A STUDY ON MANUFACTURING FINE-GRAINED CONCRETE USING SEA SAND IN THE CONSTRUCTION OF MILITARY MOBILE ROADS ON COASTAL AND ISLANDS IN THE NORTHERN-CENTRAL REGION OF VIETNAM

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Abstract

This article presents the researched content to analyze and evaluate the demand to build military mobile roads on coastal areas and islands in the northern-central region of Vietnam. It also presents the advantages and disadvantages of fine-grained concrete pavement and the benefits of fine-grained concrete made of sea sand with glass fiber reinforcement… Presentation of basis, analysis and experimental study of fine-grained concrete pavement using glass fiber reinforced sea sand with two different additives. From that, it is proposed to use fine-grained concrete pavements using glass fiber reinforced sea sand for coastal routes and on islands in the northern-central region of Vietnam.

Keywords: *Fine-grained concrete pavement; coastal military; northern-central region of Vietnam.*

1. Introduction

The northern-central region of Vietnam is located on the Central strip, including the following provinces: Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue. This area has a sea and land border adjacent to the Lao People's Democratic Republic, which is a strong area of marine economic development but also needs to build a coastal defense area firmly and effectively [1].

In parallel with above requirements, the demand for a network of military mobile roads on coastal and the islands to ensures the mobilization of the Army in the region and support the development of regional economy becomes urgent today [2].

Construction of coastal cement concrete pavement needs to satisfy the high load capacity from large vehicles and is durability under marine weather conditions (corrosion, flooding, temperature). However, at present, the source of river sand and coarse-grained aggregate is a problem for the construction of cement concrete pavement because its over-exploitation causes high cost and environmental destruction [3].

In the content of this article, based on the research on the use of fine-grained cement concrete pavement, using glass fiber reinforced sea sand with fly ash, authors

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had evaluated applacabilities of this material for construction of military mobile roads in coastal areas and islands in the northern-central region of Vietnam.

2. Overview of fine-grained cement concrete using glass fiber reinforced sea sand and fly ash

Fine-grained concrete is the concrete in which the coarse aggregate is replaced by sand (natural sand, crushed sand) or other fine materials such as ash, finely ground slag, etc. Maximum particle size used in fine-grained concrete is 10 mm [4, 5]. Coarse aggregate is an essential component in traditional concrete mixtures, in areas where there is a scarcity of coarse aggregate, fine-grained concrete can replace traditional concrete. Some overviews of fine-grained concrete using glass fiber reinforced sea sand, fly ash are analyzed as follows:

Factors affecting the strength of fine-grained concrete. Fine-grained concrete is a concrete that contains a lot of sand and subgranules, so the main factor governing its strength is the quality of the small aggregate. According to previous studies [6, 7], the replacement of coarse aggregate with sea sand in concrete may affect the strength of the concrete.

The influence of sea sand on the properties of concrete. The influence of sea sand on the hardening time of concrete. According to [6, 7], sea sand has the effect of making cement pozzolan and cement puzolan slag curing faster than fresh water.

Effect of sea sand on concrete compressive strength. According to the documents [8, 9], NaCl salt causes cement to hydrolyze quickly, the temperature of hydrolysis is high, but if the NaCl content is low (0.5% of the cement mass), it does not affect the concrete strength, and if the NaCl content is greater, the modulus of elasticity of the concrete is reduced. However, the following points should be noted: Salt very quickly increases the hardening rate of concrete without the need for adding accelerated hardening additives into the concrete mixture [10].

Research on fine-grained concrete in the world. Fine-grained concrete has long been interested and researched by scientists around the world as follows:

Since 1853, the engineer Francois Coignet has given "solid concrete" to the cast-in-place column structure that is the precursor of fine-grained concrete. This fine-grained concrete is a rock-free mixture consisting of sand, fly ash, coal slag, calcined clay, natural hydraulic lime and low water content [11].

In Russia, in 1918 an experiment was carried out by Nicolas De Rochefort in Saint-Petersburg, by mixing the sand with the clinker in a ratio of 1:1, then mixing the product with the sand in a ratio of 1:3. The results show that the final product if compared with cement mortar - sand rich in cement (ratio of sand:cement equal to 2:1), the same strength was found. At the Moscow State University of Civil Engineering (MICI) there have been many studies on this issue.

