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Physical And Mechanical Properties Of Cement-Based Skim Coat Utilizing Limestone From Northern Mindanao, Philippines As Filler Material

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Abstract:
Cement-based skim coat is a vital material for residential and commercial wall and ceiling applications. Its growing demand can be attributed to the increasing preference for energy-efficient and sustainable construction practices, which prioritize environmentally friendly materials such as paints and coatings. A key ingredient in skim coat production is limestone, commonly used as a filler material. To enhance productivity and cost-effectiveness, efforts have been made to identify locally available sources of limestone. This study investigates the potential of limestone from Northern Mindanao as a filler material in cement-based skim coat production. The limestone was analyzed, and skim coat samples were produced at varying limestone-to-cement ratios, particle sizes, and water demands. The study evaluated the effects of these factors on the ease of mixing, workability, setting time, trimming, adhesion, and compressive strength of the skim coat. Results revealed that the limestone from Northern Mindanao, with a calcium carbonate (CaCO3) content of 93.3%, is a suitable filler material, as evidenced by the physical properties of the skim coat. Additionally, the samples met the standard specification of compressive strength for skim coat materials. These findings highlight the significant potential of Northern Mindanao limestone in cement-based skim coat production.
Keywords:
Cement-based skim coat, Calcium carbonate, limestone, compressive strength, Northern Mindanao, Philippines, filler material

1. INTRODUCTION

The growing demand for residential and commercial construction, which includes walling and ceiling applications, has led to a high demand for cement-based skim coats to achieve smooth surfaces, reduce paint usage, improve energy efficiency, and promote sustainable construction practices [1]. Cement-based skim coats consist of a mixture comprising 20% white cement as a binder, 77% dolomite powder and limestone as fillers with a particle size of 0-150 microns, 1% hydrated lime, and a performance-enhancing additive in the form of re-dispersible polymer powder based on vinyl acetate [2]. The mixing ratio of water to skim coat is 39-40 parts water to 100 parts skim coat by weight. Additionally, the skim coat composition consists of 12% white cement, 87.6% dolomite powder, 0.3% re-dispersible polymer powder, and 0.1-0.7% thickener, combined with water at a mixing ratio of 35-40 parts water to 100 parts skim coat by weight [3].
Limestone is a significant component in various cement-based skim coat formulations, as identified in related literature. Limestone powder demonstrates significant potential as a filler material due to its minimal embedded CO2 emissions, extensive availability, and cost-effectiveness [4]. Northern Mindanao, Philippines is abundantly endowed with this sedimentary rock, boasting 1,706,456,723.4 metric tons of resources and 152,908,576.5 metric tons of reserves [5]. Leveraging this abundance can enable the local production of skim coats, attracting investors to establish production facilities in Northern Mindanao. Moreover, this can foster community development by creating jobs and positively impacting the local economy. The global skim coating

market is expected to experience significant growth, projected to expand from USD 3.5 billion in 2023 to USD 5.3 billion by 2032, at a Compound Annual Growth Rate of 3.8% worldwide [1]. This sizable market presents a substantial opportunity for the country's economy. However, in the Philippines, specifically in Northern Mindanao, skim coat manufacturing remains largely unexplored, as most production facilities are currently located in the Luzon area [6].

The absence of production facilities directly impacts a country's economic development and growth. This suggests that the lack of such facilities poses a significant obstacle to the progress of communities and the economy. This situation can drastically alter the lives of local communities and contribute to poverty, thereby posing a substantial threat to the economic advancement of Northern Mindanao. Given the dearth of cement-based skim coat production facilities in Northern Mindanao, this study was aimed to explore the feasibility and potential of producing a cement-based skim coat using the region's locally available limestone resources as a filler material, with the goal of enhancing productivity. Specifically, the study involved the characterization of the limestone from Northern Mindanao. Skim coat samples were then produced varying the limestone-to-cement ratios, particle sizes, and water demands. The effects of these factors on the ease of mixing, workability, setting time, trimming, adhesion, and compressive strength of the produced skim coat were then evaluated.

