Current Journal of Applied Science and Technology

40(41): 44-58, 2021; Article no.CJAST.80771
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Properties of Sustainable Concrete Containing Limestone: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i4131606

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/80771

Review Article

Received 09 October 2021
Accepted 18 December 2021
Published 20 December 2021

ABSTRACT

The most frequently used building material on this planet is concrete. Concrete is the supreme user of natural resources as a result of its widespread use as construction material. Cement production produces significant amount of greenhouse emissions. The protection of environment has become challenging in many developing countries, 7-8% of CO_2 is produced by the cement industry that causes huge damage to the environment. In concrete production, and limestone can be a partial alternative to cement. The limestone waste is transported and disposed in landfills. The disposal of limestone waste material in the open areas is causing several problems. In this study, the properties of concrete incorporating limestone waste are reviewed. Workability, compressive strength, split tensile strength, flexural strength, modulus of elasticity, and durability are among qualities of limestone waste concrete that have been discussed in this study. The cement was replaced by limestone waste in the ratio of 25% to 30% in concrete By limiting the waste of limestone in the concrete, cement content can be reduced, which turns into an eco-friendly solution.

Keywords: Limestone; cement; concrete; strength; workability; compressive strength; modulus of elasticity.

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1. INTRODUCTION

The most rapidly expanding industry around the globe is the construction industry, which consumes most of the natural resources [1]. Cement is an important building ingredient since it is utilized as a binder in the creation of mortar [2]. Cement production, on the other hand, results in the release of greenhouse gases into the atmosphere [3-5]. According to studies, every ton of cement produced emits roughly half ton of carbon dioxide, which is a considerable quantity contributing in 5% of total man-made CO_2 emissions, with India accounting for nearly 7-8% of overall carbon dioxide emissions [6,7]. In industries, waste production is unavoidable; nevertheless, by using industrial waste as a partial substitution for conventional cement, it is possible of constructing low-carbon system having lower embodied energy of production. From the previous decades the stone sector has amplified speedily due to huge infrastructural developments. In India production of stone is very huge lodging third position in the world and Rajasthan stocks about 50% of its productions. Limestone is made after the stone has been sawed and polished to the desired dimension [8]. The mining operations produce a lot of trash, with only half of the limestone being acquired [9]. The blocks of stone generate slurry during processing in gang saws, which are combined with the limestone solid to produce a limestone slurry [10, 11]. By addressing the problem of uncontrollable fine slurry powder disposal in the soil, the use of limestone waste in concrete will greatly reduce environmental pollution [12]. Due to massive infrastructural expansions, the stone sector has grown fast in the previous two decades with new technologies [13]. The annual production of the stone in India is enormous, with Rajasthan accounting for over half of the total [14].

1.1 Benefit of the Limestone Contained in Concrete Mix

At present moment, cement in concrete is considered to be the greatest significant building material [15]. Despite of its widespread use in the construction industry for more than a century, low compressive strength, low tensile and flexural strength, poor bonding, porosity and permeability, poor resistance to acid and other hostile chemical, weak elastic modulus, shrinkage, and flexibility are just a few of the defects [16-19]. Mechanical measures, like adding reinforcement and mineral admixtures like fly ash, lime, and slag, can improve the compressive, tensile, and flexural strength of cement concrete [20-22]. Lime has been employed as a binding ingredient for structural purpose since prehistoric times [23]. In various nation, powder of limestone is commonly utilized as filling material in concrete [24]. Lime is abundantly available in nature and it is also not very expensive [25]. Concrete's workability can be improved by adding limestone powder [26].

1.2 Impact of Limestone Powder on the Environment

Limestone dust created by large operations of quarry that not only utilizes valuable land but also causes a lot of environmental issues [27, 28]. Lime dust disposal and utilization are two topics that are now attracting attention Mining is done using open cast method, which is used on both big and small scales [29]. The limestone produced is mostly used for the manufacturing of cement, lime, and edible lime [30]. According to scientific studies, limestone mining has a number of negative environmental consequences, including losing of forest by deforestation, contamination of water, air and land, diminution of flora and fauna, biodiversity being reduced, soil erosion, unsteadiness of rock masses, variations in the landscape, and deprivation of land used for agriculture [31-33]. The effect of mining on various resources like water, soil, and air quality, as well as forest degradation and contamination of water are summarized and investigated [34]. The government has now implemented many policies that impact the overall influence of mining of limestone. The policies recommend that stakeholders and cement plant owners should pay a close attention to the environmental challenges that exist in zone [35, 36]. Efficient management initiatives of resources of water, forest and soil must be undertaken for preventing additional loss of cover of forest and top layer of soil, as well as declining of the quality of water, degradation of soil, noise and air pollution [37].

2. WORKABILITY OF CONCRETE

2.1 Slump

Concrete workability, which is computed by slump test, compaction factor test, etc. is an important quality in the manufacturing of concrete. Alexandra et al. [38] measured the value of slurry and compaction factor of limestone for a constant w/c ratio of 0.35 for 0, 10, 20 30, and 40% replacement of cement by limestone slurry respectively. Fig. 1 shows that as the fraction of lime cement replaced by limestone slurry increases there is an increase in the compaction factor.

