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ASSESSMENT OF CYCLIC RESISTANCE RATIO OF BABOLSAR SANDY SOIL BASED ON SEMI-EMPIRICAL RELATIONSHIPS

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ABSTRACT

Semi-empirical procedures for evaluating the liquefaction resistance of saturated sands based on N- SPT test have been re-examined and revised for use in practice by many researchers. In this paper, after presenting different Semi empirical methods based on N-SPT, liquefaction resistance of Babolsar sandy soil considering its geotechnical characteristics was evaluated by each method, Also by considering main parameters affecting on liquefaction resistance, different graphs based on CRR and significant parameters have been drawn.

KEYWORDS: *Liquefaction, Cyclic resistance ratio, saturated sand, Semi empirical method, SPT.*

1- INTRODUCTION

When the concept of critical N-value was first proposed by Koizumi (1966) and Kishida (1966) [1,2] based on their observations of Niigata earthquake of 1964, the availability of data was the primary, if not the only, justification for using the SPT results to express resistance of sands to liquefaction [3].
By assembling a vast quantity of cyclic triaxial test data obtained in Japan, Tatsuoka. et al. (1980) established a correlation based on D_{50} and N values with vertical effective overburden pressure [4].
Field and laboratory observations have shown that the resistance to liquefaction tends to increase with decreasing particle size [5]. A correlation including this effect was also proposed by Tatsuoka et al. (1980) based on corrected blow count value (N) and content of fines in percent [4].
In an effort to identify localities of high liquefaction potential in the bay area of Tokyo, a comprehensive program of undisturbed sampling by means of the Osterberg type sampler and by using a cyclic triaxial test apparatus. The results of this investigation were summarized based on corrected blow count value and fines content [6].

Youd et al. (2001) presented an updated SPT- based method that was recommended by about 20 participants of the NCEER (The National Center for Earthquake Engineering Research) (1997) workshop for liquefaction potential evaluation. [7]
In this paper, after presenting different Semi empirical methods based on blow counts by standard penetration tests, N-SPT, liquefaction resistance of Babolsar sandy soil considering its geotechnical characteristics was evaluated by each method and then different graphs based on CRR and significant parameters have been drawn.

2- SANDY SOIL SPECIFICATIONS

According to Geotechnical investigations conducted on samples of 16 boreholes drilled in the city, most of them are sandy. In addition, water table is very close to surface in the region. Table (1) indicates characteristics of the sandy materials of the region which is required for the evaluation of the soil cyclic resistance ratio by different semi empirical methods.

