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Geotechnical profiles of expansive soil hazard for road infrastructure: Case study of Takalar-Jeneponto provincial road corridor

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Abstract. This paper presents a developed geotechnical profiles which can be utlized to map expansive soil hazard for road infrastructure. The geotechnical profiles are a fundamental part of newly framework of establishing expansive soil hazard mapping which comprise of digital elevation model of area along road corridor, geological maps and geotechnical database consisting of measured in-situ and laboratory tests data, and predicted active zone by using rainfall and potential evapotranspiration data. The geotechnical profiles in the study area suggested that clay layer dominates soil formation in the area which is found to be very expansive. The thickenss of the clay layer varies due to geological structure where it is shallow in the anticline structure and deep in the sycline structure. Active zone is difficult to predict since the measurement of groundwater table is not time lapse measurement. Therefore, future study would investigate the use of SMOS and SMAP satellite platforms, and differential SAR inferometry would enhance prediction of spatial distribution of active zone of expansive soil.

1. Introduction

Road infrastructure plays important role in supporting the growth of economy in the developing countries. Conditions of road infrastructures can be deteriorated due to traffic volume, poor quality construction, tropical climate, and subsurface conditions. In several particular areas, drought and rainy weathers changes seasonally, causing the change of moisture contents in subsurface of roads. In the underlying ground condition which is clay soils, volumetric shrinking and swelling can lead to considerable structural damage to the roads. Shrink-swell susceptible clay soils or expansive soils is mostly found in several parts in Indonesia including in South and West Sulawesi. The condition of road with subsurface of expansive soils can be obviously detected at the road with longitudinal cracking mechanism as is investigated by Puppala et al. [1]. This kind of cracking can often lead to successive expansive for a longer time, leading to rapid deterioration of road subsurface [2]. This condition is mainly due to poor drainage [3].

For asset management of road infrastructures, the need of expansive soil hazard mapping is fundamental since it can become tools for decision makers to evaluate potential expansive soil hazard that affect the road assets. However, expansive soil hazard mapping is difficult to provide as it requires large insitu data for wide area particularly for national highways. Current study of this mapping is mostly based on empirical correlation data instead of direct soil surveys [4], [5]. Advanced model of 3D mapping for the geotechnical database has been examined by Pradhan and Yousef [6] and Sun [7]. Yet,

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they are invented only for earthquake. Therefore, this paper aims to investigate a novel approach of expansive soil hazard mapping for road infrastructures that can be used as a decision support tool in the asset management of national highways.

2. Research Methodology

2.1. Location an geological formation

Study case of soil database related to expansive soil was undertaken in Provincial Road Network (PRN) Takalar – Jeneponto (Figure 1) . A series of deep bor was conducted from Km. 52+000 up to Km. 76+000. This aims to obtain soil profile along the road. It can be seen at Figure 2, that the area around Km. 52+000 is late miocene Camba Formation with volcanics rocks. However, at Km. 53+000 up to Km. 56+000, late miocene Tonasa Formation with limestone. In the highway subsurface at Km. 56+000 to Km. 63+000, quarternary alluvium with clay dominated soil is found. The soil is a product of weathering of limestone which is located around. Similar alluvium is found at Km. 65+000 to 69+000. The borlogs at Figure 4 illustrate that weathering of limestone and tuff accumulating in the vast area of alluvium with clay dominated soil, at the thickness ranging from 4 m to 10 m.

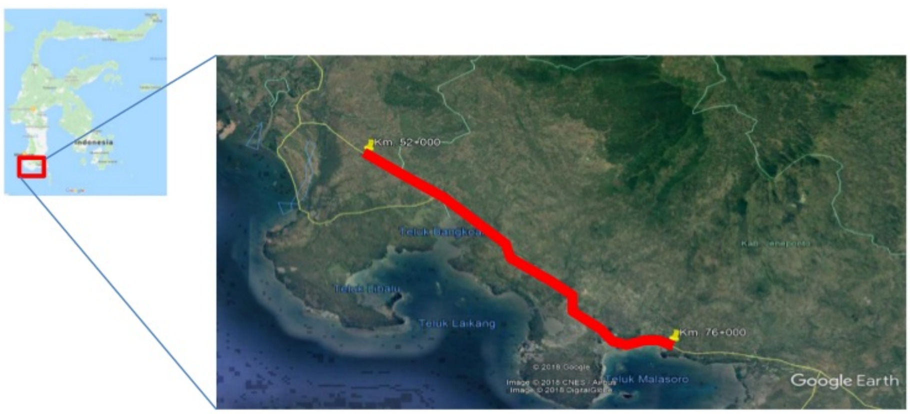

Figure 1. Location of PRN Takalar – Jeneponto Km. 52+000 – Km. 76+000.

