Seismic Bearing Capacity of Jatinangor Education Area, Bandung, Indonesia

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Abstract

Jatinangor is education area in eastern Bandung, Indonesia. It had been prepared as education area since 1980's with concept of the Project Development Area of Great Bandung, West Java, Indonesia. It caused research area experienced physical changes between 1970 until early 1980's. Rapid physical changing occurred preceding the establishment of 4 universities there.

According to earthquake vulnerability map of West Java Province, research area is located in area with high vulnerability of earthquake effects. Even earthquake occurred with epicentre in Tanjungsari (15 km east part of research area) in 1972 and in Cicalengka (18 km west part of research area) in 2000. While in north part of research area, lays a popular active fault named Lembang Fault that could increase the peak ground acceleration of research area. Therefore, it is important to calculate the relationship between those seismic factors with bearing capacity to prevent undesired failure or settlement of buildings when earthquake happen. So, the aims of this research are to calculate how much the reducing of the seismic bearing capacity value from static bearing capacity value.

Methods that were used in this research are: (1) field study such as: engineering geological mapping, soil and rock sampling from either outcrops or 20 bore holes; and geophysics analysis to get information of soil thickness, (2) laboratory analysis method for gaining information about angle of friction, cohesion, and unit weight, and (3) office method be in the form of analysis of engineering geological map, static bearing capacity (Terzhagi's Formula), seismic bearing capacity (Kharni, 1993), and geostatistic analysis for zoning the location based on the value of either static or seismic bearing capacity.

The results show that: seismic factors in research area reduce the bearing capacity about 8% - 20% for depht of footing 1 m. Geostatistic analysis shows that research area has wider area of low bearing capacity when seismic factors are calculated in bearing capacity calculation.

Keywords: Seismic bearing capacity, PGA, soil thickness, earthquake.

1. Introduction

Jatinangor is education area in eastern Bandung, Indonesia. It had been prepared as education area since 1980's with concept of the Project Development Area of Great Bandung, West Java, Indonesia. It caused research area experienced physical changes between 1970 until early 1980's. Rapid physical changing occurred preceding the establishment of 4 universities there (Anonyms, 2009).

Environmental conditions of Jatinangor at this time to be degraded by development that is not well planned. It can be seen from the construction of houses/buildings irregular, dense housing, irregularity boarding houses, slums, and narrow streets and prone to misfire, the build-up of waste that until now there is no solution. Uncontrolled land clearing the name of development resulted in Jatinangor be uncomfortable and prone to some geological constraints such as flooding, soil movement, and the air is hot. In the dry season, Jatinangor experiencing water shortage due to forest conservation area has been damaged (Anonymous, 2009).

Meanwhile, according to earthquake vulnerability map of West Java, research area is located in areas of high earthquake vulnerability. Even once an earthquake with epicentre in Tanjungsari in 1972 and the earthquake centred on Cicalengka in 2000. The study area is also close to the fault area dent located in northwest. In addition, the study area is also traversed by several faults which are indicated by the lineament (Syahbana et al., 2010).

According Kharni (1993) an area with high seismic vulnerability is not enough supportability analysed using static bearing capacity equation. However, the necessary analysis of seismic bearing capacity taking into accounts the seismic coefficient of horizontal and /or vertical. To that end, the rapid physical development of the research sites, such as the construction of housing, apartments, college territorial expansion (ITB and Unpad), and the development of road infrastructure should pay attention to the threat of geological disasters, especially earthquakes. So we need a study on the bearing capacity of the land in the study area that takes attention the effect of earthquakes.

Through those backgrounds, this research aims to determine how much influence the seismicity factor to the decline in the value of the soil bearing capacity.

1.1 Static Bearing Capacity

Bearing capacity is ability of soil for holding back pressure or load of building above it without cause shear failure and excessive settlement. The ability is depending on soil shear strength (Bowles, 1984) (See Figure 1).

