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Research Paper

Research on Using Dolomite Aggregate as Cement Treated Base for Highway Pavement Construction in Ninh Binh, Vietnam

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ABSTRACT

Dolomite is commonly used in the construction of highway pavement in the world. However, there are still no concrete specifications or regulations on the use of dolomite for highway construction. Dolomite is available in huge quantities in NinhBinh Province. This is a high potential material for grain bases of highway pavement structure. The alternative material could be a considerable contribution to diversify the supply of aggregate resources for highway pavement construction in the province, and thus contribute to the conservation of natural landscape heritages and limestone resources for related building materials manufacturing industries. In order to evaluate the use of dolomite in highway pavement construction, a research program is conducted to test the working capacity of the cement treated dolomite aggregate, which is intended to use as upper base material in pavement structure. The experimental results showed that the mechanical indicators of the mixture satisfy the requirements for the base layers of highway pavement structure.

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1 Introduction

With unique natural landscapes, many famous scenic spots and cultural and historical relics recognized by UNESCO, Ninh Binh has been identified as a national cultural, historical and tourist centre, with international significance of the country. In addition, the high quality and large reserves of limestone and clay quarries are a strong incentive and favourable conditions for the development of construction material industry, especially cement production. Therefore, the conservation of cultural heritages, limestone natural landscapes for tourism, and also the valuable raw material source for the construction material manufacturing industry should be concerned and put on top priority to ensure harmonious and sustainable development of the Province in future. Along with other provincial economic sectors, the highway

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infrastructure network system is also to be developed to meet the increasing transport and travel demand, leading to increasing demand on construction materials, including aggregates for road pavement construction. While preserving the natural landscape and using effectively precious limestone re-sources for industrial development, study to find new alternatives for traditional aggregate is urgent and necessary [1].

According to the report, there are about 2.5 million tons of dolomite in NinhBinh, which are exploited and used in many fields, including road embankment filling [2, 3]. In the world, dolomite has been used as a material in road pavement construction [4-6]. Therefore, study to use dolomite as coarse aggregate for highway routes in NinhBinh is an alternative for local material utilization. The paper presents the research results of physical properties and mechanical performance indicators of dolomite, which are used as coarse aggregate for cement treated base courses of pavement structure.

2 Material

2.1 Coarse aggregate

The physical properties of the original rock which is used as coarse aggregate for both bound or unbound grain bases or subbases of highway pavement structure are primary conditions for material choice. The main characteristics of dolomite exploited from NinhBinh quarry pits is presented in Table 1.

Table 1 – Physical properties of NinhBinh Dolomite [1, 3]

Characteristics	Values	Specification limits
Dry density (g/cm^3)	2.77	-
Tension strength (MPa)	7.8	-
Compression strength (MPa)	86.3	≥ 60 (base)
		≥ 40 (subbase)
Liquid limit (%)	21.3	≤ 25 (base)
		≤ 35 (subbase)
Plasticity index (%)	3.1	≤ 6
Proportion of flat-grain (%)	16.7	≤ 18 (base)
		≤ 20 (subbase)
Los Angeles abrasion (%)	32.9	≤ 35 (base)
		≤ 45 (subbase)

Comparing to the requirements regulated in relevant standards [7-9], NinhBinh dolomite generally meets basic important requirements to be used as aggregate for base layer.

2.2 Portland Cement

Ordinary Portland Cement (OPC) is common used as inorganic binder in highway construction, including of cement treated base (CTB) for pavement structure. In the research, OPC is also combined with dolomite to be aCTB material mixture called dolomite cement treated base and denoted DCTB for short. The purpose is to improve the stability, durability and strength of the original dolomite aggregate. The common Portland cement brand PCB40 Tam Diep, also produced in NinhBinh, was chosen for making specimens.

The main physical, chemical properties of the cement presented in Table 2 shows that the OPC used in the experiment is compliance with specification limits of TCVN 2682:1999 [10].

2.3 Water

Water used for blending and also making conditions for the hydration reaction of the cement. The water used for making specimens is normal domestic tap water, which ensures the requirements of water for concrete and mortar in TCVN 4506:2012 [11].

3 Experiment program

The main idea of the study is to use dolomite aggregate as a cement treated base (CTB) material, which is commonly used for base layers in road pavement construction. The experiment program aims to design the cement treated dolomite aggregate mixtures (DCTB) in accordance with current regulations in Vietnamese technical standards. The basic physical and mechanical indicators of designed DCTB mixtures were tested to investigate performance of the material.

