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PROBABLE LIQUEFACTION PROBLEM IN BANGLADESH

Ripon Hore, (PhD)
Senior Assistant Engineer, LGED
Email: riponhore@gmail.com

Abstract

The purpose of this research is to describe the liquefaction potential and estimate the earthquake induced liquefaction potential of selected reclaimed areas of Dhaka city (two case studies). The filling depth of the reclaimed areas varies from 1.5 to 13.5 m from the existing ground level (EGL). For the liquefaction analyses, the values of peak ground acceleration, a_{max} and the magnitude, M have been taken as 0.15g and 7.5, respectively. The range of SPT-N, Cone tip resistance (MPa), local friction (kPa) and friction ratio varies between 1~42, 0.17~18.58, 0~273.2 and 0~9.34 respectively of the ten selected sites. Liquefaction potential has been estimated based on both CPT and SPT data. It has been observed that in reclaimed areas of Dhaka city especially for the locations reclaimed by dredged soil up to a filling depth of 1.5 to 4.5m there is high probability of liquefaction occurrence. In most of the cases, liquefaction zone for CPT have been observed in two different depth zones. Liquefaction zone for CPT of Uttara and Kamrangir Char are the range of obtained values of Over consolidation ratio (OCR), Preconsolidation stress (kPa)**,** Coefficient of lateral earth pressure (K_0) and Angle of internal friction (ϕ). varies between 0.08~61.33, 2.69~463, 0.107~5.45 and 21~45 respectively for the two selected sites.

Introduction

Liquefaction problem became important when it started to affect human and social activities by disturbing the function of facilities and also after rapid urbanization by expanding the cities in reclaimed areas. Ground failures generated by liquefaction had been a major cause of damage during past earthquakes e.g., 1964 niigata, Japan and 1964 Alaska,USA, 1971 San Fernando, 1989 Loma prieta,1995 Kobe, Japan and 2004 Chuetsu, Japan earthquakes. Liquefaction affects buildings, bridges, buried pipelines and lifeline facilities etc in many ways.

The historical seismicity data and recent seismic activities in Bangladesh and adjoining areas indicate that Bangladesh is at high seismic risk. As Bangladesh is the world's most densely populated area, any future earthquake shall affect more people per unit area than other seismically active regions of the world. Bangladesh including capital city Dhaka is largely an alluvial plain consisting of fine sand and silt deposits with shallow ground water table in most places. Although the older alluvium is less susceptible to liquefaction, the deposits along the river flood plains may liquefy during a severe earthquake. Human made soil deposits also deserve attention. Loose fills, such as those placed without compaction, are very likely to be susceptible to liquefaction.

Over the past 30~40 years Dhaka city has experienced a rapid growth of urban population and it will continue in the future due to several unavoidable reasons. This high population increase demands rapid expansion of the city. Unfortunately, most parts of Dhaka city has already been occupied. As a result, new areas have been reclaimed by both government and private agencies in and around Dhaka city. In many cases, the practice for developing such new areas is just to fill lowlands of the depth 3~12m with dredged material consisting of silty sand. This causes liquefaction susceptibility for such areas.

After recognizing the liquefaction phenomenon during the 1964 great Nigata and 1964 Alaska earthquakes, many researchers have presented the liquefaction determination procedures like Japanese code of bridge design (1990) including Chinese criterion, Seed-Idriss simplified procedure, which have been updated over the years (e.g., seed et al.,1983). A few researches have conducted liquefaction possibilities at local levels in Bangladesh. Rashid (2000) developed seismic microzonation map of Dhaka city based on site amplification and liquefaction. Rahman (2004) updated the seismic microzonation maps for liquefaction as well as site amplification due to earthquake. Saha (2005) developed liquefaction potential map for Rangpur town. Islam (2005) estimated the seismic losses especially due to liquefaction for Sylhet city. Islam and Ahmed (2005) conducted preliminary evaluation of liquefaction potential of some selected reclaimed area of Dhaka city. Tanvir (2009) estimated earthquake induced liquefaction potential of selected areas of Dhaka city based on shear wave velocity. It was that some parts of the reclaimed areas are susceptible to liquefaction. But those studies were mostly based on SPT N value. The reliability of such SPT data in Bangladesh is questionable. Liquefaction potential estimated using different methods which have been based on SPT data are also different. It has been felt necessary to develop a suitable analysis method to evaluate liquefaction potential for reclaimed areas of Dhaka soil based on Cone Penetration Test (CPT) results.

Geology of Dhaka city

Dhaka city which is a metropolis as well as the capital city of Bangladesh lies between latitude 23°40’ N to 23°54’ N and longitude from 90°20’ E to 90°30’ E and covers an area of about 470 km^2 having the altitude of 6.5 to 9 m above mean sea level. Geologically, it is an integral part in the southern tip of the Madhupur tract an uplifted block in the Bengal basin, with many depressions of recent origin in it. It is bounded by the Tongi khal (Small River) in the North, the Bariganga river in the south and southeast, the Balu river in the East and Turag river in the West.

The subsurface geology of Dhaka city shows that upper formation is Madhupur clay layer and termed as aquitard and it is 6 to 12 m thick in most parts of the city. The Madhupur clay mainly consists of Kaolinite (27~53%) and Illite (14~33%) with very small amount of Illite smectite (2~13%) down to 5m depth (Zahid et al., 2004). However, below the clay layer, medium to coarse grained formation exist.

