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## Evaluation of compressive strength 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 construction material for residential and commercial wall and ceiling applications. Limestone comprises 70.2% of the cement-based skim coat product as a filler material. The limestone in the Northern Mindanao Region X has 1,706,456,723.4 metric tons of resources and 152,908,576.5 metric tons of reserves. It shows the capacity to develop and produce a high-value product, specifically a cement-based skim coat. This research aims to evaluate the compressive strength of a cement-based skim coat utilizing limestone sourced from Northern Mindanao as a filler material. The raw limestone samples were evaluated for their physical qualities and chemical composition. Statistical design experiment to evaluate the effects of limestone: cement ratio, particle size and water demand on the cement-based skim coat compressive strength involving limestone from Northern Mindanao as filler material. The results of this study indicate that the cement-based skim coat produced with limestone as a filler material from Northern Mindanao meets the standard specification of compressive strength for such materials. The limestone, sourced from Barangay Tagpangi in Cagayan de Oro City, spans an extensive area of 3,766.04 hectares contains 93.3% Calcium carbonate (CaCO<sub>3</sub>), making it appropriate for cement-based skim coat production.

**Keywords:** Calcium carbonate, limestone, Cement-based skim coat, compressive strength, Northern Mindanao, Philippines, filler material

## INTRODUCTION

Skim coating is vital in the construction sector, particularly when constructing walls and ceilings in residential and commercial structures. It is applied on rough walls following cementation as the initial layer [1]. Skim coating is primarily employed to achieve a smooth finish and serve as a foundation for paint application. A primary benefit of skim coating is its ability to decrease the paint required to attain the desired surface substantially [2]. Skim coating safeguards concrete foundations by protecting torrential rainstorms and other natural calamities, such as earthquakes, which can significantly damage structures. This protective layer, which safeguards both walls and ceilings, has been favored for its ability to extend the interval between repainting for homeowners. The typical lifespan of a skim-coated wall and ceiling varies from 20 to 30 years, contingent upon adequate maintenance over this duration. In the Philippines,

one of the rapidly expanding countries in Southeast Asia, paint and coating manufacturers have benefited significantly from consistent economic expansion in recent years. The gross domestic product (GDP) increased 6.2% in 2018.

Moreover, the World Bank projects the GDP to grow by 6.5 percent from the year 2019 and by 6.6 percent in 2020 and 2021. Regrettably, the majority of skim coat manufacturers are located in Luzon [3]. Thus, the elevated expenses in the paint and coating sector in the Philippines have emerged as an issue attributable to logistics, energy, and insufficient domestic raw materials. The absence of paint and coating production facilities in the Mindanao Region incurs extra costs for producers and consumers who must transport skim coat supplies from Luzon to Mindanao.

Cementitious skim coatings comprise various constituents and formulas. A composition consisting of 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 derived from vinyl acetate [4]. The weight mixing ratio of water to skim coat is 39-40:100. Additionally, the formulation comprises 12% white cement (binder), 87.6% dolomite powder (filler), 0.3% re-dispersible polymer powder, and 0.1-0.7% thickener, mixed with water in a weight ratio of 35-40:100 for skim coating [2]. Limestone, utilized as a filler material, is recognized as a crucial element in numerous skim coat formulations, as indicated by the pertinent literature. Limestone powder exhibits considerable potential due to its low embedded CO<sub>2</sub> emissions, abundant availability, and economic viability [5]. The formulation was duplicated owing to the accessibility of raw materials, consisting of 28% white cement CEM I, 70.2% calcium carbonate (limestone) as filler, 0.3% cellulose ether as a water retention agent, and 1.5% re-dispersible powder, with a water to skim coat mixing ratio of 35-40:100 by weight [6]. Limestone comprises 70.2% of the skim coat product as a filler material. Local sourcing is expected to decrease the cost of skim coats.

The limestone in the Northern Mindanao Region X has 1,706,456,723.4 metric tons of resources and 152,908,576.5 metric tons of reserves [7]. It demonstrates the potential to investigate and develop a high-value product, specifically a cement-based skim coat. Limestone containing above 75% CaCO<sub>3</sub> is suitable for various industrial applications, necessitating geological exploration to evaluate deposits, quality, and potential uses. This study's limestone achievable test is confined to the purity of calcium carbonate (CaCO<sub>3</sub>) for chemical analysis

and is restricted to density and water content for physical analysis. Numerous research and development initiatives must be conducted to exploit existing deposits effectively [8].

Factorial design is employed to reduce the total number of experiments in order to achieve the best overall optimization of the system. The design determines which factors have important effects on a response as well as how the effect of one factor varies with the level of the other factors. The principal steps of the statistically designed experiments are determination of response variables, factors and factor levels, choice of the experimental design, and statistical analysis of the data. Today, the most widely used kind of experimental design, to estimate main effects as well as interaction effects, is the 2<sup>n</sup> factorial design in which each variable is investigated at two levels. Research can be designed for multiple factors and treatments, but data analysis and treatment establishment becomes more complex and time consuming as the numbers of factors and treatments increase [9–11].