Mohammad et al. [39] investigated the slump and compaction factor of concrete made with limestone powder for a water cement ratio of 0.45. The slump and compaction factor were measured for substitution of limestone powder by cement at level of 0%, 20%, 30%, and 40%. With the limestone powder fineness, the slump value got increased and the compaction factor dropped with the increase in percentage of cement been replaced by the powder of limestone.

Skender et al. [40] supported an experiment for determining the workability of concrete specimens with replacement of limestone powder with the replacement level of 0%, 10%, and 15%, 20%, 25%, 30% and 35% used to replace cement. While, 0% to 40% limestone powder was used for substituting the fine aggregates. The results depict that with the increment in amount of cement replaced by limestone powder, the slump value got increased. Fig. 2 represents the results of workability of the concrete samples.

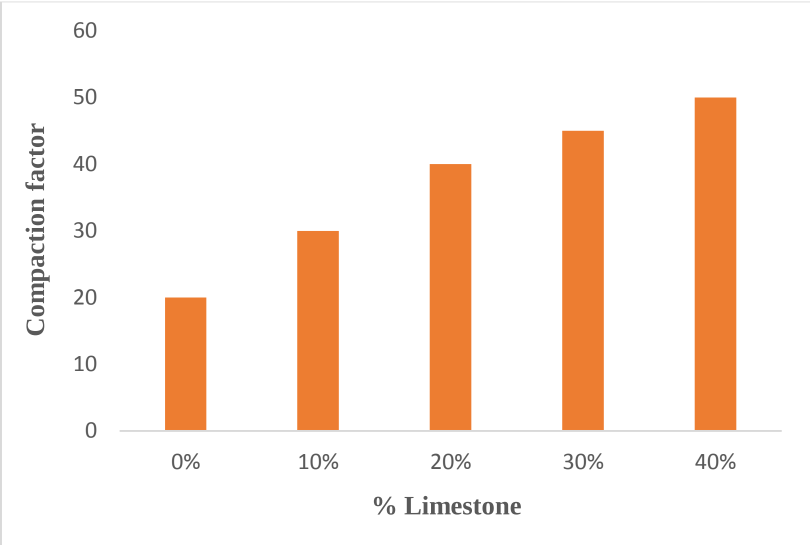

Fig. 1. Workability test results [38]

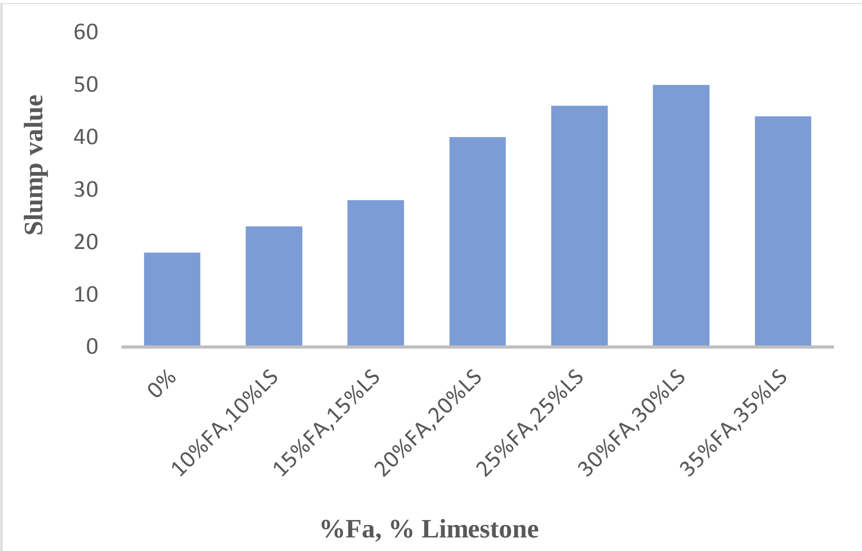

Fig. 2. Workability test results [40]

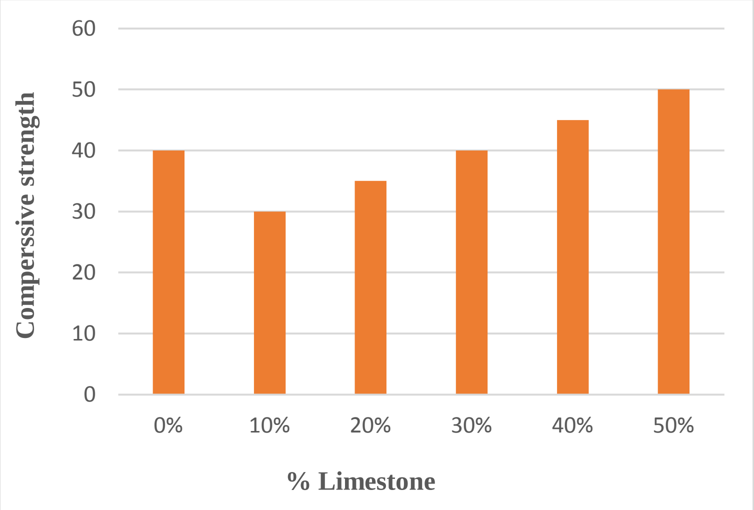

Fig. 3. Workability test results [41]

Dasilva et al. [41] measured the slump value of concrete after the cement was replaced with limestone. Concrete with water cement ratio of 0.5 was swapped in following percentages of 0%, 20%, 30%, 40% and 50%, respectively. There was an increment in the slump value and increasing in the compressive strength as the fraction of cement replaced with limestone and the water cement ratio was increased. Fig. 3 depicts the test results of workability.