Kamal and Midorikawa (2004) delineated the geomorphology of Dhaka city area, differentiating the ground of the city into seventeen geomorphic units using aerial photographs. These geomorphic units represent the soil conditions.surface geology of Dhaka with minor anthropogenic modifications. It has been observed that the city has been expanding rapidly even in the low-lying geomorphic units by fill practices for urban growth since 1960. They also classified the fill-sites into four classes based on the thickness of fills. In order to collect the fill-thickness, the boreholes and old topographic map prepared in 1961 are used. Later on, the classified fills have been integrated with the pre-urban geomorphic-soil units. Figure 1 shows the geological map of Bangladesh.

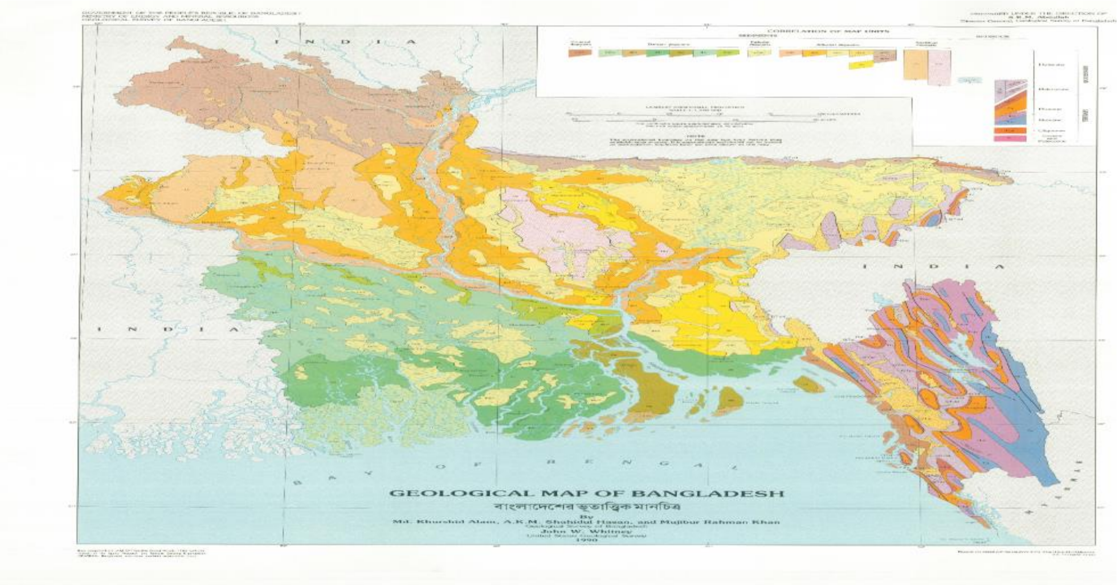

Fig 1: Geological map of Bangladesh (Geological survey of Bangladesh)

Alluvial Silt and Clay: Medium to dark grey Silt to Clay; Colour is darker as amount of organic anmaterial increases. Map unit is a combination of alluvial and paludal deposits; includes flood–basin Silt, backs wamp silty clay, and organic rich Clay in sag ponds and large depressions. Some depressions contain peat. Large areas underlain by this unit are dry only a few months of the years the deeper part of depressions and bils contains water throughout the year.

Alluvial Silt: Light to medium grey, Fine sandy to clayey silt. Commonly poorly stratified; average grain size decreases away from main channels. Chiefly deposited in flood basins and interstream areas. Units includes small backswamp deposits and varying episodic or unusually large floods. Illite is the most abundant clay mineral. Most areas have been flooded annually. Included in this unit are thin veneers of sand spread by episodic large floods over flood plain silts. Historic potery, artifact, and charcoal found in upper 4 m.

Madhupur Clay residuum: light yellowish grey, orange, light to brick red and grayish white, amicaceous silty clay to sandy clay; plastic and abundentey mattled in upper 8 m, contains small clusters of organic matter. Sand fraction dominantly quartz; minor feldspar and mica; sand content increases with depth. Dominant clay minerals are kaolinite and Illite. Iron manganese oxide modules rare.

Seismicity in Bangladesh and problem hazards

Significant damaging historical earthquakes have occurred in and around Bangladesh and damaging moderate magnitude earthquake occurred every few years. The country's position adjacent to the very active Himalayan front and ongoing deformation in nearby parts of south-east Asia expose it to strong shaking from a variety of earthquake sources that can produce tremors of magnitude 8 or greater. The potential for magnitude 8 or greater earthquake on the nearby Himalayan front is very high, and the effects of strong shaking from such an earthquake directly affect much of the country. In addition, historical seismicity within Bangladesh indicates that potential for damaging moderate to strong earthquake exist throughout most of the country.

Large earthquakes occur less frequently than serious floods, but they can affect much larger areas and can have long lasting economic, social and political effects. Bangladesh covers one of the largest deltas and one of the thickest sedimentary basins in the world. According to the report on time predictable fault modeling CDMP (2009), earthquake and tsunami preparedness component of CDMP have identified five tectonic fault zones which may produce damaging earthquakes in Bangladesh. These are :

a) Madhupur fault zone
b) Dauki fault zone.
c) Plate boundary fault zone-1
d) Plate boundary fault zone-2
e) Plate boundary fault zone-3

Considering fault length, fault characteristics, earthquake records etc, the maximum magnitude of earthquakes that can be produced in different tectonic blocks have been given in Table 1.

