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RESEARCH TO DETERMINE THE PENETRATION DEPTH OF FULLY GROUTED STONE ASPHALT COMPOSITE AND ELASTIC MODULUS OF THE STRUCTURE PROTECTING SEA DYKE ROOF

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- The National Library of Vietnam;
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INTRODUCTION

1. Research problems

Vietnam has a coastline stretching over 3260km from the North to the South, in which the sea dyke system has been formed and consolidated over time. The sea dyke system is a valuable asset of the nation and significant infrastructure for the stable development of economy, society, national defense, and security [10].

Sea dyke is a crucial type of construction. Although it is not complicated in terms of structure, it has its fixed characteristics. The length of the sea dyke is greater than its height, it passes through different geological terrain, and has been formed for a long time with dissimilar construction technologies. The safety and effectiveness of the sea dyke depend greatly on natural conditions (particularly the geology background and the impact of hydrological factors and waves) and human activities. Incidents with sea dykes can happen unexpectedly both in time and in positions. Due to a certain level of design standards, in reality, it can happen beyond the design, the design has not been fully calculated, the form of the work is not suitable, the construction does not ensure the quality somewhere, the maintenance is not quality, gradually deteriorates over time. The safety and effectiveness of sea dykes in land protection, population, economics, and disaster prevention (sea-level rise, storm waves, coastal erosion, sea encroachment, etc.) depend considerably on the scale and durability of strength, shear stability, deformation of the dyke-forming parts, structures inside and on sea dykes, including sea-dyke protection structures.

The research on sea dykes in the world has existed for a long time, especially in developed countries such as the Netherlands, the USA, Germany, and Japan. Besides traditional materials including stone, concrete, and steel-reinforced concrete, those nations have studied the application of the bituminous material, typically as the Netherlands that has been using the fully grouted stone asphalt composite since 1960. That material is still stable to this day. It is necessary to inherit the above studies in developed countries to study the structure of sea dyke protection structures in Vietnam.

In Vietnam, due to the changes in hydraulic, hydrological conditions, construction materials, and construction technology, the research will be based on the results of developed countries and adjusted accordingly.

Through the research results of countries around the world and the state-level Science and Technology topic of “Research and application of composite materials to reinforce sea dykes to withstand overtopping due to waves, storm surges, storms, and rising sea levels”, the code ĐTĐL.2012-T/06 has shown the feasibility and suitability of this type of material. However, in the ĐTĐL.2012-T/06, there are still many issues that need to be further studied, including two main contents that the postgraduate wants to go into the complete research.

Firstly: According to foreign studies, the penetration depth of the asphalt mixture into hollow cavities has no formulas for calculating, or the determination of penetration depth by experimental results will take a long time. Another problem is that during the calculation for the gradation of asphalt composite material inserted in the rock, the viscosity determination of the asphalt mixture is still based on empirical evidence. Therefore, the author researches on establishing the relationship between the penetration depth of the asphalt mixture with the rock size and the viscosity of the asphalt mixture. Thereby, it determines the penetration depth and viscosity for the design, construction, and application of this material to the structure protecting the sea dyke roof.

Secondly: In foreign countries, [31] the thickness of the reinforcement layer is calculated by two methods: using graphs or math analysis formulas. Vietnam [10] has used the technique of analyzing the charts. Though it is convenient to implement the calculation, the results are not always accurate. In order to improve the calculation method for the thickness of the reinforcement layer (h) by the analytical formula (1.8), it is necessary to determine the value of the hardness module (S) in the formula (a typical physical and mechanical indicator of the structure protecting sea dyke roof with the fully grouted stone asphalt mixture material). Therefore, the author will study the calculation method and the experiment to determine the hardness module (S).

With the earlier mentioned reasons, the author proposes the title of the thesis: "Research to determine the penetration depth of fully grouted stone asphalt composite and elastic modulus of the structure protecting sea dyke roof".

2. Research objectives

Establishing the relationship between the penetration depth of asphalt mixture with the size of the rock and asphalt mixture viscosity for structure protecting the sea dyke roof of Vietnam.

Establishing the relationship between the modulus of elasticity of the sea dyke roof protection structure with the fully grouted stone asphalt in the laboratory and the field.

The penetration depth of asphalt mixture and modulus of elasticity of the sea dyke roof protection structure is examined and calculated on the applied models.

3. Research subject and scope of the study

The research subject of the study is to protect the sea dykes in the form of inclined roof about m = 3 ÷ 4 in the Northern provinces.

The scope of the study is the penetration of the fully grouted stone asphalt composite and some mechanical properties of materials and structures.

4. Research methods

Theoretical method.

Experimental method.

Professional method.

5. The scientific and practical meaning of dissertation

In scientific: The thesis has studied the relationship between physical and mechanical properties of materials to determine the penetration depth of the fully grouted stone asphalt mixture and elastic modulus of the structure protecting the sea dyke roof.

In practical: The thesis has contributed to perfecting the determination method of the penetration depth and viscosity of asphalt mixture and elastic modulus of the structure protecting the sea dyke roof, that is servicing the calculation of the thickness of the roof protection layer, mix design, and construction (Sea dyke roof protection embankments using asphalt mixture) in Vietnam.

6. The new contributions of the dissertation

(1) The thesis has built up a methodology and established an experimental formula

to determine the penetration depth of the fully grouted stone asphalt through the formula (3.3).

(2) The thesis has built up the methodology and established the experimental fo rmula for determining the elastic modulus of the sea dyke protection structure by the fully grouted stone asphalt through the formula (3.7).

CHAPTER 1: OVERVIEW OF MATERIALS AND STRUCTURE PROTECTING SEA DYKE ROOF BY FULLY GROUTED STONE ASPHALT COMPOSITE

1.1. Overview of sea dykes and roof protection revetments

1.1.1. *Overview*

Sea dyke is a significant type of construction. Depending on the size and characteristics of the protective dyke area, it is classified into five levels. Based on people's living, economic and environmental, topography, geology, hydrometeorology, hydrology conditions, etc to choose the location of the dyke line, the shape of the dyke line, and the shape of the sea dyke cross-section.

Based on the geometrical characteristics of the seaward dyke roof, the sea dyke profile is divided into three main categories: inclined roof dykes, vertical wall dykes, and mixed dykes (the inclined type at the upper - the vertical type at the lower or the vertical type at the upper - the inclined type at the lower). Based on topographical, geological, hydrological conditions, building materials, construction conditions, and usage requirements to choose the appropriate sea dyke cross-section.

In order to ensure the safety and efficiency of the sea dyke, the calculation and selection of the scale, the form of foundation treatment, cross-sectional shape, and materials used for the dyke body, structures across the dyke body, works on dykes, including revetments to protect sea dykes, are extremely important.

The roof protection revetment has 3 main parts: The top (usually with the apical wall), body, and foot of the revetment. The embankment has many different structural types (hard-soft; concrete - masonry - crushed stone - anhydrous paving stone - geyser stone; poured in place - assembled; combined).

1.1.2. Various types of sea dyke roof protection structure in Viet Nam.

a. Reinforced by planting grass in Dong Mon, Ha Tinh 's sea dyke | b. Dropped haphazard rock in Cai Hai, Hai Phong's sea dyke | c. Maked anhydrous paving stone frame in Hai Hau, N.Dinh's sea dyke | d. Built stone divided into cells in Hai Thinh II, N.Ding's sea dyke

e. Stone gabion carpet in Lach Van Nghe An's sea dyke | f. Prefabricated concrete and separate assembled | g. Prefabricated concrete and connectly assembled in Nghia Phuc, Nam Dinh's sea dyke

Figure 1.2- Some images of Vietnam' sea dyke roof protection structure [11], [12]

1.2. Fully grouted stone asphalt

1.2.1. Compositions of material

Materials used for the fully grouted stone asphalt basically include the main aggregate (sand, stone), stone powder, additives (if any), and bituminous binder. The asphalt mixture inserted in the rock is a kind of mixed material with a high bitumen ratio (about 14-20%). At temperatures of 120°C-170°C the mixtures are in a viscous liquid so during the construction, it can fill the hollow cavities between the rocks by itself.

1.2.2. The role and properties of component materials.

1.2.2.1. Aggregate properties: The influence of aggregate on the properties and bearing capacity of asphalt composite materials is very large. The most appropriate aggregate for the mixture must have a reasonable gradation, high strength, good bearing capacity. Other properties include low porosity, rough surfaces, little fouling [15], [16].

1.2.2.2. Sand: The role of sand in asphalt composite materials is to insert gaps between large aggregate particles to increase the consistency of the mixture. It is possible to use natural sand or artificial sand, with technical specifications suitable to the norm as used for asphalt concrete [2].

1.2.2.3. Mineral powder: Mineral powder is an important component in asphalt composite material. Not only does it fill pores and increase the density of the mixture, but it also increases the contact area, making the bitumen film on the surface of the mineral particles thinner. Thus the interaction force between them rises and the intensity and durability of the composite material also increase. In addition, it makes the mixture achieve the necessary fluidity, avoiding stratification to fill in the pores of rocks [2], [14], [16], [31].

1.2.2.4. Bitumen: Bitumen acts as a binder to link the components material together. So one of the most important functions of bitumen is sticking to the surface of the aggregate particles and linking them together. There are a lot of factors that affect the adhesion quality between bitumen and mineral materials. Those factors depend on the properties of the material as well as external factors [16].

