PROJECT SYNOPSIS

1) **Project Reference Number:** 46S_BE_4250
2) **Title of the project:** Application of cashew nutshell ash in one part alkali-activated cementitious composites: A sustainable greener alternative.
3) **Name of the College & Department:** Department of Civil Engineering, St Joseph Engineering College, Mangaluru.
4) **A. Name of the students:**
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5) Keywords: One-part alkali-activated, cashew nutshell ash, agricultural waste, mechanical characteristics, durability

6) Introduction / Background:

Cement is a binder, which is a chemical substance used in construction that hardens, sets, and adheres to other materials to bind them together. The construction industry uses cement as a binding substance to hold various construction materials together. Cement is a highly utilised building material with many benefits in the construction field. Cement can provide good strength and durability to buildings, which is one of its main benefits. Even though cement has numerous benefits, there are a few drawbacks to take into account. The effect of cement on the environment is one of its primary drawbacks. Cement production contributes to climate change by releasing significant carbon dioxide and other greenhouse gases into the atmosphere. Significant energy and non-renewable natural resources, like clay and limestone, are also needed for cement production. Environmental pollution is heavily influenced by the production of cement. When limestone and other materials are heated to high temperatures in a kiln to make cement, a lot of carbon dioxide (CO_2) is released into the atmosphere. The International Energy Agency estimates that 7% of the world's CO_2 emissions come from the

production of cement. One of the other solution for reducing environmental pollution is by using an alkali-activated binder (AAB). The AAB is a sustainable and greener alternative material. As a more environmentally friendly substitute for conventional cement-based building materials, alkali-activated binders (AABs) are gaining attention. AABs are produced by combining an aluminosilicate source, such as fly ash or slag, with an alkaline activator, such as sodium silicate, sodium hydroxide, potassium hydroxide, calcium hydroxide, and magnesium hydroxide. AABs take less energy to produce and emit less carbon dioxide during production than conventional cement-based materials. AABs have the potential to be a more environmentally responsible and sustainable substitute for conventional cement-based materials, and research is ongoing to enhance their capabilities and lower their price. There are two types of alkali-activated binder, i.e., one–part alkali-activated and two-part alkali-activated material.

Two–part alkali-activated binders (AABs) represent an innovative approach to sustainable construction materials, offering an alternative to conventional Portland cement and contributing to the reduction of environmental impact in the construction industry. two-part alkali-activated materials have benefits like adaptable composition and specific properties. However, they also pose difficulties due to mixing complexity, potential compatibility problems, and a lack of standardisation. Also, the impracticalities related to handling large amounts of viscous, corrosive, and hazardous alkali activator solutions have put pressure on the development of one-part AAM or “just add water” geopolymers that could be used similarly to OPC. One-part AABs are a type of AAB that is a mixture of aluminosilicate precursor and one alkaline source. In one-part mixtures, only a dry mixture and water are needed. The dry mixture is prepared by mixing a solid alkali-activator with a solid aluminosilicate precursor with or without a calcination step. Real interest in one-part AAMs has increased substantially in recent years. One-part AAB has become a trend in recent research due to its more practical and safer use than two-part AAB. New alkaline activators are being researched as a sustainable alternative to the common use of hydroxides and silicates to generate one-part AAB. Raw materials with strong alkalinity are

generally used as activators, and one of the environmental-friendly alternatives is to use biomass ash that is rich in potassium or calcium. Hence, this study obtained ash from the cashew nutshell wastes: Cashew nutshell ash (CNSA). CNSA can act as an alkaline activator due to its high concentration of K_2O.

7) Objectives:

- To examine the material properties of ultrafine slag (UFS), fly ash (FA), and cashew nutshell ash (CNSA).
- To determine the potential utilization of cashew nutshell ash (CNSA) as an alternative alkaline material in the ultrafine slag (UFS) — fly ash (FA) based alkali-activated (AA) paste and mortars.
- To study the fresh properties of one-part AA pastes and mortars.
- To investigate the hardened properties and microstructural characteristics of one-part AA mortars.
- To assess the durability characteristics of one-part AA mixes.

