesionless soils with cementitious materials is essential for local materials to be used for construction activities, due to the lack of strength of such geomaterials in their native state. Generally, such stabilization results in enhanced mechanical properties due to formation of **pozzolan**ic compounds which may satisfy

the design requirements. However, there is a high carbon-footprint when traditional stabilizers are used. During natural disasters, such as flooding and hurricanes, pavements built using cohesionless soils may undergo significant damages. Recently, researchers have started exploring other **alternative** form of chemical additives that will be effective in stabilization yet will have low carbon footprint with high sustainable benefits. A new class of alumino-silicate-polymers, commonly known as Geopolymers have emerged due to its eco-friendly and sustainable nature and its cementitious properties. Geopolymer has received significant attention as an **alternative** to Ordinary Portland Cement (OPC) and lime for soil stabilization, and other applications for pavements, bridges, and other transportation structures. However, most of the previous studies on using Geopolymers for soil stabilization focused on stabilization of clay-rich soils. Some preliminary results also suggest that stabilization of sandy soils with Geopolymers might even results in more durable solution when compared to clay-rich soils, or use of OPC stabilizers, due to the excellent adhesion of the Geopolymers to the send particles. However, very limited studies were reported in the literature in this area and the proposed research plan aims at evaluating the performance of Geopolymers in effectively stabilizing cohesionless soils typical for coastal region of Region 6. A collaborative research study is formulated by teams from Department of Civil and Environmental Engineering and Department of Material Science and Engineering in Texas A & M University, College Station to investigate the feasibility of stabilizing cohesionless soils using Geopolymers and combination of Cement and Geopolymer for transportation infrastructure in Region 6. The effects of Geopolymer, dosage rates, and curing condition on overall performance and structural and mechanical properties of Geopolymer-stabilized soils have to be studied in order to optimize the use of Geopolymer derived from local waste and natural materials for transportation infrastructure in Region 6. As part of the proposed study, shrinkage, strength and stiffness tests in the form of unconfined compressive strength and repeated load triaxial tests will be conducted to evaluate the performance of stabilized soil. Both material characterization studies related to micro to macro behavioral changes of native soils and Geopolymer-and Cement-Geopolymer-treated soils will be carried out as a part of this research. During implementation phase, sustainable, resiliency, and life cycle analysis of Geopolymer-stabilized cohesionless soils will be evaluated. The proposed research should provide major benefits in the design of resilient, and ecofriendly infrastructure in Texas and other regional states in Region 6 where cohesionless soils are in abundance. The proposed research with Geopolymers, should provide sustainable greener **alternative** for transportation infrastructure that will be resilient with low distress problems. Therefore, proposed collaborative study focuses on these Tran-SET's areas: Area 4: Improving durability and extending the life of the infrastructure (Sub-area: Application of new materials and technologies); Area 5: Preserving the environment; Area 6: Preserving the existing transportation system. Two doctoral students will work with PIs (Dr. Radovic, Dr. Puppala, and Dr. Chakraborty) to execute the proposed research tasks. The expected deliverable from this project is a technical report summarizing all tasks from both institutes including necessary design guidelines of resilient Geopolymer-stabilized cohesionless soils. The team also anticipates to publish several high impact research publications including journal and conference articles. Results of this project will be also disseminated in transportation related workshops and committee talks at TRB annual meetings and presented to the potential industry partners.

Bahadori, Hadi; Hasheminezhad, Araz; Alizadeh, Sakineh. The Influence of Natural **Pozzolan**s Structure on Marl Soil Stabilization. Transportation Infrastructure Geotechnology, Volume 7, Issue 1, 2020, pp 46-54
https://trid.trb.org/view/1681919
Abstract: Marl as a calcareous soil has heterogeneous nature in terms of structure and properties. Any change in the water content of marl can cause significant strength loss; therefore, prior stabilization while constructing civil infrastructures is necessary. A fundamental element in soil stabilization is the relationship between soil structure and stabilizers, but this important factor has been ignored in the available literature, especially in the case of marl soil. Lately, **alternative** environmentally friendly additives (natural **pozzolan**s) as well as traditional chemical stabilizers (cement and lime) have been successfully used for stabilization of marl soil. This paper presents the results of an experimental study which investigates the influence of natural **pozzolan**s structure on marl soil stabilization. Transmission electron microscopy (TEM), X-ray fluorescence (XRF), and Fourier transform infrared spectroscopy (FTIR) tests were used for size and structure analysis of marl soil and two types of natural **pozzolan**s called Qizkorpi and Mamaloo of Iran which have been successfully used for marl soil stabilization by the authors, recently. Based on the

obtained results by TEM, FTIR, and XRF tests, due to the similarity of the structure and size of Gizkorpi volcanic ash and marl soil when compared to that of Mamaloo volcanic ash, it can be concluded that the electrostatic and magnetic interactions in marl and Gizkorpi volcanic ash lead to a better stabilization and strengthen of the marl, while these interactions are less in Mamaloo volcanic ash when mixed with the marl soil.

Wang, Dong; Tawk, Miriam; Indraratna, Buddhima; Heitor, Ana; Rujikiatkamjorn, Cholachat. A Mixture of Coal Wash and Fly Ash as a Pavement Substructure Material. Transportation Geotechnics, Volume 21, Issue 0, 2019
https://trid.trb.org/view/1641162
Abstract: The reuse of waste materials in engineering projects has become the subject of many research efforts worldwide as it provides economical as well as environmental benefits. Coal wash (CW) and fly ash (FA) are example waste materials that can be used as **alternative** aggregates in transportation infrastructure projects, specifically as base and subbase materials in roads. Class C FA has been extensively used as a stabilizing material due to its hardening potential. However, Class F fly ash, a non-**pozzolan**ic material when used alone, has not been considered in past research projects. In this study, Class F fly ash is mixed with coal wash as a void filler to enhance its compaction efficiency and produce a compact and well interlocked structure. A laboratory testing plan is performed to assess the geotechnical properties of the mixtures with 0%, 7%, 10% and 13% FA content and it includes compaction tests, unconfined compressive strength tests, California Bearing Ratio (CBR) tests, collapse potential tests and permeability tests. The mixture with 7% FA is selected as the optimum mixture and its potential for tensile cracking under service loads is further investigated using four-point bending tests. Also, the resilient modulus and permanent deformations of the mixture are evaluated under different dry-back conditions using multistage repeated load triaxial tests.

