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Study on division of foundation soil structure in Thai Nguyen City area

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Abstract: *Collecting statistics of geological data and combining experimental survey data of soil and rock samples in the area of Thai Nguyen city. The author has studied the soil and rock layers and divided the foundation structure of Thai Nguyen city into three typical types for the convenience of the foundation designer, and as a basis for the design of the planning plan. Type I is composed of clay, upper phase clay and coarse to medium grained sand and gravel below. Type II is composed of siltstone, siliceous quartzite, siltstone, and siltstone. Type III includes shale interspersed with limestone. The Kriging interpolation results show that the interpolated thickness of the soil layers is quite consistent with the actual survey results. Therefore, the interpolation results can be used to design the foundation at a location without geological survey conditions.*

Keywords: *Geology, Soil structure, Geological zoning, Kriging interpolation, Construction works.*

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I. INTRODUCTION

Most of Thai Nguyen territory has a history of formation from the Mesozoic era (starting to form 240 million years ago, ending 67 million years ago, lasting 173 million years). After the terrain was formed 67 million years ago, Thai Nguyen territory existed under a continuous continental regime for 50 million years. With that time, the terrain is leveled to become plains. Due to the creation of the Himalayas 25 million years ago, the topography was raised violently, so the topography of Thai Nguyen was also raised. Depending on the location, the terrain can rise from 200 to 500m, making the terrain younger. The uplifted areas have dissected topography and young sedimentary materials. They were eroded by external forces, so ancient mountains made of older, harder lava were exposed again. The terrain is restored to its original form (late Mesozoic).

The topography of the study area is in the midland plain, the altitude is from 1-10 m above sea level. It is located in the middle of the midland plain, with a slope of 10 - 15^0. The terrain of Thai Nguyen City is quite flat. However, this land still has the characteristics of the midland shape with artificial steps built by alluvium. The new alluvial shelf and the sloping alluvial shelf are interspersed with gently sloping hills, accounting for 50.2% of the natural area. The average agricultural land area of the city is 425.55 m^2/person, mainly concentrated in the western and southwestern communes: Phuc Xuan, Phuc Triu, Tan Cuong, Thinh Duc, Luong Son.

The Vietnam Geological Survey has conducted a geological survey, but the document is general and focuses on mineral geology. In particular, it has not yet met today's construction forms. Therefore, it is difficult to use existing documents for planning and construction. It is necessary to study the geological division of the underlying structure for sustainable urban development in Thai Nguyen. The soil structure of the study area is determined from the point of view of the spatial arrangement relationship of the geological agencies of the ground structure, quantity, shape, size, composition, structure, state status, and nature of these factors (Prof. Dr. Pham Van Ty, 1999)

II. METHODOLOGY

From the existing data of 500 boreholes and geological maps, combined with the field drilling of 500 new boreholes, the author analyzed the data to study the regional stratigraphy. At the same time, divide the land structure in Thai Nguyen city. The collected documents are guaranteed to be complete, accurate, and clear. The collected documents include all documents related to geotechnical conditions in the study area, specifically:

- Documents on geology, stratigraphy, topography, hydrogeology of the area, map of the current state of the study area.
- Construction geological survey documents have been and will be built in the study area.
- Floor plan of the city center.
- Documentation of soil sample testing at the site.
- Mineral geological map of Thai Nguyen province has been digitized on Mapinfo software.
- Collecting experimental data of soil and rock samples of 500 boreholes, each drill hole is 10-50m deep.

Based on the geological map at 1:50 000 scales of Hanoi sheets and other documents, the author summarizes and divides the stratigraphy of the survey area as follows:

Paleozoi - Song Cau Formation (D_1 *sc*): Divided into two stratigraphic subsystems

Lower formations (D_1 sc_1) : The composition of the rock includes cobblestone, grit, red-brown sandstone, green-gray siltstone, red-brown shale. The degree of cohesion of the rocks is quite tight, strongly fractured. The thickness of this formation is about 200m.

Upper formation (D_1 sc_2) : The composition of the rocks includes shale, sandstone, quartz sandstone, compacted siltstone, limestone. The rocks are weathered and fractured quite strongly. The thickness of this formation is about 200m.

Mezozoi-Trial Formation-Na Khuat Formation (T_2l *nk*): The Na Khuat Formation occurs in the Phuc Triu area, Tan Cuong. The petrographic composition of the formation includes shale, siltstone, red-brown sandstone. The rocks are weathered, poorly cracked. The thickness of the formation varies from 600 - 700m.