In the generalized tectonic map of Bangladesh as shown in Figure 2 the distribution of epicenters has been found to be linear along the Dauki fault system and random in other regions of Bangladesh. The investigation of the map demonstrates that the epicentres are lying in the weak zones comprising surface or subsurface faults. Most of the events are of moderate rank (magnitude 4~6) and lie at a shallow depth, which suggests that the recent movements occurred in the sediments overlying the basement rocks. In the northeastern region (surma basin), major events have been controlled by the Dauki fault system. The events located in and around the Madhupur tract also indicate shallow displacement in the faults separating the block from the alluvium. Figure 2 shows the major fault lines which affect seismicity in Bangladesh.

Information of earthquake in and around Bangladesh is available for the last 250 years . Among these, during the last 150 years, seven major earthquakes have affected Bangladesh. The surface wave magnitude, maximum intensity according to European Macroseismic scale (EMS) and epicentral distance from Dhaka has been presented in Table.3. Characteristics of some recent earthquakes have also been shown in Table 2.

Table 1 Maximum estimated earthquake magnitude in different tectonic faults (CDMP, 2009)

Fault zone	Earthquake events	Estimated magnitude, m_w
Madhupur fault zone	AD 1885	7.5
Dauki fault zone	AD 1897. AD 1500 to 1630 (AD 1548)	8.0
Plate Boundary-1	AD 1762, AD 680 to 980, BC 150 to AD 60, BC 395 to 740	8.5
Plate Boundary-2	Before 16th century	8.0
Plate Boundary-3	Before 16th century	8.3

Table 2 Recent earthquakes in Bangladesh

Date	Place of earthquake	magnitude	Destructions
13 november,1997	Chittagong	6.0	It caused minor damage around Chittagong town.
12 july,1999	Maheshkhali Island	5.2	Severely felt around maheshali island and the adjoining sea.
7 july,2003	Kolabunia union of barkal upazila, rangamati district	5.1	Houses cracks and landslides.

Table 3 List of major earthquake affecting Bangladesh during last 150 years (Ms>7) (Sabri, 2002)

Date	Name of earthquake	Surface wave magnitude (m_s)	Maximum intensity (EMS)	Epicentral distance from Dhaka (km)	Basis
10 january, 1869	Cachar earthquake	7.5	IX	250	Back calculation from intensity
14 july,1885	Bengal earthquake	7.0	VII to IX	170	Directly from seismograph
12 june, 1897	Great Indian earthquake	8.7	X	230	
8 july,1918	Srimongal earthquake	7.0	VII to IX	150	
2 july,1930	Dhubri earthquake	7.1	IX	250	
15 january,1934	Bihar-nepal earthquake	8.3	X	510	
15 August,1950	Assum earthquake	8.5	X	780	

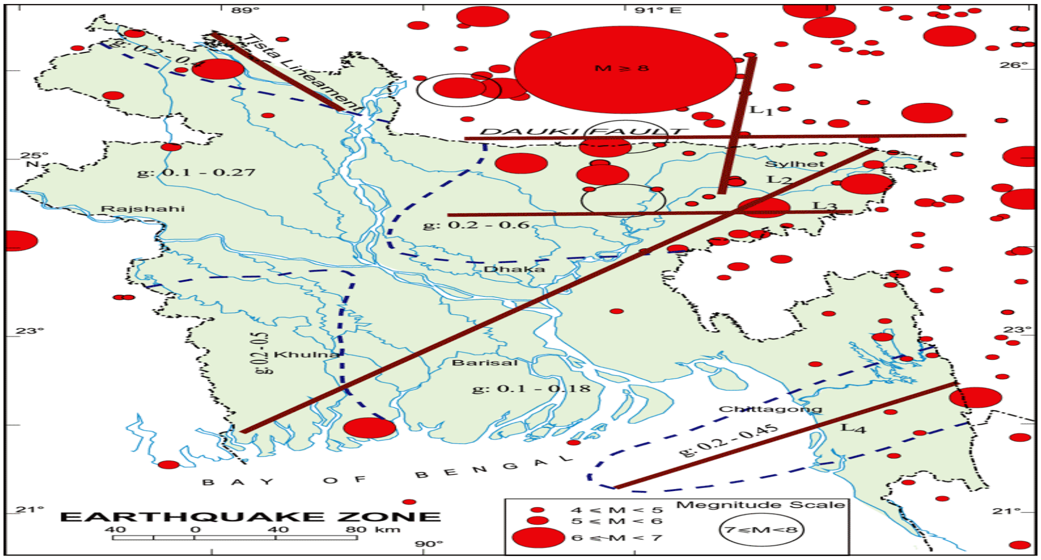

Fig 2: Seismo-tectonic lineaments capable of producing damaging earthquakes (Source: www.banglapedia.com)

