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CORRELATION ANALYSIS ON THE EFFECT OF CHEMICAL COMPOSITION OF LIMESTONE AGGREGATE UPON MECHANICAL STRENGTH OF CONCRETE

Norul Wahida Kamaruzaman, Hilman Hafiz Zulkefli & Nurazim Ibrahim
Infrastructure University Kuala Lumpur, MALAYSIA

ABSTRACT

Limestone is a sedimentary rock that is no stranger in construction work due to its chemical composition, calcium carbonate, which has a cement-like characteristic when it is mixed with water, thus resulting in a binding agent to hold concrete together. It is a very popular choice to make cement but not as an aggregate. The main problem encountered is that there is not enough information on the appropriate amount of calcium carbonate within concrete. The purpose of this research paper is to study the effect of the chemical composition of limestone aggregate towards the mechanical strength of concrete. The objective is to study the relationship between the percentage of limestone aggregate and the mechanical strength of concrete. The extraction of data from past research papers about limestone aggregate percentage as its mechanical strength were tabulated where the parameters were analysed using the Pearson correlation analysis to study the strength of the relationship between the two parameters. The result shows the relationship between the two parameters is strong as when there was an increase in the percentage of limestone aggregate, the mechanical strength tended to also increase. The result obtained shows the relationship between parameters is strong which indicated that limestone is suitable to be used as concrete aggregate.

Keywords:
Calcium Carbonate, Limestone Aggregate, Compressive Strength, Flexural Strength.

INTRODUCTION

Concrete is a composite material consisting of cement, water and aggregate. Generally, the bond between aggregate with the binding agent is the result of the hydration process. It involves the chemical reaction between water and cement which produce calcium silicate hydroxide gel (C-S-H gel). The strength of concrete is contributed by the arrangement of fine and coarse aggregate inside the concrete matric. The arrangement contributes to the density and indirectly has a significant impact on the concrete strength and durability. Thus, it is important to determine the physical and chemical properties of aggregate to achieve the targeted strength of concrete. Various aggregates are available in the market supplied to construction projects all over the country, especially in tropical regions. The availability of limestone is very wide in Malaysia. Limestone can be easily found both in Peninsular Malaysia and on the island of Borneo, also known as East Malaysia, as highlighted by Tan Boon Kong (2010). The relationship between the physical and chemical properties of aggregate with the concrete strength and performance would signify the aggregate choice during the concrete mix design stage.

The focus of this paper is to analyse the correlation between the content of calcium carbonate inside the limestone aggregate towards the compressive and flexural strength of concrete. As for the physical properties, the roughness of the limestone aggregate surface is higher as compared to the gravel which will help the bonding effect between all constituents inside the concrete matric. In terms of chemical properties, the content of calcium carbonate is considered the major chemical composition inside the limestone aggregate. The high content of calcium carbonate can be found inside the limestone aggregate. However, for gravel, there is no significant content of calcium carbonate inside the particles. The effect of this chemical composition is significantly important in order to conduct concrete mix design. So far, there is no publication on the correlation between calcium carbonate and concrete properties available.

Limestone is composed of calcium carbonate minerals calcite and dolomite (King, 2016). From the chemistry point of view, calcite is chemically a calcium carbonate ($CaCO_3$). By studying calcium carbonate at the macro and micro levels, the effect of limestone towards the mechanical strength of concrete can be seen. The coarse aggregate influences the mechanical strength of concrete through water absorption, the constitution of limestone aggregate and particle size. The mechanical strength of concrete is affected by several critical factors such as the concrete mix design, the chemical reaction inside the concrete matric and the aggregate properties. Holcim (2015) highlighted that a concrete mix design that uses too much water will reduce the mechanical strength of concrete. The chemical composition of each ingredient affects the chemical reaction when all ingredients are being mixed.

Based on previous research, the incorporation of wet coarse limestone aggregate can produce higher compressive strength compared to dry coarse limestone aggregate (Alhozaimy, 2009). On the other hand, fine aggregate will be broken down during exposition to the heat from the hydration process to create calcium hydroxide. Calcium hydroxide later will start to crystalize along with calcium silicate hydrate which was produced during the hydration process. Outcomes will birth a thick mass of crystals interconnected to each other and all the other substances present (Ernest, 2016). Limestone is composed of calcium, bearing carbonate minerals calcite and dolomite (King, 2016). From the chemistry point of view, calcite is chemically a calcium carbonate ($CaCO_3$). On the other side, dolomite chemically is a calcium magnesium carbonate. For this study, the limestone that will be used is commercial grade limestone which means the limestone consists of 80 percent calcite and dolomite, with less than 20 percent other rock materials (Missouri Department of Natural Resources, 2020).