Burroughs et al. [42] conducted an experiment for regulating the concrete workability when cement was replaced by limestone in the amount of 0%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%. The results concluded that the workability of concrete increased rapidly as water cement ratio got increased.

3. HARDENED PROPERTIES OF CONCRETE

The strength as well as performance of hardened concrete depend mainly on strength and performance under various types of load conditions. The main properties which come under hardened properties are shown below.

3.1 Compressive Strength

Strength during compression is among the main property of concrete. Compressive strength of limestone dust concrete mixes was evaluated by several researchers.

Lollini et al. [43] carried out an experiment for calculating the strength under compression of concrete cubes replacing limestone dust at 7 and 28 days. Results of concrete depend upon the water/binder ratio. Being cured at 7 days with the dosage of binder being equal to 300kg/m^3 the value got enlarged. While, after 28 days of curing, the w/b ratio got reduced from 0.61 to 0.46. So, it was concluded that increase the compressive strength decreased the water/ binder ratio.

Elgalhud et al. [44] concluded that with the wet curing of 7 and 28 days having water cement ratio of 0.45, the researchers investigated the influence of strength of compression on the permeability of paste of cement and mortar concrete with limestone powder as a limited replacement for cement. The different percentages of limestone powder in the concrete by weight of Portland cement (20%, 25%, 30%, and 40%) were studied. It was reported that limestone powder up to 25% should not increase the strength of concrete and increase in the limestone powder to more than 30% directly affected the porosity of concrete thereby reducing the compressive strength. Fig. 4 represents the test results of compressive strength of the concrete.

Li et al. [45] investigated the strength of compression of ultra-high performance concrete incorporating powder of limestone as a partial replacement of cement. The percentage of limestone powder added by weight of cement were (10%, 15%, 20%, 25%, 30% and 35%). The test was performed for M50 grade of concrete. The water cement ratios of 0.25, 0.30, and 0.35 were selected. Cube of size

(100mm×100mm×100mm) was used to determine the compressive strength for a period of 7, 28, and 90 days of curing. It was discovered that swapping cement with the powder of limestone increased the strength of concrete. The optimal dosage of replacement was found to be 30% as shown in Fig. 5.

Meddah et al. [46] analyzed compressive strength tests for M25 and M30 grade of concrete by limestone slurry at the replacement ratio of 10%, 20%, 30% and 40% for 7 and 28 days of curing. It was concluded that the limestone powder up to 40% replacement decreases the asset of concrete and at 0.52 water cement ratio with 30% replacement provide good strength concrete as shown in Fig. 6.

Mikhailova et al. [47] carried out an experiment on the strength of compression of concrete by using dolomite limestone powder. The percentage of limestone powder used varied from 0% to 30% by weight of cement and the water cement ratio was 0.5 was selected. The size of prismatic mould that was used was (40×40×160mm). While compressive strength at 7, 14 and 28 days of curing was determined. It was decided that the increase in compressive strength, when sample contained 25% to 30% powder of limestone augmented by 16.7% and 23.5% at 14 and 28 days respectively.

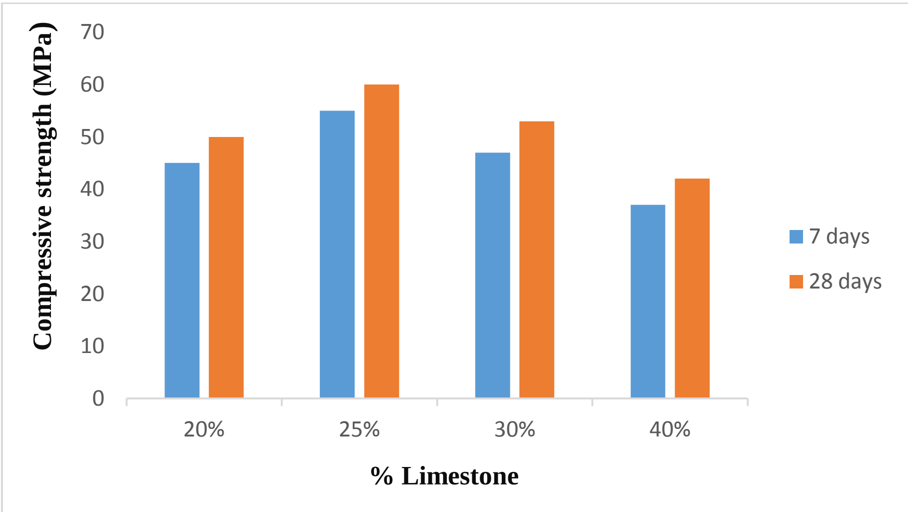

Fig. 4. Compressive strength test results [44]