2. MATERIALS AND METHODS

Characterization of Northern Mindanao limestone

Several factors must be considered when utilizing limestone, including production and price. The four main factors affecting limestone production and prices are the location (proximity to a good market, infrastructures such as roads, energy, and delivery), the grade of the limestone, the closeness to the surface, and a cheaper labor force. Considering these factors, Cagayan de Oro City emerges as an ideal sampling area because it is considered the regional growth capital of Northern Mindanao, and the focus of investment is in the region. In this study, the identified sourced of limestone is located in Barangay Tagpangi Cagayan de Oro City, which covers an expansive area of 3,766.04 hectares revealing significant limestone resources awaiting exploration and utilization. Fig. 1 shows the Geologic map of limestone areas within Cagayan de Oro City.

Collection and preparation of limestone sample

Fieldwork was conducted to examine and collect samples from limestone outcrops within the study area. During this phase, the sampling technique used was the systematic sampling technique (no randomization exists), considering a large sample size, but the process was slow. The sampling area was 10 meters by 5 meters. The sampling area was divided into 50 lots. A representative sample (2-3 kg) in each lot were intended to acquire a bulk sample.Bulk samples(10-100kg) were then mixed to execute coning and quartering to reduce the gross sample until the required amount of the sample was obtained. Coning and quartering are the appropriate processes for the reduction of bulk samples. The sample was mounted to form a conical heap, spread out into a circular, flat sample. The sample then divided radially into quarters, and two opposite quarters were combined. The other two quarters were discarded. Obtained samples (40-50kg) were ready for preparation and analysis.Samples collected from the area required processing to represent the more extensive geological formation accurately. Sample preparation includes drying, crushing, grinding, and sieving to ensure homogeneity and reduce biases introduced during collection. The limestone sample obtained from coning and quartering was sun-dried using a clean sheet of plywood as a mat for (15) five days to remove excess water. After sun drying, the limestone samples were manually crushed in plain sheet steel using a ball peen hammer and mallet. The mortar and pestle were employed to pulverize and further reduce the limestone particle size. The sample was then submitted to the screening process using 200 and 325 mesh screens Subsequently, a sample of 5 kilograms of limestone passed a 200 mesh screen obtained to determine the attainable physical analysis (density, moisture content) and chemical analysis (calcium carbonate purity).

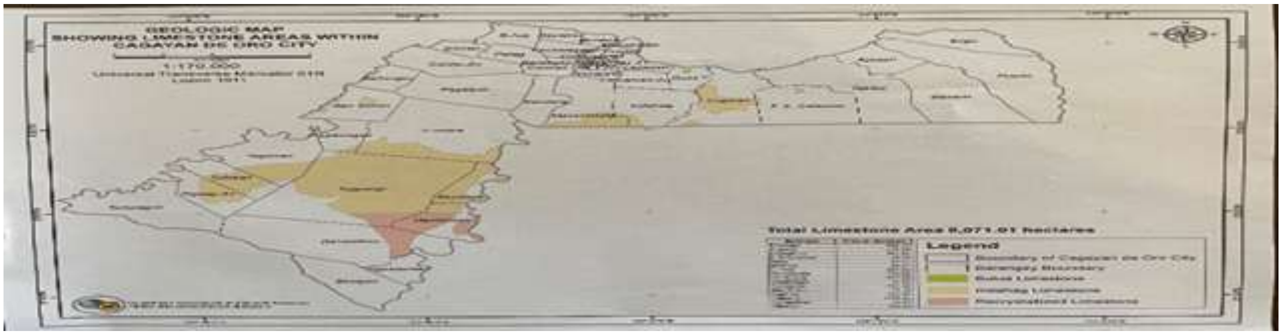

Figure 1. Geologic map of limestone areas within Cagayan de Oro City

Determination of the physical and chemical properties of limestone sample

It is vital to understand the qualities of limestone intended for use as a filler in a cement-based skim coat. Physical characteristics include density and moisture content, whereas chemical properties include calcium carbonate purity. Limestone density is an essential index of its physical properties. Limestone materials' fluidity, friction, and strength are related to their density. On the other hand, moisture content is crucial in assessing the quality and stability of the developed skim coat product. That is why measuring the density and moisture content of the obtained limestone sample is essential and the result serve as basis of the limestone sample used in this study. The limestone sample was tested at Mega testing Center Incorporation, Pagadian City for physical analysis. Chemical composition of limestone sample was analyzed at the cement company in Iligan City with X-ray fluorescence (XRF) equipment.