METHODOLOGY

A lot of research has been conducted on the mechanical strength of concrete with limestone as the aggregate. To find the strength of the relationship between two parameters, a set of data was extracted from the research paper on the percentages, which are limestone aggregate, compressive strength of concrete and flexural strength of concrete. The set of data was then tabulated in a table for the purpose of calculation of correlation analysis. The method of analysis that was used to study the degree of relationship between the parameters is the Pearson Correlation formula.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

After the value had been obtained from all three parameters, a formation of graph was made to show the degree of magnitude between the relationships of the two parameters**.** The formation of graph was done using Microsoft Excel with additional value of r^2 shown on the graph. Tables 1-2 show the details of the parameters.

Table 1: Parameter percentage of limestone aggregate and compressive strength

No	Author	Year	Title	Percentage of Limestone Aggregate (%)	Compressive Strength (Mpa)
1	H. Beshr , A.A. Almusallam , M. Maslehuddin	2002	Effect of Limestone Fillers the Physic-Mechanical Properties of Limestone Concrete	5	27.8
2	Md. Umar Khan, S.Sridhar	2015	Technology of Flexural Strength, Workability, Compressive Strength and Split Tensile Strength Assessment of Limestone Aggregate Concrete	20	29
3	Md Zeeshan, Prof. Rohan S Gurav, Prof. Brij Bhushan S, Prof. Maneeth P D	2015	Experimental Investigation on Partial Replacement of Natural Fine Aggregate by Steel Slag and Natural Coarse Aggregate by Waste Limestone Aggregate in Cement Concrete	25	31.186
4	S. Kitouni, H. Houari	2013	Lightweight Concrete with Algerian Limestone Dust. Part I: Study on 30% Replacement to Normal Aggregate at Early Age	30	34.99
5	A.Jayaraman , V.Senthilkumar , M.Saravanan	2014	Compressive and Tensile Strength of Concrete Using Lateritic Sand and Limestone Filler as Fine Aggregate	40	36.12
6	Dr.Muyasser M. Jomaa'h	2012	Using of Local Limestone as Aggregate in Concrete Mixture	47	36.33
7	Omar M. Omar, Ghada D. Abd Elhameed, Mohamed A. Sherif , Hassan A. Mohamadien	2012	Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties	50	41.9
8	Naum Sapozhnikov	2007	Concrete with Enriched Quarry Limestone Waste as a Coarse Aggregate	52	42.2
9	Manikanta. D, Sanjith. J and Ranjith. A	2016	Effect of Limestone Aggregate on High Strength Concrete in Both Fresh and Hardened	75	54.81
10	A. M. Kilic, O. Kilic and M. O. Keskin	2010	The Effect of The Rock Type Forming the Aggregate in Lightweight Polymer Concrete on Compressive and Flexural Tensile Strength	100	74.1

Table 2: Parameter percentage of limestone aggregate and flexural strength

No	Author	Year	Title	Percentage of Limestone Aggregate (%)	Flexural Strength (Mpa)
1	Awodiji ChiomaTemitope Gloria, Onwuka Davis Ogbonnaya, Awodiji Olayinka Olujide	2007	Flexural and Split Tensile Strength Properties of Lime Cement Concrete	3	4.16
2	Pathan Maaz Khan L , Farhan A. Vahora	2015	Influence of Limestone and Fly Ash (Class F) as Partial Replacement Materials on the Mechanical Properties of Concrete	12	4.3
3	Md. Umar Khan, S.Sridhar	2015	Technology of Flexural Strength, Workability, Compressive Strength and Split Tensile Strength Assessment of Limestone Aggregate Concrete	20	4.7
4	Khalid M. Shaheen, Ehab E. Aziz	2012	A Sustainable Method for Consuming Waste Concrete and Limestone	25	6.1
5	S. Kitouni, H. Houari	2013	Lightweight concrete with Algerian limestone dust. Part I: Study on 30% replacement to normal aggregate at early age	30	6.39
6	Tahir Kibriya, Leena Tahir	2017	Sustainable Construction—High Performance Concrete Containing Limestone Dust as Filler	55	6.4
7	Jayant Damodar Supe & Dr. M.K.Gupta	2014	Flexural Strength – A Measure to Control Quality of Rigid Concrete Pavements	58	6.587
8	Rozalija Kozul, David Darwin	1997	Effects of Aggregate Type, Size, and Content on Concrete Strength and Fracture Energy	69	8.8
9	A. Kılıc, C.D. Atis, A. Teymen, O. Karahan, F. O¨ zcan, C. Bilim, M. O¨ zdemir	2007	The Influence of Aggregate Type on the Strength and Abrasion Resistance of High Strength Concrete	74	12.8
10	A. M. Kilic, O. Kilic and M. O. Keskin	2010	The Effect of The Rock Type Forming the Aggregate in Lightweight Polymer Concrete on Compressive and Flexural Tensile Strength	100	13.2