Figure 2. Geological formation of PRN Takalar – Jeneponto Km. 52+000 – Km. 76+000.

2.2. Framework methodology

To achieve this aim, a framework of expansive soil hazard mapping along national highway was established (figure 3). In this way, digital elevation model (DEM) on particular area along the national

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highway is intersected with geogical map, and weather data in the area. A number of critera are created to represent situational condition of the highway in relation to expansive soil such as topography, spatial distribution of expansive soil along the highway. Geotechnical database about lithology, soil mechanic parameters in the ground below the highway surface are compiled. Patterns of rain and dry seasons are obtained to provide its relation to the change of moisture content of the expansive soil. The criterias are weighted by using Analytical Hierarchy Process (AHP) and Fuzzy Logic in order to produce indices of hazard. The indices are converted to grid map by using Arc-GIS.

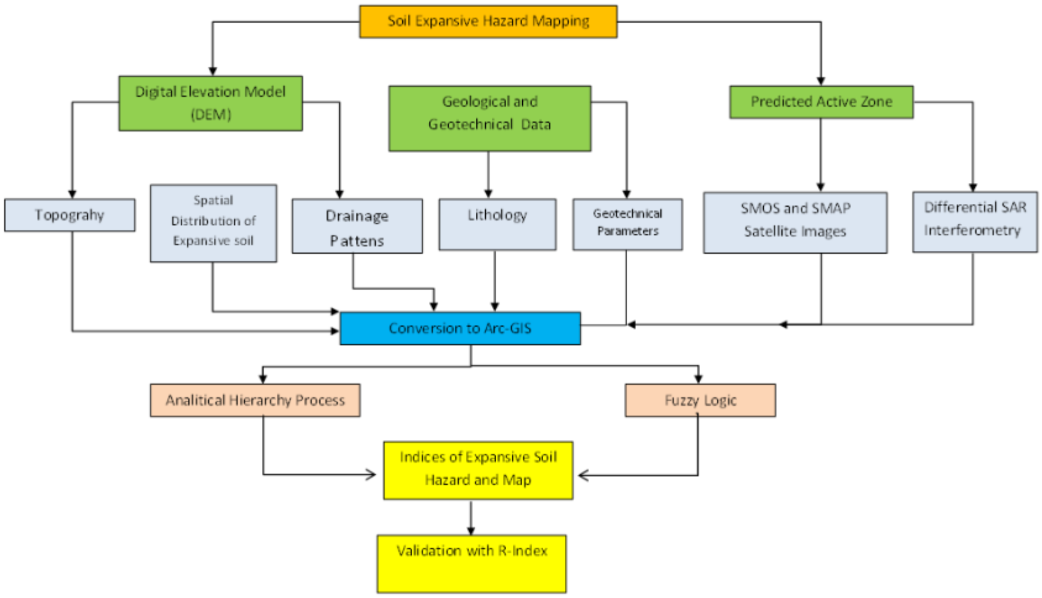

Figure 3. Framework of expansive soil hazard mapping for national highway.

3. Results and discussion

3.1. Stratigraphy of soil

Figure 4 presents the stratigraphy of soil along the road Takalar-Jeneponto Km. 52+000 – Km. 76+000. It can be found that clay soil is deposited at the beginning stage of the road. However, deep embankment to be existed in the part of the stage, particularly at the Km. 52+500 - Km. 57+000. Below the clay soil, there is a limestone layer in the Km. 52+000. This changes to Tuff rock at the Km. 52+500 – Km. 57+000. Andesit igneous rock is found below the tuff rock where is located very closed to clay layer at the Km. 57+500. From Km. 52+000 to Km. 57+000, the clay layer is variously thin with about 3 m thick. This is due to anticline in geological structure in the andesit igneous rock (bedrock). In contrast, syncline bedrock is found at the Km. 57+500 on ward. The formation changes from Tuff volcanic rocks to be limestone. Clay layer seems to be very thick more than 10 m deep. At the the end of location for research, the formation is still limestone with a typically forming a basin and clay soil sedimented at the top of limestone.