Since the 2000s, N. P. Gorlenko et al. [11] studied fabrication of fine-grained concrete reinforced with fibers of secondary mineral cotton materials in the production of concrete structures subject to dynamic loads. S. Klyuev et al. [12] studied the production of fine-grained concrete with combined reinforcement of polypropylene fibers.

Research on fine-grained concrete in Vietnam. In our country, there are also many researches on fine-grained concrete such as the thesis of Tong Ton Kien, Tran Van Cuong and for concrete strength reaching 50-60 MPa. There are also a number of other studies and publications, but specific for the proportion of selected mixes is also based on the needs of concrete. However, the above studies are not specific to the northern-central region of Vietnam and to the types of sea sand in the locality [4, 5].

3. Base of experimental research determining some indicators for fine-grained cement concrete using sea sand

3.1. Selection of fine-grained cement concrete using sea sand in experimental research

Military routes in coastal areas and on nearshore islands mainly serve infantry operations and certain types of armored vehicles, military weapons in training, drills and combat readiness. According to [3], the cement concrete pavement for the above roads depends on the load, traffic flow and functionality, the limited bending strength is not less than 40 daN/cm^2, the limited compressive strength is not less than 300 daN/cm^2.

For current coastal routes according to classification and practice, coastal traffic requirements and for military operations are usually of grades I and II. Therefore, cement concrete for pavement is often concrete grade M300 to M400 [3].

3.2. The scientific basis of the selection of aggregates

Aggregates used for fine-grained cement concrete may be natural or artificial sand. The requirements for sand shall comply with ASTM C33 and TCVN 7572:2006 [8]. Crushed aggregates also can be used to fabricate fine-grained concrete in many different ways. It is possible to use 100% crushed aggregates, or combination of crushed aggregates with sea sand when fabricating concrete [9] and can reach strength above 40 MPa [9].

3.3. Scientific basis of binder selection

The use of mineral additives such as fly ash, silica fume, blast furnace slag and metakaolin... has been shown to increase the strength of concrete, by strengthening the bond, reducing chloride permeability, improving the pore size distribution and structure of concrete. Mineral admixtures when incorporated into concrete mixtures can be used as single substances or mixtures of two, three or four different substances. Most of these materials are cheaper than cement, so their use brings economic benefits, in addition to the benefits that contribute to solving the problem of environmental pollution [9]. Type of additives considered to be used in the experimental study is fly ash combined with cement. The research results show that the replacement of cement by FA with spherical grain structure, smooth surface has an ability to reduce friction, increase the density and flexibility to help concrete have great advantages in water requirements and concrete workability [8].

4. Design of fine-grained cement concrete components using glass fiber reinforced sea sand, fly ash

4.1. Aggregates chosen for experimental research

4.1.1. Cement

The cement used is VICEM But Son PC40, which has a chemical composition and physical qualities that meet the current standard (TCVN 6016:2011, TCVN 6017:2015, TCVN 4030:2003) [4].

4.1.2. Sea sand

Sea sand used in the experimental study is taken at Ky Anh beach (Ha Tinh). This sand is of good quality: the specific weight is 2.63 g/cm^3 and the dry unit mass is 2.495 g/cm^3. The grain composition of sand meets ASTMC33. The content of Ion Cl-, alkalinity reduction and dissolved silicon content meet the current standards of Vietnam. In the experimental study, sea sand taken from Ha Tinh was replaced with 100% normal sand of normal concrete in the experiment. The properties of sand according to ASTM C33 are shown in Table 1 and Figure 1.

Table 1. Some physical and mechanical indicators of Ha Tinh salty sand

No	Criteria	Unit	Result
1	Specific weight	g/cm^3	2.63
2	Dry unit mass	g/cm^3	2.495
3	Water-saturated unit mass	g/cm^3	2.549
4	Water absorption	%	1.238
5	Unit mass at naturally compacted	g/cm^3	1.532
6	Unit mass at completely dry compacted	g/cm^3	1.485

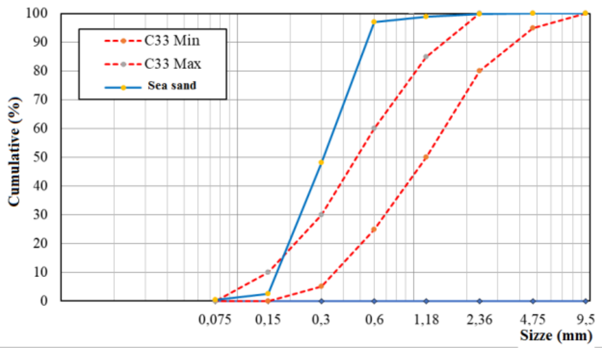

Figure 1. Grain size distribution curve of salty sand taken from Ha Tinh.