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Borehole	Depth to groundwater table (m)	Depth(m)	$\sigma'_v\ (KN/m^2)$	Mean particle size, D_{50} (mm)	N_{SPT}	Fines content (%)	Borehole	Depth to groundwater table (m)	Depth(m)	$\sigma'_v\ (KN/m^2)$	Mean particle size, D_{50} (mm)	N_{SPT}	Fines content (%)
BH1		2	33.55	0.218	19	3.39	BH9	2.0	12	130.58	0.249	38	1.1
BH1		3.5	46.88	0.228	20	2.8	BH10		3.5	49.76	0.314	28	0.1
BH1		5	60.82	0.222	18	3.08	BH10		5	63.55	0.314	30	0.1
BH1		6.5	74.98	0.207	25	0.8	BH10	2.0	6.5	77.78	0.205	28	1.1
BH1		8	89.51	0.212	21	1.1	BH10		8	91.27	0.203	23	1.1
BH1	1.7	10	109.09	0.195	24	0.897	BH10		10	109.95	0.215	33	0.1
BH1		12	128.77	0.199	26	0.9	BH10		12	129.83	0.221	37	0.1
BH1		14	148.35	0.201	31	0.8	BH11		3.5	38.34	0.219	6	1.1
BH1		16	167.33	0.226	29	0.6	BH11		5	50.93	0.209	12	1.1
BH1		18	186.61	0.198	34	0.8	BH11		6.5	63.06	0.209	15	0.1
BH1		20	206.79	0.233	35	0.5	BH11		8	75.50	0.208	20	0.1
BH2		2	34.98	0.194	22	0.81	BH11		10	93.68	0.208	22	1.1
BH2		3.5	49.36	0.182	20	1.11	BH11	1.8	12	112.06	0.211	28	1.1
BH2		5	63.67	0.186	25	1.3	BH11		14	130.84	0.21	37	0.1
BH2		6.5	78.28	0.206	23	1.01	BH11		16	150.52	0.212	36	0.1
BH2		8	93.27	0.194	23	1.12	BH11		18	170.00	0.208	39	1.1
BH2	1.7	10	112.55	0.203	26	2.14	BH11		20	189.48	0.212	44	1.1
BH2		12	131.63	0.197	29	1.53	BH11		22.5	215.58	0.207	49	0.1
BH2		14	151.51	0.194	32	1.21	BH12		3.5	42.28	0.205	19	0.1
BH2		16	171.99	0.224	25	0.2	BH12		5	56.29	0.207	20	1.1
BH2		18	193.07	0.203	37	0.41	BH12	1.8	6.5	68.65	0.207	16	1.1
BH2		20	214.25	0.252	36	0.2	BH12		8	81.08	0.212	22	0.1
BH3	2.0	18	163.84	0.121	20	36.82	BH12		10	99.06	0.2	34	0.1
BH3		20	182.22	0.164	24	16.93	BH12		22.5	222.61	0.198	47	1.1
BH4	2.0	18	148.84	0.1808	22	41.47	BH13		3.5	46.09	0.233	10	1.1
BH4		20	166.62	0.241	27	25.65	BH13		5	58.67	0.297	9	0.1
BH5		3.5	51.71	0.239	23	0.3	BH13		6.5	71.18	0.286	26	0.1
BH5		5	66.32	0.215	24	0.3	BH13		8	84.52	0.264	21	1.1
BH5		10	115.22	0.153	25	1.697	BH13		10	103.80	0.272	26	1.1
BH5		12	135.00	0.167	28	1.29	BH13		12	122.98	0.261	35	0.1
BH5	2.0	14	153.58	0.173	33	0.9	BH13	2.0	14	142.56	0.225	33	0.1
BH5		16	172.96	0.172	33	1	BH13		16	162.44	0.208	27	1.1
BH5		18	193.44	0.141	29	1.9	BH13		18	182.12	0.22	33	1.1
BH5		20	213.02	0.137	28	1.9	BH13		20	202.10	0.212	38	0.1
BH5		22.5	237.37	0.137	43	1.91	BH13		22.5	227.70	0.201	32	0.1
BH5		25	262.47	0.161	42	1.5	BH13		25	252.92	0.207	42	1.1
BH6		3.5	44.39	0.346	8	12.62	BH13		27.5	278.77	0.208	41	1.1
BH6		5	56.30	0.206	29	5.82	BH13		30	304.50	0.219	48	0.8
BH6		10	98.80	0.263	27	0.3	BH14		3.5	45.24	0.201	13	4
BH6		12	117.78	0.243	31	0.1	BH14		5	56.77	0.196	10	0.6
BH6	2.0	14	137.76	0.156	34	0.9	BH14		6.5	68.38	0.194	15	0.7
BH6		16	157.24	0.133	29	1.1	BH14		8	80.97	0.196	20	0.6
BH6		18	175.92	0.134	34	1.11	BH14		10	98.35	0.25	20	0.6
BH6		20	194.50	0.147	34	1	BH14		12	115.93	0.224	26	0.8
BH6		22.5	218.22	0.177	47	0.8	BH14	2.0	14	134.41	0.234	30	0.7
BH6		25	242.82	0.14	43	0.91	BH14		16	153.49	0.223	36	0.9
BH7		2	33.36	0.168	10	6.9	BH14		18	173.67	0.2	39	1.2
BH7	1.7	3.5	48.64	0.284	28	5.2	BH14		20	193.85	0.224	36	0.8
BH7		5	63.18	0.223	26	0.5	BH14		22.5	218.20	0.223	34	0.9
BH8		2	35.69	0.168	23	5.5	BH14		25	243.05	0.238	44	0.7
BH8	1.8	3.5	51.12	0.284	26	5.2	BH14		27.5	268.27	0.202	44	1.1
BH8		8	98.78	0.217	34	0.7	BH14		30	293.50	0.279	46	0.5
BH9		3.5	48.86	0.237	18	0.2	BH15	3.0	3.5	63.00	0.267	4	0.3
BH9		5	62.12	0.226	24	0.1	BH15		8	103.40	0.225	10	9.7
BH9	2.0	6.5	76.66	0.206	28	0.1	BH16		3.5	64.00	0.228	5	0.3
BH9		8	90.82	0.262	31	0.8	BH16	3.0	5	76.28	0.234	28	0.3
BH9		10	110.00	0.255	35	0.9	BH16		8	100.85	0.218	12	3.1