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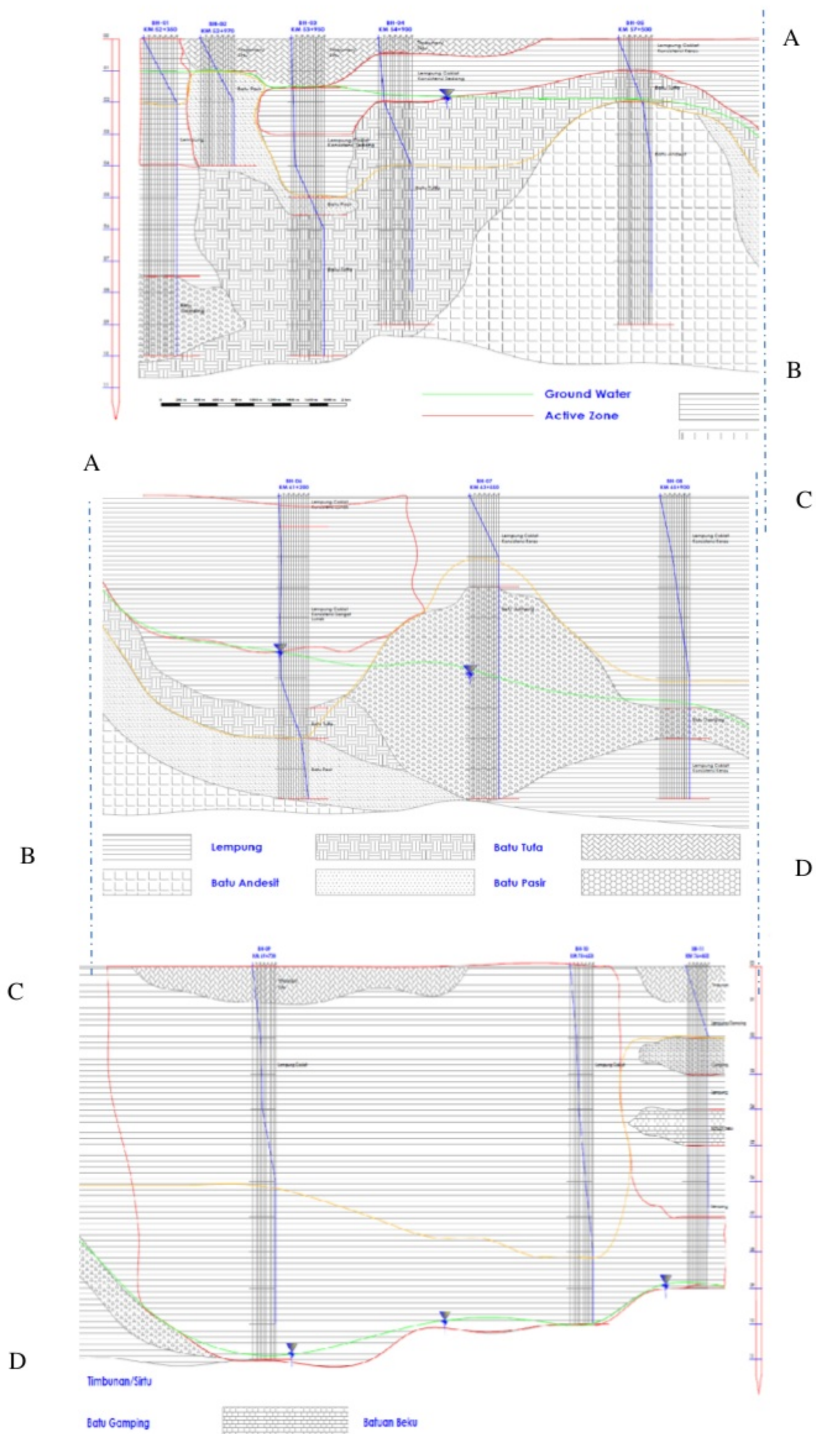

Figure 4. Stratigraphy of PRN Takalar – Jeneponto Km. 52+000 – Km. 76+000.

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3.2. Geotechnical database
Laboratory test are undertaken including physical properties tests (sieve analysis and atterberg test), and mechanical properties (oedometer, swelling) and mineralogy tests (x-ray diffraction test). Expansive soil criteria is based on PI, activity index, swelling potential, and mineralogy. Table 1 shows that mostly subsurface soil below the highway is expansive,except at soil in Km. 53+000 (BH 2) and Km. 66+000 (BH 7). The geotechnical database can be seen in table 2.

Table 1. Expansive soil criteria based on laboratory tests.