4.1.3. Fly ash

The Ha Tinh Petroleum Power Company's Vung Ang 1 Thermal Power Plant in Ha Tinh has a rich source of fly ash and satisfies the necessary standards. Therefore, in the paper for experimental research, the author selects fly ash of Vung Ang 1 Thermal Power Plant. According to the American standard ASTM 618 [10], fly ash is classified into several types, however types F and C are used extensively as additives or materials for concrete production based on their chemical composition due to the type of coal burned. The chemical composition and particulate composition of Vung Ang fly ash are presented in Tables 2-3.

Table 2. Chemical composition of Vung Ang fly ash

CaO (%)	**MKN (%)**	**SiO_2 (%)**	**Fe_2O_3 (%)**	**Al_2O_3 (%)**	**MgO (%)**	**MnO (%)**	**TiO_2 (%)**	**K_2O (%)**	**Na_2O (%)**	**SO_3 (%)**	**Cl- (%)**	**Humidity**
4.27	6.27	53.88	6.7	21.82	1.45	0.08	0.4	3.4	0.67	0.2	0.001	0.21

Table 3. Particle distribution of Vung Ang fly ash

Fly ash	**Sieve penetration amount at particle size (µm)**				
	1	**10**	**45**	**100**	**1000**
% passing	1.30%	21.90%	69.40%	96.50%	100%

The quality indicators of Vung Ang fly ash meet the requirements of TCVN 10302:2014, ASTM C618 (type F) [10], BS. EN 450; have high strength and activity indicators, the quality indicators are in accordance with the provisions of ASTM C618 type F or according to European standards of type B.

4.1.4. Crushed sand

Crushed aggregate (crushed sand) is used with a particle size in the range of 0.6 ÷ 9.5 mm in combination with sea sand for concrete fabrication. Origin of crushed sand aggregate in Ha Nam [7].

4.1.5. Water for testing

Water used for concrete must be of good quality to avoid impacting cement curing duration and corrosion of rebar. Domestic water sources like public supplied water or well water are acceptable. The conditions must be met for the water, which is frequently domestic water, to avoid negatively impact on the quality of test samples [5].

4.1.6. Alkali-resistant glass fiber

Slender (chopped) AR-glass (alkali-resistant glass) fiber is a basic and important material, used for reinforcement of glass fibre reinforced cement (GRC) concrete. This material is lightweight, high strength, non-explosive, easy to mix and shape the product (Figure 2).

Figure 2. Reinforced glass fiber.

4.1.7. Superplastic additive

In the study, the author uses two types of superplastic additives available on the market to evaluate the suitability for later application:

Sikament NN additive: NN Sikament Additive is a very popular superplastic additive for concrete.

BASF MasterGlenium ACE 8588 superplastic additive: BASF MasterGlenium ACE 8588: is a new-generation additive, synthesized from high-molecular polymers used as peroxygen initiators.

4.2. Theoretical basis of design method for fine-grained concrete composition using salty sand with compressive strength of 30-40 MPa

4.2.1. ACI (American Concrete Institute) method [11]

This method uses the required strength according to the prescribed casting pattern. It is a semi-experimental method and is based on absolute volume theory [8].