Table 2 – Cement properties

Indicators	Value (Average)	Specification limits
Compression strength (MPa)		
3-day	18.9	≥ 18
28-day	40	≥ 40
Setting time		
Initial setting time (min.)	45	≥ 45
Last setting time (min.)	220	≤ 420
Fineness		
Remaining on sieve 0.09 (%)	1.2	10
Specific surface area (cm2/g)	4540	2800
SiO3 (%)	1.45	≤ 3.5

3.1 Mixture design

The cement treated dolomite aggregate, or DCTB mixture, intended for use as base or subbase layers of road pavement structure is designed based on experience and regulations in current standard TCVN 8858:2011 [7]. The ratio of the main content of the mixture is presented in Table 3.

Table 3 – DCTB content design

Sample groups	Aggregate Composition (wt.%)	
	Dolomite	PCB30
DCTB1	97	3
DCTB2	96	4
DCTB3	95	5
DCTB4	94	6
DCTB5	93	7

3.2 Test methods

The main important mechanical indicators for use in construction and design of the highway pavement are selected for making tests in the laboratory condition. The DCTB mixture was prepared with the mix proportions presented in Table 3. The type, dimension and number of samples, and testing procedures are conducted in accordance with the current standards and shown in Table 4.

Table 4 – Test indicators and related standards

Test Indicators	Sample Size	Number of Samples	Test Standards
Gradation Analysis	Dolomite aggregate	200 kg	TCVN 8858:2011
Compaction test	Cylinder D152, H117	5x5	TCVN 12790:2020
Compression	Cylinder D152, H117	3x5	TCVN 3118:1993
Split Tensile	Cylinder D152, H117	3x5	TCVN 8862:2011
Elastic Modulus	Cylinder D152, H117	3x5	TCVN 9843:2013

The samples used in the experimental test were moulded according to the instructions in the standard TCVN 12790:2020, having prismatic shape with 152 mm in diameter and 117 mm in height. The graded aggregate dolomite and cement were blended at optimum water content and cured in moisture condition for 2 hours before used for making samples.

For compressive and split tensile tests, the samples were measured at 14-day age. After moulded, the samples were cured in moisture condition for 7 days and soaked in water for 7 days before being tested according to standards of TCVN 3118:1993 and TCVN 8862:2011, respectively. For the modulus of elasticity tests, the samples were 28-day age, with curing time in moisture condition for 21 days and soaking time in water for 7 days before being tested according to the standard TCVN 9843:2013.

4 Result and Discussion

4.1 Gradation test

The grain analysis was conducted to test whether particle size distribution of DCTB located inside the limit boundary regulated in current standard or not TCVN 8858:2011 [7].