Production of the cement-based skim coat at various mixtures of limestone: cement ratio, particle size of **limestone and water demand**

In this study, the raw materials used to develop a skim coat included white cement, calcium carbonate (limestone) as filler material, cellulose ether as a water retention agent, and re-dispersible powder as an additive. A total of 12 mixtures were prepared based on the variation of limestone: white cement ratio, limestone particle size and water demand. At the same time, the re-dispersible powder dosage will remain constant at 1.5% and cellulose ether at 0.3%. Table 1 shows the various mixtures of cement-based skim coat with corresponding value of parameters considered in the study. All the raw materials were properly gathered, weighed, mixed and stored.

Table 1. Mixtures of cement-based skim coat with corresponding value of parameters considered in the study

Mixture	Limestone: cement ratio	Weight %		Limestone particle size	Water demand (skim coat: water ratio)
		Limestone	White Cement		
1	80:20	78.56	19.64	-325 mesh	100:35
2	80:20	78.56	19.64	-325 mesh	100:40
3	80:20	78.56	19.64	-200 mesh	100:35
4	80:20	78.56	19.64	-200 mesh	100:40
5	70:30	68.74	29.46	-325 mesh	100:35
6	70:30	68.74	29.46	-325 mesh	100:40
7	70:30	68.74	29.46	-200 mesh	100:35
8	70:30	68.74	29.46	-200 mesh	100:40
9	60:40	58.93	39.28	-325 mesh	100:35
10	60:40	58.93	39.28	-325 mesh	100:40
11	60:40	58.93	39.28	-200 mesh	100:35
12	60:40	58.93	39.28	-200 mesh	100:40

Evaluation of the effects of various mixtures of cement-based skim coat in terms of ease of mixing, workability, setting time, trimming, adhesion, and compressive strength

The assessment of the parameters was a continuous process, beginning with assessing ease of mixing, followed by evaluations of workability, setting time, trimming, adhesion and compressive strength. Each mixture underwent sequentially to ensure consistency across all parameters and the results were categorized as either 'pass or fail' by visual or actual observation, merely the compressive strength test result from the compression machine.

Ease of mixing

In the plain steel sheet, the developed mixtures of each cement-based skim coat were mixed with water using a steel trowel based on the ratio of 100:35 and 100:40 (skim coat powder: water) by weight. By actual observation, the result is either easy to mix or difficult to mix (fail), but the favorable outcome is easy to mix (pass).

Workability

Subsequently, apply the skim coat paste using a steel trowel to walling and ceiling materials, such as Hardieflex and plastered hollow blocks, that are free from loose material and other contaminants that inhibit bonding. During the application, test the workability through actual observation of either good (pass) or bad (fail)

Setting time

The fresh skim coat paste samples were allowed to dry naturally (ambient temperature). Most of the products found in the industry settle within 2-3 hours. The setting time of the skim coat paste was evaluated practically by visual and actual observation of the dry surface and touching to see finger marks in 5-minute intervals. After preparation and keeping it as a lump, the surface gradually dried due to the evaporation of water.On touch, the surface gave finger marks easily before setting, and it was difficult to place the finger marks after setting. The minimum time taken for the lump of skim coat to dry and give no finger marks on the surface was recorded as the setting time.

Trimming

After applying both layers, at least 6 hours of curing period in the standard condition (ambient temperature) before trimming (sandpapering) with the use of sandpaper #200; if the trimming was easier, more matter was removed with dust using sandpaper and smooth surface was obtained. After trimming, the surface should be free of sandpaper marks. If the trimming was too difficult(fail), a certain portion of the coating may be removed upon application of high force. The trimming was evaluated practically, and the favorable outcome was easy to trim(pass).

Adhesion

The crosshatch adhesion test evaluated the adhesion of the skim coat. The water-based paint primer was applied after curing the applied skim coat in standard condition for 24 hours and followed by a water-based semi-gloss top coat after 45 minutes to the applied skim coat and cured in standard condition. After seven days, the wall was crosshatched using a blade cutter and covered with masking tape. The masking tape was pulled off, revealing how well the paint layer adheres to the skim coat surface. If the paint was pulled off, that means the paint did not adhere to the skim coat, which indicates failed adhesion.

Compressive Strength

The compressive strength test of the produce skim coat sample refers to ASTM C 109/ C 109M-02, with a standard specification of 7-12 N/mm2 or 1015.26-1800 psi [7], and was conducted at Mega Testing Center Incorporation, Pagadian City.