Table 1: characteristics of the sandy materials of the region

3- CRR BASED ON EMPIRICAL METHODS

Using different methods presented by researchers based upon N-SPT and Geotechnical parameters impacting on soil liquefaction resistance, cyclic resistance ratio of the sandy soil of the region has been evaluated. There are three major characteristics in these methods impacting on the evaluation of liquefaction resistance of sandy soils including normalized blow counts by standard penetration tests with overburden (N_1), mean particle size (D_{50}), and percent of fine content of soil (FC).

By assembling a vast quantity of cyclic triaxial test data obtained in Japan, Tatsuoka. et al. (1980) established a correlation as Eq (1) [4].

$$(\frac{\tau_d}{\sigma'_0})_{20} = 0.0676\sqrt{N_1} + 0.225\log_{10}(\frac{0.35}{D_{50}}) \qquad 0.04mm \le D_{50} \le 0.6mm \qquad \text{(1-a)}$$

$$(\frac{\tau_d}{\sigma'_0})_{20} = 0.0676\sqrt{N_1} - 0.05 \qquad 0.6mm \le D_{50} \le 1.5mm \qquad \text{(1-b)}$$

where D_{50} is the mean particle diameter in millimeters, $(\frac{\tau_d}{\sigma'_0})_{20}$ denotes the cyclic stress ratio required to cause initial liquefaction or 5% double amplitude strain in 20 cycles of shear stress application and N_1 means the N-value of SPT normalized to an effective overburden pressure of 1 kgf/cm^2 and based on the formula by Meyerhof (1957) [8] as Eq (2).

$$N_1 = C_N.N$$

$$C_N = \frac{1.7}{\sigma'_V + 0.7} \qquad (2)$$

where σ'_V is the vertical effective overburden pressure in kgf/cm^2.

While the 50 percent particle diameter, D_{50}, is used in Eq. (1) to allow for the effect of particle size, the amount of fines contained in sandy soils may also be used as an index parameter to account for the same effect. A correlation including this effect was also proposed by Tatsuoka et al. (1980) as Eq.(3) [4].

$$(\frac{\tau_d}{\sigma'_0})_{20} = 0.0676\sqrt{N_1} + 0.0035C \qquad (3)$$

where C is the content of fines in percent passing the # 200 mesh and N_1 , corrected blow count value of standard penetration test, defined as Eq.(2).

In an effort to identify localities of high liquefaction potential in the bay area of Tokyo, a comprehensive program of undisturbed sampling by means of the Osterberg type sampler and by using a cyclic triaxial test apparatus. The results of this investigation were summarized by Ishihara (1979) based on Eq. (4) [5].

$$(\frac{\tau_d}{\sigma'_0})_{20} = 0.009(N_1 + 13 + 6.5\log_{10} C) \qquad (4)$$

where $(\frac{\tau_d}{\sigma'_0})_{20}$ denotes the cyclic stress ratio in 20 cycles of shear stress application, C content of fines in percent and N_1 is based on that proposed by Peck et al. (1974) as Eq.(5) [9].

$$N_1 = C_N.N$$

$$C_N = 0.77\log_{10}(20/\sigma'_V) \qquad (5)$$

Where σ'_V is the vertical effective overburden pressure in KN/m^2.

Youd et al. presented an updated SPT- based method that was recommended by about 20 participants of the NCEER workshop for liquefaction potential evaluation [7].