RESULT AND DISCUSSION

The analysis of the data was used to determine the relationship between the percentages of limestone aggregate in concrete with compressive and flexural strength and lastly, the relationship between two mechanical strength sets as can be seen in Tables 3 to 6.

Table 3: Calculations based on data percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \times (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	5	27.8	-39.4000	-13.0436	513.9178	1,552.3600	170.1355
2	20	29	-24.4000	-11.8436	288.9838	595.3600	140.2709
3	25	31.186	-19.4000	-9.6576	187.3574	376.3600	93.2692
4	30	34.99	-14.4000	-5.8536	84.2918	207.3600	34.2646
5	40	36.12	-4.4000	-4.7236	20.7838	19.3600	22.3124
6	47	36.33	2.6000	-4.5136	-11.7354	6.7600	20.3726
7	50	41.9	5.6000	1.0564	5.9158	31.3600	1.1160
8	52	42.2	7.6000	1.3564	10.3086	57.7600	1.8398
9	75	54.81	30.6000	13.9664	427.3718	936.3600	195.0603
10	100	74.1	55.6000	33.2564	1,849.0558	3,091.3600	1,105.9881
	$\underline{x}$ = 44.4000	$\underline{y}$ = 40.8436			$\sum$ = 3,376.2516	$\sum$ = 6,874.4000	$\sum$ = 1,784.6295

$$r = \frac{3376.2516}{\sqrt{(6874.4000 \ x \ 1784.6295}} = 0.9639$$

$$r^2 = 0.9639^2 = 0.9292$$

Table 4: Calculations based on data set percentage of limestone aggregate and compressive strength:

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \times (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	3	4.16	-41.6000	-3.1837	132.4419	1,730.5600	10.1359
2	12	4.3	-32.6000	-3.0437	99.2246	1,062.7600	9.2641
3	20	4.7	-24.6000	-2.6437	65.0350	605.1600	6.9891
4	25	6.1	-19.6000	-1.2437	24.3765	384.1600	1.5468
5	30	6.39	-14.6000	-0.9537	13.9240	213.1600	0.9095
6	55	6.4	10.4000	-0.9437	-9.8145	108.1600	0.8906
7	58	6.587	13.4000	-0.7567	-10.1398	179.5600	0.5726
8	69	8.8	24.4000	1.4563	35.5337	595.3600	2.1208
9	74	12.8	29.4000	5.4563	160.4152	864.3600	29.7712
10	100	13.2	55.4000	5.8563	324.4390	3,069.1600	34.2962
	$\underline{x}$ = 44.6000	$\underline{y}$ = 7.3437			$\sum$ = 835.4358	$\sum$ = 8,812.4000	$\sum$ = 96.4970

$$r = \frac{835.4358}{\sqrt{(8812.4000 \ x \ 96.4970)}} = 0.9060$$

$$r^2 = 0.9060^2 = 0.8208$$

Table 5: Calculations based on data set percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \text{ x } (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	3	4.16	-41.6000	-3.1837	132.4419	1,730.5600	10.1359
2	12	4.3	-32.6000	-3.0437	99.2246	1,062.7600	9.2641
3	20	4.7	-24.6000	-2.6437	65.0350	605.1600	6.9891
4	25	6.1	-19.6000	-1.2437	24.3765	384.1600	1.5468
5	30	6.39	-14.6000	-0.9537	13.9240	213.1600	0.9095
6	55	6.4	10.4000	-0.9437	-9.8145	108.1600	0.8906
7	58	6.587	13.4000	-0.7567	-10.1398	179.5600	0.5726
8	69	8.8	24.4000	1.4563	35.5337	595.3600	2.1208
9	74	12.8	29.4000	5.4563	160.4152	864.3600	29.7712
10	100	13.2	55.4000	5.8563	324.4390	3,069.1600	34.2962
	$\underline{x}$ = 44.6000	$\underline{y}$ = 7.3437			$\sum$ = 835.4358	$\sum$ = 8,812.4000	$\sum$ = 96.4970