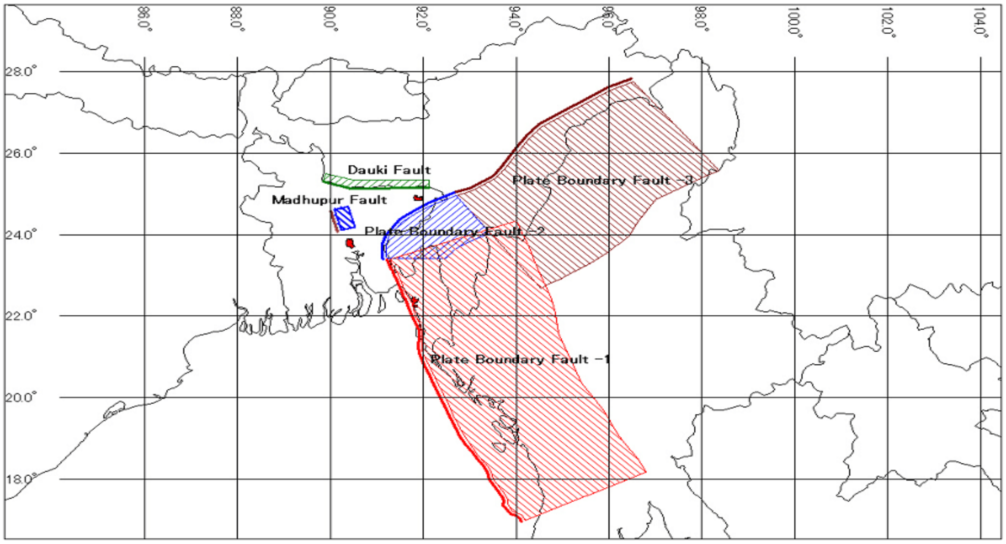

Fig 3: The major fault lines which affect seismicity in Bangladesh (CDMP,2009)

Liquefaction and its significant

If saturated sand has been subjected to ground vibrations, it tends to compact and decrease in volume; if drainage is unable to occur/prevented, the tendency to decrease in volume results in an increase in pore water pressure, and if the pore water pressure builds up to the point at which it is equal to the overburden pressure, the effective stress become zero, the sand loses its strength completely, and it develops a liquefied state.

The liquefaction problem has been attracting engineering concern for about past 35 years. It was not considered important before, although large earthquakes had caused liquefaction in loose sand deposits. This seems so because cities in old times were not too large and were confined within areas of state deposits, reclaimed land was rare, and attention was paid mostly to such seismic effects as collapse and burning of buildings. The liquefaction problem became important for the first time when it started to affect human and social activities by disturbing the function of facilities. The loss of function can be follows:

a) Subsidence of road embankments which leads to cracking in surface pavements and block traffic.

b) Building subsidence and tilting to such an extent that its normal use is not possible.

c) Lateral movement of bridge abutments and piers, as well as , in the most extreme cases, collapse of a bridge.

d) Breakage and separation of buried pipes, which take supply of water and gas out of service.

e) Floating of sewerage treatment tanks and buried pipes, which make normal flow of water impossible.

Liquefaction phenomena can affect buildings, bridges, buried pipelines and other constructed facilities in many different ways. Liquefaction can also influence the nature of ground surface motions. Flow liquefaction can produce massive flow slides and contribute to the sinking or tilting of heavy structures, the floating of light buried structures, and to the failure of retaining structures. Cyclic mobility can cause slumping of slopes, settlement of buildings, lateral spreading and retaining wall failure. Substantial ground oscillation, round surface settlement, sand boils and post-earthquake stability failures can develop at level ground sites. Figure 4 shows the some effects of liquefaction during the 1964 Niigata, Japan earthquake.

Soil liquefaction describes the behavior of soils that, when loaded, suddenly go from a solid state to a liquefied state, or having the consistency of a heavy liquid. Liquefaction is more likely to occur in loose to moderate saturated granular soils with poor drainage, such as silty sands or sands and gravels capped or containing seams of impermeable sediments. During loading, usually cyclic undrained loading, e.g. earthquake loading, loose sands tend to decrease in volume, which produces an increase in their pore water pressures and consequently a decrease in shear strength, i.e. reduction in effective stress**.**

Liquefaction can cause damage to structures in several ways. Buildings whose foundations bear directly on sand which liquefies will experience a sudden loss of support, which will result in drastic and irregular settlement of the building. Liquefaction causes irregular settlements in the area liquefied, which can damage buildings and break underground utility lines where the differential settlements are large. Pipelines and ducts may float up through the liquefied sand. Sand boils can erupt into buildings through utility openings, and may allow water to damage the structure or electrical systems. Soil liquefaction can also cause slope failures. Areas of land reclamation are often prone to liquefaction because many are reclaimed with hydraulic fill, and are often underlain by soft soils which can amplify earthquake shaking. Soil liquefaction was a major factor in the destruction in San Francisco's Marina District during the 1989 Loma Prieta earthquake. Mitigating potential damage from liquefaction is part of the field of geotechnical engineering.

If saturation sand has been subjected to ground vibrations, it tends to compact and decrease in volume; if drainage is unable to occur/prevented, the tendency to decrease in volume results in an increase in pore water pressure, and if the pore water pressure builds up to the point at which it is equal to the overburden pressure, the effective stress become zero, the sand loses its strength completely, and it develops a liquefied state.