3. RESULT

Physical and chemical properties of limestone The result of the physical analysis of the collected limestone sample indicated in Table 2. The result of chemical composition of the collected limestone sample shown in Table 3. Chemical Analysis of $CaCO_3$ wih 93.31% implies potential to be used as filler material in a cement based skim coat production.

Table 2. Result of physical test

Physical properties	Result
Bulk Specific Gravity, Saturated Surface Dry (SSD)	2.62
Moisture Content, %	18.73

Table 3. Chemical analysis of limestone

Compound	%
$CaCO_3$	93.31
Al_2O_3	1.18
Fe_2O_3	0.77
CaO	52.28
MgO	0.44
SO_3	0.05
K_2O	0.04
Na_2O	0.04
Ti_2O	0.07
P_2O_5	0.02

Assessment of performance of the cement-based skim coat at various mixtures in term of ease of mixing, workability, setting time, adhesion and compressive strength

As shown on Table 4, only Mixture 10 and 12 successfully passed all the parameters. Mixture 10 contains a 60:40 of limestone and cement ratio, -325 mesh particle size of limestone with 40% water demand. On the other hand, Mixture 12 contains a 60:40 limestone and cement ratio, -200 mesh particle size of limestone with 40% water demand.

Table 4. Assessment of performance at various mixtures of cement- based skim coat

	Ease of mixing	Workability	Setting time	Trimming	Adhesion	Compressive strength(psi)
1	Fail	Fail	Fail	Fail	Fail	534
2	Pass	Pass	Pass	Fail	Fail	422
3	Fail	Fail	Fail	Fail	Fail	506
4	Pass	Pass	Pass	Fail	Fail	506
5	Fail	Fail	Fail	Fail	Fail	871
6	Pass	Pass	Pass	Fail	Fail	759
7	Fail	Fail	Fail	Fail	Fail	1180
8	Pass	Pass	Pass	Fail	Fail	815
9	Fail	Fail	Fail	Fail	Fail	1124
10	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**1180**
11	Fail	Fail	Fail	Fail	Fail	1798
12	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**1208**

4. DISCUSSION

Limestone is chiefly made of calcium carbonate ($CaCO_3$); its percentage in analyzed samples ranged from 82.24±0.65 to 96.67±0.28 with a percent-age mean value of 93.01±4.47. Any limestone with $CaCO_3$ over 75% can find some industrial use. Many research and development programs must be undertaken to utilize existing deposits correctly [8]. Chemical analysis indicated that the limestone sample has 93.31% $CaCO_3$ which exceed on the limestone with 75% calcium carbonate content for industrial use. This implies that the limestone sample is suitable for use as filler material in a cement-based skim coat production.On the other hand, among the various mixtures, 10 and 12 have passed successfully all the parameters considered in the study. Both mixtures feature a 60:40 ratio of limestone to white cement, which ensures a balance between ease of mixing, workability, setting time, adhesion, and smooth finish. Mixture 10 incorporates limestone with a finer particle size of -325 mesh. In contrast, Mixture 12 utilizes limestone with a coarser particle size of -200 mesh. Both mixtures demonstrate optimal water demand at 40%, facilitating ease of mixing and application without compromising adhesion or curing properties. These mixtures highlight the versatility of locally sourced limestone, showcasing its suitability in cement-based skim coat production.

5. CONCLUSION

This study developed a cement- based skim coat utilizing the limestone as filler material from Northern Mindanao, Philippines, particularly from Barangay Tagpangi Cagayan de Oro City covering an expansive area of 3,766.04 hectares, that contains 93.31% purity of $CaCO_3$, which implies a vast potential for industrial use. Furthermore, among the cement- based mixtures developed, mixtures 10 and 12 have successfully passed all the parameters in terms of ease of mixing, workability, setting time, adhesion and compressive strength. This concludes that the limestone in Northern Mindanao has a huge potential to be used as filler material to develop a cement- based skim coat, and it presents a compelling opportunity for further laboratory evaluation and innovation. When scaled up, this can also create additional economic activity in the region that will be involved in supplying limestone to the manufacturing industry.

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8. **Data availability-** Data sharing is not applicable to this article.
9. **Conflict of interest-** The authors declare that there is no conflict of interest.

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