4.2.2. Proposal of designed test samples

Basis of proposal: According to the experience of the conducted research and recommendation from experts in the field of construction materials, the authors select the ratio of cement replacement ash of 20%, 30% and 40% in the samples, 100% sea sand replaces river sand and there are samples of cement concrete 100% sea sand without fly ash, reinforced fiber reinforcement for reference. Cement concrete in the road surface should achieved minimum strength of R_n = 30 MPa according to [5]. In addition, in the experimental study, the author also used the two types of above mentioned additives for comparison: Sikament admixture (2% CKD) and BASF 8588 admixture (1% CKD). Mix design: Selection of CP0-N control sample is designed concrete with target R_n of 30 MPa with the proposed design mix according to the norms of the Ministry of Construction for 1 m^3 of concrete (Table 4):

Table 4. M300 concrete grading level according to the Ministry of Construction

R_n target	Cement (kg)	Sea sand (kg)	Crushed aggregate (kg)	Water (kg)	Glass fiber (kg)
30 MPa	450	905	905	202.5	6.75

The test samples and control samples are designed according to the provisions of the standard. The designed test samples with percentages of fly ash replacing cement of 20%, 30% and 40% in 1 m^3 concrete for the test samples (Table 5).

Table 5. Components of concrete mix to make samples

Casting concrete samples	Cement (kg)	Sea sand (kg)	Crushed aggregate (kg)	Water (kg)	Fly ash (kg)	Glass fiber (kg)
CP1-N	360	950	950	202.5	90	6.75
CP2-N	315	950	950	202.5	135	6.75
CP3-N	270	950	950	202.5	180	6.75

4.2.3. Determination of the modulus of elasticity of concrete

The modulus of elasticity of the concrete is determined according to the empirical formula according to the strength at 28 days:

$$E = 5000.\sqrt{\mathrm{R}_n^{28}}$$

in which R_n^{28} is the compressive strength of concrete at 28 days of age (MPa).

Experimental work was conducted by the research team at the Construction Quality Assurance Laboratory - LAS-XD1035 of the Institute of Techniques for Special Engineering/Military Engineering Academy.

5. Experimental research, analysis of results and proposal of construction technology process

As mentioned above, the authors under the guidance of the instructor and laboratory staff conducted experimental work at the Laboratory - Quality control of construction works - LAS-XD1305 of the Institute of Institute of Techniques for Special

Engineering/Military Engineering Academy. The samples were tested as mentioned above with the samples used to determine the compressive strength of CP1-N (8 samples), CP2-N (8 samples), CP3-N (8 samples) with the proportion of fly ash of 20%, 30% and 40% respectively, sea sand replacing 100% normal sand for Sikament NN additives. The samples serve to determine the compressive strength of CP1-B (8 samples), CP2-B (8 samples), CP3-B (8 samples) with the proportion of fly ash of 20%, 30% and 40% respectively, sea sand replacing 100% normal sand for BASF 8588 additive. Correspondingly, 4 CP0-N samples were cast without fiberglass reinforcement with sea sand and no fly ash additive for Sikament NN additive. 4 CP0-B samples were cast without fiberglass reinforcement with sea sand and no fly ash additive for BASF 8588 additive. With the samples used to determine the bending tensile strength CP4-B, CP5-B, CP6-B with the proportion of reinforced glass fibers of 20%, 30% and 40% respectively, sea sand replaces 100% normal sand. The samples after casting will be tested at days 7, 14, 28 and 56 with the compressed samples remaining with flexural tensile samples only determining the strength when the samples after casting will be tested at days 14 and 28. The samples were stored under laboratory conditions. After conducting experiments with the above samples, some specific results are as follows:

Concrete using Sikament NN additives

The results on the development of compressive strength of glass fiber reinforced sea sand and fly ash concrete at different curing time when using Sikament NN admixture is shown in Figure 3.

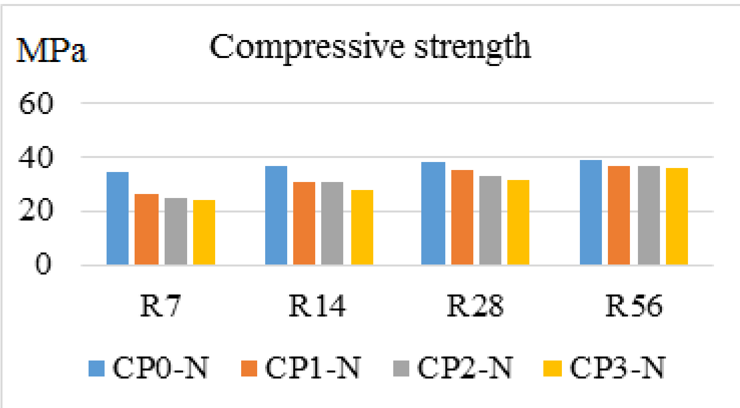

Figure 3. The development of compressive strength (using Sikament NN additives).