$$r = \frac{835.4358}{\sqrt{(8812.4000 \text{ x } 96.4970)}} = 0.9060$$

$$r^2 = 0.9060^2 = 0.8208$$

Table 6: Calculations based on data set percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \text{ x } (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	27.8	4.16	-13.0436	-3.1837	41.5269	170.1355	10.1359
2	29	4.3	-11.8436	-3.0437	36.0484	140.2709	9.2641
3	31.186	4.7	-9.6576	-2.6437	25.5318	93.2692	6.9891
4	34.99	6.1	-5.8536	-1.2437	7.2801	34.2646	1.5468
5	36.12	6.39	-4.7236	-0.9537	4.5049	22.3124	0.9095
6	36.33	6.4	-4.5136	-0.9437	4.2595	20.3726	0.8906
7	41.9	6.587	1.0564	-0.7567	-0.7994	1.1160	0.5726
8	42.2	8.8	1.3564	1.4563	1.9753	1.8398	2.1208
9	54.81	12.8	13.9664	5.4563	76.2049	195.0603	29.7712
10	74.1	13.2	33.2564	5.8563	194.7595	1,105.9881	34.2962
	$\underline{x}$ = 40.8436	$\underline{y}$ = 7.3437			$\sum$ = 391.2918	$\sum$ = 1,784.6295	$\sum$ = 96.4970

$$r = \frac{391.2918}{\sqrt{(1784.6295 \text{ x } 96.4970)}} = 0.9429$$

$$r^2 = 0.9429^2 = 0.8891$$

After the value has been obtained from all three parameters, a formation of graph was made to show the degree of magnitude between the relationships of the parameters as can be seen in Figures 1 - 3.