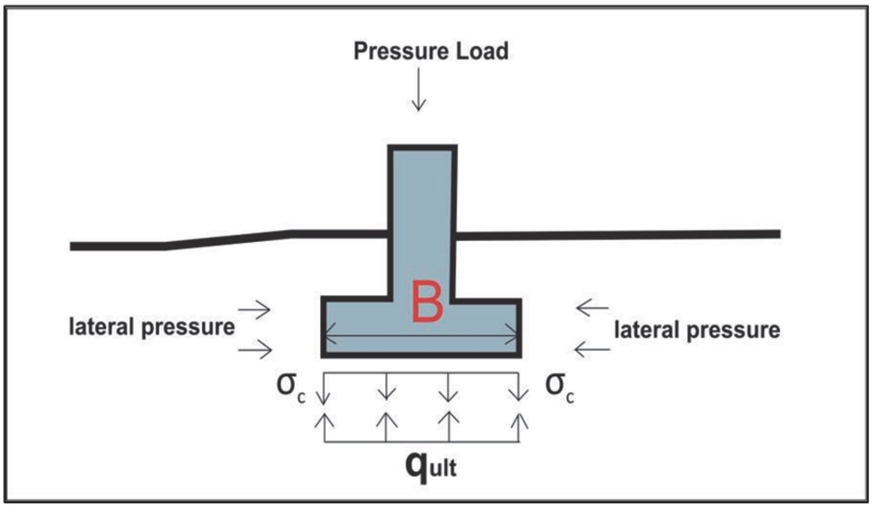

Fig. 1 Bearing Capacity (Bowles, 1984)

Terzhagi in Zakaria (2006) discuss the influence of foundation shape toward value of ultimate bearing capacity. The influence is analysed based on continuous foundation that applied for the other shapes of foundation.

Continuous footing also known as general equation of bearing capacity, i.e:

$$q_u = c \cdot Nc + \gamma\, D_f \cdot Nq + 0.5\, \gamma \cdot B.N\gamma \qquad (1)$$

Which:

q_u = Ultimate bearing capacity, (kN/m^2)
B = Wide of foundation (m)
D_f = Depth of foundation (m)
γ = Unit weight (kN/m^2)
c = Cohesion (kN/m^2)
N_c, N_q, N_γ = Bearing capacity factor
φ = Angle friction (^{0})

Terzhagi in Zakaria (2006) presented a bearing capacity formula which was calculated in ultimate bearing capacity condition (q_{ult}). It means an equilibrium value that will result in failure or collapse if it is passed over. Therefore the value of allowable bearing capacity (q_a) must be lower than ultimate bearing capacity.

Allowable bearing capacity depends on how great the chosen safety factor (F). In general, value of safety factor that is chosen is in range of 2-5. The formula of allowable bearing capacity is:

$$q_a = \frac{q_u}{F} \qquad (2)$$

Which:

q_a = allowable bearing capacity (kN/m^2)
q_u = ultimate bearing capacity (kN/m^2)
F = Safety factor.

1.2 Seismic Bearing Capacity

Seismic vibrations such as earthquakes can reduce the bearing capacity of the soil and can lead to excessive reduction or collapse of the foundation. Therefore, it is important to calculate the seismic bearing capacity. The analysis was developed using horizontal and vertical seismic coefficient obtained from the data of peak ground acceleration (PGA) which is caused by the earthquake (Al-Karni, 1993).

Seismic bearing capacity factors that offered by Al-Karni (1993) can be used to modify the existing equations of static bearing capacity (Terzhagi, 1973; Meyerhof, 1963, Hansen, 1970, Vesic, 1973). For example, soil bearing capacity equation Meyerhof (1963) for the vertical load can be modified into a general equation to include the effects of the earthquake as follows:

$$q_{uE} = cN_{cS}s_c d_c e_c + q_f N_{qS} s_q d_q e_q + 0.5B\gamma N_{\gamma S} s_\gamma d_\gamma e_\gamma \quad (3)$$