8) Materials and Methodology:

Figure 1: Materials used in the present study

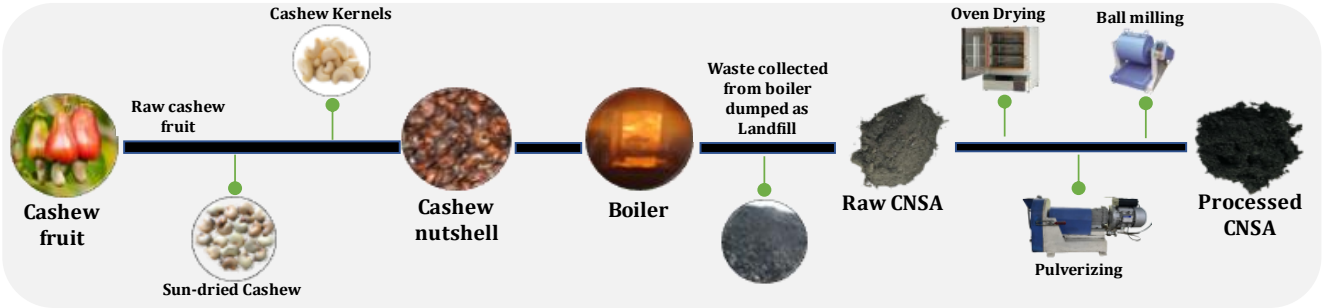

Figure 2: Generation of Processed CNSA

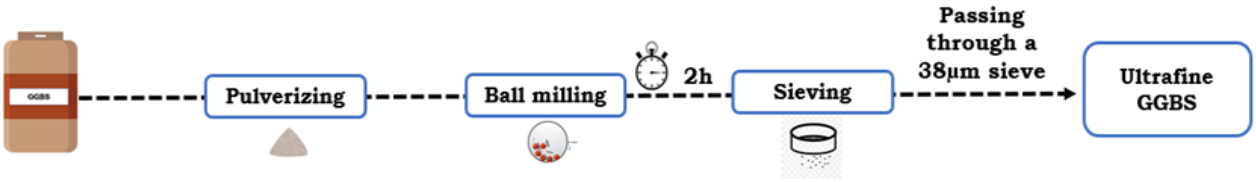

Figure 3: Process of UFS

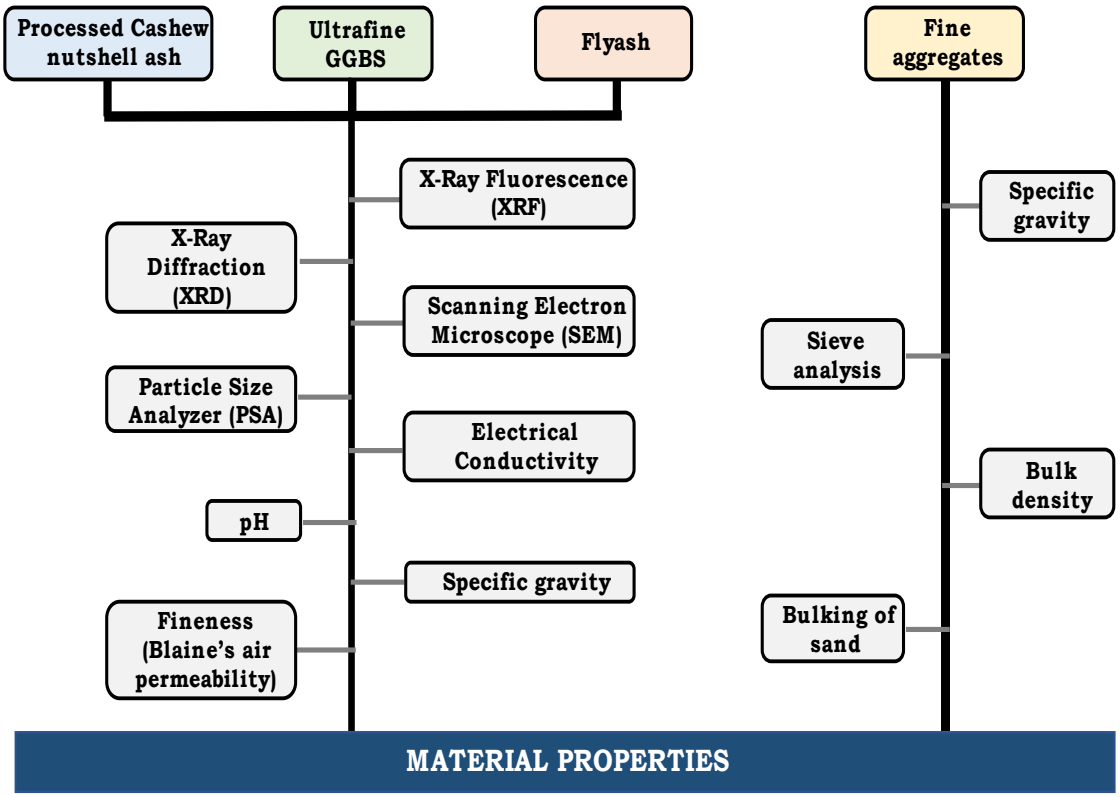

Figure 4: Tests for conducting physical properties of the materials

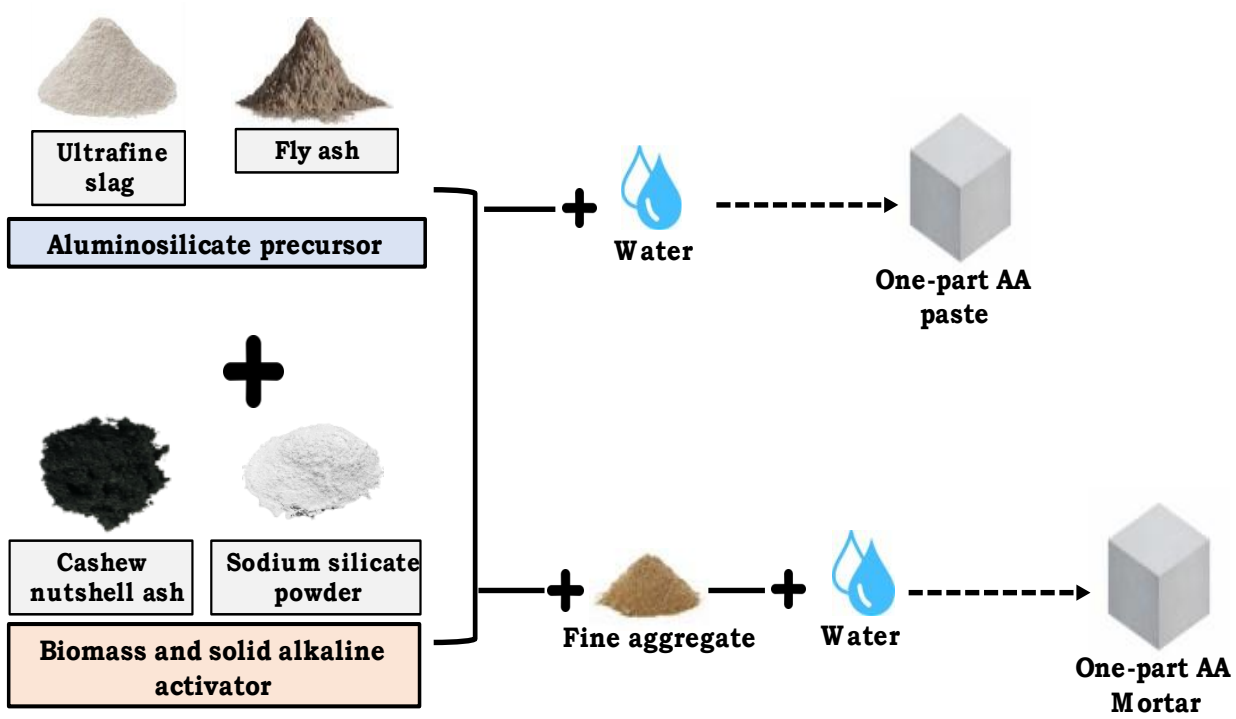