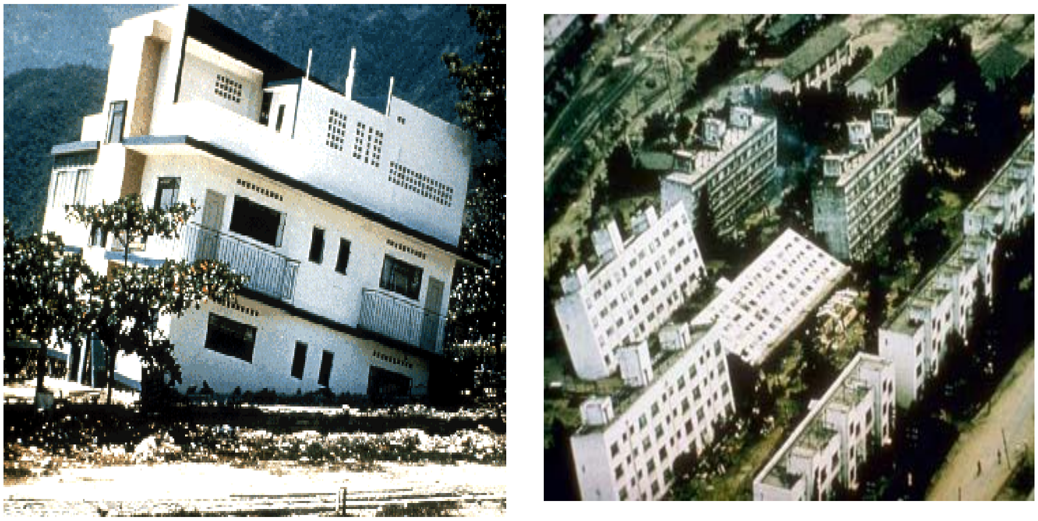

Fig 4: Some effects of liquefaction during the 1964 Niigata, Japan earthquake.

Main Factors that Govern Liquefaction

There are many factors that govern the liquefaction process for in situ soil. Based on results of laboratory tests as well as field observations and studies, the most important factors that govern liquefaction are as follows:

1. Earthquake Intensity and Duration

In order to have earthquake induced liquefaction of soil, there must be ground slinking. The character of the ground motion, such as acceleration and duration of shaking, determines the shear strains that cause the contraction of the soil particles and the development of excess pore water pressures leading to liquefaction. The most common cause of liquefaction is due to the seismic energy released during an earthquake. The potential for liquefaction increases as the earthquake intensity and duration of shaking increase. Those earthquakes that have the highest magnitude will produce both the largest ground acceleration and the longest duration of ground shaking. Although data are sparse, there would appear to be a shaking threshold that has been needed produce liquefaction. These threshold values are a peak ground acceleration a_{max} of about 0.10_g and local magnitude M_L of about 5 (Ishihara 1985). Thus, a liquefaction analysis would typically not be needed for those sites having a peak ground acceleration a_{max} less than 0.l0g or a local magnitude M_L less than 5. Besides earthquakes, other conditions can cause liquefaction such as subsurface blasting, pile driving and vibrations from train traffic.

2. Groundwater Table

The condition most conducive to liquefaction is a near-surface groundwater table. Unsaturated soil located above the groundwater table will not liquefy. If it can be Unsaturated that the soils are currently above the groundwater table and are highly Unlikely to become saturated for given foreseeable changes in the hydrologic regime, then such soils generally do not need to be evaluated for liquefaction potential. At sites, where the ground water table significantly fluctuates, the liquefaction potential Will also fluctuate. Generally, the historic high groundwater level should be used in the liquefaction analysis unless other information indicates a higher or lower level is appropriate (Division of Mines and Geology, 1997).

Poulos et al. (1985) state that liquefaction can also occur in very large masses of Sands or silts that are dry and loose and loaded so rapidly that the escape of air from the voids is restricted. Such movement of dry and loose sands is often referred to as running soil or running ground Although such soil may flow as liquefied soil does, in this text, such soil deformation will not be termed liquefaction. It is best to *con*sider that liquefaction only occurs for soils that are located below the groundwater table.

3. Soil Type

In terms of the Soil Types most susceptible to liquefaction, Ishihara (1985) states: “The hazard associated with soil liquefaction during earthquakes has been known to be encountered in deposits consisting of fine to medium sand and sands containing low plasticity fines. Occasionally, however, cases are reported where liquefaction apparently occurred in gravelly soils.” Thus, the soil types susceptible to liquefaction are non-plastic (cohesionless) soils. An approximate listing of cohesionless soils from least to must resistant to liquefaction is clean sands, non-plastic silty sands, non-plastic silt and gravels. There could be numerous exceptions to this sequence. For sample Ishihara (1985 and 1993) describes the case of tailings derived from the industry that were essentially composed of ground-up rocks and were clasified as rock flour. Ishihara (1985 and 1993) states that the rock flour in a water saturated slate did not possess significant cohesion and behaved as if it were clean sand. These tailings were shown to exhibit as low a resistance to liquefaction as clean sand.

Seed et al. (1983) stated that based on both laboratories testing and field performance, the great majority of cohesive soils will not liquefy during earthquakes. Using criteria originally staled by Seed and Idriss (1982) and subsequently confirmed by Youd and Oilstrap (1999): in order for a cohesive soil to liquefy, it must meet all the following three criteria:

- The soil must have less than 15 percent of the particles, based on dry weight, that are finer than 0.005 mm (i.e., percent finer at 0.005 mm < 15 percent).
- The soil must have a liquid limit (LL) that is less than 35.
- The water content, w of the soil must be greater than 0.9 of the liquid limit**.**

If the cohesive soil does not meet all three criteria, hence it is generally considered to be not susceptible to liquefaction. Although the cohesive soil may not liquefy, there could still be a significant undrained shear strength loss due to the seismic shaking.

4. Soil Relative Density, D_r

Based on field studies, cohesionless soils in a loose relative density state are susceptible to liquefaction. Loose non-plastic soils will contract during the seismic shaking which will cause the development of excess pore water pressures. Upon reaching initial liquefaction, there will be a sudden and dramatic increase in shear deplacement for loose sands. For dense sands, the state of initial liquefaction does produce large deformations because of the dilation tendency of the sand upon of the cyclic shear stress. Poulos et al. (1985) state that if the in situ soil can be shown to be dilative, then it need not be evaluated because it will not be susceptible to liquefaction. In essence, dilative soils are not susceptible to liquefaction because undrained shear strength is greater than their drained shear strength.