Bor No.	PI > 32 (Chen, 1975)	A > 1.25 (Skempton, 1953)	C>20% A>1,25 (Seed, 1962)	Mineral type	Swelling Potential (Snethen, 1984)	Chen Criteria (1988)
1	Very high	active	high	Montmorillonite	High	Expansive
2	-	inactive	low	-	-	Non-expansive
3	Very high	active	high	Kaolinite Montmorillonite	High	Expansive
4	Very high	active	high	Montmorillonite	High	Expansive
5	Very high	active	high	Montmorillonite	High	Expansive
6	Very high	active	medium	Montmorillonite	High	Expansive
7	moderate	inactive	low	-	High	Non-expansive
8	high	normal	medium	Kaolinite	High	Expansive
9	Very high	active	high	Kaolinite and Illite	High	Expansive
10	Very high	active	medium	Kalolinite, Illine and Montmorillonite	High	Expansive
11	Very high	active	medium	Illite Montmorillonite	High	Expansive

3.3. Active zone
The most difficult task in the case study of expansive soil of PRN Takalar-Jeneponto is predicting the active zone that may significant affect the deterioration of road. Without collecting data of tempo-spatial distribution of groundwater table, the active zone cannot be mapped. The groundwater table data must be related to topograhy data that is not provided in the previous study. Therefore,future study of our research is focusing on how to map reliable active zone with sufficient data of weather, and remote sensing.

4. Future research
The framework of expansive soil hazard mapping can be improved by developing a method of predicting active zone. Vast database of in situ dan laboratory tests data cannot play alone to describe active zone. Therefore seasonal groundwater table data is required. Measuring lapsed groundwater table in would be time-consuming and costly. Therefore, a new method is mapping the potential evapotranspiration, rainfall, combined with a coarse visual inspection. SMOS (Soil Moisture and Ocean Salinity) and SMAP (Soil Moisture Active Passive) satellite platforms, and differential SAR interferometry can be used to obtain real-time data to predict active zone.

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Table 2. Geotechnical database