Triassic Formation - Van Lang Formation (T_3n-r*vl*) : The sediments of the Van Lang Formation are scatteredly distributed in Quan Trieu, Tan Long, Quang Vinh wards and a part of Phuc Ha commune, Quang Trung ward. They are divided into two strata.

Lower formations (T_3n-rvl_1): The composition of the rock includes: siliceous quartzite, siltstone, gritstone, shale, coal clay, coal seam with limestone lens. The thickness is about 200-300m.

Upper formation (T_3n-rvl_2): The composition of the rock includes: siltstone, grit. The thickness is about 600-800 m.

Mezozoi -Jurassic system of the middle and lower system - Ha Coi Formation (J_{1-2} - *hc*): The petrographic composition of the rock includes: Cobblestone, gravel, sandstone alternating layers of clamping shale. The thickness varies from 300-400m.

Jura system below – Ha Coi system (J_1hc)

Below system (J_1hc_1): Ertiary sediments, siltstones, siliceous quartzite gravels, coarse to medium-grained sandstones, siltstones, mahogany siltstones. In siltstone, yellow-gray siltstone contains petrified plants: Czekandwskia rigida Heer, Equisetites sp. Gray-brown, dark-gray sandstone: Thick layer structure, fine grain. The powder is gray-brown, dark gray, gray due to: medium layer structure, fine-grain architecture. Slope angle $20\text{-}45^0$.

Upper system (J_1hc_2): Tertiary sediments, coarse to medium-grained sandstone, siltstone, mahogany siltstone, siltstone, siltstone, calcareous-limestone (lime-lime), micro-granular limestone containing powdery clay (lime - clay), siliceous quartz aggregates. Clay containing powder and containing lime includes sericite from 74-87%; calcite from 7-15%; Quartz from 5-10%. Limestone and clay include calcite from 60-97%; lightning from 1-30%; quartz from 2-15%. Silica rock includes silicon from 60-65%; chlorite from 34-39%.

Jurassic Cretaceous Formation - Tam Lung Formation (J_3 – K *tl*): The Tam Lung Formation has the composition of rocks: cobblestone, grit, sandstone, and shale clamp, with medium cohesion, weak fracture.

Kainozoi-Undivided Quaternary System (Q): Quaternary formations are scattered throughout the city, along the banks of rivers and streams. They form riparian plains and pre-mountain valleys. Soil composition includes clay, sand, gravel, crushed rock. They are formed from many different origins such as ruins, floods. The thickness varies from 15-20m (riverside) to 4-8m (small streamside). Aluva and diluvian sediments are distributed in the study area with quite a large thickness. The composition includes clay, mixed clay, and coarse-grained to medium-grained sand below. The distribution of modern river sediments is very complicated, the thickness varies unevenly in the study area. In the study area, the presence of intrusive and eruptive magma masses has not been found.

The author then aggregates data for 1000 holes, including 500 existing holes and 500 newly drilled holes. They conducted a study of the rock layers distributed throughout the area. The study area is divided into the following typical rock layers:

Layer 1: Cropland, backfill soil, pond mud
Layer 1a: Soft clay
Layer 2: Phase clay, hard plastic, medium, and weak structure
Layer 3: Mixed clay, hard plastic, medium compact structure.
Layer 4: Fine-grained sand, coarse-grained, medium-tight, less dense.
Layer 4a: Coarse sand mixed with gravel, medium compact structure.
Layer 5: Clay mixed with siltstone, semi-hard, medium-tight.
Layer 6: Weathered siltstone clay alternating with phase clay circuits, in a hard, tight state.
Layer 7: Cracked clay rock, hard state, tight texture.
Layer 8: Clay rock, hard state, tight structure.
Layer 9: Cobblestone
Layer 10: Slate alternating with limestone

Figure 1. Soil sampling

Figure 2. Testing rock samples

III. RESEARCH RESULTS

3.1. Geological zoning

The author has collected from engineering geological survey reports, has collected 500 holes drilled from documents [1,7], and drilled 500 new holes. The density of the borehole is relatively evenly covered over the study area. The average borehole depth is 25m, of which about 300 holes have a depth of 10-20m, 500 holes have a depth of 20-30m, 200 holes have a depth of 30-50m. The depth of foundation burial is affected by the construction load. Soil structure is layered according to depth. The structural model divides the land according to the homogeneity of the geological cross-section. A homogeneous foundation is considered to be a foundation composed of a layer of soil of the same or nearly identical properties with acceptable accuracy within the operating range of the load under consideration.