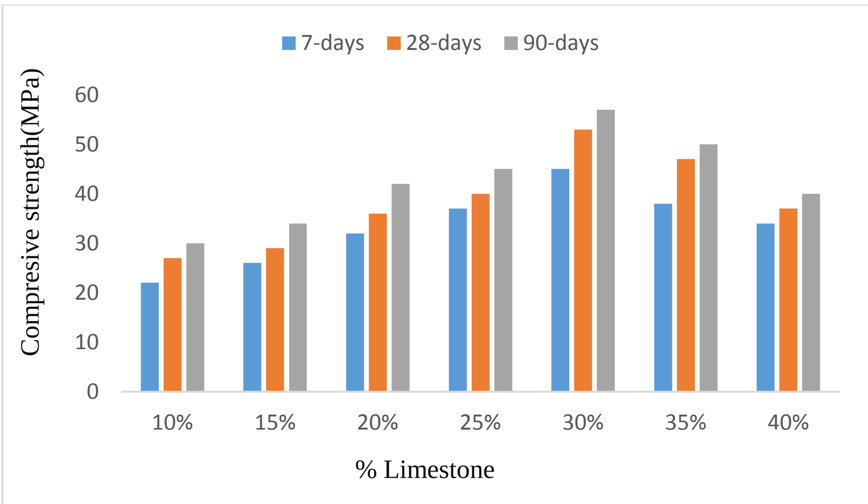

Fig. 5. Compressive strength results [45]

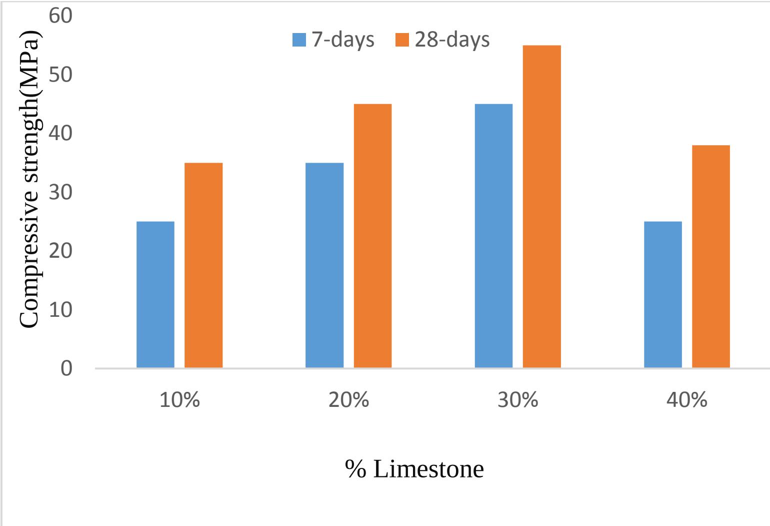

Fig. 6. Compressive strength results [46]

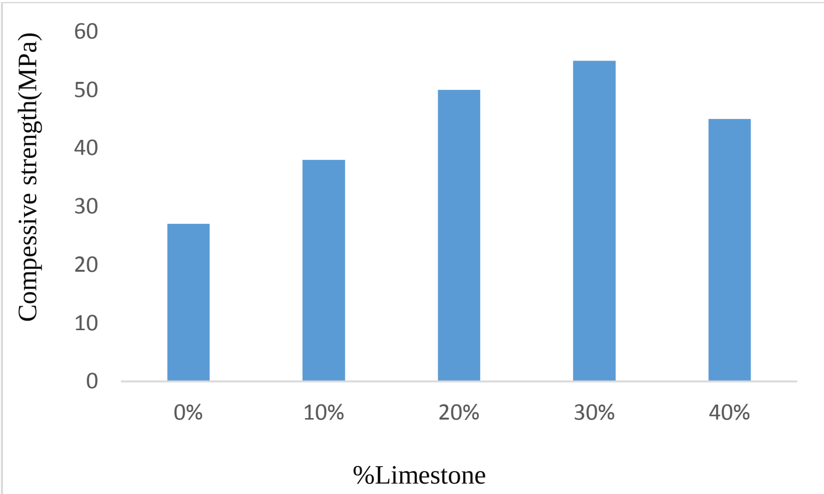

Fig. 7. Compressive strength test results [48]

The properties of concrete incorporating limestone were examined by Zatitri et al. [48] the compressive strength that was obtained varied between 50 MPa to 75 MPa for concrete having limestone as a substitution of cement with percentage of 0,10,20,30 and 40 respectively. It was noticed that a combination comprising of 20 to 30% limestone had the highest compressive strength as shown Fig. 7.

Characteristics of strength of compression of large quantity of fly ash concrete containing limestone were studied by yoshitake et al. [49] the strength of compression was depicted to be maximum in sample of concrete containing 30% limestone as a partial substitution of cement at the ages of 7, 28, and 91 days.

3.2 Tensile Strength

Largest load sustained by a material without shattering while it is strong, divided by original cross section area of the material, is referred to as tensile strength.

Zhou et al. [50] deliberated the tensile strength of the limestone as partial replacement of the cement. They substituted limestone powder for cement in a ratio of 0% to 50%. At less than 30% cement replacement with limestone powder, greatest split tensile strength was recorded. Fig. 8 depicts the findings of their research.

Zenggi et al. [51] investigated the properties of large volume powdered limestone of concrete. With curing of 28 days the water cement ratio was 0.4. While replacement ratios were 20%, 25%, 30% and 35%. When 25 to 30% of cement was substituted with limestone powder, the maximum split tensile strength was found. Results of their finding are represented in Fig. 9.