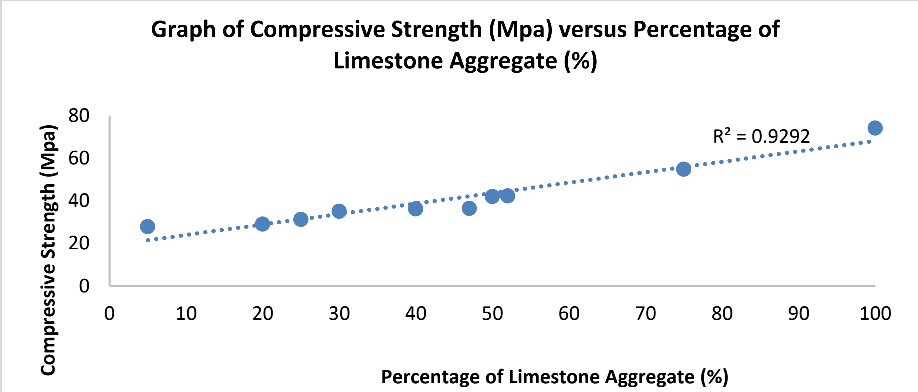

Figure 1: Graph of Compressive Strength versus Percentage of Limestone

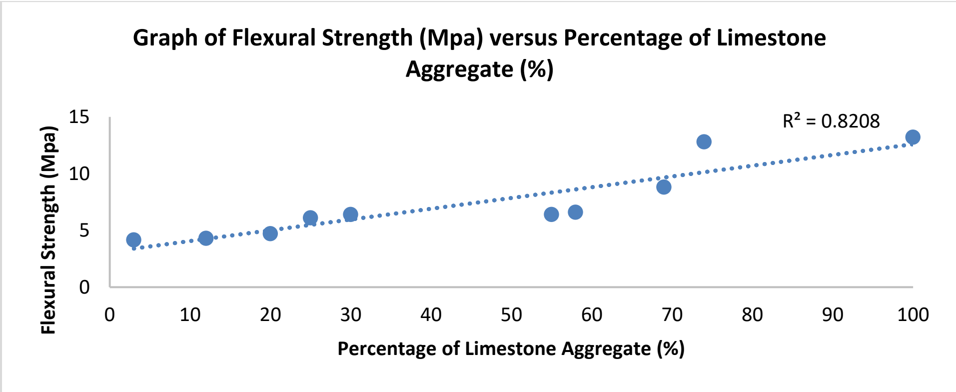

Figure 2: Graph of Flexural Strength versus Percentage of Limestone

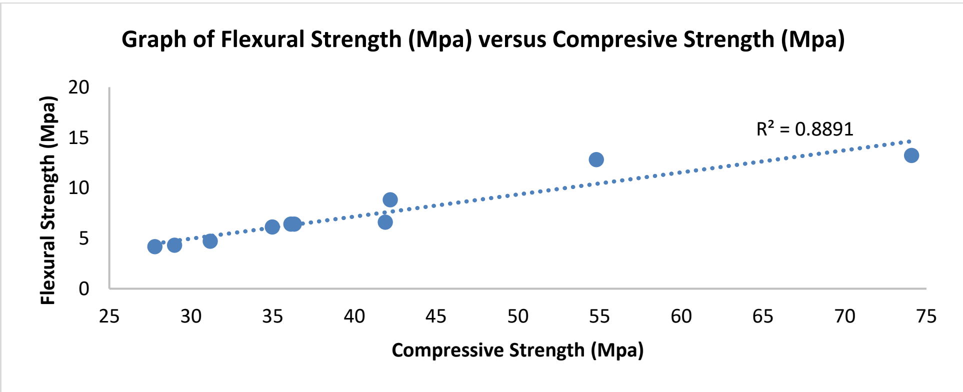

Figure 3: Fraph of Flexural Strength versus Compressive Strength

DISCUSSION

Firstly, the relationship between the percentage of limestone aggregate and compressive strength has been found to have a very strong relationship with the correlation value 0.9292. This is due to the arrangement of material within concrete which gives it a quality of adhesiveness which makes it very strong in compressive strength (Ashish, 2021). Second, the relationship between the percentage of limestone aggregate and flexural strength has been found to also have a strong relationship but not as strong as the first objective with the value only reaching up to 0.8208. This is due to the weakness of the concrete which is very weak in tensile strength (Ashish, 2021). Things could be different if the research is done on reinforced concrete which has reinforcements to help with tensile strength (Bag of Concrete, February 2021). Lastly is the relationship between the two mechanical strengths which is compressive and flexural value at 0.8891. Because the two have a strong relationship with the percentage of limestone aggregate, supposedly the two mechanical strengths have a strong relationship with each other. The graph is formed and the r^2 value falls under a very strong relationship. From each of the tables, it is shown that the value is almost up to 1.0. The increase in the variable will lead to the other variable to also increase (Statistics Solutions, 2022) which is one of the characteristics of the very strong relationship between the parameters.

CONCLUSION

To sum up, everything that has been stated so far in this research paper, it can be concluded that all three objectives have successfully been achieved. It is expected that increasing the percentage of the limestone aggregate will lead to an increase in concrete mechanical strength and the Pearson correlation analysis method has confirmed it. It is recommended to classify the research to only coarse or fine aggregate instead of aggregate as whole to understand the effect of the different sizes of aggregate from the same chemical composition. Research can be done by extracting from past studies which had used the same size of concrete grade to get better correlation values and even on the same concrete mixture for every data of research paper. The research could be done on reinforced concrete in order to get a better reading for flexural strength and other strengths associated with the tensile force.

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AUTHOR BIOGRAPHY

Norul Wahida Kamaruzaman, Ts. PhD is a lecturer in the Infrastructure University Kuala Lumpur. She research focused on alleviating problems associated with construction materials and technologies. *Email: wahida@iukl.edu.my*

Hilman Hafiz Zulkefli is a final year student at Infrastructure University Kuala Lumpur. He is studying in Bachelor of Civil Engineering (Hons)

Nurazim Ibrahim, Ts. PhD is a lecturer in the Civil Engineering & Construction Department of Infrastructure University Kuala Lumpur. She research focused on alleviating problems associated with solid waste management and water pollution issues. *Email: nurazim@iukl.edu.my*

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