Fig (1) is the flowchart showing the equations and procedures to calculate the cyclic resistance ratio at earthquake moment magnitude of 7.5, $CRR_{7.5}$, using the NCEER SPT-based method [7].

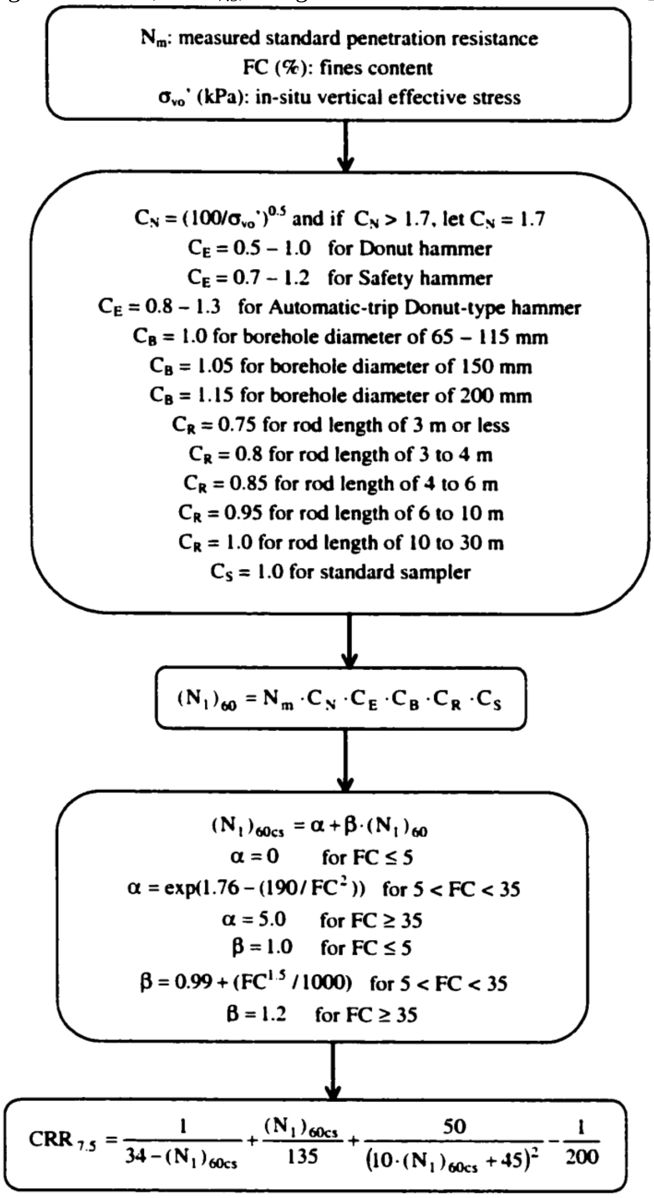

Figure 1: Flowchart for estimating the cyclic resistance ratio at earthquake magnitude of 7.5

using the NCEER SPT-based method

4- EFFECT OF MAIN PARAMETERS ON LIQUEFACTION RESISTANCE

A number of factors influence liquefaction resistance of soil, including soil density, soil composition and grain characteristics, in-situ stress condition, soil structure and age, and previous strain history. [10].
The most important parameters impacting on aforesaid factors will be enumerated and their effects on soil liquefaction will be evaluated as follows:

4-1- EFFECT OF MEAN PARTICLE SIZE (D_{50}) ON CRR

Lee and Fitton [11], showed a strong dependence of liquefaction potential on mean grain size of the soil. As the mean grain size increases, the resistance to liquefaction also increases. As data by Wong et al [12], when mean grain size increases from 0.1 to 30 mm, there is a 30% increase in cyclic strength to cause 2.5% strain. As the mean grain diameter passes 0.2 mm, which is the typical silt size, an increase in cyclic strength is observed.
Fig (2) depicts the effect of mean particle size (D_{50}) against cyclic resistance ratio of Babolsar sand calculated by using different methods and data on sand of the region. As the figure shows, point distribution dose not indicate an obvious trend. It is possible to attribute this issue to the narrow range of mean grain size ($0.121mm \le D_{50} \le 0.341mm$), 70% of which are about 0.2 mm that indicates the uniformity of the sandy soil of the region. In most methods presented by different researchers, the impact of mean grain size on liquefaction resistance of sandy soils is of a wider range.