A reasonable bitumen content, just enough to cover and bind mineral aggregates also allows the improvement of the quality of asphalt composite materials. Bitumen used to make the fully grouted stone asphalt, which is a dense bitumen, petroleum-based bitumen, and satisfies the technical requirements are specified in TCVN 7493-2005.

1.3. Overview of research results on application of the fully grouted stone asphalt for the sea dyke roof protection structure

1.3.1. In the world

Many countries around the world, including the Netherlands, have successfully researched and used very popular sand, rock and bitumen materials to protect the sea dyke roof since 1960 and are still sustainable until now. Which is compared to the previously used materials such as concrete or reinforced concrete, asphalt, sand and stone composite materials has more advanced features, that is: a good better resistance to erosion in seawater environment, a good deformation, resilience, flexible adaptability to the deformation of the dyke base and dyke body, limited local subsidence, erosion of sea dykes and it has long durability and longevity.

There are many researches and studies on the asphalt usefulness in irrigation engineering. And many books and documents were published, among those studies have been many specific studies on models or actual application works.

Some of the first sea dykes to apply asphalt composite materials.

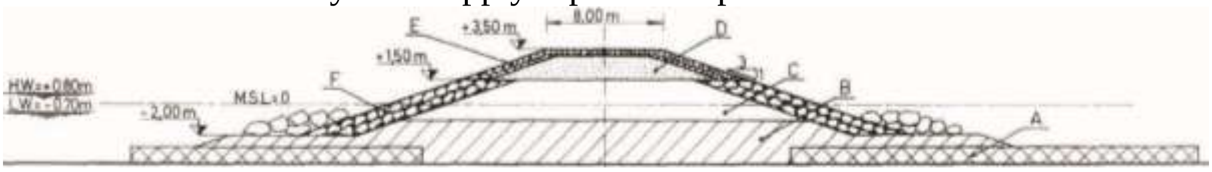


Figure 1.4- Typical section of Hook-Netherlands breakwater [30]

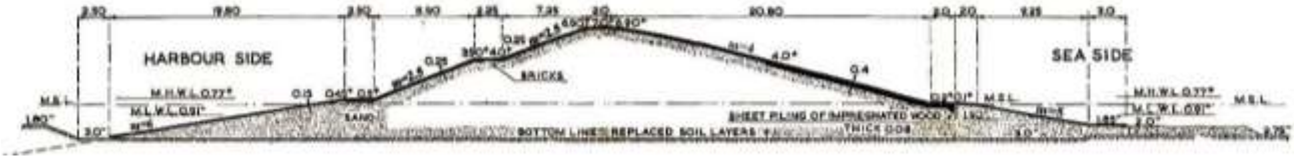


Figure 1.6 - Dyke cross section using asphalt material in north habor of Harlingen [21]

Figure 1. 7- Southwest Netherlands' seawall using asphalt mortar to insert basalt [33]

1.3.2. In Vietnam

In our country, asphalt composite material is mainly used in the form of asphalt concrete to make roads. Vietnam Academy for Water Resouces is the unit that initially researched the application of this material in the constructions of irrigation through the state-level scientific and technological project "the research of the application of composite materials to reinforce sea dykes to withstand overflowing water caused of waves, tides, storm and sea level rise. "

1.4. Studies about penetration depth of asphalt mixture and elastic modulus of sea dyke roof structure.

1.4.1. Penetration depth of asphalt mixture into hollow cavities

Fully grouted stone asphalt, which inserted in during construction, can fill the hollow cavities between the crushed stones (no need to compact). Therefore, the penetration depth of asphalt mixture is an important factor to determine the strength, bearing capacity of the structure protecting the sea dyke roof.

Research issues about the penetration depth of fully grouted stone asphalt mixture according to domestic and foreign documents are very limited, recommendations are based on practical experience. The depth of penetration depends greatly on the viscosity of the asphalt mixture. Studies [10], [31] have analyzed the factors affecting viscosity of asphalt mixture. However, the determination of the required viscosity so that the asphalt mixture after being poured into the hollow cavity reaches the level penetration depth has not been specifically studied. Therefore, this appearance of problem in here is a need for a study of the penetration depth of fully grouted stone asphalt composite, which depends on the required viscosity of asphalt mixture and the size of the rock in sea dyke roof protection structures.

1.4.2. Elastic modulus of sea dyke roof structure with fully grouted stone asphalt composite material

For materials such as soil, sand, (gravel-sỏi), asphalt concrete ... used for constructions. Experimental models of defining elastic modulus have been studied and became standard.

In order to determine the value of elastic modulus, field and laboratory experiments should be used. Equipment and laboratory instruments for field typically will larger and costlier than for laboratory. There are some case studies such as [1] that have formulated an experimental relationship on the correlation between Eo (determined in the field) and CBR load capacity index (determined by laboratory sample in the laboratory) of some materials.

According to [10], [31] there are two types of hardness: Elastic hardness is shown when the material actives under low temperature conditions, the duration of the load effect is short; (viscosity plasticity) viscous plastic hardness shown when the material is activated at a high temperature, long-lasting workload. In the study of asphalt mixture working in elastic condition, the hardness module (S) is the elastic modulus (E).

Measuring the hardness module (by experiment) is not easy. Therefore, in 1977, Shell Corporation has given the mathematical diagram presented in Figure 1.13 to estimate the hardness of bitumen materials. The advantage of this method is easy to use but the disadvantages of this method is existed certain errors, the ranges of values on the large chart so the accuracy is not high.

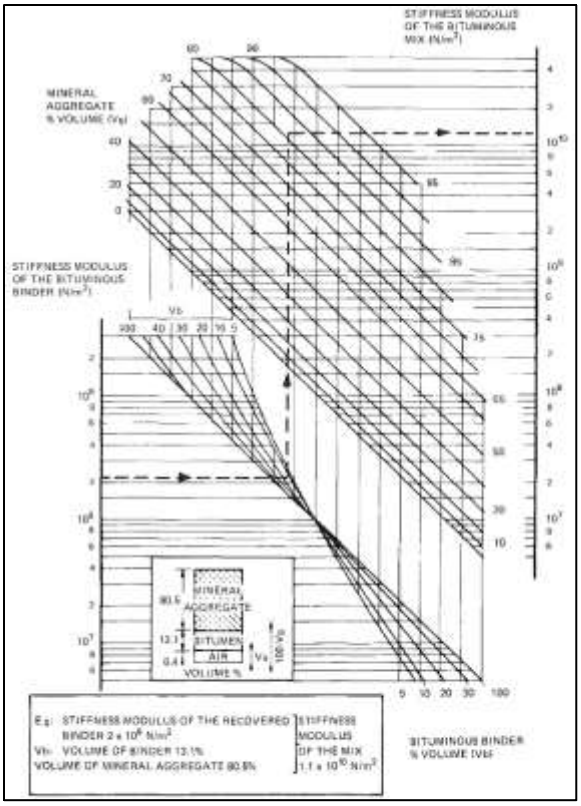


Figure 1.13- Diagram for estimation of hardness modulus of VLHH with bitumen [17]

The elastic modulus determination of the sea dyke roof protection structure can also be measured on a real model, however, building an experimental model will be very large volume and finding out the appropriate elastic modulus value will be practice many times, that take a lot of time and costs.

1.5. The issues for the research of the thesis

1.5.1. Studying the penetration depth of fully grouted stone asphalt mixture

The optimum penetration depth value is the depth sufficient to fill the thickness of the pavement. If the penetration depth is less than the thickness of the paving stone, the structure is less dense, reducing the bearing capacity and the life of the project. Oppositely, if the penetration depth is large, the asphalt mixture requires a lower viscosity (amount of high bitumen), leading to the phenomenon that the mixture will tend to sag down the inclined roof base, creating a mortar redundant surface, consuming more materials, taking increase construction costs.

The penetration depth depends on influencing factors such as asphalt mixture viscosity, diameter of the rock, roughness of the rough surface of the rock... In this study, the author will focus on establishing the relationship between the penetration depth of asphalt mixture with the rock size and the asphalt mixture viscosity. That determines the penetration depth, viscosity of asphalt mixture to calculate gradation composition as well as quality control during the construction process.

1.5.2. Studing on elastic modulus of the sea dyke roof protection structure with fully grouted stone asphalt composite material.

One of the design calculation criterias is to determine the thickness of reinforcement layer of sea dyke roof. The thickness determination of the reinforcement layer protecting the sea dyke roof is calculated by the analytical formula (1.8) [31]:

$$h = 0{,}75.\sqrt[5]{\frac{27}{16}.\frac{1}{(1-\nu^2)}.(\frac{p}{\sigma_b})^4.(\frac{S}{c})} \qquad (1.8)$$

In the formula above the hardness module is the most typical mechanical and physical characteristic of the fully grouted stone asphalt composite which must to be determined (In the case of hardness modulus (S) is the elastic module (E)).

Determining the elastic modulus of the sea dyke roof protection structure is a difficult problem, currently according to the research documents, there are two defined methods, one is based on the diagram of figure 1.13, but the calculated value is not high accuracy, secondly, it conduct an experiment directly on a test dyke segment, that requires take construction costs, a lot of time on field experiments. The problem here is to determine E follow a simple method, to ensure a certain degree of accuracy, which can be done in the laboratory with minimize funding and time.