Which:

q_{uE} = ultimate seismic bearing capacity (kN/m^2)
B = Wide of foundation (m)
D_f = Depth of foundation (m)
γ = Unit weight (kN/m^2)
c = Cohesion (kN/m^2)
N_c, N_q, N_γ = Bearing capacity factor
φ = Angle friction (^{0})
s and d = shape and depth factors
e_c, e_q, and e_γ = seismic factors of Al-Karni (1993), the equation is as follows:

$$e_c = -4.3k_h^{1+D} \quad (4)$$

$$e_c = (1-k_v)\exp[-(\frac{5.3k_h^{1.2}}{1-k_v}) \quad (5)$$

$$e_\gamma = (1-\frac{2}{3}k_v)\exp[-(\frac{9k_h^{1.1}}{1-k_v}) \quad (6)$$

Which,
k_h = horizontal seismic coefficient
k_v = vertical seismic coefficient = ½.k_h
k_h = PGA/g
with:
PGA = Peak Ground Acceleration
g = acceleration due to gravity (10m /s^2)

1.3 Seismicity of Research Area

According to the earthquake disaster vulnerability map of West Java, study area is located in the area of high earthquake vulnerability. Even earthquakes have occurred around the site area in 1972 (its epicenter was in Tanungsari about 10 km from research area) and 2000 (its epicenter was in Cicalengka, about 5km from research area). The study area is also close to the fault area dent located in northwest. In addition, the study area is also traversed by several faults are indicated by the lineament (Syahbana et al., 2010).

For comparison in Bandung basin area, based on the results of the seismic risk analysis, the maximum PGA values at the bedrock is about 0.09 g. After taking account of the soil, it was found that the maximum PGA is about 0.17 g in the north-west and increase gradually until 0.35 g in the south-east (Suharman, 2000). Research area is in the eastern part of the Bandung Basin. The soil materials of it consist of local Cibiru volcano (Silitonga, 1973). Engineering geological characteristics of the study area have the same soil with Cibiru region i.e, silty clay and sandy clay with a thickness of 2-20 meters and low – moderate allowed bearing capacity (Djadja and Hemawan, 1996). So that the average value of PGA (peak ground acceleration) maximum in the study area is approximately from 0.34 to 0.35 g.

2. Methodology

This research used three methods, they are: (1) field sampling of soils and engineering geological mapping; (2) Laboratory analysis method, for getting data cohesion (c), angle of friction (φ), and unit weight (γ); and (3) studio analysis method for getting value of both static and seismic bearing capacity, geostatic analysis to show the zone of bearing capacity (static and seismic), and statistics analysis to show how different between seismic and static bearing capacity values.

3. Results and Discussions

3.1 Static Bearing Capacity

Table 1 Static Bearing Capacity of Research Area

Local-Shear Soil Condition						
Borholes	Continues		Square		Circle	
	qult (kN/m^2)	q_a (kN/m^2)	q_{ult} (kN/m^2)	q_a (kN/m^2)	qult (kN/m^2)	q_a (kN/m^2)
UDS 1	416,176	138,729	403,233	134,414	364,493	121,501
UDS 2	548,259	182,750	540,278	180,089	451,897	150,636
UDS 3	357,459	119,150	349,398	116,469	304,609	101,533
UDS 4	716,691	238,897	704,006	234,672	595,738	198,583
UDS 6	571,864	190,621	548,070	182,690	515,856	171,949
UDS 7	697,769	232,590	683,032	227,677	586,262	195,424
UDS 8	302,916	100,975	298,312	99,441	251,631	83,877
UDS 9	136,038	45,346	124,939	41,650	143,502	47,837
UDS 10	581,459	193,820	574,634	191,548	473,101	157,700
UDS 11	315,729	105,240	308,844	102,948	268,510	89,507
UDS 12	538,654	179,551	523,748	174,579	464,462	154,821
UDS 13	551,737	183,916	534,399	178,136	482,168	160,719
UDS 14	931,305	310,438	893,681	297,894	831,486	277,159
UDS 15	438,157	146,052	430,325	143,442	365,848	121,949
UDS 16	413,885	137,962	393,229	131,076	384,311	128,107
UDS 17	466,554	155,518	439,054	146,351	444,155	148,055
UDS 18	527,923	175,974	520,071	173,354	435,347	145,116
UDS 19	500,442	166,817	484,519	161,506	437,958	145,983
UDS 20	911,696	303,902	881,555	293,848	794,161	264,724
UDS 22	317,672	105,887	312,272	104,094	265,451	88,480