No	STA	BORE HOLE	DEPTH (meter)	CLASSIFICATION USCS	Index Properties: Determination of dry density & moisture content: w_n (%)	g_d (gr/cm³)	g (gr/cm³)	Void Ratio e	Porosity n	Sr (%)	Spesific Gs	Atterberg Limits: LL (%)	PL (%)	SL (%)	PI (%)	Grain Size: GRAVEL (%)	FINE SAND (%)	Silt (%)	CLAY <0,002 mm (%)	% finer by weight passing no. 200 sieve	Activity: A = (PI/% C)	Active Zone: x = (w/ PI)	(LL-w/	Engineering Properties: Swelling Pressure: P(Nayak&Christensen,1970) (kg/cm²)	P(Komornik&David,1969) (kg/cm²)	Swelling Potensial: PU Method S (%)	Swell Test S (%)	Swelling e	Consolidation Test: e	P' kg/cm²	CBR: LAB. (%)	DCP (%)	X-RD Test (Clay Mineral) (%)
1	KM 52+350	BH - 01	0.00 - 1.00	CH	54	1.41	0.914	1.94	0.66	74.75	2.69	69.4	22.18	16.4	47	4.4	27.8	35.49	37.16	67.8	1.27	1.14	0.33	3.49	0.29	4.45%	6.16%	0.084	0.403	1.3	-	-	Quartz= 6,4; Kaolinite= 0; Illite= 0; Bentonite (Montmorillonite)= [illegible]
2			1.00 - 2.00	CH	55.09	1.41	0.909	1.96	0.66	75.63	2.69	58.05	23.19	17.8	35	6.6	37.8	26.47	25.59	55.6	1.36	1.58	0.09	2.9	0.16	-	-	-	-	-	-	-	-
3			2.00 - 3.00	CH	53.11	1.43	0.933	1.88	0.65	75.92	2.69	58.25	19.18	13.46	39	5	39.4	29.11	28.23	55.6	1.38	1.36	0.13	3.04	0.19	-	-	-	-	-	-	-	-
4			3.00 - 4.00	CH	56.62	1.41	0.898	2	0.67	76.25	2.69	53.8	17.86	11.97	36	13.2	30.4	27.31	26.43	56.4	1.36	1.58	0.08	2.91	0.12	4.56%	6.47%	0.088	0.461	1.3	-	-	-
5			4.00 - 5.00	-	57.77	1.4	0.89	2.02	0.67	76.84	2.69	NON PLASTIS				10.4	32.8	24.94	24.05	56.8	-	-	-	-	-	-	-	-	-	-	-	-	-
6			5.00 - 6.00	CL	56.43	1.43	0.912	1.96	0.66	77.77	2.7	45.91	20.75	13.15	25	12	29	29.29	28.38	59	0.89	2.24	0.42	2.85	0.08	-	-	-	-	-	-	-	-
7			6.00 - 7.00	-	57.77	1.43	0.904	1.97	0.66	78.7	2.69	NON PLASTIS				10.2	31.4	25.58	24.67	58.4	-	-	-	-	-	-	-	-	-	-	-	-	-
8			7.00 - 8.00	CL	62.16	1.41	0.869	2.1	0.68	79.77	2.7	44.44	23.53	13.62	21	11	33.2	27.1	24.48	55.8	0.85	2.97	0.85	2.73	0.05	-	-	-	-	-	-	-	-
9			8.00 - 9.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10			9.00 - 10.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	KM 52+970	BH - 02	0.00 - 1.00	-	43.6	1.42	0.992	1.69	0.63	68.75	2.67	-	-	-	-	4.6	23.6	36.58	35.44	71.8	-	-	-	-	-	-	-	-	-	-	-	-	-
12			2.00 - 3.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13			3.00 - 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14			4.00 - 5.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	KM 53+950	BH - 03	0.00 - 1.00	-	14.29	2.03	1.775	0.5	0.33	76.32	2.66	-	-	-	-	35.4	60.8	1.23	1.19	3.8	-	-	-	-	-	-	-	-	-	-	-	-	Kaolinite= 22; Illite= 0; Montmorilonite (Phyrophyllite)= 73
16			1.00 - 2.00	CL	44.3	1.37	0.952	1.82	0.65	65.31	2.69	48.17	27.27	17.09	21	2	23	36.9	35.71	75	0.59	2.12	0.19	3.1	0.2	-	-	-	-	-	-	-	-
17			2.00 - 3.00	CH	48.88	1.35	0.907	1.97	0.66	66.86	2.69	68.02	23	15.28	45	2.4	25	36.82	35.67	72.6	1.26	1.09	0.43	3.55	0.37	4.20%	5.26%	0.076	0.407	1.5	-	-	Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= 22
18			3.00 - 4.00	CL	49.36	1.38	0.924	1.91	0.66	69.5	2.69	45.15	25.51	15.25	20	6.2	28.2	29.14	28.1	65.6	0.7	2.51	0.21	2.84	0.12	-	-	-	-	-	-	-	-