This study evaluates the effects of limestone: cement ratio (80:20, 70:30 and 60:40), particle size (-325 and -200 mesh) and water demand (35% and 40%) on the cement-based skim coat compressive strength involving limestone from Northern Mindanao as filler material. In conclusion, limestone is utilized across several industrial sectors, particularly in constructing new residential and commercial structures, increasing the need for limestone. Considering the region's massive limestone resources, this study evaluates the performance of a cement-based skim coat involving limestone from Northern Mindanao as a filler material.

## **MATERIALS AND METHODS**

### **Assessment of Northern Mindanao limestone's chemical and physical properties**

This study identifies a limestone source in Northern Mindanao, specifically located in Barangay Tagpangi, Cagayan de Oro City, encompassing an extensive area of 3,766.04 hectares, indicating substantial limestone resources available for exploration and usage. Figure 1 illustrates the geological geography of limestone locations in Cagayan de Oro City.

Fieldwork was performed to investigate and gather samples from limestone outcrops in the research area. In this phase, the systematic sampling technique was employed, devoid of randomization, while utilizing a substantial sample size; however, the process was lengthy. The sampling area measured 10 meters by 5 meters and divided into 50 lots. A representative sample (2-3 kg) from each batch was selected to obtain a bulk sample.



Limestone materials' fluidity, friction, and strength are correlated with their density. Conversely, moisture content is essential for evaluating the quality and stability of the formulated skim coat product. Consequently, assessing the density and moisture content of the acquired limestone sample is crucial, and the results will serve as the foundation for the limestone sample utilized in this study. The limestone sample underwent physical analysis at Mega Testing Center Incorporation, Pagadian City.

### **Statistical design**

Factorial design is employed to reduce the total number of experiments in order to achieve the best overall optimization of the system. The design determines which factors have important effects on a response as well as how the effect of one factor varies with the level of the other factors. This study utilized the three factorial design 2x2x3, it is an experiment with three factors, two factors at two levels and one factor at three levels at 0.05 (95% confidence), resulting in 12 treatment combinations

Factor 1 Limestone: cement ratio

- 80:20
- 70:30
- 60:40

Factor 2 Particle size of limestone

- -325 mesh
- -200 mesh

Factor 3 Water demand

- 35%
- 40%

The variable studied are limestone: cement ratio (80:20, 70:39and 60:40), particle size (-325 and -200 mesh) and water demand (35% and 40%), resulting in 12 treatments combinations to evaluate the effects on a cement based skim coat compressive strength. This study developed a cement-based skim coat using white cement, calcium carbonate (limestone) as a filler, cellulose ether as a water retention agent, and re-dispersible powder as an additive. The dosage of re-dispersible powder consistently be 1.5%, while cellulose ether will remain at 0.3%. Table 1 presents the designs mixtures of cement-based skim coats and the associated parameter values examined in the study. All raw materials were appropriately collected, measured, combined, and stored. The compressive strength test of the develop cement – based skim coat sample refers

to ASTM C 109/ C 109M-02, with a standard specification of 7-12 N/mm<sup>2</sup> or 1015.26-1800 psi [6], and was conducted at Mega Testing Center Incorporation, Pagadian City.

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

For treatment of data, IBM SPSS (Version 30) was employed to investigate the effects and interaction of variables. The p-values were used as tools to check the significance of each of the interaction among the variables, which in turn may indicate the patterns of the interactions among the variables. In general, larger the magnitude of t and smaller the value of p, the more significant is the corresponding coefficient term [12].

## RESULTS

### Chemical and physical properties of a limestone sample

Table 2 shows the chemical composition of the collected limestone sample. The chemical analysis of CaCO<sub>3</sub>, which is 93.31%, implies the potential to be used as filler material in cement-based skim coat production. The result of the physical analysis of the collected limestone sample is shown in Table 3.

Table 2. Chemical analysis of limestone

Compound	%
CaCO <sub>3</sub>	93.31
Al <sub>2</sub> O <sub>3</sub>	1.18
Fe <sub>2</sub> O <sub>3</sub>	0.77
CaO	52.28
MgO	0.44
SO <sub>3</sub>	0.05
K <sub>2</sub> O	0.04
Na <sub>2</sub> O	0.04
Ti <sub>2</sub> O	0.07
P <sub>2</sub> O <sub>5</sub>	0.02

Table 3. Result of physical test

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

## Statistical analysis

Table 4 show the 12 treatment combination of three factorial design 2x2x3. The effects of limestone: cement ratio, particle size of limestone and the water demand on the compressive strength of the cement- based skim coat with a standard specification of 7-12 N/mm<sup>2</sup> or 1015.26-1800 psi as shown in Table 5.