Calculation of static bearing capacity in research area was done based on data of soil mechanics from 20 boreholes, places of taking undisturbed sample. The type of failure in this research is assumed as local shear failure (due to plastic soil in research area) with wide of foundation 2 m and depth of foundation are 1 m. The results of bearing capacity calculation are shown in table 1.

3.2 Seismic Bearing Capacity

Calculation of seismic bearing capacity in research area was done based on data of soil mechanics from 20 boreholes, places of taking undisturbed sample. The type of failure in this research is assumed as local shear failure (due to plastic soil in research area) with wide of foundation 2 m and depth of foundation are 1 m. The results of bearing capacity calculation are shown in table 2.

Table 2 Seismic Bearing Capacity of Research Area

Local-Shear Soil Condition						
Borheoles	Continues		Square		Circle	
	qult (kN/m2)	q_a (kN/m2)	q_{ult} (kN/m2)	q_a (kN/m2)	qult (kN/m2)	q_a (kN/m2)
UDS 1	350,543	116,848	394,495	131,495	404,608	134,873
UDS 2	357,927	119,309	398,929	132,980	410,517	136,836
UDS 3	297,176	99,062	345,292	115,094	351,590	117,197
UDS 4	569,791	189,934	682,713	227,568	692,637	230,876
UDS 6	486,333	162,114	528,341	176,114	546,934	182,311
UDS 7	571,774	190,591	674,413	224,808	685,932	228,644
UDS 8	249,678	83,229	298,023	99,341	301,620	100,537
UDS 9	132,571	44,190	118,691	39,567	127,360	42,457
UDS 10	465,269	155,090	569,034	189,675	574,365	191,458
UDS 11	225,097	75,029	255,756	85,252	261,137	87,046
UDS 12	449,317	149,769	514,750	171,580	526,398	175,466
UDS 13	455,793	151,931	515,009	171,670	528,560	176,183
UDS 14	778,816	259,602	856,934	285,648	886,328	295,443
UDS 15	359,850	119,947	427,396	142,465	433,514	144,508
UDS 16	376,101	125,367	393,568	131,186	409,710	136,567
UDS 17	431,531	143,840	438,217	146,072	459,699	153,236
UDS 18	423,968	141,319	511,641	170,544	517,779	172,596
UDS 19	422,085	140,692	475,084	158,358	487,519	162,503
UDS 20	773,565	257,858	873,145	291,048	896,700	298,900
UDS 22	263,687	87,892	312,541	104,184	316,766	105,589

3.3 Reduction of Bearing Capacity Value Due To Seismicity

Calculations of static and seismic bearing capacity indicate reduction. The average reduction of the bearing capacity of the soil is about 3,013 Ton/m^2 or about 19.12%. Based on statistical analysis, t-test, the values of the static and seismic bearing capacity indicates that the values of both of them are different. This statistical test used a significance level of 0.05.

Zone of static and seismic bearing capacity can be seen in figure 2 and figure 3 on page 5 and 6. The pictures show that areas with smaller value of bearing capacity are more widespread in seismic bearing capacity map. It indicates that there is change of bearing capacity value after calculating the seismicity factors (i.e. peak ground acceleration) into bearing capacity formula. Zoning is done using the software Surfer v.10 with geostatistics methods (Kriging).

4. Conclusion

Based on static bearing capacity analyses, seismic bearing capacity analyses, and statistical analyses (with significance level 0.05), it is concluded that seismicity factors reduce the value of bearing capacity in research area. The average reduction of the values is about 3.013 Ton/m^3 or 19.12%. Geostatistical analyses also show that there is reduction of the bearing capacity in research area. It is represented by wide spreading of smaller bearing capacity value when seismicity is calculated on bearing capacity formula.