1.6. Conclusion of chapter 1

From the research results, the application of fully grouted stone asphalt composite for the sea dyke roof protection structure in the world and in Vietnam, which mentioned above shows that the superiority and the potential of using this material in the construction of sea dykes.

Through analysis of domestic and foreign studies, there are still some shortcomings as follows: The determination of penetration depth, viscosity of asphalt mixture is currently based on practical experience and testing, so it will take a lot of time and costs, especially when you have to experiment many times; Determining the elastic modulus to serve the design calculation of the sea dyke roof thickness structure according to analytical formula (1.8) has many limitations, such as: The results which determined by the method of analyzing the charts is not high accuracy, taking a lot of time and money for the determined method on the actual model.

Therefore, it is necessary to continue researching and completing the method of determining the penetration depth of the fully grouted stone asphalt composite, viscosity of asphalt mixture and elastic modulus of the sea dyke roof protection structure for the design and construction of sea dykes in real conditions in Vietnam.

CHAPTER 2: SCIENTIFIC BASES AND RESEARCH METHODS

2.1. Penetration depth of the fully grouted stone asphalt mixture

2.1.1. Factors affecting penetration depth

2.1.1.1. Viscosity of asphalt mixture

Viscosity has a great influence on the penetration depth of the grouting mortar mixture. The higher viscosity asphalt mixture is, the lower ability to penetrate into the cavity is, and contra.

There are many factors that affect the viscosity of asphalt mixture: temperature of the mixture, proportion of mixed compositions, physical and mechanical properties of aggregate, fine fillers, and type of bitumen v.v....

2.1.1.2. Size of the stone

The size of the stone is the typical quantity for the type of stone, the choice of the rock size depends on the design thickness of the roof protection structure. The larger rock is, the larger the gap between rocks will form, so the greater ability of the asphalt mixture to penetrate into these voids and contra.

2.1.1.3. Surface roughness of the stone

The rougher the stone surface is, the greater its ability to penetrate is. The roughness of the flat stone depends on the origin of rock, each rock has a different roughness. The influence of roughness decreases when the size of the stone increases, meaning the pore size increases, so in the case of using large size the stone, the effect of roughness on the penetration ability of the mixture asphalt is negligible.

2.1.1.4. Ambient temperature

The ambient temperature (rock cavity temperature) affects the temperature of the asphalt mixture, so it can affect the ability of penetration depth. The construction temperature of asphalt mixtures is usually from 130 ÷ 170^{0}C [13] much higher than the temperature of the rock about 15 ÷ 35^{0}C. However, the time the asphalt mixture flows into hollow cavities is very short, the ability to reduce the temperature due to ambient temperature effects is negligible. Therefore, the penetration depth ability of the asphalt mixture into the gap between the rocks is not much affected.

2.1.1.5. Roof tilt

If the viscosity of the asphalt mixture is less than the required viscosity. In this case, after the asphalt mixture penetrates the full thickness of the hollow cavity in the vertical direction from top down, it will continue to flow along the slope of the dyke slope, forming an excess asphalt mixture on the surface. The larger the slope of the roof is, the more asphalt mixture flows down the roof.

If the viscosity of the asphalt mixture is greater than or equal to the required viscosity then the penetration depth is less than or equal to the thickness of the rock structure, the asphalt mixture tends to flow vertically from the top down. When the asphalt mixture has not penetrated depthly or has stopped flow fitting with the thickness of the rock and cannot flow anymore. In this case, roof tilt does not affect the depth of penetration.

2.1.2.Determining the depth of penetration according to the experimental planning method

2.1.2.1. Research bases

As analyzed above, factors affecting the penetration depth of asphalt mixture into the hollow of paving stone include:

Viscosity of asphalt mixture (characteristic for material composition, mechanical properties, temperature of the mixture)

Porosity of paving stone (the characteristic quantity of porosity is the size of the stone used)

Roughness (friction) of the surface of the stone: In this thesis, the author raises the research problem for the stone that is commonly used in the construction of sea dyke roofs in the Northern provinces, specifically the stone is originated from limestone quarrying in Ninh Binh, thus this influence factor is not mentioned in the research scope.

Roof tilt: As analyzed above, in the case of the study of required penetration depth, the inclination of the slope does not significantly affect the depth of penetration, so it is not mentioned in the scope of the study.

Thus, based on the analysis above, the author hypothesizes that the penetration depth of the fully grouted stone asphalt composite is a function between the stone size (the size of the hole in the stone) and viscosity of asphalt mixture.

2.1.2.2. Research Methods

Using experimental planning method to determine the relationship between penetration depth of asphalt mixture with the size of the stone and the viscosity of asphalt mixture

The objective function can be expressed in general fomular as follows (2.1):

$$y = \sum_{i}^{n} b_i x_i + \sum_{i<j}^{n} b_{ij} x_i x_j + \sum b_{ijk} x_i x_j x_k + ... + \sum_{i}^{n} b_{ii} x_i^2 + ... \quad ; \qquad (2.1)$$

The experimental planning method with quadratic regression equation aims to build a statistical mathematical model, based on the influence level assessment of factors on the penetration depth of asphalt mixture, giving the relationship between penetration depth and asphalt viscosity and stone size.

The principle of the method is as follows:

Choose variables and the range of variables

In the research topic, select two variables: Z_1: Size of the stone (cm)

Z_2:Viscosity of asphalt mixture (Pa.s)

Requirements of the problem: Choose Z_1 and Z_2 optimally

Dependent functions: Penetration depth of asphalt mixture (ℓ).

Methods of building models are carried out in 5 steps:

Step 1: Encryption of experimental elements (Encoding variables)

Step 2: Set up an experimental planning matrix

Step 3: Calculate quadratic regression coefficient

Step 4: Evaluate the significance of the regression coefficients according to the inequality and the formula for $t_t > t_b$ (P, $f_0 = N_0$-1) (here "t" is the student standard calculation value)

Step 5: From the regression equation determines the extreme point of the function, which is the experimental optimal point.

2.2. Elastic modulus of sea dyke roof protection structure

2.2.1. Factors affecting the modulus of elasticity

2.2.1.1. Aggregate

Aggregates include coarse-grained aggregate, fine-grained aggregate with the function of creating a bearing frame for the mixture.

Based on the mathematical diagram of 1.13 of [17]. The value of the elastic modulus of the mixture depends on the modulus of the bitumen, volumes of the bitumen in the mixture and volumes of the mineral aggregate in the mixture. The modulus of bitumen increases, the modulus of elasticity of the mixture also increases, the volume of bitumen in the mixture decreases, the modulus of elastic elasticity decreases, volumes of mineral aggregate in the mixture increases, the modulus of elasticity of the mixture also increased. Thus, it can be seen that the modulus of elasticity in the mixture depends on the percentage of aggregate in the mixture and does not depend much on the particle size of the aggregate.

2.2.1.2. Bitumen and mineral powder.

The modulus of elasticity varies greatly depending on the amount of mineral powder, specifically the ratio of bitumen and mineral powder. When the amount of bitumen is high, the mineral powder is small, the mineral powder particles are covered with thick plastic film, does not come in direct contact with each other, the elastic modulus decreases. As the mineral powder increased, the bitumen/mineral powder ratio decreased, until the amount of resin was enough to wrap the mineral powder particles with a thin plastic film and the particles contacted each other in an orientation, the elastic modulus increased. If the mineral powder continues increase further, bitumen will not be enough to create a film covering the particles, then the micro structure will increase the pores, the particles are not interlinked, the elastic modulus will decrease again.

2.2.1.3. Temperature

Because asphalt mixed materials are very sensitive to temperature, it will change significantly when the temperature changes.

At high temperatures, the fully grouted stone asphalt composite on the inclined roof will be unstable due to molten bitumen, the adhesives on the surface will flow downwards, causing the change of mixed material composition, leading to the change of elastic modulus.

The temperature changes too large, causing the oxidized of bitumen after many changes from plastic to hard state and then to plastic, that reduce bitumen quality, result of which the elastic modulus of the mixture decread.

2.2.1.4. Load capacity:

The modulus of elasticity of the sea dyke roof protection structure is influenced by the characteristics of the load such as: value of load magnitude, load mode, load wave shape, rest period and load frequency effects.

2.2.2. Determine elastic modulus by experimental method

2.2.2.1. Research database

Based on the analysis of the above influencing factors, the elastic modulus of the roof protection structure with the fully grouted stone asphalt mixture depends on the content of aggregate (stone), bitumen type, impact time of the load, the temperature of the

material does not depend much on the size of aggregate (stone) in the mixture, that is the basis for the author to build a similar simulation model in the laboratory with conditions as follows:
1) The simulated asphalt mixture in the laboratory is similar to the field in terms of aggregate content (stone), the type of bitumen, replacing the stone with 20x40mm macadam to ensure the conditions of sample casted and to test experience; 2) Test conditions are equivalent about material temperature and load increase rate.

The basis for defining field elastic modulus is to propose a testing model and to conduct a series of elastic modulus experiments on field and elastic modules in the room. Using linear regression analysis theory, testing correlation coefficients and constructing linear regression models of two experimental data series, finding the correlation formula between field elastic modulus and elastic modulus in the room.