5. Particle Size Gradation

Uniformly graded non-plastic soils tend to form more unstable particle arrangements and are more susceptible to liquefaction than well-graded soils. Well-graded soils will also have small particles that fill in the void spaces between the large particles. This lends to reduce the potential contraction of the soil, resulting in less excess pore water pressures being generated during the earthquake. Kramer (1996) states that field evidence indicates that most liquefaction failures have involved uniformly graded granular soils.

6. Placement Conditions or Depositional Environment

Hydraulic fills (fill placed under water) tend to be more susceptible to liquefaction because of the loose and segregated soil structure created by the soil particles falling through water. Natural soil deposits formed in lakes, rivers, or the ocean also tend to a loose and segregated soil structure and are more susceptible to liquefaction, Soils that are especially susceptible to liquefaction are formed in lacustrine, alluvial, and marine depositional environments.

7. Drainage. Conditions

If the excess pore water pressure can quickly dissipate, the soil may not liquefy. Thus highly permeable gravel drains or gravel layers can reduce the liquefaction potential of adjacent soil.

8. Confining Pressures

The greater the confining pressure, the less susceptible the soil is to liquefaction. Conditions that can create a higher confining pressure are a deeper groundwater Table, soil that is located at a deeper depth below ground surface, and a surcharge pressure applied at ground surface. Case studies have shown that the possible zone of liquefaction usually extends from the ground surface to a maximum depth of about 50 ft (15 m). Deeper soils generally do not liquefy because of the higher confining pressures. This does not mean that a liquefaction analysis should not be performed for soil that is below depth of 50 ft (15 m). In many cases, it may be appropriate to perform a liquefaction analysis for soil that is deeper than 50 ft (15 m). An example would be sloping ground, such as a sloping berm in front of a waterfront structure or the slopingg shell of an earth dam. In addition, a liquefaction analysis should be performed for any soil deposit that has been loosely dumped in water (i.e., the liquefaction analysis should be performed for the entire thickness of loosely dumped fill in water, even if it exceeds 50 ft in thickness). Likewise, a site where alluvium is being rapidly deposited may also need a liquefaction investigation below a depth of 50 ft (15 m). Considerable experience and judgment are required in the determination of the proper depth to terminate a liquefaction analysis.

9. Particle Shape

The soil particle shape can also influence liquefaction potential. For example, soils having rounded particles tend to densify more easily than angular-shape soil particles. Hence, a soil containing rounded soil particles is more susceptible to liquefaction than a soil containing angular soil particles.

10.Aging and Cementation

Newly deposited soils tend to be more susceptible to liquefaction than older deposits of soil. It has been shown that the longer a soil is subjected to a confining pressure, the greater the liquefaction resistance (Yoshim, M.,1991). The increase in liquefaction resistance with time could be due to the deformation or compression of soil particles into more stable arrangements. With time, there may be the development of bonds due to cementation at particle contacts.

11.Historical Environment

It has also been determined that the historical environment of the soil can affect its liquefaction potential. For example, older soil deposits that have already been seismic shaking have an increased liquefaction resistance compared to specimen of the same soil having an identical density. Liquefaction resistance also increases with an increase in the ratio (OCR) and the coefficient of lateral earth pressure at rest k_o (Ishihara et al., 1978). An example would be the removal of an upper layer of soil due to erosion. Such a soil that has been preloaded will be more resistant to liquefaction than the same soil that has not been preloaded.

12.Building Load

The construction of a heavy building on top of a sand deposit can decrease the liquefaction resistance of the soil. For example, suppose a mat slab at ground surface supports a heavy building. The soil underlying the mat slab will be subjected to shear stresses caused by the building load. These shear stresses induced into the soil by the balding load can make the soil more susceptible to liquefaction. The reason is that a smaller additional shear stress will be required from the earthquake in order to cause liquefaction and hence liquefaction of the soil. For level-ground liquefaction considered in this research, the effect of the building load is ignored. The building loads must be included in all liquefaction- induced settlement and bearing capacity.

Problems Due to Liquefaction

1. Common Damages

Liquefaction can cause damage to structures in several ways. Buildings whose foundations bear directly on sand which liquefies will experience a sudden loss of support, which will result in drastic and irregular settlement of the building. Liquefaction causes irregular settlements in the area liquefied, which can damage buildings and break underground utility lines where the differential settlements are large. Pipelines and ducts may float up through the liquefied sand. Sand boils can erupt into buildings through utility openings, and may allow water to damage the structure or electrical systems. Soil liquefaction can also cause slope failures. Areas of land reclamation are often prone to liquefaction because many are reclaimed with hydraulic fill, and are often underlain by soft soils which can amplify earthquake shaking.

2. Hazards to Buildings and Bridges

When liquefaction occurs, the strength of the soil decreases and, the ability of a soil deposit to support foundations for buildings and bridges are reduced as seen in the of the overturned apartment complex buildings in Niigata in 1964.

3. Hazards to Retaining Walls

Liquefied soil also exerts higher pressure on retaining walls, which can cause them to tilt or slide. This movement can cause settlement of the retained soil and destruction of structures on the ground surface.

4. Hazards to Dam due to Landslide

Increased water pressure can also trigger landslides and cause the collapse of dams. Lower San Fernando dam suffered an underwater slide during the San Fernando earthquake, 1971. Fortunately, the dam barely avoided collapse, thereby preventing a potential disaster of flooding of the heavily populated areas below the dam.

