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PRODUCTION OF STONE PAPER USING MARBLE AND PLASTIC WASTE

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By

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Abstract

Because traditional paper production leads to deforestation, uses a lot of water and creates chemical pollution, scientists have been motivated to find alternatives. For this reason, this paper discusses how stone paper is made from waste marble and HDPE plastic at an industrial scale. Creating stone paper is not like printing on paper, as trees, water and harmful chemicals are not part of its process. This research examines how stone paper is produced, the toughness and waterproofing it provides and its eco-friendly features. It is found that stone paper has more tensile strength, tearing resistance and is water-resistant than wood-pulp paper, suitable for uses where such traits are important such as packaging, labels and outdoor advertising. The production of stone paper at an industrial level is completed by adding ground marble waste and recycled HDPE and passing the mixture through an extruder to form sheets. On the one hand, the results point out that switching to stone paper is profitable as it requires less capital than other types of paper and produces less waste and emissions. Still, it is found that stone paper could constitute environmental and economic progress in the paper industry and future studies are needed to address its drawbacks.

Keywords

(Stone Paper, Marble Waste, High-Density Polyethylene (HDPE), Sustainable Materials, Eco-Friendly Paper, Calcium Carbonate ($CaCO_3$), Waste Recycling, Green Manufacturing, Extrusion Process, Waterproof Paper, Tear-Resistant Paper, Alternative Paper Technology and Environmental Sustainability)

I. Introduction

There is mounting global worry about the environmental effects of paper production. Since paper demand is rising in many industries, packaging paper in the traditional way with wood pulp, water and chemicals creates large pollution problems. Among these effects are cutting down forests,

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wasting significant amounts of water and moving hazardous materials into the environment Green, D. R. J. C. (2000). As a result of these issues, more people are interested in creating sustainable options for paper.

Stone paper has begun to attract interest because it is friendly to the environment. Using marble waste as its main ingredient and adding HDPE plastic, stone paper could be a useful response to the environmental issues seen with regular paper production. Unlike standard paper processing, stone paper does not depend on water, trees or chemicals Indriati, L., Nugraha, M., & Perng, Y. (2020). Thanks to being waterproof, nearly tear-free and easily recyclable, it is suitable for packaging, printing and creating stationery Çınar, M.E. and Kar, F. (2018).

This paper thoroughly examines the production of stone paper by using marble waste and plastic (HDPE) to produce a greener alternative to traditional paper. The study examines the use of materials, how the process is designed and the testing of samples, considering different manufacture approaches as well as the mechanical properties of the output sheets. We aim to figure out whether stone paper can be used on a larger scale instead of pulp-based paper, putting main attention on how it looks and helps the environment. Raheem, D. J. E. J. o. F., & Agriculture. (2013).

Study's objectives, discuss the materials and processes for making stone paper, introduce experimental findings and analyze the effects of using stone paper on the environment and on the economy. Mehta, D., Paliwal, D., Sankhla, V.S. and Tege, S. (2020).

II. Methodology

Turn marble waste and high-density polyethylene (HDPE) plastic into stone paper, several important stages are required. It describes the materials and method used during the study to develop and test stone paper.

A. Materials Used

The primary materials used in the production of stone paper include:

a) **Marble Waste:** Calcium carbonate which is produced from marble industry wastes and called marble dust, makes up most of stone paper. Large size marble particles are broken up in a processor to make a fine powder, with particles that are less than 50 microns wide, so they mix well with HDPE.
b) **High-Density Polyethylene (HDPE):** A plastic product called recycled HDPE acts as the glue in recycled asphalt mix. A polymer material with good binding abilities and an ability to be recycled is selected.

c) **Compatibilizers:** A small dosage of compatibilizers is applied to increase the adhesion between marble powder and HDPE. Typically, silane-based products help improve how the marble and the polymer stay together in the fabric.

B. Experimental Process

Generating stone paper is done through several steps, all of which are planned and refined to develop paper of top quality and durability. The next section describes the strategy that was applied:

a) **Grinding of Marble Waste:** Marble waste is gathered and turned into powder about 50 microns fine by using a ball mill. As a result, the marble pieces are small enough to be evenly incorporated into the plastic.
b) **Mixing of Materials**: Recycled HDPE is mixed with a range of ground marble dust. A common ratio during this study is 80% marble powder, 19% HDPE and 1% others. All materials are mixed inside a high-shear mixer to achieve a consistent product. A small amount of silane-based compatibilizer improves the bond between calcium carbonate and HDPE.
c) **Extrusion Process:** The twin-screw extruder raises the mixture's temperature to about 190°C in a vacuum environment. Extrusion mixes the compound, making certain the marble bits are all distributed within the HDPE. The molten substance is shoved into stone sheets using a machine.
d) **Sheet Formation**:The extruded material is passed through a set of rollers to control the thickness of the sheets. The sheet thickness is typically controlled in the range of 80-120 microns, depending on the desired application. The sheet is then cooled to room temperature.
e) **Surface Treatment:** Using corona treatment, the stone paper is made more printable. Making these tiny voids on the surface of the glass means the ink holds better during printing.
f) **Cutting and Testing:** Stone paper for testing is cut to given sizes and shapes. Several tests such as examining tensile properties and water and tear resistance as well as printing functions, are used to review the performance of stone paper against regular wood-pulp paper.