The result of the study is to find a method to determine the elastic modulus of the structure to calculate the thickness of the structure protecting the sea dyke roof.

2.2.2.2. Laboratory experiments (E_{tp})

The determination of E in the laboratory is close to the most practical working condition of this material used for the sea dyke roof structure. The author uses a cylindrical compression test model with circular cylindrical shape under conditions of hip expansion because: This is an experimental model that has been regulated in the standard (22TCN 211-06) and is used most commonly in the laboratory; Experimental equipment that can maintain the sample temperature throughout the measurement period; The test samples under hip expansion conditions were in close proximity to the actual working conditions and were made from asphalt mortar poured into the stone mixture without compaction so the value of the modulus of elasticity would be small.

2.2.2.3.Field experiments (E_{ht}).

Determining the E value at the site of the sea dyke roof protection structure used asphalt composite material inserted in the stone on the model of practical application at Con Tron - Hai Hau - Nam Dinh sea dyke [10].

With practical characteristics in the field, the author chose to use an experimental model that calculated backwards from the deflection measured on the surface of the dyke roof by hard pressed sheets.

2.2.2.4. Establishment correlation between in-room elastic modulus and field elastic modulus using R software.

To analyze the two series of experimental data, E_{tp} and E_{ht} are correlated or not. Using the theory of linear regression analysis, testing correlation coefficients and building linear regression models of two experimental data series. By using the R software as follows:

From the value of two experimental data series E_{ht} and E_{tp}. Use R to plot the scatter diagram between $E_{ht} \sim E_{tp}$.

To "measure" this relationship, we can use the correlation coefficient.

Correlation coefficient (r):

Model of simple linear regression: Room elastic modulus is xi and field elastic modulus is yi. Linear regression model: $y_i = \alpha + \beta x_i + \varepsilon$ (2.15)

Assumption of linear regression analysis.

Predictive model

After the predictive model has been checked and the validity has been established, next step is draw a line of the relationship between Etp and Eht.

2.3. Conclusion of chapter 2

Determination of penetration depth (ℓ) is a function depending on the viscosity of asphalt mixture (η) and size of the stone (d). The relation formula ℓ = f(d, η) is determined by the field experimental and in-room experimental planning method.

Proposing experimental models of elastic modulus in the room and in the field is a basis for establishing the calculation formula of elastic modulus in the field $E_{ht} = f(E_{tp})$ by using the theory of linear regression analysis, testing correlation coefficients and building linear regression models of two series of experimental data.

CHAPTER 3: DETERMINING THE PENETRATION DEPTH OF THE FULLY GROUTED STONE ASPHALT COMPOSITE AND ELASTIC MODULUS OF THE STRUCTURE PROTECING THE SEA DYKE ROOF

3.1. Penetration depth of the fully grouted stone asphalt composite

As chapter 2 stated, the penetration depth of grouting mortar mixture ℓ = f (d, η).

In studying sea dyke roof structure, the factors ℓ, d and η need to be determined by the method of experimental planning.

3.1.1. Mathematically simulation

In the study, we use the experimental planning model of the quadratic regression equation with the influence factor is the viscosity of asphalt mixture and the stone to the depth of penetration.

Size of the stone (d): The type of the stone commonly used in sea dyke roof protection structure in Vietnam is from 10 ÷ 30 centimet.

Viscosity of asphalt mixture (η): According to the references of countries in the world, the viscosity of asphalt mortar has a range of about 30 ÷ 80 Pa.s

In the thesis choose two variables:

Z_1: Size of the stone (cm)

Z_2: Viscosity of asphalt mixture (Pa.s)

To build mathematical models expressing the influence of asphalt viscosity (η), the size of rock face (d) on the depth of penetration (ℓ)

Table 3.1- Variation range of variables

Variables	**Z_1**	**Z_2**
Z_{max}	30	80
Z_{min}	10	30
Z_{tb}	20	55
ΔZ	10	25

Constructing Oxygen coordinate system with d, η as real variables X1, X2 as corresponding code variables, the study objective function is the penetration depth of the fully grouted stone asphalt composite. The selected planning model has the following form:

$$Y = b_o + b_1x_1 + b_2x_2 + b_{12}x_1x_2 + b_{11}x_1^2 + b_{22}x_2^2 \qquad (3.2)$$

Number of experiments N = 2n + 2n + No = 22 + 2x2 + 1 = 9. To increase the accuracy of the obtained model, conduct experiments 5 times at the center of the plan so the total number of experiments N = 8 + 5 = 13. The coding scheme is described in Figure 3.1.

Table 3. 2- Experimental planning matrix

No	X_o	Variant		Real variable		X_1X_2	X_1^2	X_2^2
		X_1	X_2	Z_1	Z_2			
1	+1	+1	+1	10	30	+1	+1	+1
2	+1	+1	-1	30	30	-1	+1	+1
3	+1	-1	+1	10	80	-1	+1	+1
4	+1	-1	-1	30	80	+1	+1	+1
5	+1	-1.414	0	5	55	0	1	0
6	+1	+1.414	0	35	55	0	1	0
7	+1	0	-1.414	20	20	0	0	1
8	+1	0	+1.414	20	90	0	0	1
9	+1	0	0	20	55	0	0	0
10	+1	0	0	20	55	0	0	0
11	+1	0	0	20	55	0	0	0
12	+1	0	0	20	55	0	0	0
13	+1	0	0	20	55	0	0	0

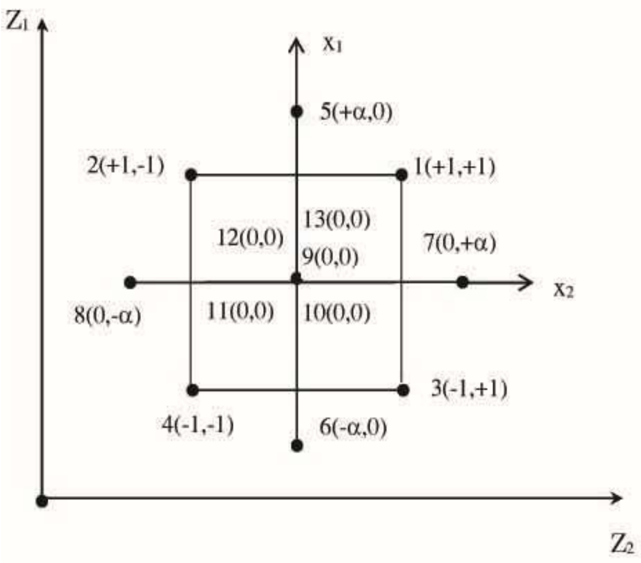


Figure 3. 1- Diagram of experimental plan

3.1.2. Sample requirements and laboratory equipment

Sample size: 600 mm x 600 mm x 700mm.

The number of samples: For each scenario with the stone size of value pair and the corresponding viscosity need to cast at least 3 samples, totaling 13 x 3 = 39 samples, resulting in the depth of penetration is the average value of 3 experimental samples.

3.1.3. Experimental sequence

Each sample will be conducted in the following sequence:

Preparing molds, materials, machinery and equipment for testing → Pouring stone into molds → Mixing aspahlt mixture materials → Checking asphalt mixture temperature → Checking asphalt mixture viscosity → Pouring asphalt mixture into the mold that has been filled with rock pit → Determining the depth of penetration.

3.1.4. Experimental results

Materials used: Using research materials of the topic [10]

Determination of mixing and casting temperature: Normally for 60/70 plastics, the mixing temperature is from 155°C to 160°C and the pouring temperature of asphalt mortar mixture into the the stone is from 145°C to 150°C [10], [31].

Figure 3.2- Some laboratory equipment and devices

Figure 3.3. Some pictures during the experiment

Table 3.8- Experimental results of penetration depth of asphalt mortar

No	X_o	Variant		Real variable		Depth of penetration(cm)
		X_1	X_2	Z_1	Z_2	ℓ
1	+1	+1	+1	10	30	20,6
2	+1	+1	-1	30	30	67,5
3	+1	-1	+1	10	80	15,7
4	+1	-1	-1	30	80	47,7
5	+1	-1	0	5	55	07,8
6	+1	+1	0	35	55	69,2
7	+1	0	-1	20	20	38,9
8	+1	0	+1	20	90	21,3
9	+1	0	0	20	55	26,8
10	+1	0	0	20	55	28,5
11	+1	0	0	20	55	26,3
12	+1	0	0	20	55	27,7
13	+1	0	0	20	55	28,4

** Evaluation of experimental results*

Experimental values in accordance with laws and theoretical basis. The larger the size of the cavity creates a void between the large rocks and the deeper penetration capacity of the asphalt mixture (the same η = 30 Pa.s, with d = 10cm → ℓ = 20,6cm, with d = 30cm → ℓ = 67.5cm). The smaller the viscosity of the asphalt mixture is, the greater the ability to penetrate is (the same d = 20cm, with η = 20 Pa.s → ℓ = 38.9 cm, with η = 55 Pa.s → ℓ = 26.3 - 28.5 cm). Preliminary can see the effect of the diameter of the cavity to the penetration depth is greater than the effect of viscosity on the penetration depth.

3.1.3. Find experimental equations.

Using Design Expert 11 software to solve the experimental planning problem, with experimental data in Table 3.8, the results are as shown in Table 3.9.