Experimental results on the development of flexural strength of glass fiber reinforced sea sand and fly ash concrete at different curing time is shown in Figure 4.

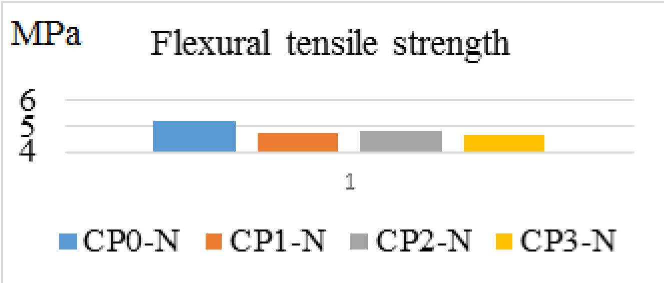

Figure 4. The development of flexural strength (using Sikament NN additives).

Concrete using BASF 8588 additive

The development of compressive strength (using BASF 8588 additive) is shown in Figure 5.

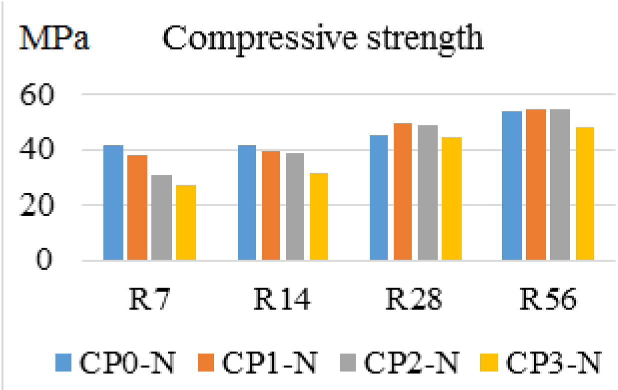

Figure 5. The development of compressive strength (using BASF 8588 additive).

The development of Flexural tensile strength (using BASF 8588 additive) is shown in Figure 6.

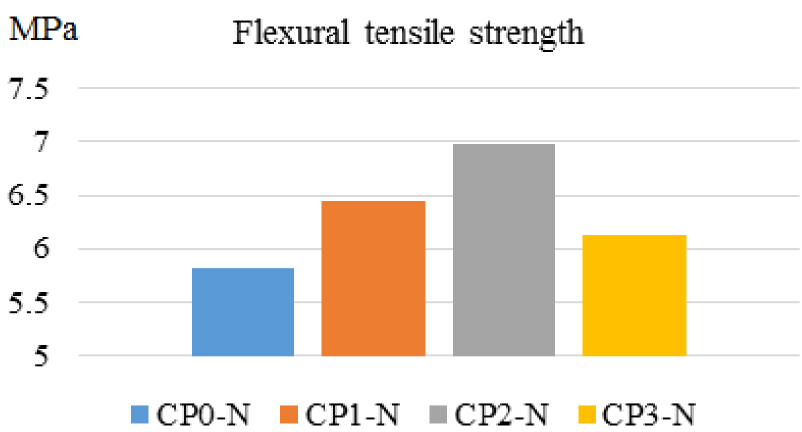

Figure 6. The development of Flexural tensile strength (using BASF 8588 additive).

From Figures 3, 4, 5 and 6 we have the following observations:

- Workability of concrete mixtures:

With the content of additives (1%, 2% binder), the results show that when using BASF 8588 additive, it is possible to reduce the N/X ratio from 0.45 to 0.43 but still maintain the plasticity of concrete mixtures (minimum drop of 18 cm). Which shows that the water reduction efficiency of the new generation additive BASF 8588 is superior to that of the conventional additive Sikament NN.

From the plasticity achieved through the actual mixing of concrete mixtures, the content of superplastic additives used is suitable at 1% and 2% of the binder mass, the plasticity of concrete mixtures will be achieved in accordance with modern construction technology (pumped concrete).

- Compressive strength:

The concrete mix group using Sikament NN additive results in lower compressive strength than the mix group using BASF 8588 additive, because the N/X ratio is higher. Concrete that uses more water should have reduced compressive strength.