19			4.00 - 5.00	CL	43.72	1.35	0.938	1.86	0.65	63.11	2.68	40.98	20.25	15.67	21	2	20.6	38.13	34.44	77.4	0.6	2.11	0.13	3.07	0.15	-	-	-	-	-	-	-	Kaolinite= 0; Illite= 0; Montmorilonite= 0
20			9.00 - 10.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	KM 54+900	BH - 04	0.00 - 1.00	-	21.28	1.82	1.504	0.77	0.43	73.74	2.66	NON PLASTIS				5.78	49.28	22.25	20.1	44.94	-	-	-	-	-	-	-	-	-	-	-	-	Kaolinite= 0; Illite= 0; Montmorilonite= 0
22			1.00 - 2.00	CH	52.28	1.41	0.926	1.91	0.66	73.78	2.69	64.62	21.15	16.82	43	3.6	29	34.19	33.12	67.4	1.31	1.2	0.28	3.29	0.26	3.58%	4.69%	0.063	0.314	1.4	-	-	Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= 82
23			8.00 - 9.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	KM 57+500	BH - 05	0.00 - 1.00	CH	54.17	1.47	0.952	1.83	0.65	79.73	2.69	57.86	19.12	13.92	39	3.8	30.2	31.37	30.32	66	1.28	1.4	0.1	3.08	0.18	3.38%	4.41%	0.058	0.29	1.1	-	-	Quartz= 12; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= 1,9
25			2.00 - 3.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26			8.00 - 9.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	KM 61+200	BH - 06	0.00 - 1.00	CH	54.13	1.41	0.913	1.95	0.66	74.79	2.69	55.94	22.77	18.68	33	5.6	36.6	29.32	28.4	57.8	1.17	1.63	0.05	2.96	0.15	4.04%	5.21%	0.069	0.35	1.35	-	-	Quartz= 35; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= 28
28			1.00 - 2.00	CH	55.3	1.42	0.911	1.94	0.66	76.33	2.68	58.42	26.26	17.2	32	7.8	36.6	24.73	23.85	55.6	1.35	1.72	0.1	2.84	0.16	-	-	-	-	-	-	-	Quartz= 14; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= 32
29			2.00 - 3.00	CH	60.18	1.38	0.862	2.13	0.68	76.2	2.7	52.57	22.41	18.2	30	5.6	39.2	28.84	27.97	55.2	1.08	2	0.25	2.86	0.08	-	-	-	-	-	-	-	-
30			3.00 - 4.00	CH	59.64	1.38	0.867	2.1	0.68	76.26	2.69	52.12	20.88	17.48	31	9.8	38.2	24.73	23.91	52	1.31	1.91	0.24	2.8	0.08	-	-	-	-	-	-	-	-
31			4.00 - 5.00	CH	59.37	1.37	0.862	2.11	0.68	75.44	2.68	56.68	21.05	15.66	36	2.8	36.4	29.93	27.03	60.8	1.32	1.67	0.08	2.89	0.11	4.22%	5.26%	0.077	0.393	1.36	-	-	Quartz= 25; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)= [illegible]
32			5.00 - 6.00	CH	62.14	1.36	0.841	2.2	0.69	76.02	2.69	51.85	25.44	13.27	26	4.4	33.8	29.41	28.43	61.8	0.93	2.35	0.39	2.82	0.07	-	-	-	-	-	-	-	-
33			6.00 - 7.00	CH	58.47	1.4	0.885	2.05	0.67	77.04	2.7	52.57	25.44	16.35	27	1.6	35.6	30.83	29.84	62.8	0.91	2.15	0.22	2.87	0.09	-	-	-	-	-	-	-	Kaolinite= 0; Illite= 0; Montmorilonite= 0
34			7.00 - 8.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35			9.00 - 10.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	KM 63+550	BH - 07	0.00 - 1.00	CL	41.06	1.4	0.99	1.71	0.63	64.41	2.68	41.72	21.07	17.67	21	2.4	20.2	38.13	36.9	77.4	0.56	1.99	0.03	3.21	0.19	-	-	-	-	-	-	-	Quartz= 2,9; Kaolinite= 0; Illite= 0; Montmorilonite= 0
37			1.00 - 2.00	CL	41.95	1.4	0.986	1.73	0.63	65.24	2.69	44.42	22.62	16.76	22	0.6	22.4	34.17	32.95	77	0.66	1.92	0.11	3.09	0.21	3.68%	4.69%	0.065	0.326	1.4	-	-	Quartz= 3,6; Kaolinite= 0; Illite= 0; Montmorilonite= 0
38			4.00 - 5.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39			9.00 - 10.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