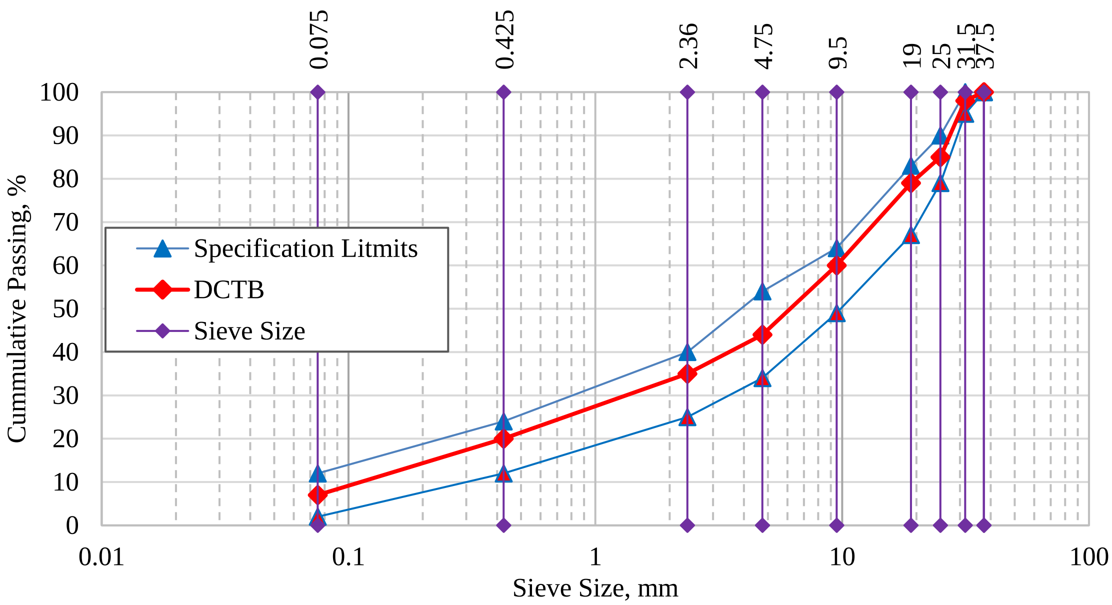

Fig. 1 – Particle distribution curve of Dolomite aggregate

The Fig. 1 shows that there are some kinks on the distribution curve, however, the curve goes within the regulated boundary limits. It implies that the gradation of DCTB satisfies the requirements of current Vietnam standards.

4.2 Compaction test

The compaction test was conducted to find out maximum dry unit weight and the optimum water content (O.M.C.). The test was conducted following the standard of TCVN 12790:2020 [12].

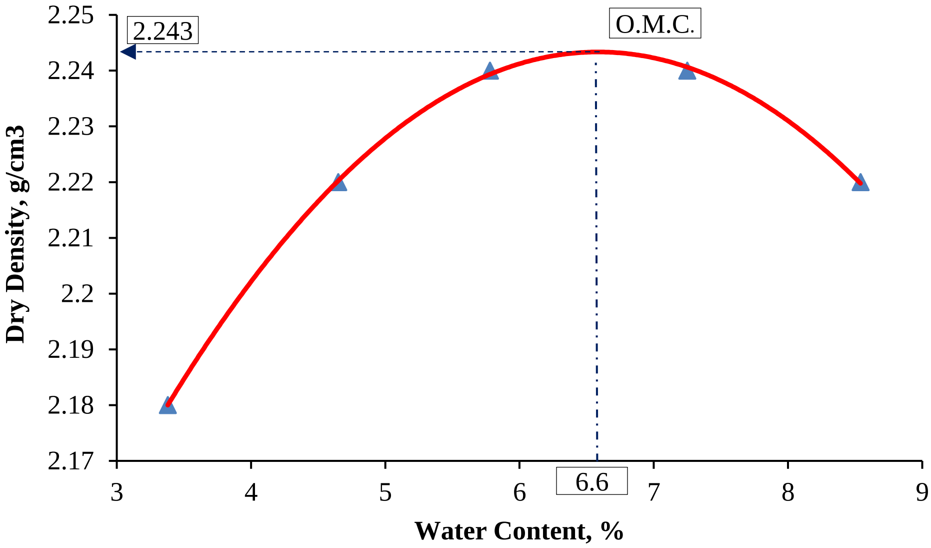

Fig. 2 – The optimum moisture content of dolomite aggregate

The Fig. 2 reveals that the optimum water content of DCTB was 6.6%, and the corresponding dry density is 2.243 g/cm^3.

4.3 Compressive strength

The compression strength is the primary indicator for testing the vertical loading capacity of base or subbase material in a pavement structure. The tests for measuring DCTB compressive strength were implemented for the 14-day age samples in accordance with the instructions in TCVN 8858:2011 and TCVN 3118:1993 [7, 13].