Acknowledgements

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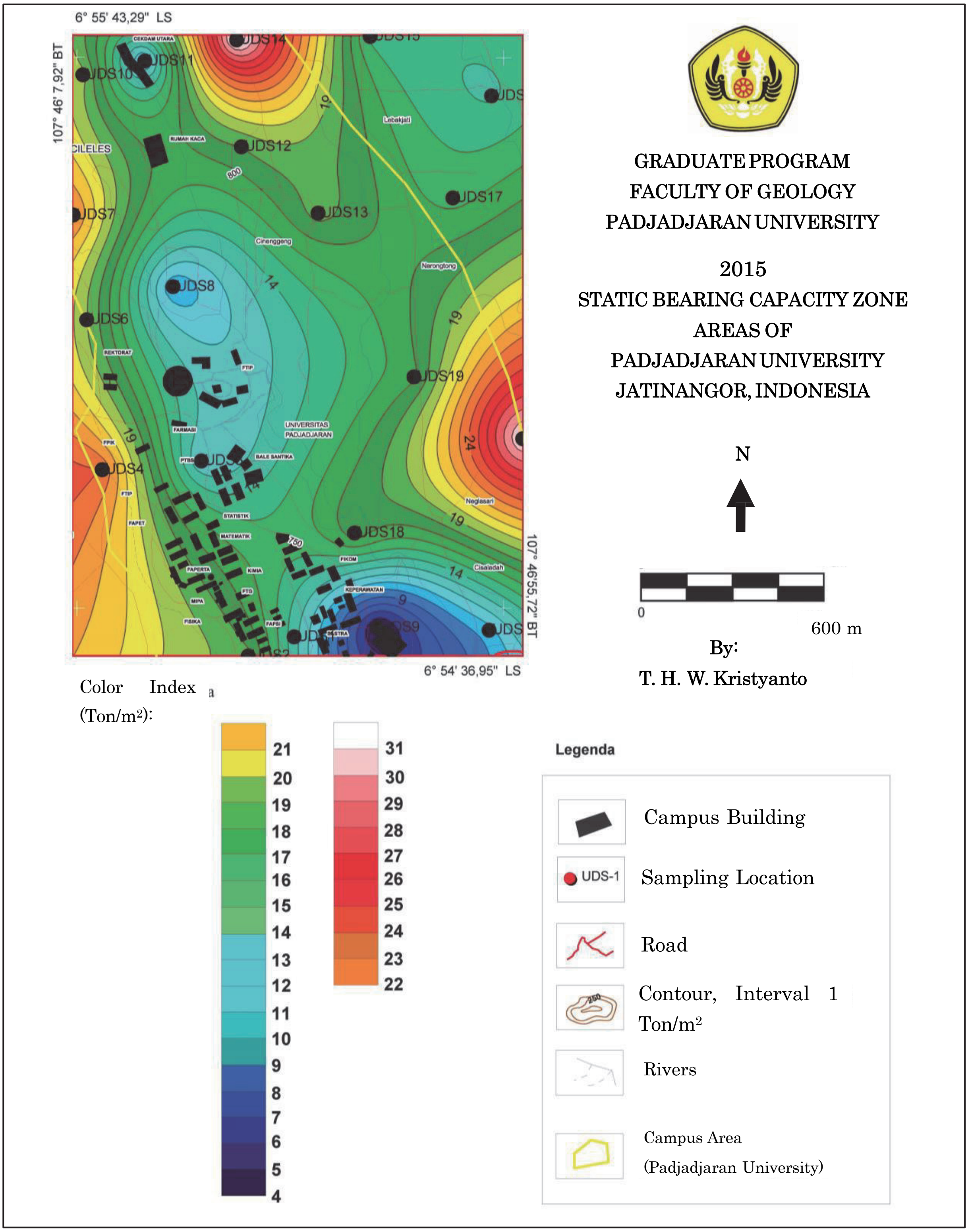