Table 3. 9- Model and results of ANOVA analysis with the objective function of depth of penetration of the fully grouted stone asphalt composite (ℓ):

Source	***Sum of squares***	***df***	***Men squares***	***F-value***	***p-value***	
Model	4091,68	5	818,34	153,97	< 0,0001	Significant
A-diameter of stone(d)	3433,42	1	3433,42	646,01	< 0,0001	
B- Viscosity (η)	307,40	1	307,40	57,84	0,0001	
AB	55,50	1	55,50	10,44	0,0144	
A^2	282,61	1	282,61	53,17	0,0002	
B^2	32,87	1	32,87	6,18	0,0418	

The Model F-value of 153.97 implies the model is significant. F-test of the model (or Fisher test). The Pvalue < 0.0001 means that there is only less than 0.01% of the change in F-value is the noise that the model cannot calculate. This result shows good compatibility of the regression equation compared with the experimental data, thereby showing high statistical reliability.

P-values less than 0.0500 indicate model terms are significant. In this case A, B, AB, A^2, B^2 are significant model terms.

Fit Statistics			
Std. Dev.	2,31	**R^2**	0,9910
Mean	32,80	**Adjusted R^2**	0,9846
C.V. %	7,03	**Predicted R^2**	0,9410
		Adeq Precision	37,4123

The Predicted R^2 of 0.9410 is in reasonable agreement with the Adjusted R^2 of 0.9846, so the difference is less than 0.2.

Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The model's ratio of 37.412 indicates an adequate signal. This model can be used good.

The test results show the correctness of the built model. From there, the mathematical expression describes the relationship between the penetration depth of the fully grouted stone asphalt mixture and variables d, η as formula (3.3).

$$\ell = 19,37 + 0,342\, d - 0,333\, \eta - 0,015\, d\, \eta + 0,064\, d^2 + 0,003\, \eta^2 \qquad (3.3)$$

in which: l - penetration depth (cm)

d- size of stone (cm)

η- asphalt mortar viscosity (Pa. s)

This is also the relationship formula between the penetration depth of asphalt mixture with the rock size and the viscosity of asphalt mixture.

In addition to the relationship formula (3.1), variables also represent correlation values in the form of graphs. The surface shows the influence of asphalt mixture viscosity and rock size to the depth of penetration of the grouting mortar mixture as shown in Figure 3.4 and Figure 3.5. Table 3.10 investigates penetration depth when knowing viscosity and size of rock.

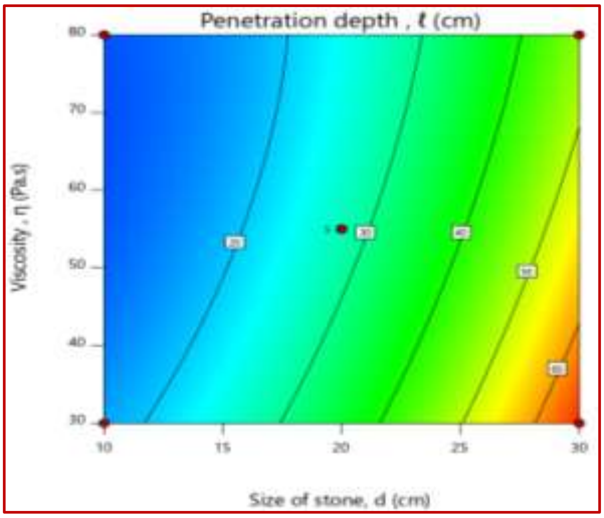


Figure 3. 4- Diagram of relationship between penetration depth and cavity size and viscosity, 2D format

Table 3.10- Table of the penetration depth of the fully grouted stone asphalt compostie

Viscosity η (Pa.s)	**Penetration depth ℓ** (cm)				
	d=10 (cm)	**d=15** (cm)	**d=20** (cm)	**d=25** (cm)	**d=30** (cm)
30	17,4	24,9	35,5	49,4	66,4
35	16,0	23,0	33,3	46,8	63,5
40	14,7	21,4	31,3	44,4	60,7
45	13,5	19,9	29,4	42,1	58,1
50	12,5	18,5	27,7	40,0	55,6
55	11,7	17,3	26,1	38,1	53,2
60	11,0	16,2	24,6	36,2	51,1
65	10,5	15,3	23,3	34,6	49,0
70	10,1	14,5	22,2	33,1	47,1
75	9,8	13,9	21,2	31,7	45,4
80	9,8	13,5	20,4	30,5	43,8

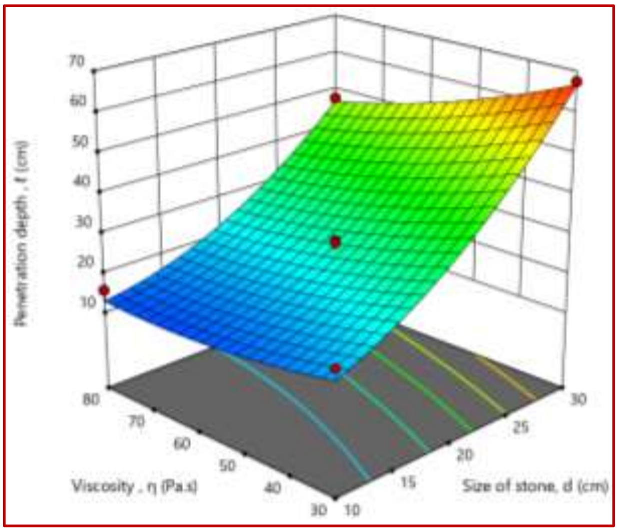


Figure 3. 5- Diagram of relationship between penetration depth and size of the rock and viscosity, 3D form

3.2. Modulus of elasticity of the sea dyke roof protection structure with the fully grouted stone asphalt composite

As presented in chapter 1 and chapter 2, the elastic modulus of the sea dyke protection structure is determined to serve the calculation of structural thickness according to formula (1.8). The determination used empirically the two series of laboratory and field test data series. Field experimental data series was determined on the actual construction model of the Con Trieu - Hai Hau - Nam Dinh sea dyke section [10]. The data series in the room identified on a cylindrical casting model is simulated similar to the actual construction site. From the experimental results, we have developed the experimental formula Eht = f (Etp).

3.2.1. Determining elastic modulus in the laboratory

3.2.1.1. Manufacturing experimental samples

The manufacture of a cylindrical model in a simulation laboratory is similar to that of a construction site. In order to simulate the thesis, the replacement of the rock with 2x4 cm macadam poured naturally into the mold (the proportion of macadam replaced by the ratio of the stone in the field) and then poured asphalt mixture (including sand, stone powder, asphalt) with the ratio equal to the rate used in the field into the mold, so that the asphalt mixture penetrates naturally into the void of macadam in the mold (not using compaction).

Figure 3.8- Some pictures of molding lab samples in the room

3.2.1.2. Experimental results

For each temperature point, the sample was casted and tested with 12 sample groups (03 members for each group). Experimental results are shown in Table 3.7.

Figure 3.9- Some pictures of experiments in elastic modulus in the laboratory

Table 3.11- Summary of experimental values of elastic modulus in the room

No	Elastic modulus in room Etp (MPa)									
	Sample	T=15ºC	Sample	T=20ºC	Sample	T=25ºC	Sample	T=30ºC	Sample	T=35ºC
1	M15-01	178,3	M20-01	161,9	M25-01	152,3	M30-01	110,5	M35-01	85,3
2	M15-02	197,4	M20-02	173,8	M25-02	143,4	M30-02	109,6	M35-02	72,6
3	M15-03	182,4	M20-03	150,6	M25-03	128,8	M30-03	121,4	M35-03	87,2
4	M15-04	192,8	M20-04	165,7	M25-04	150,5	M30-04	97,8	M35-04	90,7
5	M15-05	209,6	M20-05	143,3	M25-05	121,6	M30-05	105,2	M35-05	95,6
6	M15-06	175,7	M20-06	158,6	M25-06	146,4	M30-06	113,3	M35-06	82,6
7	M15-07	202,2	M20-07	170,3	M25-07	120,7	M30-07	109,7	M35-07	78,2
8	M15-08	185,6	M20-08	151,5	M25-08	156,3	M30-08	126,7	M35-08	86,8
9	M15-09	205,5	M20-09	148,9	M25-09	132,6	M30-09	98,5	M35-09	83,2
10	M15-10	176,8	M20-10	182,0	M25-10	147,8	M30-10	115,3	M35-10	75,2
11	M15-11	165,7	M20-11	155,7	M25-11	136,3	M30-11	127,5	M35-11	88,7
12	M15-12	199,2	M20-12	162,3	M25-12	137,6	M30-12	103,6	M35-12	78,1
$\bar{E}_{tp}$		**189,3**	**$\bar{E}_{tp}$**	**160,4**	**$\bar{E}_{tp}$**	**139,5**	**$\bar{E}_{tp}$**	**111,6**	**$\bar{E}_{tp}$**	**83,7**

** Evaluation of experimental results*

The experiment result of E_{tp} has an average value of 83.7 ÷ 189.3 MPa (corresponding to T^0_{tn} from 35 ÷ 15^{0}C), the correlation between T^0_{tn} and E_{tp} in accordance with the rule, the higher temperature is, the longer elastic module reduces. The E_{tp} <E value of asphalt concrete used for making common roads varies from 225 ÷ 1800 MPa (corresponding to T^0_{tn} from 30 ÷ 15^{0}C) with hollow asphalt to tight asphalt. The smaller value of E_{tp} is appropriate because the fully grouted stone asphalt mixture uses more bitumen about 14 ÷ 20% [31] compared to asphalt concrete about 5 ÷ 7% [16].