Table 4. Univariate Analysis of Variance Between-Subjects Factors

	Label	Value	
		Label	N
Limestone	1	8020	4
cement ratio	2	7030	4
	3	6040	4
Particle size	1	325	6
	2	200	6
Water demand	1	35	6
	2	40	6

Table 5. Experimental data

Limestone:cement ratio	Water demand 35%		Water demand 40%	
	Particle size of limestone		Particle size of limestone	
	-325 mesh	-200 mesh	-325 mesh	-200 mesh
80:20	534	506	422	506
70:30	871	1180	759	815
60:40	1124	1789	1180	1208

From the IBM SPSS output, in Table 6 shows the interactions of variables with the p values of 0.048, 0.228, .228, 0.580 ,0.733 and 0.353 for the limestone to cement ratios, particle size, water demand, limestone cement ratio \* particle size, limestone cement ratio \* water demand and particle size \* water demand, results show only one factor has a significant effect to the compressive strength of cement based skim coat which is the limestone cement ratios at 0.05 (95% confidence). Moreover, interaction of limestone cement ratio\* particle size \* and water demand interaction has no p value as shown in Table 7.

Table 6. Tests of Between-Subjects Effects

Dependent Variable: Compressive strength

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1722143.500 <sup>a</sup>	9	191349.278	5.456	.164
Intercept	9889936.333	1	9889936.333	282.005	.004
Limestone cement ratio	1388626.167	2	694313.083	19.798	.048
Particle size	103416.333	1	103416.333	2.949	.228
Water demand	103416.333	1	103416.333	2.949	.228
Limestone cement ratio * Particle size	50736.167	2	25368.083	.723	.580
Limestone cement ratio * Water demand	25508.167	2	12754.083	.364	.733
Particle size * Water demand	50440.333	1	50440.333	1.438	.353
Error	70140.167	2	35070.083		
Total	11682220.000	12			
Corrected Total	1792283.667	11			

a. R Squared = .961 (Adjusted R Squared = .785)

Table 7. Tests of Between-Subjects Effects

Dependent Variable: Compressive strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1792283.667 <sup>a</sup>	11	162934.879	.	.
Intercept	9889936.333	1	9889936.333	.	.
Limestone cement ratios	1388626.167	2	694313.083	.	.
Particle size	103416.333	1	103416.333	.	.
Water demand	103416.333	1	103416.333	.	.
Limestone cement ratio *	70140.167	2	35070.083	.	.
Particle size * water demand					
Limestone cement ratio *	50736.167	2	25368.083	.	.
Particle size					
Limestone cement ratio *	25508.167	2	12754.083	.	.
water demand					
Particle size * water demand	50440.333	1	50440.333	.	.
Error	.000	0	.		
Total	11682220.000	12			
Corrected Total	1792283.667	11			

a. R Squared = 1.000 (Adjusted R Squared = .)

## DISCUSSION

Limestone primarily consists of calcium carbonate ( $\text{CaCO}_3$ ), with examined samples exhibiting a range from  $82.24 \pm 0.65$  to  $96.67 \pm 0.28$  and a mean percentage of  $93.01 \pm 4.47$ . Any limestone containing over 75%  $\text{CaCO}_3$  can be utilized industrially. Numerous research and development initiatives must be conducted to exploit existing deposits effectively [8]

Chemical research revealed that the limestone sample contains 93.31%  $\text{CaCO}_3$ , above the 75% calcium carbonate threshold required for industrial use. This indicates that the limestone sample is appropriate for utilization as filler material in a cement-based skim coat production. Additionally, based on the evaluation of the effects of limestone to cement ratio, particle size

and water demand on a cement-based skim coat compressive strength, only one factor has a significant effect of the compressive strength of cement based skim coat which is the limestone cement ratios and combination of 60:40 limestone cement ratio compressive strength result passed the standard specification 7-12 N/mm<sup>2</sup> or 1015.26-1800 psi as shown in Figure 2 and 3.