Wang et al. [52] tested the tensile strength of the concrete comprising powder of limestone. It was replaced cement with powdered limestone having proportions of 10%, 20%, and 30%. At 20% cement replacement with limestone powder, the greatest split tensile strength was recorded.

Varhen et al. [53] examined the effect of switching the cement by filler of limestone. It was discovered that there was an upsurge in the percentage of filler of limestone at a limit of 30% with cement. Also, the split tensile strength was increased in concrete containing replacement of 25% to 30 %.

Turk et al. [54] premeditated the tensile strength of powdered limestone of grade M30. It was replaced by silica sand with limestone powder in the proportion of 25%, 50% and 75% for curing of 3, 28, 90 days. Supreme tensile strength was detected at 25% to 50% of silica sand replacement with limestone powder. Fig. 10 represents the test results.

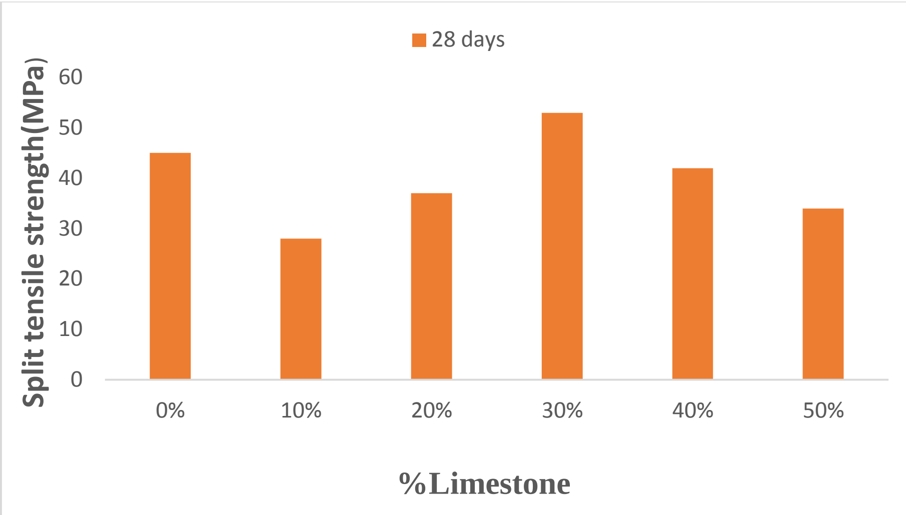

Fig. 8. Split tensile strength test results [50]

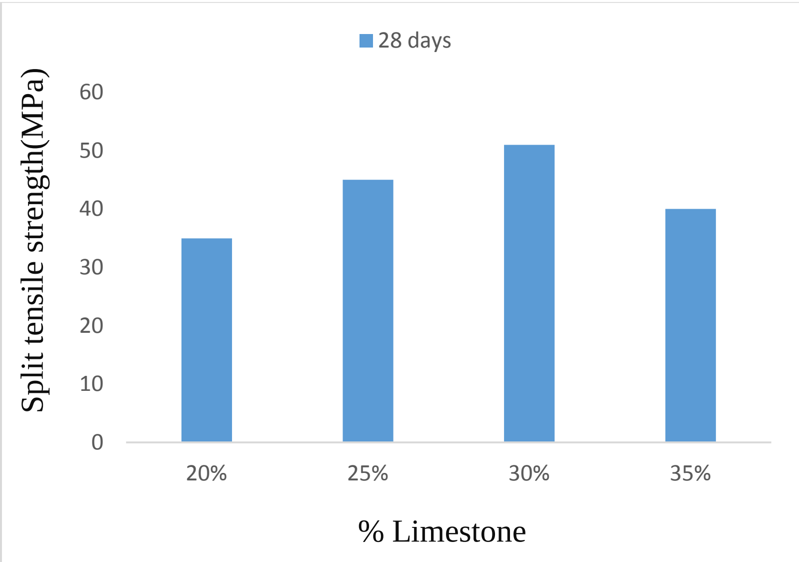

Fig. 9. Split tensile strength test results [51]

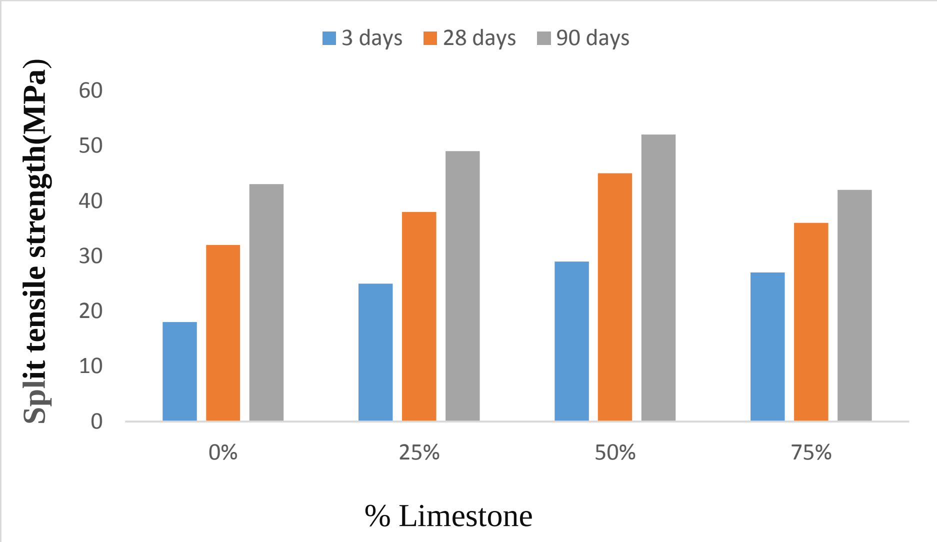

Fig. 10. Split tensile strength test results [54]