3.2.2. Identifying modulus of elasticity in the field

Picture 3.11- Load system by excavator

Picture 3.12- Hydraulic jack

Picture 3.13- Hard pressed plate

Picture 3.14- Deformation gauges

- *Elastic modulus is determined by formula 3.2 [6]:*

$$E = 1000 \text{ x } \frac{\pi}{4} \text{ x } \frac{\text{p.D.}(1-\mu^2)}{\ell} \quad (3.4)$$

- *Time of experiment:*

With the temperature point T ≈ 15 ° C, the experiment is in middle of February.

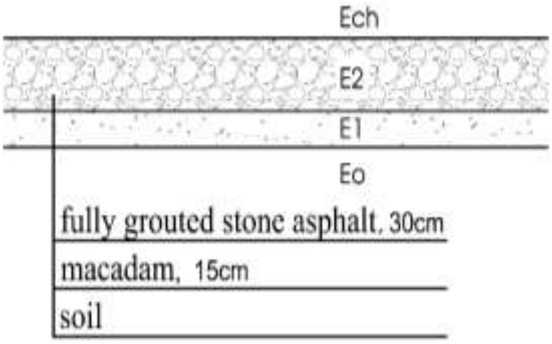
With temperatures point T ≈ 20oC ÷ 25oC, experiments in early May.

With temperature point T ≈ 30oC ÷ 40oC, the experiment is last May to early June

- *Experimental results*

Table 3.12- Summary of general elastic modulus measurement results in the field

No	**Measuring point**	**Experimental temperature and general elastic modulus in the field**									
		T°C	**E_{ch}(MPa)**	**T°C**	**E_{ch}(MPa)**	**T°C**	**E_{ch}(MPa)**	**T°C**	**E_{ch}(MPa)**	**T°C**	**E_{ch}(MPa)**
1	HT - 01	15,6	166,8	20,3	155,0	25,5	148,9	30,6	139,6	36,7	98,7
2	HT - 02	16,2	158,9	22,1	152,0	27,0	141,1	32,1	127,7	36,2	118,8
3	HT - 03	15,0	168,0	20,5	146,2	25,9	139,3	30,2	135,3	35,0	125,2
4	HT - 04	15,1	149,8	19,8	161,7	24,7	152,5	29,5	135,5	36,5	116,9
5	HT - 05	15,5	165,4	21,2	155,0	24,5	145,6	30,0	131,2	37,8	134,9
6	HT - 06	15,0	174,7	22,0	146,7	25,0	145,9	30,7	139,5	35,0	116,9
7	HT - 07	16,6	159,7	20,6	151,6	26,9	139,7	31,6	130,6	35,1	123,8
8	HT - 08	15,0	163,6	19,5	156,4	25,0	144,5	30,3	130,4	35,9	117,3
9	HT - 09	15,6	158,8	21,7	154,7	26,1	150,3	29,9	142,0	34,5	130,7
10	HT - 10	15,7	170,2	20,0	163,1	23,0	160,2	31,4	125,7	38,0	108,2
11	HT - 11	14,9	197,1	22,3	147,7	26,1	145,4	30,0	144,6	35,0	127,1
12	HT - 12	15,1	169,6	21,8	149,4	25,5	142,5	30,8	133,1	36,8	95,8



E_{ch} - General elastic modulus of the whole structure.
E_2 - Modulus of elasticity of structure layer by the fully grouted stone asphalt.
E_1 - Modulus of elasticity of filter layer with macadam of 1x2cm.
E_0 - Module of soil elasticity.

Figure 3.16- Structure details of sea dyke roof structure layers

From E_{ch}, E_o, E_1 calculated to E_2 corresponding to the actual experimental temperature in the field. From this determine E_2 corresponding to the experimental temperature points of 15^0C, 20^0C, 25^0C, 30^0C, 35^0C. We have a summary of E_{ht} experiment results, table 3.14

** Evaluation of experimental results*

The results of E_{ht} experiments have an average value of 91.2 ÷ 202.6 MPa corresponding to T^0tn from 35 ÷ 15^0C, the correlation between T^0tn and E_{ht} in accordance with the rule, the higher temperature is, the longer elastic modulus reduces. The E_{ht} <E value of asphalt concrete used for making common roads varies from 225 ÷ 1800 MPa, corresponding to T^0_{tn} from 30 ÷ 15^0C for hollow asphalt to tight asphalt (table 1.4). A smaller Eht value is appropriate because the fully grouted stone asphalt mixture uses more bitumen about 14 ÷ 20% [31] compared to asphalt concrete about 5 ÷ 7% [16].

Table 3.14- Summary of E_{ht} test results of the structural layer with the fully grouted stone asphalt composite

No	Measuring point	Field elastic modulus Eht (MPa)				
		T=15°C	T=20°C	T=25°C	T=30°C	T=35°C
1	HT - 01	205,7	166,6	154,6	127,3	83,7
2	HT - 02	192,5	173,4	134,7	119,6	90,6
3	HT - 03	206,3	150,9	125,5	121,8	99,5
4	HT - 04	179,2	180,7	163,6	110,7	87,7
5	HT - 05	198,6	173,1	140,0	109,5	104,3
6	HT - 06	221,5	155,8	142,3	130,7	82,1
7	HT - 07	203,7	170,3	126,5	123,5	93,3
8	HT - 08	189,1	168,4	138,9	111,3	88,6
9	HT - 09	193,5	171,8	159,2	133,9	100,5
10	HT - 10	211,2	192,5	162,7	106,5	78,4
11	HT - 11	220,8	155,9	140,8	139,1	103,2
12	HT - 12	209,1	167,2	128,8	124,9	82,8
medium E_{ht}		**202,6**	**168,9**	**143,1**	**121,6**	**91,2**

3.2.3. Construction of experimental formula to identify elastic modulus.

From the values of two experimental data series Eht and Etp, Use R to draw scatter chart between E_{ht} ~ E_{tp} (Figure 3.20).

The correlation factor r = 0,99422 (≈ 1) means that the two variables are very closely related, almost absolute. In addition to the correlation factor, it also shows that the confidence factor of 95% varies from 0.99031 to 0.99656, the p index < 2,2e-16 is very small.

Model of simple linear regression

$$\hat{y}i = 1,061\ xi \qquad (3.6)$$

Predictive model: After the predictive model has been tested and rationality has been established, drawing a line representing the relationship between the field elastic modulus and the elastic modulus in the room.

The line represents the relationship between E_{ht} and E_{tp} (Figure 3.21).

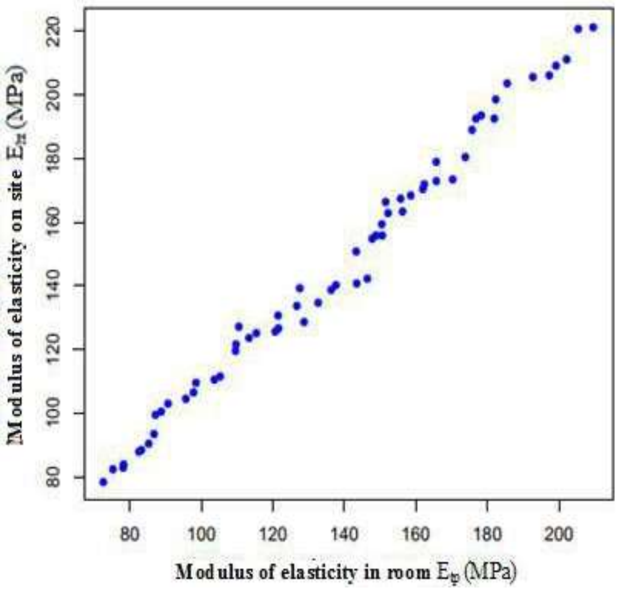


Figure 3. 20 - Scatter diagram between E_{ht} and E_{tp}

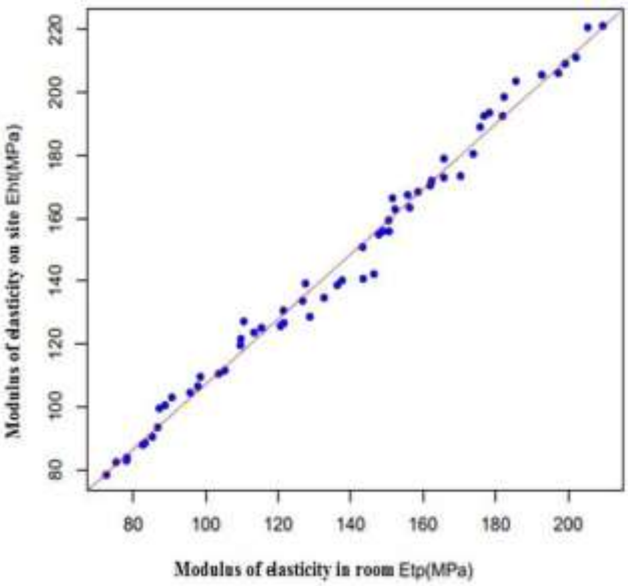


Figure 3.22- Line showing relationship between E_{ht} and E_{tp}

- Conclusion: With the use of R software to verify the relationship between Eht and Etp determined the close relationship between these two parameters, almost absolute correlation. Through linear equation $\hat{y}_i = 1{,}061\, x_i$.