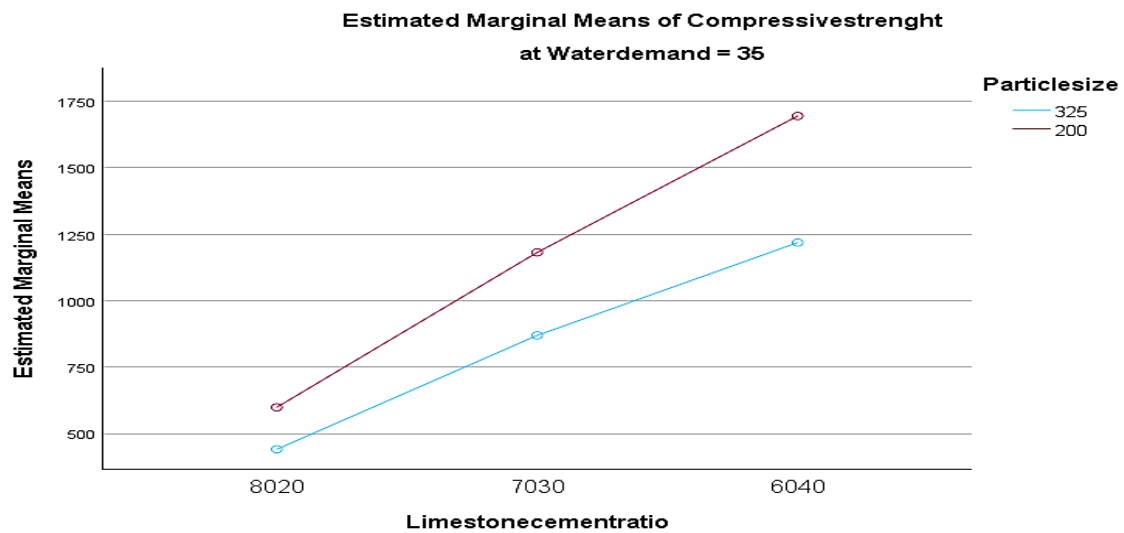


Figure 2. Effects of limestone to cement ratio, particle size and water demand at 35% on a cement-based skim coat compressive strength

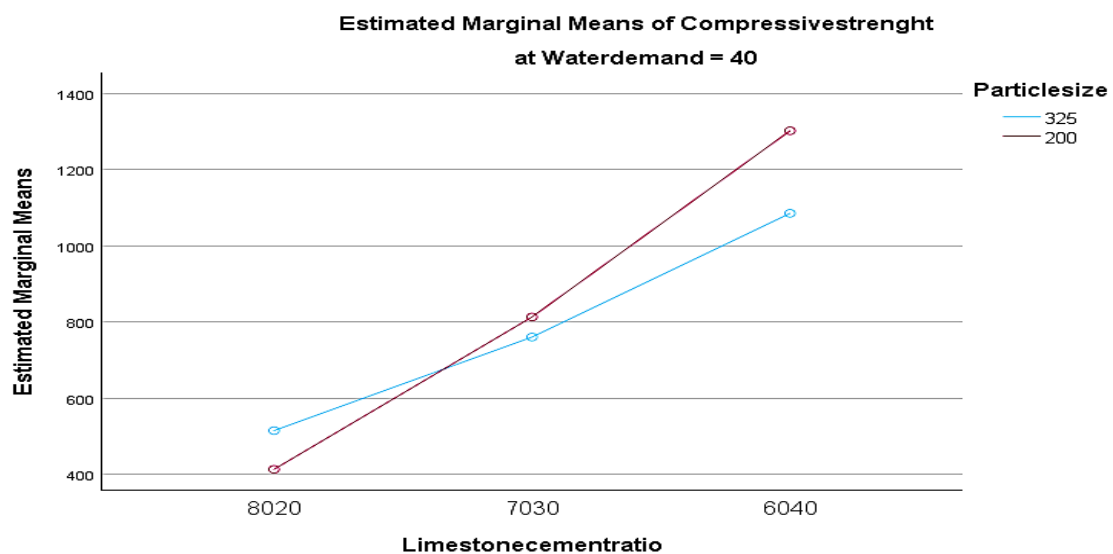


Figure 3. Effects of limestone to cement ratio, particle size and water demand at % 40 on a cement-based skim coat compressive strength

Furthermore, limestone is usually used as inert fillers to complete a large variety of final properties without increasing the costs by replacing a more expensive material with an inexpensive one. Fillers also improve characteristics such as hardness, brittleness, impact strength, compressive strength, softening point, fire resistance, surface texture, electrical conductivity, and so on [13], [14]. On the other hand, White cement is a high-performance cement containing a patented formula of naturally and highly reactive pozzolans found in geologic deposits. It quickly reacts with water and forms calcium hydroxide since calcium carbonate is a significant constituent of white cement. Formed calcium hydroxide reacts with the other minor constituents in white cement and forms a dense matrix, providing the skim coat strength [15].

## CONCLUSION

The limestone in Barangay Tagpangi, Cagayan de Oro City, Northern Mindanao, Philippines, spans an area of 3,766.04 hectares and possesses a  $\text{CaCO}_3$  purity of 93.31%, indicating significant economic potential. Furthermore, among the design mixtures of cement-based skim coats incorporating limestone from Northern Mindanao, 60:40 limestone to cement ratio have effectively met the compressive strength specification. This indicates that the limestone in Northern Mindanao possesses significant potential as a filler material for cement-based skim coat production, presenting a desirable opportunity for additional laboratory evaluation and innovation.

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