Recenzja spełnia wymogi formalne

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Civil and Environmental Engineering

REPORT FOR DOCTORAL THESIS SUPPORT

of **JYOTI RASHMI NAYAK**

with the title

" ANALYSIS OF IMPACT OF SELECTED NATURAL WASTE FIBERS AND ASHES ON PROPERTIES OF MORTARS"

The manuscript is a document of 155 pages. The introduction (Chapter 1) describes the necessity to create substitute materials that will produce lower CO2 emissions and other hazardous gas releases into the atmosphere. It is explained, as it is known, that the primary contributor to global warming is CO2 emissions. The production of cement and steel, two widely used commodities in the building sector, uses a significant amount of energy. Along with the rising demand in the building industry, cement production is also rising. As a result, the building sector manages the depletion of numerous non-renewable resources. This activity produces millions of tonnes of mineral waste and carbon dioxide emissions. Half of the greenhouse gases produced by this industry's emissions are caused directly by transporting, producing, and using materials during construction phase. There is an exciting introduction to how and why Natural waste has become increasingly popular as an additive or partial replacement in construction materials in recent decades. Utilization of natural materials, such as wood, agricultural waste, and plant fibers, is expanding significantly in industry and research. These materials are renewable, readily available, less dense, inexpensive, and have excellent mechanical properties, making them an attractive, sustainable alternative to synthetic fibers in composite material production. Motivated by the desire to accomplish desirable material properties, such as good mechanical and durability crack resistance and good surface hardness, the investigation is conducted. In Chapter 2, the properties and importance of mortar in construction are described, focusing on plaster mortar, masonry mortar, cement mortar, and cement-lime mortar, in which the research work has been carried out.

The main objective of the doctoral thesis is clearly described as **Natural waste fibers (jute and sisal) and ashes (of rice husk and sugarcane bagasse) influence properties of mortars, both mechanical and physical, including structural features. Moreover, the optimal content of these additives may have a beneficial effect on some properties**. In the opinion of the reviewer, we (the researcher community) must take this research work`s line. The Objectives and the experimental phase are critical and clearly explained, as we need to reduce CO_2 emissions and find sustainable resources as construction materials.

The PhD work consisted of two parts. An extensive state of the art has been developed in the first part, and in the second part, research was carried out through a comprehensive experimental campaign.

In the first part of the State of the Art (Chapter 3), clearly and extensively the properties (chemical, physical and mechanical) and the influence of Natural waste fibers (jute and sisal) in the properties of cementitious materials are described from which the reader can get different aspects of the essential previous works. In addition, the properties of polypropylene fibers and their properties of cementitious materials have been described compared to those of natural waste fibers. Following the research objective, the main aspects (and research work) have been exposed about Biomass ash as supplementary cementitious materials (SCM), given their composition and chemical properties and influence in the fresh and hardened state properties as cementitious material in mortar and concretes.

The research experimental work was carried out based on three experimental phases. First, the determination of the employed materials (Natural waste fibers (jute and sisal) and ashes (of rice husk and sugarcane bagasse) properties (Chapter 6). Second, the influence of Natural waste fibers (jute and sisal) influence the properties of mortars, both mechanical and physical, including structural features (Chapters 7 and 8). Third, ashes (of rice husk and sugarcane bagasse) influence the properties of mortars, both mechanical and physical (Chapters 7 and 9).

The reviewer considers it of great value to add some references and discussion together with the description of the properties of the materials in Chapter 6. Chemical, physical and mechanical properties of waste additives (sugarcane bagasse ash, SCBA; Rice husk ash, RHA), as well as the Jute and Sisal fibers have been described. The properties and the references (including technical discussion) about the polypropylene fibers and Limestone powder LS were also described.