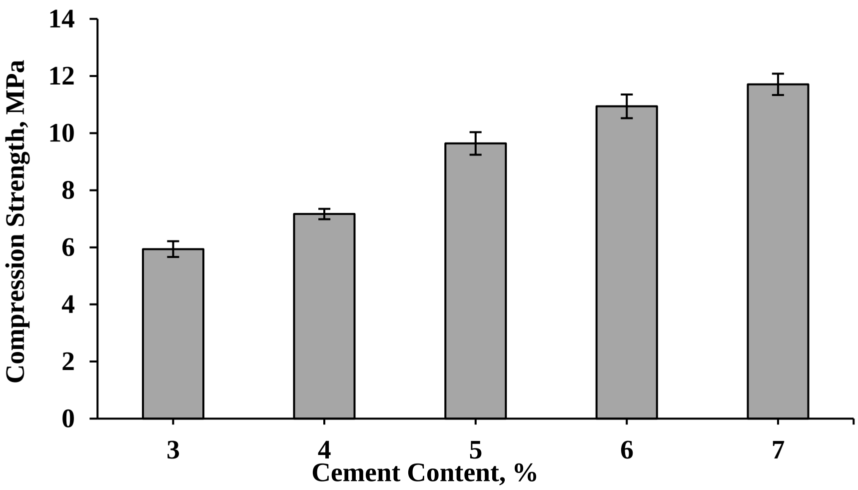

Fig. 3 – Compression strength of DCTB groups

The testing results in Fig. 3 show that the compressive strength of sample groups steadily increases while cement ratio in the DCTB mixtures increase. The average compression strength values were 5.94, 7.17, 9.64, 10.94, 11.71 MPa, corresponding to the cement ratios of 3, 4, 5, 6, 7 %wt., respectively. The rates of changes in compressive strengths were

20.7%, 34.5%, 13.5% and 7.0% when comparing the successive couple of sample groups of 3% and 4%, 4% and 5%, 5% and 6%, and 6% and 7%, respectively. It can find that the change of compression strength between the 4% and 5% was the largest and reveals that the 5% cement was the most effective ratio content of cement on DCTB compressive strength improvement.

4.4 Split tensile strength

Split tensile test was conducted to check the indirect tensile strength of the mixture. The experiment was carried out following the guideline in the TCVN 8862:2011 [14].