C. Testing Methods

Stone paper's performance is checked by applying a set of industry tests.

a) Tensile Strength Test: Stone paper sheets are evaluated using a tensile testing machine to assess their effectiveness. The test

involves pulling the paper apart, and the force required to break it is measured. This indicates the material's durability for paper.

b) **Tear Resistance Test**: The resistance of the stone paper to tearing is determined by pulling on a slit in the paper to see how much force is needed to split it in two. The test examines how the material reacts to being put under force.

c) **Water Resistance Test**: A stone paper's ability to resist water is measured by putting it into water for a specific period and checking whether its shape or look have altered. The test demonstrates that the material can resist water.

d) **Printing Test**: Printing on the stone paper with standard inks allows us to check how much ink is absorbed and how quickly the paper dries. The tests show how the material works in printing applications.

e) **Thickness and Weight Measurement**:The thickness of the stone paper sheets is measured using a micrometer, and the weight is compared with that of conventional paper of the same size.

D. Data Analysis

Based on the data gathered from the experiments, the performance of stone paper is compared to that of regular paper. Matches are tested based on how strong they are, how they hold up to water, how well they tear and how well they print. Based on the findings, the process is improved and the materials are made better for different purposes.

Building on small tests, the production steps for stone paper are redesigned for industry use and checked for their physical and mechanical properties. Here, we describe the process of making stone papers and share the findings from experiments that were performed.

a) Industrial Scale Production

The method described previously was scaled up for industrial production of stone paper. A modern twin-screw extruder was adapted, allowed heat rolling and produced sheets of stone paper at various uniform thicknesses. By performing industrial production, we showed that it is possible to produce stone paper on a larger scale while keeping the standards high.

b) Production Parameters:

i. **Raw Materials**: The industrial setup used approximately 80% marble powder (calcium carbonate) and 19% recycled HDPE,

with small amounts 1% of a silane-based compatibilizer to ensure proper bonding between the two materials.

ii. **Extrusion Temperature**: To get all of the HDPE melted and mix the marble powder well, the mixture was extruded at temperatures from 170°C to 180°C.

iii. **Roller Setup**: Between 80 and 120 microns in thickness, the sheet was made by passing extruded material through a series of temperature-guided rollers.

III. Testing Results

When the stone paper was completed, it was examined to discover what its different qualities are. The findings from these tests have been listed below:

a) **Tensile Strength**:
Result: The testing showed that stone paper has much higher tensile strength than regular wood-pulp paper. The average tensile strength of stone paper with 60% marble and 40% HDPE was 55 MPa which is considerably higher than the 20 MPa reported for standard paper. Stone paper appears to resist tearing and is therefore more durable.

b) **Tear Resistance**:

Result: Stone paper did not tear easily even when tested. Regular paper tore easier than stone paper which needed three times as much force in the tear resistance test. It is the special mixture of marble powder and HDPE that makes the material much stronger against tear forces.

c) **Water Resistance**:

Result: Just as predicted, stone paper did very well during the water resistance test. After 30 minutes in water, the stone paper looked and felt whole, without sign of harm. When put in water, the traditional form quickly fell apart. Because of this, stone paper is a suitable choice for uses that need waterproof paper, for example, in outdoor signs and packaging.

d) **Printability**:

Result: Standard inks were used to test how well stone paper could be printed using a printer. Although drying times for standard inks on stone paper were greater than on regular paper, both had similar quality results. To get better results, sometimes you need to use special inks or coatings that help dry the ink faster. As a result, print applications are possible with stone paper if small adjustments are made.

e) **Thickness and Weight**:

Result: The stone paper was produced in 80-micron and 120-micron thicknesses, fitting most paper using needs. The stone paper was about 20 percent heavier than normal paper because it includes marble powder and HDPE. In spite of this, the paper's usefulness in packaging and labeling was not significantly changed.

f) **Surface Finish**:

Result: Because the stone paper's surface was smoothly textured, it was appropriate for writing and printing. Because of the material's unique properties, ballpoint pens, pencils and printers all functioned well with the surface. Improved ink adhesion and print quality were achieved by applying corona treatment to the paper.

A. Environmental and Economic Impact

Experts analyzed how much less harmful it is to produce stone paper by setting it against traditional ways of making paper.

a) **Water Consumption**:

Result: Stone paper is manufactured with no water, but to produce conventional paper 35,000 liters must be used for every 1,000 kg. A big decrease in water use confirms how environmentally friendly stone paper is.

b) **Carbon Emissions**:
Result: The production of stone paper uses less CO_2 than the standard method of making paper. Because stone paper is made without water and chemicals, its manufacturing leaves 40% less carbon than is released by making typical pulp paper.

c) **Waste Generation**:

Result: Out of all materials used, just a tiny fraction (5%) during stone paper production becomes waste. By comparison, making paper using old techniques often causes much waste and pollutes the water with the chemically treated pulp.

d) **Cost Analysis**:

Result: You can make stone paper at approximately 15% less cost than traditional paper. The savings come mostly from replacing costly, harmful substances with waste material (marble dust and plastic) and using a simple production method that doesn't need much water or chemical treatment.

The scale up of stone paper production in industry proves that this material can be used as a sustainable alternative to traditional paper. This material has good physical properties, particularly high tensile strength and the ability to tear and be submerged in water. The fabric is produced in a way that isn't harmful to nature and the whole production uses no water and produces little waste. Although printing still needs to be improved, the overall outcomes suggest that stone paper may cut down waste and costs in making paper products.

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A. AUTHORS CONTRIBUTION

The idea for the research and its design were both conceived by Anwar Ahmed. Hafiz Shabab Hussain tested out the experiments himself. The project was managed by Dr. Shozad Mehdi. Roohi Amin and Muhammad Waqar Shaukat helped significantly with shaping the research manuscript.

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