Wang, S; BAAJ, H; Zupko, S; Smith, T. Field and lab assessment for cement-stabilized subgrade in Chatham, Ontario. TAC 2018: Innovation and Technology: Evolving Transportation - 2018 Conference and Exhibition of the Transportation Association of Canada, Transportation Association of Canada (TAC), 2018, 1 PDF file, 699 KB, 19p.
https://trid.trb.org/view/1563634
Abstract: Cement stabilized subgrades have been extensively used to improve the engineering performance of pavement structures. Due to the effects of cementitious hydration, **pozzolan**ic reaction, as well as, cation exchange, chemical bonding is generated between fine soil particles. Therefore, the geotechnical characteristics of difficult clay soils will be improved in terms of plasticity, strength, stiffness, and durability. The cement modified soils (CMS) will then function as a new pavement layer which partially or totally preplaces the thickness of granular base layer as commonly found in traditional road constructions. This paper first introduced a subgrade stabilization project located in Chatham-Kent, Ontario, followed by the field testing of subgrade stiffness using a light weight deflectometer (LWD) test on the stabilized subgrade surface. Five different low-volume roads were chosen as test sections for LWD stiffness test. The stiffness of the subgrades was measured before the construction, 3 hours after the stabilization followed by testing at 3 days, 7 days, 28 days, and 1 year respectively. Field test results indicated a significant increase of the subgrade stiffness after the cement stabilization and compaction; moreover, the stiffness continued growing along with the curing time. Soil sampled from one of the test sections was tested in lab facilities. Laboratory testing including: unconfined compressive strength (UCS) at 7 days and 28 days, durability test and pH values test for cement stabilized soil. Stabilized soil had 7 days UCS value of 0.83 MPa with 6% cement, and 1.43 MPa with 12% cement. Moreover, 5% to 6% cement stabilized T38 soil specimens had improved durability properties against freezing and thawing and met the weight loss limit requirements. Results also indicated that the cement stabilization changed the soil environment from slightly acidic to alkaline, and reduced the potential for growing of organics. It is also recommended future studies evaluate mixes with supplementary cementing materials to provide a more environmentally friendly stabilized subgrade. The paper finally introduces **alternative** Hydraulic road binders (HRB) as a more economic, sustainable and environmentally friendly solution to the construction and rehabilitation of Canada's low-volume roads.

The Use of Mt. Mazama Volcanic Ash as Natural **Pozzolan**s for Sustainable Soil and Unpaved Road Improvement. [Project]. Office of the Assistant Secretary for Research and Technology, Oregon Institute of Technology. Start date: 1 Nov. 2016.
https://trid.trb.org/view/1434750
Description: The Klamath Basin, located in Southern Oregon is a small, rural community with significant agricultural and timber resources. The formation of this community in the early part of the 20th century began with 'reclaiming' wetlands for agricultural use. A series of canals, levees, dams and pumping stations were constructed to irrigate reclaimed wetland areas. Recently the Bureau of Reclamation has reclaimed some of these former wetland areas back to wetlands. These wetlands serve as wildlife refuges and natural areas for the community of Klamath Basin. These wetlands are accessed along roads atop levees that are constructed of soft, compressible soils. A graduate student studied one of these access roads and found that several areas had settled significantly and were in need of repair. To repair these access roads, soil improvement was suggested. Conventional methods of soil improvement include compaction, excavation and replacement and mixing the soils in place with either powdered portland cement or lime. Powdered portland cement and lime are both expensive materials, and require significant amounts of energy to produce. In addition the environmental effects of adding these materials to an ecologically sensitive site like the Wood River Wetland are unknown. For these reasons we investigated **alternative** materials to be mixed with the soils to improve their properties for access roads. Through research, we found that the eruption of Mt. Mazama approximately 7,000 years ago blanketed the Klamath Basin region with a thick layer of volcanic ash that is known to behave similarly to portland cement. These deposits have been previously mapped for their economic value. Using these materials in place of portland cement for soil stabilization of access roadways has three distinct benefits: (1) They do not introduce materials to the environment that are not already present. (2) They require only transportation to be produced, thus they have a significantly smaller carbon footprint than portland cement which consumes energy to manufacture. (3) If found to be beneficial, they would create a new, relatively untapped economic product found in the Klamath Basin. Preliminary research conducted by students show that these materials do have some beneficial properties but more research is necessary. In addition to soil stabilization for access roadways, there is the potential to use these materials to reduce the dust produced from gravel roadways. The Environmental Protection Agency (EPA) has listed particulate pollution (PM) as one of the six principle air pollutants. A 2005 study by the EPA showed that 33% of this pollutant comes from the dust of unpaved roads. Dust produced by gravel roadways has been linked to asthma, emphysema, heart disease, and chronic bronchitis among others (https://www3.epa.gov/pm/pdfs/pm-color.pdf). It is anticipated that cementitious reaction of these natural **pozzolan**s may reduce road dust and particulate pollution from gravel roads. It is anticipated that with the data collected from this preliminary research, further efforts can be made regarding dust abatement and roadway improvement using natural **pozzolan**s from Mt. Mazama.