Case study 1 (Liquefaction Potential of UTTARA)

On the basis of soil characteristics of this locations that have been presented. Liquefaction potential based on CPT (Robertson and Wride, 1998) and SPT (Seed et al; 1983) data have been estimated. A typical liquefaction potential analysis has been shown in Fig 5. Liquefiable zone is where F_l <1, on the other hand Non liquefiable zone is where F_l >1. The liquefaction analyses results by different procedures have been presented below:

- Liquefaction susceptibility has been estimated based on the method proposed by Seed et al;1983 at different depths. The liquefaction zones vary between 1.5~4.5 m. (Fig 5).
- Liquefaction susceptibility has been estimated based on the method proposed by Robertson and Wride, 1998. From the Fig 5, liquefaction zones vary between 2.7 ~4.8 m and from 8.7~12.3 m.

From the above discussion, it has been seen that liquefaction potential result slightly varies in the two methods. It may be concluded that the soil may liquefy from 1.5~4.8

m and from 8.7~12.3 m depth if an earthquake of sufficient energy occurs. CPT is more reliable than SPT as it is performed at each 0.1m depth.

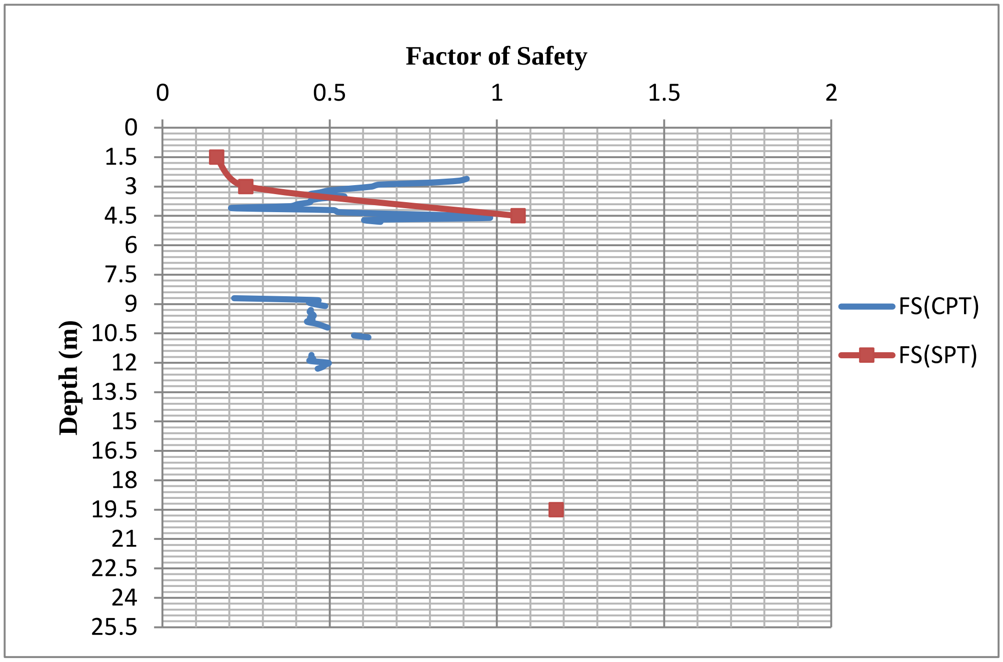

Fig 5: Depth(m) vs FS at UTTARA

Case Study 2 (Liquefaction Potential of KAMRANGICHAR)

On the basis of soil characteristics of this locations that have been presented in chapter 3. Liquefaction potential based on CPT (Robertson and Wride, 1998) and SPT (Seed et al; 1983) data have been estimated. A typical liquefaction potential analysis has been shown in Fig 6. Liquefiable zone is where F_l <1, on the other hand Non liquefiable zone is where F_l >1. The liquefaction analyses results by different procedures have been presented below:

- Liquefaction susceptibility has been estimated based on the method proposed by Seed et al;1983 at different depths. The liquefaction zones vary between 1.5~7.5 m and from 10.5~11.5 m (Fig 6).
- Liquefaction susceptibility has been estimated based on the method proposed by Robertson and Wride, 1998. From the Fig 6, liquefaction zones vary between 1.5 ~6 m and from 7.5~12 m.

From the above discussion, it has been seen that liquefaction potential result slightly varies in the two methods. It may be concluded that the soil may liquefy from 1.5~12 m depth if an Earthquake of sufficient energy occurs. CPT is more reliable than SPT as it is performed at each 0.1m depth.