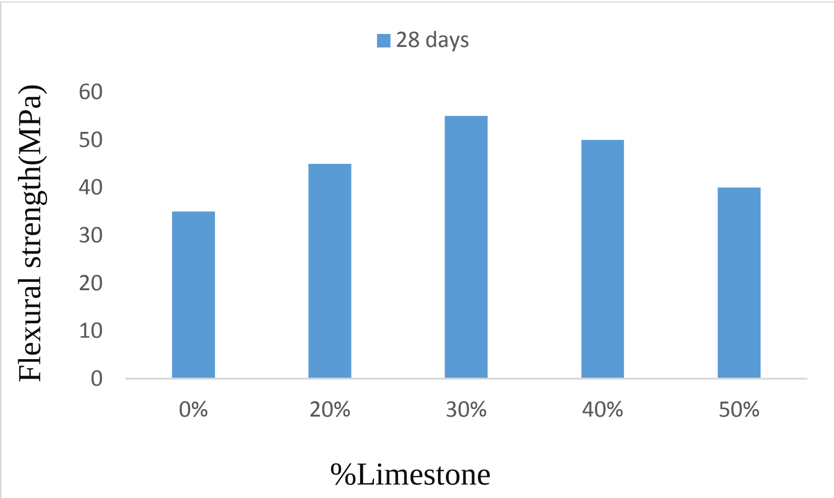

Fig. 11. Flexural strength test results [58]

Sua-iam et al. [55] used the combination of both limestone powder as well as rice husk ash by partially replacing the cement. The combination of concrete containing 30% limestone powder with 50% to 70% rice husk ash had the highest tensile strength.

3.3 Flexural Strength

Flexural strength which is a measurement of tensile strength of concrete is used to determine the ability of an unreinforced concrete beam or slab to counterattack the failure during bending.

Acharya et al. [56] investigated the flexural strength of concrete which improved with the addition of limestone quantity leading to sustainable construction. Mix of Portland pozzolana cement containing 30% of limestone showed the highest flexural strength in the mix of concrete.

Coo et al. [57] steered an investigation to determine the flexural strength of limestone concrete. It was found that the value of flexural strength of concrete containing limestone increased with time. The results showed that when limestone powder was replaced up to 30% with cement it showed a higher value than the conventional concrete.

Hesami et al. [58] analyzed the flexural strength tests for 0%, 20%, 30%, 40% and 50% for 7 as well as 28 days of curing. It was reported that flexural strength rose up to 30 % by substituting limestone powder in concrete with cement. At 30% replacement, the ultimate flexural strength was found to be 83 KN. Fig. 11 demonstrates that by increasing the amount of powdered limestone in concrete the flexural strength was reduced.

Huang et al. [59] inspected the properties of ultra-high performance concrete with admixing cementitious material such as limestone powder and fly ash. Flexural strength increased when limestone concentration was increased and fly ash content decreased according to the researchers.

Shaker et al. [60] investigated the flexural strength of concrete with 10%, 20%, 30%, and 40% replacement of powdered limestone as a substitution for cement. The test results are represented in Fig. 12 according to the test results 30% limestone powder showed maximum flexural strength. The sample of 30% limestone powder demonstrated an 80% improvement in flexural strength of the concerning control mix.

Ibrahim et al. [61] replaced cement with limestone in the ratios of 0%, 20%, 30% 40% and 50% in concrete. It was found that the strength of flexure in concrete is maximum for 30% of limestone replacement by cement.

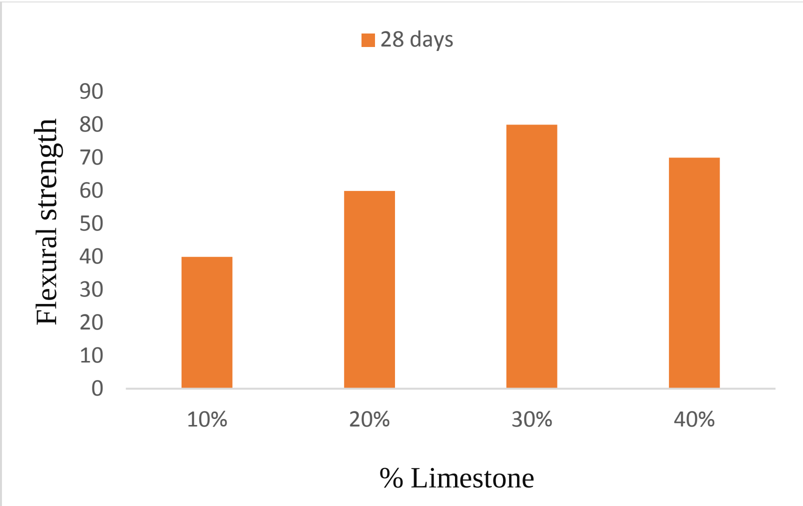

Fig. 12. Flexural strength test results [60]