In both mix groups, the concrete strength at early age (≤ 14 days) of the mixes is developed according to the normal rules. In particular, the intensity of the mixes using more fly ash is lower, and the intensity development is slower. This is because the presence of fly ash slows down the solidification process in the early days. Concrete with fly ash usually develops in late age intensity.

Compressive strength of concrete at the age of 28 days: To achieve the target strength, the percentage of fly ash should not exceed 20% if using Sikament NN additive (1% binder content). If using BASF 8588 additive (1% binder content), the rate of using fly ash can be up to 40% but still reach the strength of over 40 MPa. This is because the high water reducing effect of the BASF 8588 additive and the anions surrounding the cement particles are quickly broken so it does not interfere with the hydration process of the cement, helping the cement develop in strength faster than other types of additives.

Late age (after 28 days): Ash-intensive concrete mixes show that strength development continues to be strong after the age of 28 days. It is due to the slow hydration of fly ash, which occurs after the hydrated cement has reached the maximum possible level. Therefore, the more fly ash the mixes use, the more the intensity development is evident at the late age of the concrete.

- Tensile strength at bending of concrete:

In both groups of concrete mixes, the tensile strength at bending state is significantly improved when using fiberglass with 1.5% of the cement mass. The value of flexural strength in the mix group using BASF 8588 additive reached a higher value, reaching over 6 MPa due to the combined effect of the strong water reduction of the additive and the reinforcement capacity of glass fiber.

Tensile strength at bending state of concrete varies proportionally with compressive strength. When increasing the content of fly ash within 30% of cement, the amount of fly ash used is increased, the strength of bending strength is increased, although the compressive strength is reduced. Conversely, when the amount of ash used exceeds 30%, the tensile strength when bending decreases.

Through the study of experimental results, it is shown that: *The mix selection rate is in accordance with the target requirements, it is possible to use concrete with the designed mix as a road surface for roads on coastal and islands in the northern-central region of Vietnam.*

6. Conclusions

Northern-central region of Vietnam has an important position in ensuring the National Defense and Security of the Army and the country in the current period. In order to ensure both economic development and National Defense and Security, the region should have a system of routes on coastal and islands that meet the requirements for military operations and civilian transportation.

It is perfectly possible to fabricate fine-grained concrete using sea sand combined with crushed aggregate, fine mineral admixtures and superplastic admixtures appropriately. The properties of the concrete ensure that the concrete can be well applied for the construction of cement concrete pavements for roads on coastal and islands with concrete strengths of 30-40 MPa.

Through experimental analysis, it is shown that cement concrete using sea sand and superplastic admixtures is eligible to works as material to fabricate cement concrete pavements for roads on coastal and islands. However, with the BASF 8588 additive for better concrete strength, it is technically recommended to use this additive. Specifically, the project should consider the economic factors to ensure the economy.

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NGHIÊN CỨU CHẾ TẠO BÊ TÔNG HẠT MỊN SỬ DỤNG CÁT BIỂN TRONG XÂY DỰNG ĐƯỜNG CƠ ĐỘNG QUÂN SỰ VEN BIỂN VÀ CÁC ĐẢO VEN BỜ THUỘC KHU VỰC BẮC TRUNG BỘ VIỆT NAM

Hoàng Quốc Long, Nguyễn Trọng Chức

Tóm tắt: *Bài báo trình bày nội dung nghiên cứu nhằm phân tích và đánh giá sự cần thiết xây dựng các tuyến đường cơ động quân sự ven biển và trên các đảo ven bờ thuộc Bắc Trung Bộ, Việt Nam. Trình bày các ưu nhược điểm của mặt đường bê tông xi măng (BTXM) hạt nhỏ và lợi ích khi sử dụng cát biển có gia cường cốt sợi thủy tinh trong BTXM hạt nhỏ... Trình bày cơ sở, phân tích và nghiên cứu thực nghiệm mặt đường BTXM hạt nhỏ sử dụng cát biển có gia cường cốt sợi thủy tinh với hai loại phụ gia khác nhau. Từ đó đề xuất việc sử dụng mặt đường BTXM hạt nhỏ sử dụng cát biển có gia cường cốt sợi thủy tinh cho các tuyến ven biển và các đảo ven bờ thuộc khu vực Bắc Trung Bộ, Việt Nam.*

Từ khóa: Mặt đường bê tông xi măng hạt nhỏ; đường quân sự; Bắc Trung Bộ.

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