Therefore, the correlation between Eht and Etp of the fully grouted stone asphalt composite for sea dyke roof structure and above experimental conditions are determined according to equation

$$E_{ht} = 1{,}061\, E_{tp} \qquad (3.7)$$

3.3. Conclusion of chapter 3

• Based on the analysis of the factors affecting the penetration depth of the grouting mortar mixture, using experimental planning methods to formulate and establish the relationship formula, that identified the main influencing factors are: the stone size and the viscosity of asphalt mixture, the range of influences, the experimental planning and the experimentation according to the planning, using Design Expert 11 software, therefore, found the formula to calculate the penetration depth of asphalt mixture into hollow cavities:

$$\ell = 19{,}37 + 0{,}342\, d - 0{,}333\, \eta - 0{,}015\, d\, \eta + 0{,}064\, d^2 + 0{,}003\, \eta^2$$

The above formula also shows the relationship between the depth of penetration of asphalt mixture with the rock size and the viscosity of asphalt mixture. Thereby it is also possible to determine the viscosity required to design a mixture of the fully grouted stone asphalt composite.

The relationship between penetration depth of asphalt mixture with the stone size and the viscosity of asphalt mixture is also shown through the chart system: (3.4), (3.5), (3.6) and (3.7).

• The author also analyzed the factors that affect the elastic modulus of the sea dyke protection structure, which is the scientific basis for simulating similar experiments in the laboratory, using mathematical tools including excel software, R software for correlation evaluation and the correlation result of the value of field elastic modulus and room elastic modulus of the dyke roof protection structure through the formula:

$$E_{ht} = 1{,}061\ E_{tp}$$

The research results have built a testing method for determining the elastic modulus of the sea dyke roof protection structure in the laboratory with the same results as the field test, which is the basis for the testing and calculation of reinforcement layer thickness of sea dyke roof with the fully grouted stone asphalt mixture.

CHAPTER 4: APPLICATION OF RESEARCH RESULTS TO HAI HAU – NAM DINH SEA DYKE PROTECTION STRUCTURE

4.1. Features of the section of the sea dyke constructed for testing

Location of the experimental dyke section from K21 + 003 - K21 + 058 belongs to Con Tron - Hai Hau - Nam Dinh sea dyke, Figure 4.1 and Figure 4.2

Picture 4.1- Location of the sea dyke studied *Picture 4.2- Status of sea dyke damage [10]*

The repair plan for the section of Con Tron - Hai Hau - Nam Dinh sea dyke is as follows: Replace the hexagonal concrete structure layer on the damaged sea dyke roof with a new reinforcement layer using the fully grouted stone asphalt composite. The range is from K2+ 003 - K21+ 058, and from the elevation of -0,5 to + 2,1m, Figure 4.

a. on May, 2017 *b. on March, 2020*

Figure 4. 3- Dyke section after test execution

4.2. Application of research results to determine elastic modulus for the design of sea dyke roof protection structural with the fully grouted stone asphalt composite material

4.2.1 Determination of boundary conditions

According to [7], the height of the dyke crest that not allow wave overtopping is determined by the formula 4.1:

$$Z_{đ} = Z_{tkp} + R_{slp} + a + b \qquad (4.1)$$

Plug the numbers into the formulas (4.4) and (4.5):

$H_s = 0{,}93$ m; $T_p = 3{,}91$ s; $L_s = 23{,}1$ m.

Instead of the formula for calculating the climbing wave: $R_{slp} = 1{,}7$m

Instead of the formula (4.1) we have: $Z_{đ} = +5{,}5$ m.

4.2.2. Calculating the thickness of the fixed layer

4.2.2.1. Method of looking up charts

With m = 4; H_s = 0,93m; Hai Hau embankment is a fine compacted sandy soil with a dyke jet module of c = 1.10^8 N/m^3 (Table 20.3 of document [31]) we have the dyke roof protection layer thickness is h = 0,15 m.

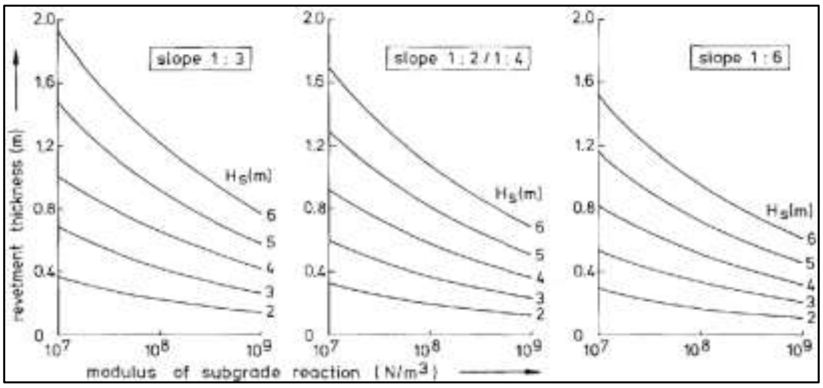


Figure 4. Relationship of thickness, dyke jet and standard wave height, dyke tilt for reinforcement layer made of the grouting mortar mixture material [31]

4.2.2.2. Application of research results to calculate the thickness of the reinforcement layer by analytical method

After the results of the research, the check for re-calculation of the reinforcement layer thickness of the sea dyke section was applied in Hai Hau and Nam Dinh [10] by analytical method (formula 1.8).

We have the elastic modulus in the room at the test temperature T = 20^0C as E_{tp} = 160.4 MPa (results of laboratory sample testing)

According to the formula 3.7: E_{ht} = 1,061 E_{tp} = 170,2. 10^6 N/m^2

Replace the calculated values in Equation 1.8, calculating the thickness of the reinforcement layer with FGSA for the sea dyke roof in Hai Hau and Nam Dinh: h ≈ 0,28m.

The value for calculating the thickness of the reinforcement layer h ≈ 0,28 m, choose h = 0,3m.

4.2.3. Checking the reinforcement layer safety conditions

The result of calculating the thickness of the sea dyke reinforcement layer.

According to the method of looking up in the chart h = 0,15 m.

By the method of analytical formula h = 0,3 m.

4.2.3.1. Checking the safety conditions for reinforcement layer to be subjected to impact waves

According to the formula: $\frac{\varphi}{\xi_z^{2/3}} \leq \frac{H_s}{\Delta d}$ (4.9)

In both cases, the wave bounced into the reinforcement layer (with a thickness of 0,3m and 0,15m) was not pushed locally because the water body in the dyke body did not drain in time.

4.2.3.2. Checking the calculation of floating and sliding pressure

a - Checking the design thickness to ensure sliding standards

Case thickness of reinforcement is h = 0,3m. Replace in the formula (4.12)

$$h \geq \frac{\sigma_{w0} f}{\rho_a g(f \cos\alpha - \sin\alpha)} = \frac{4631 \times 0,839}{2300 \times 9,81(0,839 \times 0,97 - 0,242)} = 0,30m$$, no slipping.

Case thickness of reinforcement is h = 0,15m. Replace in the formula (4.12)

$$h \geq \frac{\sigma_{w0} f}{\rho_a g(f \cos\alpha - \sin\alpha)} = \frac{3169 \times 16939}{2300 \times 3001(0,839 \times 0,97 - 0,242)} = 0,21m$$, slipping.

b - Checking the design thickness to ensure the floating standard

Case thickness of reinforcement is h = 0,3 m. Replace in the formula (4.13):

$$h \geq \frac{\sigma_{w0}}{\rho_a.g.cos\alpha} = \frac{4631}{2300x9,81x0,97} = 0,21m,$$ The dyke roof will not be pushed.

Case thickness of reinforcement is h = 0,15m. Replace in the formula (4.13):

$$h \geq \frac{\sigma_{w0}}{\rho_a.g.cos\alpha} = \frac{3169}{2300x9,81x0,97} = 0,14\text{m},$$ The dyke roof will be pushed.

After checking the safety conditions, the thickness of the reinforcement layer structure with the fully grouted stone asphalt mixture applied to the testing dyke section in Hai Hau, Nam Dinh, is determined h = 0,3m.

4.2.4. Comparison and Evaluation of research results

The thickness of the sea dyke reinforcement layer is determined by two methods:

- Method of looking up charts according to previous studies [10], [31] calculates the thickness h = 0,15m.

- Method of using the analytical formula to apply the research results of the thesis calculates the thickness h = 0,3m.

The results of safety calculation of reinforcement layer when subjected to the impact of waves and examination of floating and sliding conditions, the thickness of reinforcement layer h = 0,3m ensures safety conditions. Through the results of the calculation research, the reinforcement layer thickness of the sea dyke roof is determined by the method of chart survey like previous studies with large errors (h = 0,15m) compared to the test results and actual value (h = 0,3m). The results of calculating the reinforcement layer thickness by analytical formula give high accuracy results (h = 0,3m), ensuring the safety test conditions and actual values.

Therefore, it is possible to conclude that the results of determination E used for calculating the structural thickness according to formula (1.8) are accurate and consistent with actual results.