Figure 5: Preparation of One-Part AA paste and mortar

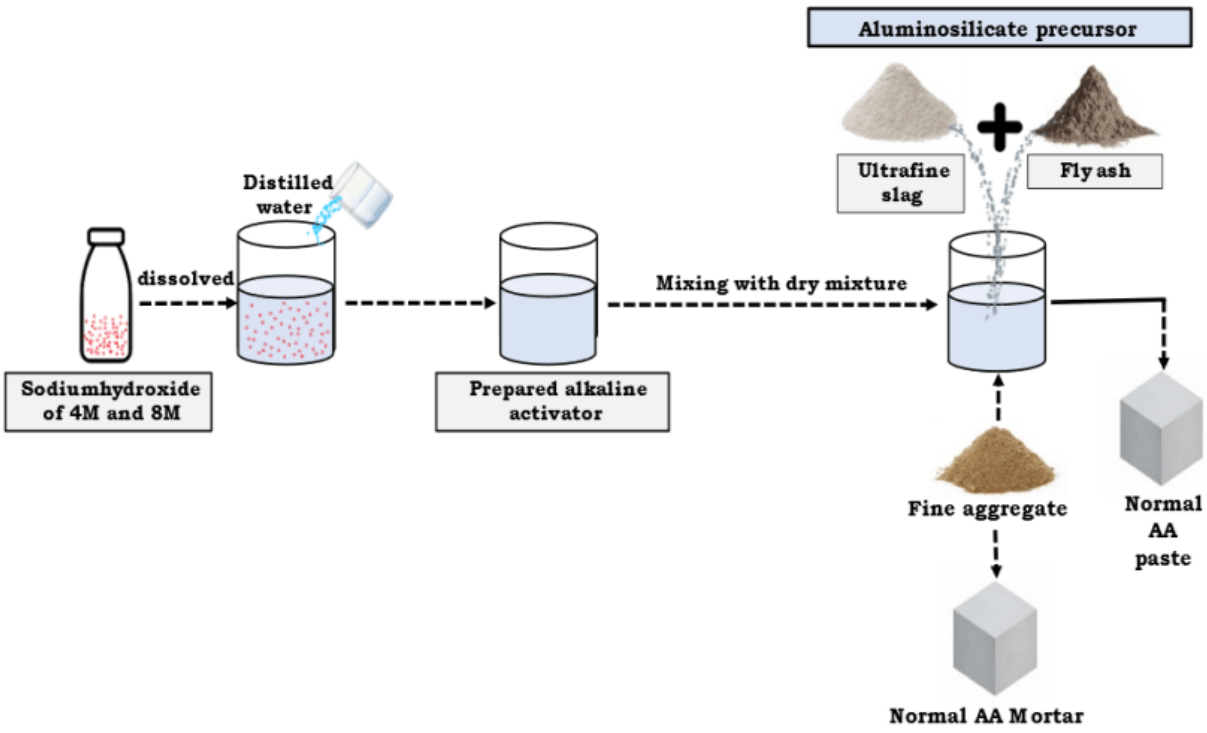

Figure 6: Preparation of Two-Part AA paste and mortar

Total 9 mixes, M1, M2, M3, M4, M%, M6, M7, M8, and M9. CNSA and sodium silicate activator at 30% and 10% constant for all the mixes. UFS and FA precursor at 20%, 25%, 30%, 35%, 40% and 60%. M8 and M9 are traditional two-part AABs with 4M and 8M NaOH. Specimens were cast while maintaining w/cm and cm/sand ratios of 0.4 and 2.75, respectively.

Table 1: Mix proportions

Mix ID	Ultrafine slag	Fly ash	CNSA	Sodium silicate	NaoH
M1	60%	-	30%	10%	-
M2	-	60%	30%	10%	-
M3	30%	30%	30%	10%	-
M4	25%	35%	30%	10%	-
M5	20%	40%	30%	10%	-
M6	35%	25%	30%	10%	-
M7	40%	20%	30%	10%	-
M8	50%	50%	30%	10%	4M
M9	30%	30%	30%	10%	8M