Three reference samples were considered in mix design: one with OPC in proportion 1:6 (cement: sand, CM), cement -lime with 1:1:6 (cement: lime: sand, CL) and APA cement with 1:6 (cement: sand. CA) binder ratio and 0.50% APA to weight of cement. There were three fiber samples with Jute, sisal, and polypropylene with the addition of 1% and 2% weight to cement as a reinforcement. For biomass ashes, rice husk ash, sugarcane bagasse ash, and limestone powder with replacement up to 5, 10, and 15% of the weight of cement were employed. To maintain consistency, the weight of fine aggregate, cement, and water in the mortar with a w/c ratio was taken to maintain consistency.

The reviewer thinks that fresh state consistency is a fundamental property in mortar application. Consequently, the reviewer thinks the approach to modifying the

water/cement ratio in mortar production and maintaining the workability is a correct condition to validate it for real application. In all the mixtures produced, the fresh properties of Consistency and air content were assessed.

In hardened properties, the compressive strength, flexural strength, shrinkage, pore structure and surface morphology were determined and analysed. All the mortars were made using waste additives (fibers or SCM) with the same consistency value. The reviewer considered that an extensive experimental phase was carried out in order to achieve the objective defined for this research work, analyzing the influence of natural fibers and SCM waste materials on the fresh properties. In addition, among the hardened properties, not only was focus placed on mechanical properties, but also the shrinkage values and microstructure of mixtures (using MIP and SEM) were assessed.

After the experimental work, the obtained conclusions (Chapter 10) can be summarized as:

- The use of natural fibers:
  - Fresh properties: Included jute and plastic fibers reduce flowability by 5%. In addition, C-S2 and CA-S2 (with sisal fibers) cement mortar samples showed better flowability than others.
    Jute and polypropylene fibers appeared to have little impact on air content in mortar. Sisal fibers increased cement and cement-lime mortar air content by fourfold. This is presumably due to sisal fiber hydrophilic cellulose, which absorbs water.
  - Hardened properties:
    Compressive strength: After 28 days, including 1% and 2% jute fibers results in significant increases in compressive strength. 11% and 15% higher than that of the reference sample. Similarly, with the addition of 1%, the strength of polypropylene and sisal fibers improves by 10% each after 28 days.
    Flexural strength: 1% and 2% jute fiber mortars have significantly increased flexural strength in all the mortar types. Sisal fibers improve only cement-lime mortar flexural strength.
    The MIP and SEM results reveal that sisal fiber in cement-sand mortar has poorer adherence to the cement matrix than other fibers.
    The incorporation of jute in all samples, regardless of the amount, leads to an improvement in shrinkage value and decreases the occurrence of cracks.
- The use of natural waste ashes:
  - Fresh properties: the flowability shows that replacing cement with RHA and SCBA reduced workability in cement mortars. However, the flowability of the cement-lime mortar was similar to the mortar without additions. The RHA influence on losing workability was higher than the use of SCBA.

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The use of SCM increases air content in cement and cement-lime mortars. In contrast, the CA mortar air content dropped.

- Hardened properties:
  Compressive strength: the incorporation of 10% and 5% RHA (rice husk ash) results in higher strength performance than the control mortar. In addition, CA-SBA5, CA-SBA10, and CA-SBA15 also achieved higher strength than the control mortar. The 5% of RHA and CA-SBA15 achieved the highest value. At 28 days, the compressive strength of the samples CA-SBA5, CA-SBA10, and CA-SBA15 increased to 12%, 5%, and 28%, respectively, in cement mortars.

According to all the results and analysis, it can be concluded that the amounts of jute, 1% and 2% fibers, and SCBA 10-15% ash improve desirable properties over polypropylene and limestone powder.

Finally, I can say that the experiment phase was carried out adequately, and the obtained result was amply analyzed and discussed. Moreover, the manuscript has been written correctly with few imperfections. As a result, based on the results obtained, it can be concluded that the objectives of the work were achieved, and the thesis of the work was confirmed. In addition, in my opinion, the employment of jute and SCBA for mortars production is a significant achievement to get an optimum sustainable construction material.

After analysing the written manuscript, her opinion is **favourable** for the doctoral defence of MSc. **Eng. Jyoti Rashmi Nayak** for the title of doctor of the Silesian University of Technology.

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