Fig. 2 Zoning Map of Static Bearing Capacity of Research Area

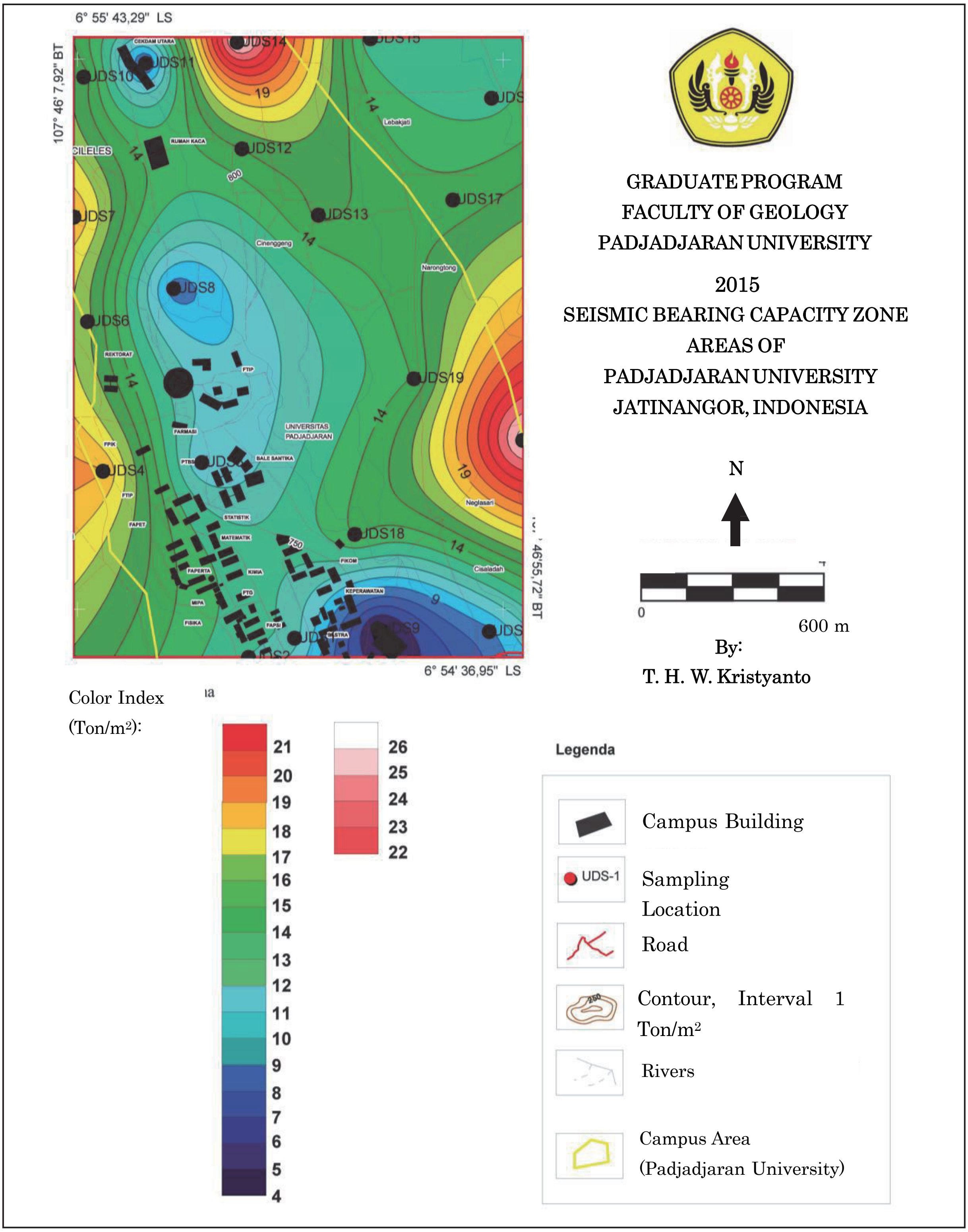

Fig. 3 Zoning Map of Seismic Bearing Capacity of Research Area