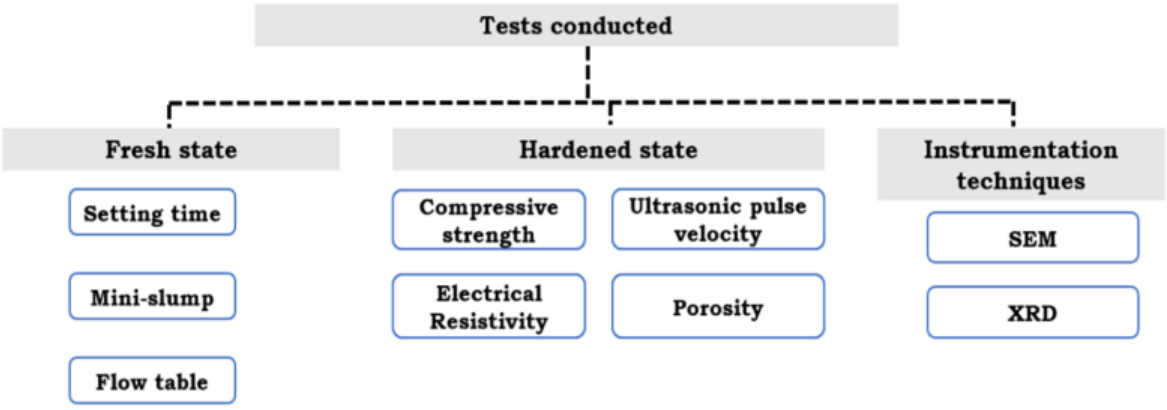

Figure 7: Tests conducted on AA paste and mortars

Figure 8: Instruments used for the present study

9) Results and Conclusions:

This study investigated the fresh properties, mechanical characteristics, and durability performance of one-part AA developed using binders containing slag and fly ash as the precursors, with cashew nutshell ash as a biomass activator and sodium silicate powder as a solid activator. The study also evaluated the properties of Two-part AA. From a series of experimental studies, the following conclusions were made.

1. The mini-slump flow of the mixes showed significant differences. The mixes that contained fly ash showed the highest flow. Conversely, the mixes with UFS had a diminished flow attributed to their greater surface area.
2. According to the code provision, the mixing time for all mixes was satisfactory except for mix M2. Mix M2 tends to have a longer final setting time compared to the other mixes. This is caused by the less surface area of the fly ash and its spherical morphology, which increases the setting time.
3. The flow table results are consistent with the mini-slump flow. However, when UFS is present in the mix, the flow rate decreases due to its high surface area, requiring more water to flow.
4. There are noticeable variations in the hardened properties of one-part and two-part AA mortars. The compressive strength of one-part AA ranges from 1.85 to 6.73 MPa after 28 days, while two-part AA ranges from 11.62 to 27.22 MPa. Nevertheless, all the mixtures comply with the codal provision for compressive strength.
5. The UPV values of one-part AA mortars are negatively impacted due to their higher porosity, which is consistent with their compressive strength. However, two-part AA mortars possess a dense structure, resulting in increased UPV values.
6. The electrical resistivity of all the mortar mixes was >10000 Ω-cm, thereby less likely to corrode.
7. The porosity of one-part AA mortars was found to be greater than that of two-part AA mortars.

The ash obtained from cashew nutshell is a good candidate for preparing 100% waste-based alkali-activated systems. This investigation reveals the potential

of a new biomass residue valorization, CNSA, as a commercial reagent in the preparation of AAM. Making low-to-medium-strength eco-friendly mortars with 100% waste is possible and suitable for low-load applications.

10) Innovation in the project

- This study aims to produce sustainable mortar by replacing 100% cement with ultrafine slag and fly ash to develop a one-part AA binder.
- The current study investigates the potential use of locally available waste material CNSA, obtained from boiler combustion at a cashew processing plant as a potential biomass alkaline activator. Although the research on waste-derived solid activators is still in its initial stages, a few candidates, such as biomass ashes, have demonstrated considerable potential.
- From this project, low-to-medium-strength eco-friendly mortars with 100% waste is possible and suitable for low-load applications.

11) Scope for future work:

- To advance towards a more sustainable future, it is crucial to address important issues such as finding alternative substitutes for FA and GGBS precursors and improving the environmental sustainability of solid activators.
- Further research can build upon the current findings and identify additional ingredients to develop concrete mixes with unparalleled qualities in terms of fresh, mechanical strength, and durability properties.
- The cost of producing one-part AAMs can be significantly impacted by the use of commercial synthetic solid activators, especially those of high purity, which can make up to 80% of the total production cost. However, an alternative option is to utilize solid activators derived from waste products.
- Although the research on waste-derived solid activators is still in its initial stages, a few candidates, such as biomass ashes, have demonstrated considerable potential.
- Research on one-part AAMs has mainly focused on pastes and mortars, but it's crucial to also conduct concrete-level studies that include fine and coarse aggregates. This will provide valuable insights into their fresh properties, mechanical strength, and durability characteristics.