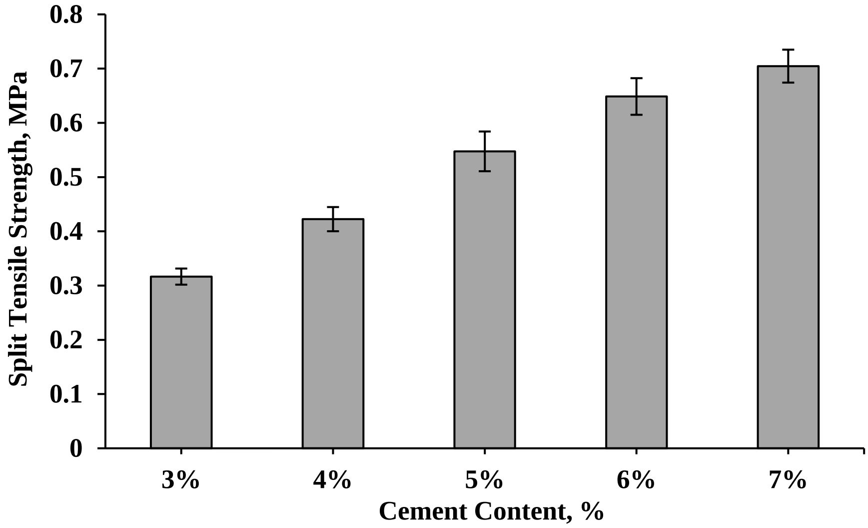

Fig. 4 – Split tensile strength of DCTB groups

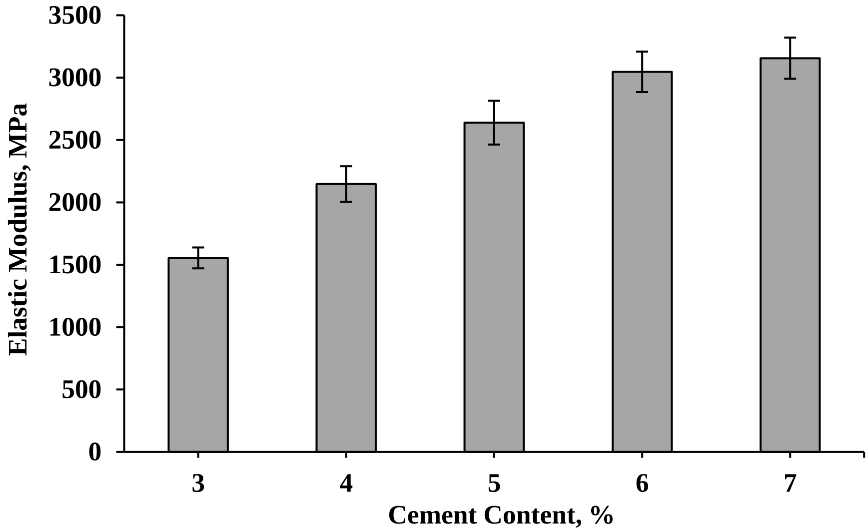

Fig. 5 – Elastic Modulus of DCTB groups

The split tensile strengths of tested samples are 0.32, 0.42, 0.55, 0.65, 0.70 MPa corresponding to cement ratios of 3, 4, 5, 6, 7 %wt. The test results show that the tensile strength increased when cement content increased. However, the increments of split tensile values were different among sample groups by cement contents. There was a big change between the 3% and the 4% cement content groups, with the rate of 33.5%. Then it was slightly decreased to 29.6% between the 4% and the 5% groups. The rates continuously declined to 18.5% and 8.6% between 5% and 6%, and between 6% and 7%, respectively.

4.5 Elastic Modulus

The elastic modulus of DCTB was defined by the static compressing method on cylindrical samples according to TCVN 9843:2013 [15]. The testing results presented in Fig. 3 revealed that the relationship between cement content and elastic modulus of DCTB is smoothly represented by a polynomial order 2 with squared correlation R2 coefficients of 0.952.

The test result shows that average elastic modulus of DCTB at the age of 28-day groups are 1554.75, 2147.11, 2639.15, 3046.43, 3155.97 MPa corresponding to cement ratios of 3%, 4%, 5%, 6%, 7%, respectively. In general, the elastic modulus among the sample groups increased along with the cement content in the mixtures. However, it can be seen that the rate decreases gradually. Specifically, the difference between sample groups with treated cement content of 3% and 4% attained the maximum of 38.1%, between groups of 4% and 5% was 22.9%, between groups of 5% and 6% was 15.4%, while between 6% and 7% was the smallest, only 3.6%.

4.6 Discussion

According to the provisions of the standard on cement treated aggregate bases for road pavement - specification for construction and acceptance [7], the required strength of material mixture must satisfy two criteria of minimum compressive strength and split tensile strength at 14-day age as show in Table 5.

Table 5 – Requirements for strength of cement treated aggregate

Location of base layer	Level of Requirement (*)	Strength Requirement, MPa	
		Compression (14-day age)	Split Tensile (14-day age)
The base course of pavement with surface layers of asphalt concrete or Portland cement for expressway, highway grade I/grade II or bituminous treatment	1	≥ 4,0	≥ 0,45
Base course for other type of pavement structures	2	≥ 3,0	≥ 0,35
Subbase course for all pavement structures	3	≥ 1,5	Not required

For simplifying, we rank the requirements from the standard by the three level of assurance of technical requirements as shown as (*) in Table 5, where Level 1 is the highest quality, Level 2 is medium, and Level 3 is the lowest. Comparing the test results with the requirements in the standard, there are some remarks for DCTB material as follows: (1) For compressive strength: all sample groups satisfy requirement of the Level 1; (2) For split compressive strength: the groups with treated cement content equal or greater than 5% meet the highest requirement of Level 1; the group of 4% cement satisfy the requirement of Level 2; the group of 3% cement guarantee the requirement of Level 3, the lowest level for cement treated materials for road base pavement; (3) Regarding elastic modulus: DCTB material with all treated cement content having the elastic modulus greater than the minimum values required for cement treated aggregate materials specified in current standards [16].

5 Conclusion and Recommendation

The experimental results show that the physical and mechanical properties of NinhBinh dolomite satisfy the requirement for the aggregates used for the base or subbase layers of pavement structure. The performance indicators of DCTB mixture such as compressive strength, split tensile strength, and elastic modulus also satisfy the limit values or normal required ranges for the CTB materials.

The technical suitability of dolomite aggregate in term of DCTB brings about important benefits: (1) open a new direction in the application of dolomite rock, diversifying the aggregate supply for pavement construction, therefore, proactively contributing to the road infrastructure development of NinhBinh province, and also for the provinces with rich resources of dolomite; (2) make an significant contribution to the mission of conserving limestone mountains, which having high values of natural landscapes for tourism and the cement industry; (3) bring significant economic benefits to the projects located in the province, and also ensuring the efficiency of natural resources utilization for economic development.

The dolomite rock evidently is a promising natural aggregate for road pavement construction. Thus, there should be concrete steps to bring the material into real application. Along with the material experimental tests in the laboratory condition, there should also be further studies in terms of pilot projects, where the material could be monitored and evaluated under real conditional operation. The practical results will be a solid basis for large scale application in future.

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