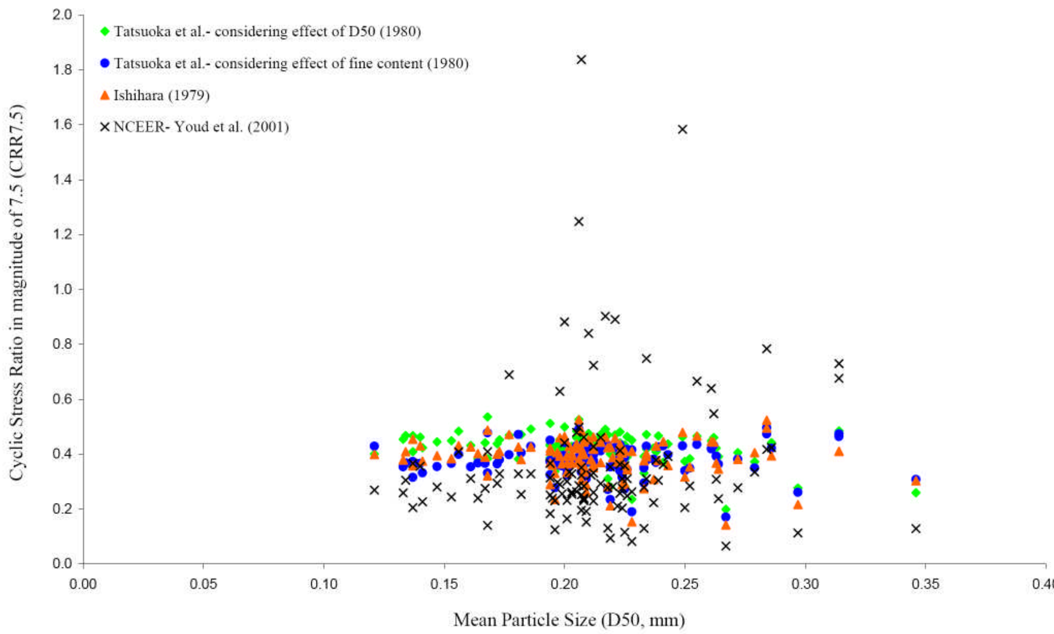

Figure 2: Effect of mean particle size (D_{50}) against cyclic resistance ratio of Babolsar sand

4-2- EFFECT OF FINE CONTENT ON CRR

In addition to D_{50}, percentage of soil fine content (FC) is impacting on cyclic resistance and susceptibility of soil to liquefaction. Field and laboratory observations have shown that liquefaction resistance tends to increase with decrease in particle size. Therefore, cyclic stress ratio leading to liquefaction increases with decrease in particle size for the same penetration resistance (N-SPT) [5].
The Presence of fines (passing #200 sieve), has substantial effect on cyclic undrained behavior of sands. The difference in behavior between pure sand specimens and specimens prepared by adding 10% non-plastic silt is not significant. The effect is more pronounced when the silt content exceeds 10%.

Fig (3) indicates the effect of soil fine content versus cyclic resistance ratio of Babolsar sand calculated by using different methods and data on sand of the region. As the figure shows fine content distribution up to 10% does not indicate an obvious trend denoting to have an impact on the soil liquefaction resistance, but exceeding 10% a certain trend announcing an increase in cyclic resistance ratio is observed. This trend has been determined as curves for various methods of calculating soil liquefaction resistance and their relationship gained from regression of exponential function has been presented.