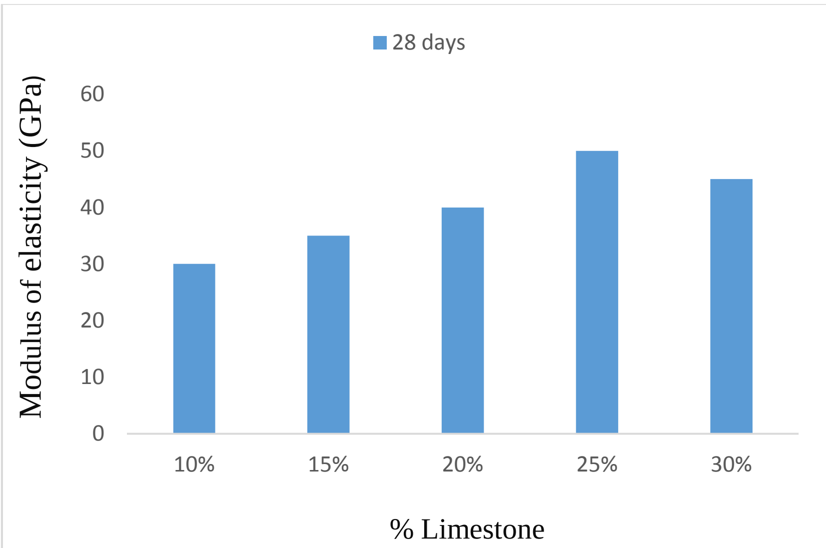

Fig. 13. Modulus of elasticity test results [63]

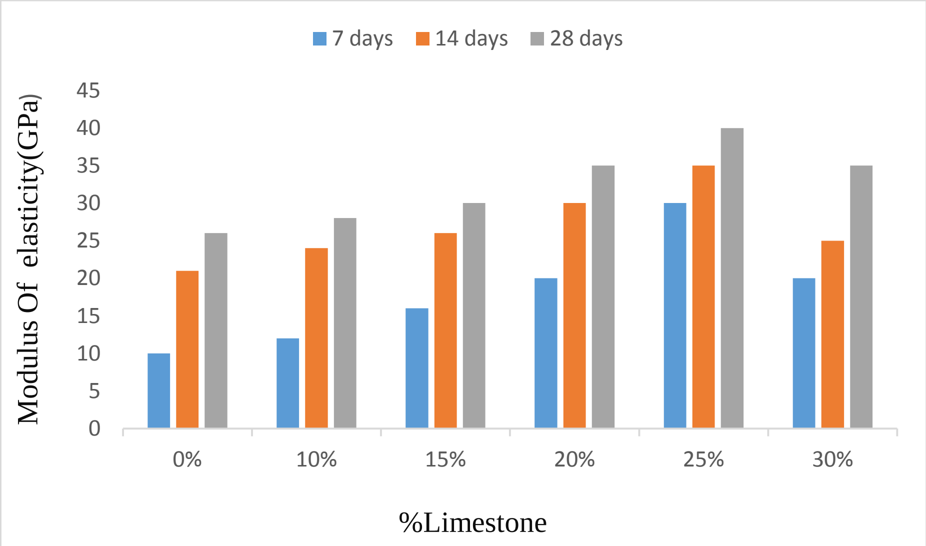

Fig. 14. Modulus of elasticity test results [64]

3.4 Modulus of Elasticity

When stress is applied to an object its elastic modulus is a measurement of its resistance for being deformed.

Shen et al. [62] examined the elasticity modulus of concrete with powdered limestone and silica fume. The results showed that the elasticity and time had been increased for 25% powdered limestone and 10% silica fume.

Mohammad et al. [63] studied the elasticity modulus of limestone concrete of grade M30. The cement was replaced with limestone in the proportion of 10%, 15%, 20%, 25% and 30%. The maximum modulus of elasticity was observed at 25% of cement replacement with limestone. Results of their finding are represented in Fig. 13.

Revani et al. [64] investigated the elasticity modulus of concrete comprising powdered limestone. The percentage of powdered limestone added by the weight of cement was 10%, 15%, 20%, 25%, and 30%. The modulus of elasticity was calculated using the w/c ratio of 0.35, 0.40 and 0.45 after 7, 14 and 28 days of curing. It was discovered that by replacing 25% of cement with powdered limestone flexibility of concrete was improved as shown in Fig. 14.

Silva and Brito [65] inspected the elasticity modulus of self-compacting concrete including powdered limestone as a fraction all stand by for cement. It was found an upsurge in the values of modulus of elasticity with powdered limestone of 0% to 30%. Maximum modulus of elasticity was found at 30% replacement after that it decreased.

3.5 Durability

The ability of concrete to resist the wearing and deterioration is termed as durability of concrete.

Palm et al. [66] carried out a permeability test to check durability of concrete with limestone powder as a substituent for cement. An increase in durability was observed in the concrete containing 30% to 35% limestone powder at 0.35 w/c ratio for 28 days. The trial of 30%lime stone powder demonstrated highest durability.

Mostofinejad et al. [67] investigated long-term durability of limestone concrete. The quantity of powdered limestone in the cement was 0% to 30% by weight, with water cement ratio of 0.45 and the micro silica and slag content was 10% to 15% by weight. The addition of limestone enhanced durability. The concrete containing 15 to 25% limestone powder showed the highest durability.