40	KM 65+900	BH - 08	0.00 - 1.00	CL	43.72	1.35	0.938	1.86	0.65	63.1	2.68	49.8	20.25	16	29.6	2.4	27.6	33.38	32.26	70	0.92	1.48	0.21	3.21	0.22	-	-	-	-	-	-	-	Quartz= 10; Kaolinite= 0,6; Illite= 0; Montmorilonite= 0
41			1.00 - 2.00	CL	44.3	1.37	0.952	1.82	0.65	65.3	2.69	48.17	27.27	17	20.9	2.6	31.2	29.42	28.37	66.2	0.74	2.12	0.19	2.92	0.2	-	-	-	-	-	-	-	-
42			2.00 - 3.00	CL	48.88	1.35	0.907	1.97	0.66	66.9	2.69	49.88	25	15	24.9	2.4	25.2	37.87	36.72	72.4	0.68	1.96	0.04	3.12	0.16	3.47%	4.27%	0.059	0.3	1.4	-	-	Kaolinite= 6,5; Illite= 0; Montmorilonite= 0
43			3.00 - 4.00	CL	49.36	1.38	0.924	1.91	0.66	69.5	2.69	48.15	25.51	15	22.6	2	21.2	37.77	36.55	76.8	0.62	2.18	0.05	3.06	0.14	-	-	-	-	-	-	-	-
44			4.00 - 5.00	CL	42.33	1.39	0.975	1.75	0.64	64.8	2.68	48.2	20.29	18	27.9	2.4	19.4	41.01	39.77	78.2	0.7	1.52	0.21	3.52	0.24	2.69%	2.94%	0.043	0.2	1.3	-	-	Quartz= 7,0; Kaolinite= 2,2; Illite= 0; Montmorilonite= 0
45			5.00 - 6.00	CL	42.04	1.4	0.984	1.73	0.63	65.4	2.68	43.25	20.51	16	22.7	2.4	22	36.02	34.82	75.6	0.65	1.85	0.05	3.17	0.2	-	-	-	-	-	-	-	-
46			6.00 - 7.00	CL	45.7	1.39	0.957	1.82	0.65	67.8	2.7	49.15	18.87	15	30.3	5.6	16.6	40.65	39.42	77.8	0.77	1.51	0.11	3.45	0.2	-	-	-	-	-	-	-	-
47			7.00 - 8.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48			8.00 - 9.00	CL	46.89	1.39	0.948	1.83	0.65	68.8	2.68	46.21	18.52	13	27.7	2.6	21.4	36.23	35.02	76	0.79	1.69	0.02	3.18	0.16	-	-	-	-	-	-	-	-
49			9.00 - 10.00	CL	44.44	1.43	0.987	1.73	0.63	69.3	2.69	45.35	24.35	17	21	4.8	25.6	30.89	29.79	69.6	0.7	2.12	0.04	2.95	0.19	-	-	-	-	-	-	-	-
50	KM 69+700	BH - 09	0.00 - 1.00	CH	50.29	1.41	0.938	1.86	0.65	72.5	2.69	55.76	25.22	16	30.5	4.6	23.4	35.43	32	72	0.95	1.65	0.18	3.07	0.2	-	-	-	-	-	-	-	Quartz= 19; Kaolinite= 26; Illite= 0; Montmorilonite= 0
51			1.00 - 2.00	CH	47.99	1.43	0.963	1.79	0.64	72.1	2.69	54.34	19.32	15	35	4	21	34.47	32.09	75	1.09	1.37	0.18	3.21	0.22	3.23%	4.06%	0.055	0.3	1.25	-	-	Quartz= 27; Kaolinite= 0; Illite= 3; Montmorilonite=
52			2.00 - 3.00	CH	51.69	1.4	0.924	1.91	0.66	72.8	2.69	58.15	20.29	19	37.9	4.8	21.4	37.43	36.26	73.8	1.04	1.37	0.17	3.33	0.2	-	-	-	-	-	-	-	-
53			3.00 - 4.00	CH	48.31	1.43	0.966	1.78	0.64	72.8	2.69	59.21	20.3	20	38.9	3.8	21	39.36	38.17	75.2	1.02	1.24	0.28	3.54	0.28	-	-	-	-	-	-	-	-
54			4.00 - 5.00	CH	55.9	1.38	0.885	2.03	0.67	73.9	2.68	55.63	19.05	16	36.6	8.8	40.4	25.02	24.21	50.8	1.51	1.53	0.01	2.87	0.13	3.23%	4.06%	0.055	0.3	1.25	-	-	Quartz= 31; Kaolinite= 0; Illite= 3,4; Montmorilonite= 0
55			5.00 - 6.00	CH	61.73	1.35	0.834	2.22	0.69	74.6	2.69	50.89	22.5	18	28.4	7.4	41.2	22.03	22.21	51.4	1.28	2.17	0.38	2.75	0.07	-	-	-	-	-	-	-	-
56			6.00 - 7.00	CH	56.5	1.39	0.888	2.03	0.67	74.9	2.69	54.62	19.38	13	35.2	6.8	43	26.29	25.5	50.2	1.38	1.6	0.05	2.89	0.12	-	-	-	-	-	-	-	-
57			7.00 - 8.00	CH	57.66	1.38	0.873	2.08	0.68	74.5	2.69	53.64	26.09	21	27.6	8.2	41.3	24.01	23.21	50.5	1.19	2.09	0.15	2.78	0.1	-	-	-	-	-	-	-	-
58			8.00 - 9.00	CH	60.49	1.36	0.846	2.18	0.69	74.6	2.69	54.43	20.47	17	34	9.1	39.7	25.97	25.15	51.2	1.35	1.78	0.18	2.84	0.09	-	-	-	-	-	-	-	-
59			9.00 - 10.00	CH	60.15	1.38	0.862	2.11	0.68	76.4	2.68	59.91	22.62	17	37.3	7.6	41.8	24.12	23.32	50.6	1.6	1.61	0.01	2.83	0.12	3.23%	4.06%	0.055	0.3	1.25	-	-	Quartz= 28; Kaolinite= 0,7; Illite= 13; Montmorilonite= 0
60			10.00 - 11.00	CH	56.43	1.43	0.912	1.96	0.66	77.8	2.7	56.14	22.06	18	34.1	8.3	40.9	24.94	22.53	50.8	1.51	1.66	0.01	2.82	0.13	-	-	-	-	-	-	-	-
61	KM 74+650	BH-10	0.00 - 1.00	CH	50	1.41	0.94	1.85	0.65	72.4	2.68	59.65	20.47	18	39.2	4.6	23.4	32.04	30.9	72	1.27	1.28	0.25	3.19	0.24	-	-	-	-	-	-	-	rtz= 14,6; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)=