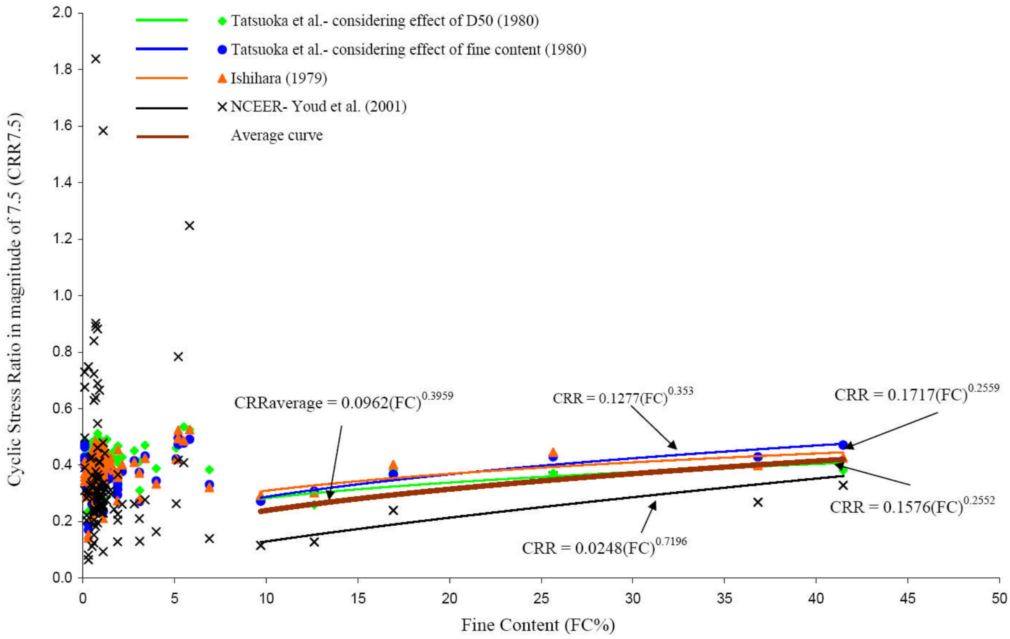

Figure 3: Effect of soil fine content versus cyclic resistance ratio of Babolsar sand

4-3- EFFECT OF SPT NUMBER AND OVERBURDEN ON CRR

The quantity of N gained from Standard Penetration Test is used as a proper parameter to describe cyclic resistance of sandy soils against liquefaction as well. Since, SPT is an insitu test reflecting the effects of history of stress and strain, soil fabric, and horizontal effective stress. In addition, it contains compositional effects of relative density and vertical stress, which all aforesaid factors are known to impacting on the resistance of sands against liquefaction [13]. Relationships presented based on field and laboratory observations by various researchers show that liquefaction resistance tends to increase with increase in corrected SPT number (N_1) with overburden. In most relationships offered by different researchers based on SPT test, soil cyclic resistance has a direct relation with correction coefficient of overburden (CN) for N-SPT, (eq 1&3). Also in relations of correction coefficient of overburden (CN), insitu overburden stress has an inverse relation ($\sigma'_V \approx 1/C_N$,eq 2&5) with the coefficient, which indicates the decrease in corrected N-SPT with increase in stress level. After calculating cyclic resistance ratios by using suggested methods, it was observed that cyclic resistance of the soil has a powerful relation with the ratio of N-SPT to square overburden vertical effective stress ($N/\sqrt{\sigma'_V}$). Fig (4) indicates the relation between cyclic resistance ratio, N-SPT and square vertical overburden stress of sandy soil of the region.