4.3. Applying the research results to determine penetration depth and compare, evaluate with research results of the project ĐTĐL.2012-T/06

4.3.1. Construction test model

From the results of calculating the sea dyke roof protection structure by the fully grouted stone asphalt composite with the structure as shown in Figure 4.9.

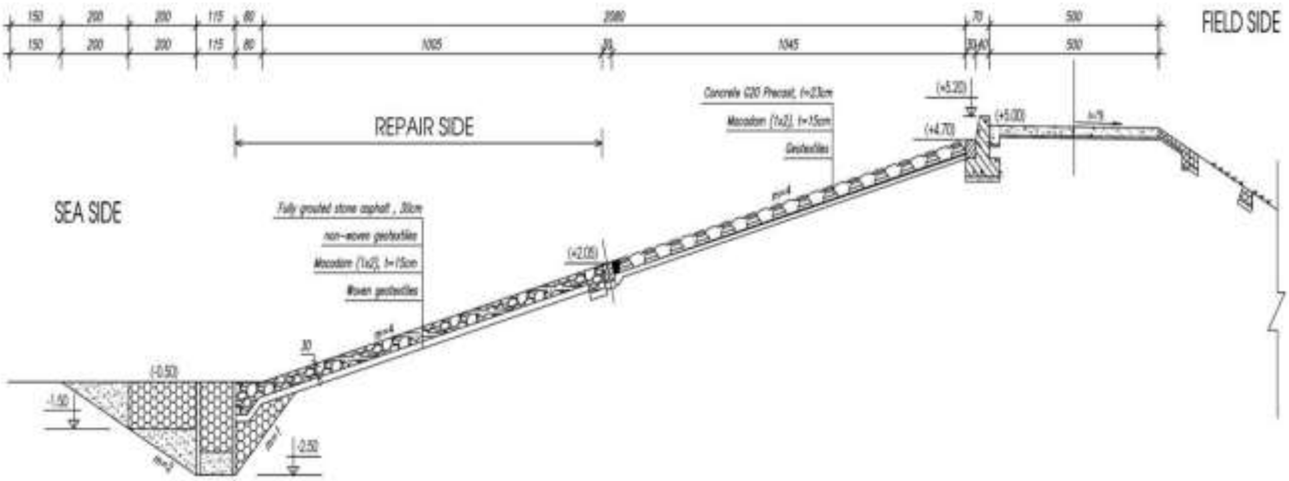


Figure 4. 9- Cross section of sea dyke protection structure

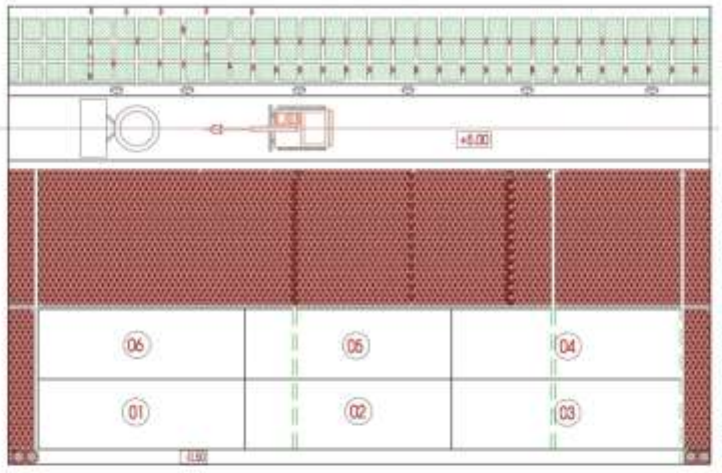


Figure 4. 10 - Layout of overall construction site [10]

Table 4. 1- Test results of quality criteria of asphalt mixture [10]

No	Sample	Viscosity	
		T (^{0}C)	η(Pa.s)
1	M2/4-6-2015	145	37
2	M5/5-6-2015	154	30
3	M3/6-6-2015	152	39
4	M5/7-6-2015	148	34
5	M4/8-6-2015	151	30
6	M2/9-6-2015	153	45
7	M3/10-6-2015	149	32
8	M1/11-6-2015	150	32
9	M2/12-6-2015	153	29
10	M6/13-6-2015	146	36
11	M5/14-6-2015	148	42
12	M4/15-6-2015	151	31

4.3.2. Comparision and valuation of the research viscosity of asphalt mixture with research results of the project ĐTĐL.2012-T/06

+ Viscosity value determined from the formula (3.3)

With the thickness of the structure protecting the sea dyke roof is h = 0.3m, m = 4, looking up table 3.10 with the value ℓ = 0,31 m; d = 20cm → η = 40 Pa.s

+ Viscosity value of the experimental research results of the project [10].

Research results on the test model of the project [10] have viscosity is: η = 29 ÷ 45 Pa.s.

+ Assessing the research results of the thesis and the research results of the project [10].

The required viscosity value determined from research results (3.3) is η = 40 Pa.s within the viscosity value range, which constructed on the test model of the project [10] η = 29 ÷ 45 Pa.s.

Through the above comparison and evaluation results, it is possible to conclude that the viscosity value determined through the formula (3.3) is very convenient for the user, the viscosity value is found to be suitable for the actual implementation.

4.4. Conclusion of chapter 4

The trial dyke section in Hai Hau, Nam Dinh sea dykes [10] is an experimental model of the field elastic modulus for the study to determine the elastic modulus of the dyke roof protection structure, which is also the basis for evaluating research results to determine the depth of penetration and elastic modulus of the thesis.

- Comparing the results of calculating the thickness of the roof protective structure layer of [10] on model with the results of calculating the thickness according to the analytical formula of the research thesis, thereby evaluating the research results to determine the elastic modulus in accordance with reality.

- The research results determine the penetration depth and viscosity of asphalt mixture of the thesis compared to the viscosity research results on the experimental model of [10] and confirm that the research results are completely consistent with reality.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Structural protection of sea dyke roof with the fully grouted stone asphalt composite has been applied in many countries around the world, especially the Netherlands. The study shows the feasibility and suitability of our sea dyke. Within the scope of the research, new scientific contributions have been made with the structure protection of sea dyke roof, which is a kind of the stone with the asphalt mixture covered:

- Studying the influencing factors, building and establishing the relationship between the penetration depth of asphalt mixture with the stone size and the viscosity of asphalt mixture through an experimental formula to determine penetration depth:

$$\ell = 19,37 + 0,342\, d - 0,333\, \eta - 0,015\, d\, \eta + 0,064\, d^2 + 0,003\, \eta^2$$

The relationship between the penetration depth of asphalt mixture with the rock size and the viscosity of the asphalt mixture is also shown through the system of charts and tables. Accordingly, determining the penetration depth, the required viscosity of asphalt mixture to calculate gradations and to control the construction process.

- Proposing an experimental model of elastic modulus in the room and the field of the sea dyke roof protection structure. Building and establishing the relationship between the elastic modulus of the sea dyke roof protection structure in the laboratory and the field by the formula:

$$E_{ht} = 1,061\, E_{tp}$$

Thereby determining the elastic modulus to test and design thickness of the structure protecting the sea dyke roof by analytical formula (1.8).

- The research results have been applied to calculate and verify the experimental project in Hai Hau, Nam Dinh with results consistent with reality.

2. Limitations

Within the scope of the thesis, the author has only researched the type of structure protecting the sea dyke roof with asphalt composite material inserted in the stone, used for inclined roof form m = 3 ÷ 4 seaward dykes, with type of the stone materials, which is form exploited limestone in Ninh Binh, is commonly used in the construction of sea dyke roofs in the Northern provinces.

3. Proposal

- For the shape of the sea dyke section: Continue to research with sea dyke cross-tilt section profiles over the range of m = 3 ÷ 4 seaward dykes, to expand the diverse applicability to most construction sea dykes throughout the country.

- For the rock materials: Expanding the scope of researching for stone materials with other stone sources or exploited in many regions of the country to facilitate their use.

- The fully grouted stone asphalt composite used for the sea dyke roof protection structure was first applied in an experimental model in Vietnam, and there is a necessity for further research to evaluate the durability of this material over time.

LIST OF PUBLISHED CATEGORY

1. Nguyen Thanh Bang, Nguyen Manh Truong and Vu Xuan Thuy (2015) “Some results of calculating the structure of the sea dyke roof reinforcement layer using fully grouted stone asphalt composite at Con Tron - Hai Thinh sea dyke, Hai Hau, Nam Dinh”, *Journal of water resources science and technology (ISSN: 1859-4255), April 26, 2015,* pp. 21-29.

2. Nguyen Manh Truong, Dinh Anh Tuan (2017), "The ability to apply Vietnam sea dyke roof structure with fully grouted stone asphalt composite", *Journal of Water Resources (ISSN: 1859-3771), No. 01 January 2017*, pp. 36-46

3. Nguyen Manh Truong (2019), "Studying methods for determining elastic modulus of fully grouted stone asphalt composite for sea dyke roof protection structure", *Journal of water resources science and technology (ISSN: 1859-4255), No. 52, January 2019,* pp. 65-75.

4. Nguyen Manh Truong (2019), "Studying the relationship between penetration depth and size of the stone and viscosity of fully grouted stone asphalt composite for the sea dyke roof protection structure", *Journal of water resources science and technology (ISSN: 1859-4255), No 53 April 2019*, pp. 52-63.