Based on hydrogeological characteristics, engineering geological features, topographical, geomorphological, and neotectonic characteristics. Through data analysis of boreholes of the study area, the foundation structure located at a depth of 30-50m is classified into 3 typical types of foundation soil structure (Figures 3 a, b, c). The sign of the division is the similarity of the structure of the upper and lower soil layers.

Type I: Distributed mainly in the communes of Phuc Xuan, Phuc Triu, Tan Cuong, Tan Thanh, Cam Gia, Gia Sang, Dong Bam Cao Ngan, Phan Dinh Phung, and a part of Dong Quang. This is a quaternary sedimentary area aQ. It is distributed over the study area with quite a large thickness. The composition includes clay, mixed clay above and coarse to medium-grained sand, and gravel below.

Type II: Commonly distributed in the study area. This is the Jura-Kreta terrigenous sedimentary area (J1-2hc). The composition includes siltstone, siliceous quartz grit, siltstone, siltstone.

Type III: Distributed in Quang Vinh, Quan Trieu, Tan Long, Quang Trung areas. The distribution area is not large, belongs to the Upper Triassic terrigenous sediments (T3n-rvl). It consists of shale interspersed with limestone.

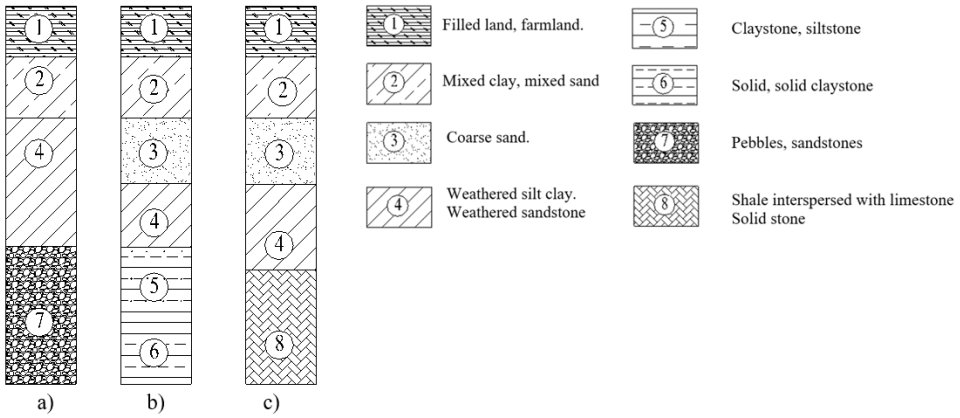

Figure 3. Typical types of background structures a)-Type I; b) Type II; c) Type III

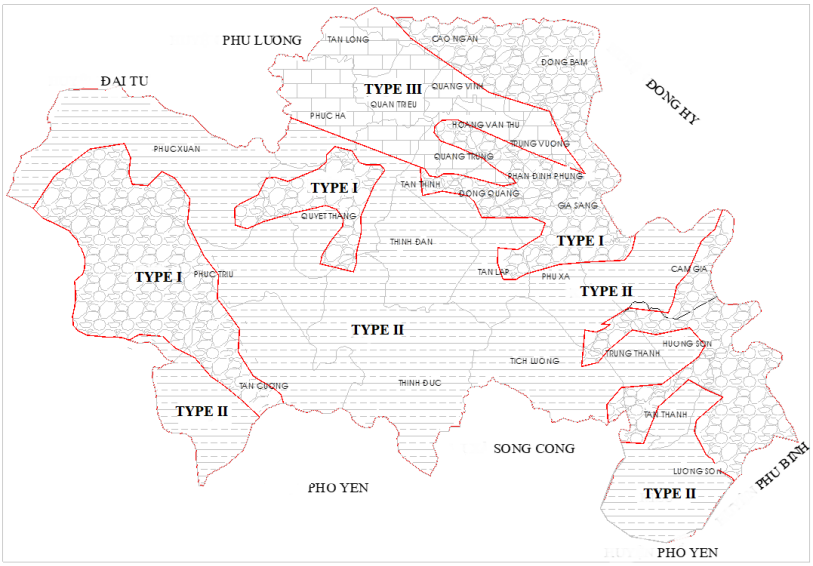

Figure 4. Geotechnical zoning diagram of the project

3.2 Interpolates the extent and thickness of the geological layer

After surveying and evaluating the distribution of geological layers, the Indicator Kriging (IK) interpolation method in ArcGIS 10.1 software is applied to determine the distribution range of soil layers. Then, using the Ordinary Kriging (OK) interpolation method to predict the soil thickness variation. The interpolation results are shown in Figure 5.