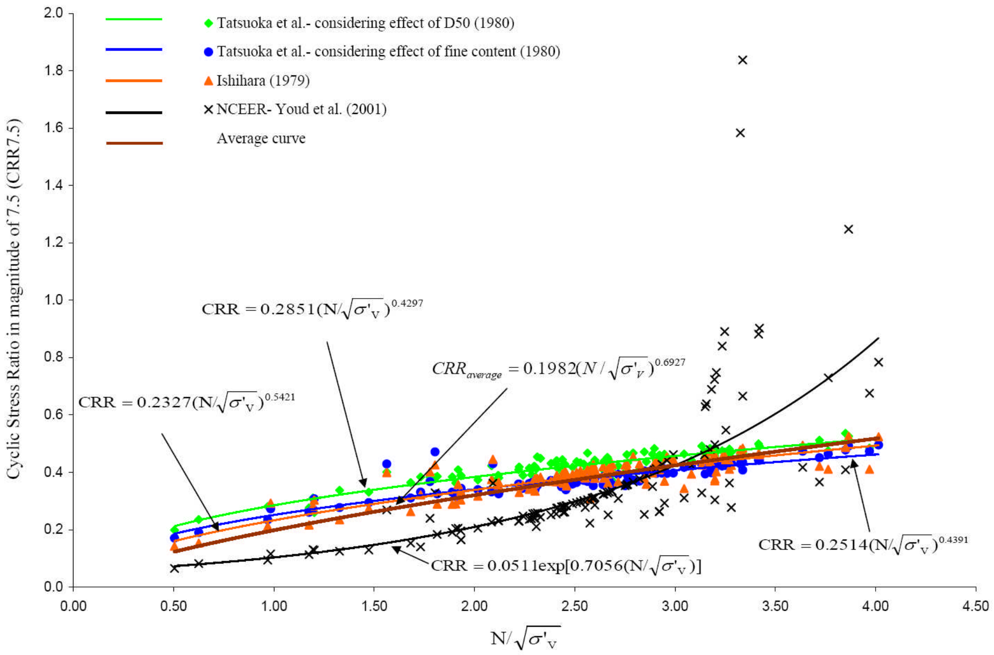

Figure 4: relation between cyclic resistance ratio, N-SPT and square of vertical overburden stress of sandy soil of the region

5- CONCLUSION

Liquefaction resistance of sandy soil of Babolsar considering its geotechnical characteristics was evaluated using different semi-empirical methods based upon N-SPT. different graphs based on CRR and considering main parameters affecting on liquefaction resistance, such as N-SPT, overburden, mean grain size, and fine content, have been drawn.

6- References

[1] Koizumi, Y. (1966) “Changes in density of sand subsoil caused by the Niigata Earthquake,” Soil and Foundation, Vol.6, No.2, pp.38-44.

[2] Kishida, H. (1966) “Damage to reinforced concrete buildings in Niigata City with special reference to foundation engineering,” Soil and Foundation, Vol.6, No.1, pp.71-88.

[3] Tokimatsu, K. and Yoshimi, Y. (1983), “Empirical Correlation of Soil Liquefaction Based on SPT N-Value and fines Content,” Soils and Foundations, Vol.23, No.4, pp.56-74.

[4] Tatsuoka, F., Iwasaki, T., Tokida, K., Yasuda, S., Hirose, M., Imai, T. and Kon-no, M. (1980), “Standard Penetration Tests and Soil Liquefaction Potential Evaluation,” Soils and Foundations, Vol. 20, No.4, pp.95-111.

[5] Ishihara, K. (1985), “Stability of Natural Deposits during Earthquakes,” Proc. 11th International Conference on Soil Mechanics and Foundation Engineering, San Francisco, Vol. 2, pp.321-376.

[6] Ishihara, K. (1979), “Evaluation of liquefaction Potential in Tokyo Bay Area,” Report to Tokyo Metropolitan office.

[7] Youd, T.L., Idriss, I.M., et al. (2001) “Liquefaction Resistance of Soils: Summary Report form the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils”, Journal of Geotechnical and Geoenvironmental Engineering, 127(4): 297-313.

[8] Meyerhof, G. G. (1957), “Discussion of Session 1,” Proc. 4th International Conference on Soil Mechanics and Foundation Engineering London, Vol.3.

[9] Peck R. B., Hanson, W. E. And Thornburn, T. H. (1974), “Foundation Engineering”, 2nd Ed. Willey, New York, pp.113-115.

[10] Zhang, G. (2001), “Estimation of Liquefaction-induced Ground Deformations by CPT&SPT-based Approaches” PhD thesis, Edmonton, University of Alberta.

[11] Lee, K. L. and Fitton, J.A. (1969) “Factors Affecting the Cyclic Loading Strength of Soil” ASTM STP 450, American Society of Testing Materials, pp. 71-95.

[12] Wong, R. T., Seed, H. B., and Chan, C. K., (1975) Journal of Geotechnical Engineering Division, ASCE, Vol. 101, No. GT6 pp. 571-583.

[13] Seed, H. B. (1979), “Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground during Earthquakes,” Proc. ASCE, Vol. 105, GT2, pp.201-255.