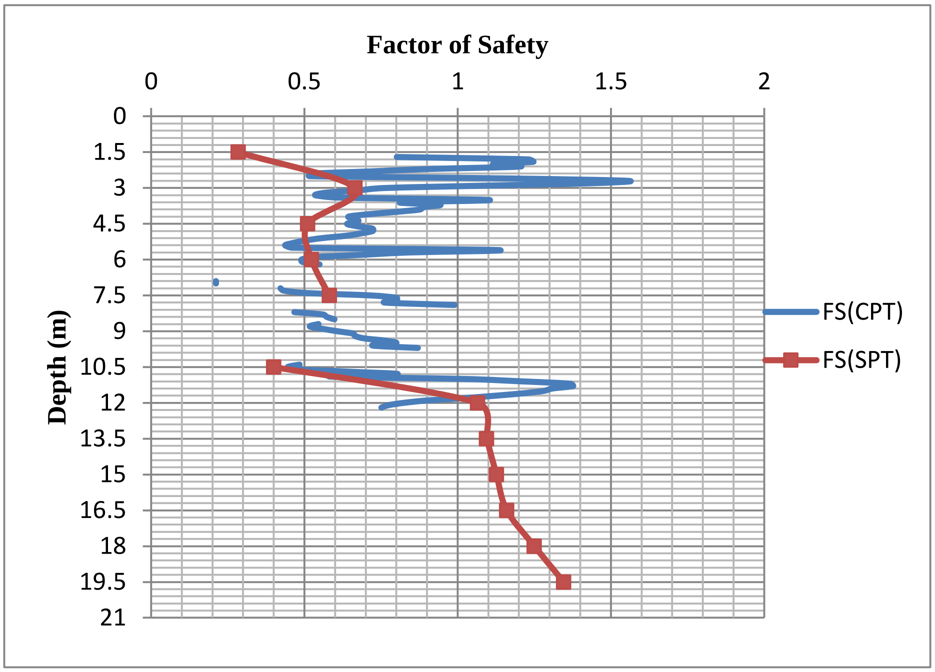

Fig 6 Depth(m) vs FS at KAMRANGICHAR

Conclusions

Liquefaction potential of two case study from SPT and CPT data have been obtained in this research. Most of the case liquefaction susceptible soil have been found upper 1.5 to 4.5 m depth of the filling sand. Liquefaction zone for CPT of Uttara and Kamrangirchar are 2.7 ~4.8 m and 8.7~12.3 m, and 1.5 ~6 m and 7.5~12 m respectively. In fact, in the around the Dhaka city, filling land may cause huge liquefaction damage due to earthquake.

References:

1. Ahamed, S.(2005). Soil Characteristics and Liquefaction Potential of Selected Reclaimed Areas of Dhaka City. M.Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

2. Ali, M. H. (1998). Earthquake database and seismic zoning of Bangladesh, proceedings of International Symposium-Information Technology tools for Natural Disaster Risk Management, INCEDE report 11, pp. 59-73.
3. Andrus R.D. and Stokoe, K.H., (1997). Liquefaction resistance based on shear wave velocity, Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soil, National Center for Earthquake Engineering Research, State University of New York at Buffalo, pp.89-128.
4. Andrus R.D. and Stokoe, K.H., (2000). Liquefaction resistance of soils from shear wave velocity. J Geotech Geoenviron.Eng.2000; 126(11):1015-25.
5. Ansary, M.A. and Rashid,M.A.(2000), Generation of liquefaction potential map for Dhaka, Bangladesh, proceeding of 8th ASCE speciality conference on probabilistic Mechanics and Structural and Reliability, paper no. PMC 200-061.
6. Chang, M.F. (1988). In-situ testing of residual soils in Singapore. Proceedings 2nd International Conference Geomechanics in Tropical Soils. V1 97-108, Singapore.
7. Chin, C., S. Duann, et al. (1988). SPT-CPT correlations for granular soils. International Symposium on Penetration Testing.
8. Demers, D. and Leroueil S.(2002), “Evaluation of Preconsolidation Pressure and the Overconsolidation Ratio from Piezocone Tests of Clay Deposits in Quebec,” Canadian Geotechnical Journal, Vol. 39, No. 1, pp. 174–192.
9. Hossain, S.M.Z., Alam, M.S. and Islam, M.S., (2003). Geotechnical characterization and liquefaction potential of sub-soil of Mirpur DOHS, Undergraduate thesis, Department of Civil Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh.
10. Idriss and Boulanger (1988), Semi-empirical procedures for evaluating the liquefaction potential of saturated cohesionless soils during earthquakes.
11. Ishihara,K. (1985). “Stability of natural deposits during earthquake.” Proceedings of the Eleventh International Conference on Soil Mechanics and Foundation Engineering, vol. 1, San Francisco, pp.321-376.
12. Ishihara, K.(1993). Liquefaction and flow failure duing earthquakes, 33rd Rankine Lecture of the British Geotechnical Society, Geotechnique 43,, No. 3 The Institute of Civil Engineers, pp.349-415.

13. Ishihara et al.,(1978), Liquefaction susceptibility map of Downtown Tokyo, Proceedings of 2nd International Conference on microzonation, San Francisco, Vol. 2, pp.897-910.
14. Kulhawy, F.H. and Mayne P.W.(1990), Manual on Estimating Soil Properties for Foundation Design, Report EPRI EL-6800, Electric Power Research Institute, Palo Alto, Calif., 306 pp.
15. Mayne, P.W.(2001), “Stress-Strain-Strength-Flow Parameters from Enhanced In-Situ Tests,” Proceedings, International Conference on In-Situ Measurement of Soil Properties and Case Histories, Bali, Indonesia, pp. 27–48.
16. Poulos, S.1., Castro, G. and France, W. (1985) "Liquefaction evaluation procedure." Of Geotech Eng, ASCE, J 11(6), 772-792.
17. Rahman, M.G.(2004),“Seismic Damage Scenario for Dhaka City”, M.Sc. Engg. Thesis, Department of Civil Engineering, BUET,Dhaka ,Bangladesh.
18. Rashid, A.(2000), “Seismic Microzonation of Dhaka City based on site amplification and liquefaction”, M. Engg. Thesis, Department of Civil Engineering, BUET,Dhaka ,Bangladesh.
19. Zahid et al (2004). Groundwater Level Declining Trend in Dhaka City Aquifer. In: Water Resource Management in Dhaka City, Hassan, M.Q. (Ed.). Goethe-Institute, Dhaka, pp: 17-32.