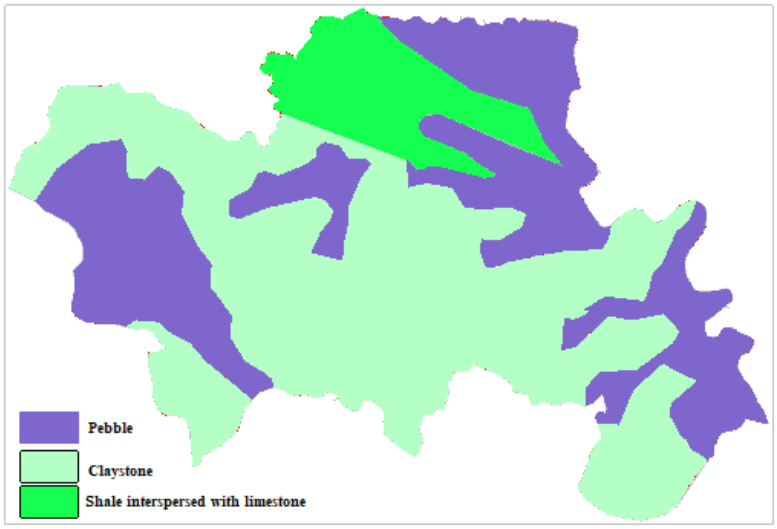

Figure 5. Results of interpolation of soil layers

Table 1. Comparison of direct results with interpolation results (3 types comparison)

Borehole	Drilling location		Thickness of the actual soil layer (m)	Interpolated soil thickness (m)
	X	Y		
Organic soil layer (1)				
1	419427,89	2383593,48	1	1±0,5
2	430521,25	2386665,23	2	2±0,7
3	429443,66	2390229,81	1,5	1,5±0,5
Hard plastic clay layer (2)				
1	419427,89	2383593,48	3,6	3,6±0,8

2	430521,25	2386665,23	4,2	4,2±1
3	429443,66	2390229,81	6,6	6,6±1,2
Medium and coarse-grained sandy soil layer (3)				
1	419427,89	2383593,48	Not available	
2	430521,25	2386665,23	6,1	6,1±1,5
3	429443,66	2390229,81	9,7	9,7±1,7
Weathered silt clay layer (4)				
1	419427,89	2383593,48	15	15± 2
2	430521,25	2386665,23	6,8	6,8±1,7
3	429443,66	2390229,81	8,5	8,5±2,2
Layer of claystone - siltstone (5)				
1	419427,89	2383593,48	Not available	
2	430521,25	2386665,23	10	10±2,5
3	429443,66	2390229,81	Not available	
Solid layer of clay rock (6)				
1	419427,89	2383593,48	Not available	
2	430521,25	2386665,23	12,8	12,8±2
3	429443,66	2390229,81	Not available	
Pebble layer (7)				
1	419427,89	2383593,48	16	16±2,7
2	430521,25	2386665,23	Not available	
3	429443,66	2390229,81	Not available	
Layer of shale interspersed with limestone (8)				
1	419427,89	2383593,48	Not available	
2	430521,25	2386665,23	Not available	
3	429443,66	2390229,81	12,5	12,5±3

3.3 Evaluate the reliability of interpolation results

The interpolation results are compared with the direct survey results from the penetration test drilling at 1000 locations to evaluate the interpolation model's reliability.

The interpolation results are different from the actual geological survey results but at an acceptable level. Prove reliable interpolation results. This error is due to the fact that when leveling the surface, the thickness of the layer of soil to be compensated is larger than the thickness of the weak layer to be removed.

IV. CONCLUSION

Dividing the ground structure of Thai Nguyen city into three typical types, Type I, Type II, and Type III. This division is for the convenience of the foundation designer. At the same time, it is used as the basis for the design of the planning scheme and the planning of underground works.

The Kriging interpolation results show that the interpolated thickness of the soil layers is quite consistent with the actual survey results. Therefore, the interpolation results can be used to design the foundation at a location without geological survey conditions.

Conflict of interest
There is no conflict to disclose.

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