Elhundiapani et al. incorporated the use of limestone powder in concrete. The researchers observed that 25% limestone and 10% clay imparted the highest durability with an increase in the substitution percentage of limestone.

Proge et al. [68] examined the use of limestone in the percentage of 0%, 10%, 20%, 30% and

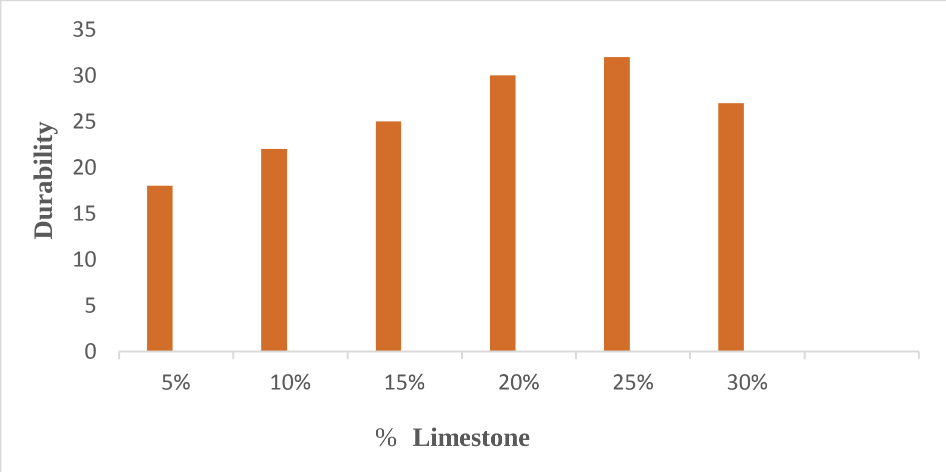

Fig. 15. Permeability test results [67]

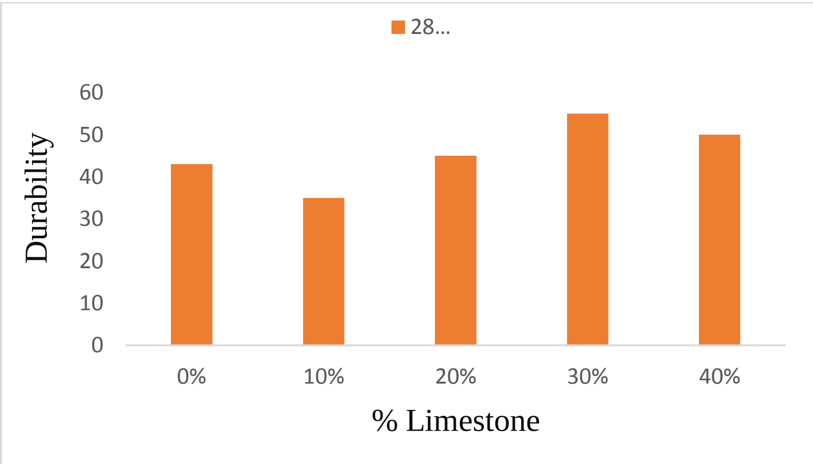

Fig. 16. Permeability test results [69]

40% that replaced cement in concrete. It was found that the durability of concrete was maximum when 30% of limestone was replaced by cement. Fig. 15 shows the representation of the test values.

Shaker et al. [69] examined the durability of concrete that was tested by the means of limestone as a partial substitution for cement at levels of 10%, 20% and 30% of cement. The durability was found to be maximum at 30% replacement.

5. CONCLUSION

Construction activities must now take into account sustainability. Several investigations on various materials to replace cement in concrete have been undertaken in the past. The impact of limestone slurry on concrete qualities like freshness, mechanical strength, and durability is discussed in this study. A review of limestone slurry and its impact on concrete as a cement substitute has been attempted.

The following conclusions can be derived from the researcher's work on using limestone slurry as a partial substitute for cement in concrete production:

- Based on a number of study articles, results subjected to various limestone slurry percentages in concrete, it can be concluded that the optimum utilization of limestone slurry shall be 25 to 30% by the mass of cement in concrete.
- The fresh properties of limestone concrete had different results, according to most of

the researchers there was an increase in workability 20% to 30%.

- From the above study, researchers concluded that there was an increment in compressive strength with the increase in limestone quantity up to 30%, after that, as the percentage of limestone in concrete increased the strength got reduced.
- As the proportions of limestone increased to a certain limit, the split tensile strength increased. Optimum replacement of cement was around 30 percent by limestone after that strength decreased.
- The various studies showed that there was an enhancement in flexural strength just like compressive strength up to 30% of limestone content, after that limit it also got reduced as limestone content enhanced in concrete.
- Modulus of elasticity of concrete increased up to 25% when limestone was utilized to partially substitute cement.
- From the above study, researchers concluded that there was an increment in the durability of concrete up to 25 to 30% replacement of limestone.

Concrete with limestone as a substitute is a sustainable construction material that decreases pollution as well as disposal-related issues which is harmful to the environment. The optimum substitution level of cement with limestone was found to be 25-30%. Concrete's mechanical as well as durability properties were amended by utilizing limestone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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