62			1.00 - 2.00	CH	54.13	1.41	0.913	1.95	0.66	74.8	2.69	60.54	22.77	19	37.8	4	21	38.04	36.85	75	1.02	1.43	0.17	3.28	0.19	-	-	-	-	-	-	-	-
63			2.00 - 3.00	CH	55.3	1.42	0.911	1.94	0.66	76.3	2.68	64.82	21.05	17	43.8	4.8	21.4	36.35	35.17	73.8	1.24	1.26	0.22	3.3	0.22	-	-	-	-	-	-	-	artz= 47; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)=
64			3.00 - 4.00	CH	60.18	1.38	0.862	2.13	0.68	76.2	2.7	59.27	20.41	18	38.9	3.8	21	39.43	38.23	75.2	1.02	1.55	0.02	3.21	0.11	-	-	-	-	-	-	-	-
65			4.00 - 5.00	CH	59.64	1.38	0.867	2.1	0.68	76.3	2.69	52.12	20.88	17	31.2	8.8	40.4	24.13	23.33	50.8	1.34	1.91	0.24	2.79	0.08	-	-	-	-	-	-	-	-
66			5.00 - 6.00	CH	59.37	1.37	0.862	2.11	0.68	75.4	2.68	54.68	21.05	16	33.6	7.4	41.2	26.93	26.12	51.4	1.29	1.77	0.14	2.86	0.1	-	-	-	-	-	-	-	-
67			6.00 - 7.00	CH	62.14	1.36	0.841	2.2	0.69	76	2.69	55.18	25.44	13	29.7	6.8	41.2	22.3	21.5	52	1.38	2.09	0.23	2.75	0.08	4.31%	5.97%	0.084	0.4	1.28	-	-	Quartz= 31; Kaolinite= 0; Illite= 1,2; Montmorilonite= 0
68			7.00 - 8.00	CH	58.47	1.4	0.885	2.05	0.67	77	2.7	57.26	25.44	16	31.8	8.2	43	24.79	23.99	48.8	1.33	1.84	0.04	2.81	0.12	-	-	-	-	-	-	-	-
69			8.00 - 9.00	CH	48.65	1.44	0.966	1.77	0.64	73.5	2.68	52.62	20.24	11	32.4	9.1	41.3	24.41	23.6	49.6	1.37	1.5	0.12	2.9	0.2	4.31%	5.97%	0.084	0.4	1.28	-	-	Quartz= 26; Kaolinite= 12; Illite= 6; Montmorilonite= 0
70			9.00 - 10.00	CH	52.03	1.43	0.938	1.87	0.65	74.9	2.7	51.66	21.78	12	29.9	7.6	39.7	24.83	22.43	52.7	1.33	1.74	0.01	2.82	0.15	-	-	-	-	-	-	-	-
71	KM 76+450	BH-11	0.00 - 1.00	CL	57.59	1.3	0.825	2.11	0.68	70	2.57	48.24	31.37	14	16.9	4.4	27.8	33.19	29.87	67.8	0.56	3.41	0.55	2.77	0.07	4.11%	5.34%	0.075	0.4	1.3	-	-	Quartz= 7,8; Kaolinite= 0; Illite= 0; Montmorilonite= 0
72			2.00 - 3.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73			3.00 - 4.00	CH	56.31	1.33	0.849	2.06	0.67	70.9	2.6	59.2	30.67	19	28.5	6.6	37.8	27.01	24.31	55.6	1.17	1.97	0.1	2.81	0.14	4.39%	6.01%	0.083	0.4	1.45	-	-	Quartz= 9,3; Kaolinite= 0; Illite= 34; Montmorilonite= 0
74			4.00 - 5.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75			5.00 - 6.00	CH	54.76	1.33	0.862	2.06	0.67	70.1	2.63	55.86	27.97	18	27.9	13.2	30.4	26.79	24.11	56.4	1.16	1.96	0.04	2.81	0.13	-	-	-	-	-	-	-	Quartz= 4,8; Kaolinite= 0; Illite= 0; Montmorilonite=
76			6.00 - 7.00	CH	56.92	1.33	0.849	2.12	0.68	71.1	2.65	56.78	28.05	14	28.7	10.4	32.8	26.99	24.29	56.8	1.18	1.98	0	2.81	0.12	-	-	-	-	-	-	-	-
77			7.00 - 8.00	CH	56.76	1.34	0.856	2.06	0.67	72.2	2.62	59.52	26.8	17	32.7	12	29	27.95	25.15	59	1.3	1.73	0.08	2.86	0.14	3.34%	3.96%	0.061	0.3	1.6	-	-	artz= 25; Kaolinite= 0; Illite= 0; Montmorilonite (Phyrophyllite)=
78			8.00 - 9.00	CH	60.51	1.32	0.821	2.19	0.69	72.3	2.62	58.01	25.17	15	32.8	11	33.2	26.69	24.02	55.8	1.37	1.84	0.08	2.81	0.1	3.34%	3.96%	0.061	0.3	1.6	-	-	rtz= 20; Kaolinite= 0; Illite= 2,9; Montmorilonite (Phyrophyllite)=

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5. Conclusions

This paper has presented a developed geotechnical profiles of expansive soil hazard for road infrastructure. The geotechnical profiles can be extended and succesfully applied to map potential expansive soil hazard and would be realible if the predicted active zone can be provided. Therefore, future study will examine the use of weather data of rainfall, and measure potential evapotranspiration along the highway, intersecting with coarse visual inspection of the highway. The data would be converted into grid of Arc-GIS, overlaid with DEM and geotechnical database. The use of SMOS and SMAP satellite platforms would enhance the mapping in which weather data is insufficient.

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