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RESEARCH ARTICLE

Review of earthquake-induced liquefaction potential in reclaimed urban areas: Insights from Dhaka city

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ABSTRACT

This review paper examines the potential for earthquake-induced liquefaction in reclaimed urban areas, with a focus on Dhaka City as a case study. Rapid urbanization and land reclamation in Dhaka have increased concerns about the stability of reclaimed lands during seismic events. This paper synthesizes findings from prior studies, focusing on geotechnical parameters such as SPT-N values, cone tip resistance, local friction, and friction ratio. Key influencing factors, including peak ground acceleration, earthquake magnitude, soil type, and reclamation methods, are analyzed to assess their role in liquefaction susceptibility. Evidence suggests that areas reclaimed with dredged soil, especially at shallow to moderate depths, are more prone to liquefaction under seismic loading. Variability in parameters such as over-consolidation ratio, lateral earth pressure, and internal friction angle highlights the need for localized investigations. This review emphasizes the importance of integrating advanced geotechnical techniques and seismic risk assessments to ensure the resilience of reclaimed urban areas.

Keywords: Earthquake; Liquefaction; Soil properties; Geotechnical

1. Introduction

The liquefaction problem has become increasingly important due to its impact on human and social activities, disrupting the functionality of facilities and infrastructure. This issue has been further exacerbated by rapid urbanization and the expansion of cities into reclaimed areas. Ground failures caused by liquefaction have been a significant source of damage during past earthquakes, including the 1964 Niigata (Japan), 1964 Alaska (USA), 1971 San Fernando, 1989 Loma Prieta, 1995 Kobe (Japan), and 2004 Chuetsu (Japan) earthquakes. Liquefaction has far-reaching consequences, affecting buildings, bridges, buried pipelines, and lifeline facilities.

Historical seismicity and recent earthquake activity in Bangladesh and its surrounding areas indicate a high seismic risk for the region. Being one of the most densely populated countries in the world, Bangladesh faces the potential for catastrophic damage and significant human impact during a severe earthquake. Much of Bangladesh, including the capital city Dhaka, comprises alluvial plains with fine sand and silt deposits, coupled with shallow groundwater tables. While older alluvium is less susceptible to liquefaction, deposits along river floodplains and man-made soil deposits, particularly loose fills placed without compaction, are at

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high risk. Over the past 30–40 years, Dhaka has experienced rapid urban population growth, necessitating the expansion of the city into new areas. Due to limited available land, government and private entities have reclaimed lowlands (3–12 m deep) using dredged materials, primarily consisting of silty sand. This practice increases the susceptibility of these areas to liquefaction during seismic events.

Since the 1964 Niigata and Alaska earthquakes, numerous researchers have developed liquefaction assessment methods, such as the Japanese Code of Bridge Design[1] , the Chinese criterion, and the Seed-Idriss simplified procedure. These methods have been refined over the years[2]. Although some studies have addressed liquefaction potential in Bangladesh, they are often limited to local-scale assessments. Rashid and Rahman's research[3,4] developed seismic microzonation maps for Dhaka City, emphasizing liquefaction potential and site amplification. Saha's[5] focused on liquefaction mapping in Rangpur, while Islam (2005) estimated seismic losses due to liquefaction in Sylhet. Preliminary evaluations for reclaimed areas in Dhaka were conducted by incorporated shear wave velocity for liquefaction assessment in selected areas[6,7]. However, these studies predominantly relied on Standard Penetration Test (SPT) data, which may have questionable reliability in the local context. Liquefaction potential estimates based on SPT data alone show variability across methods. This necessitates the development of robust methods, including Cone Penetration Test (CPT)-based evaluations, to assess liquefaction potential more reliably in reclaimed areas of Dhaka.

Recent studies have made significant contributions to advancing liquefaction assessment techniques. The analyzed liquefaction potential using both CPT and SPT data, providing insights into their comparative effectiveness[9,10]. In another study, conducted seismic analyses of wrap-faced retaining walls using sands from Bangladesh, offering a deeper understanding of soil behavior under seismic loads[11]. The modeled seismic soil-pile-structure interactions for tall buildings with pile mat foundations, emphasizing the importance of dynamic soil properties[12]. The reviewed the current state of soil properties and infrastructure challenges, while some researcher proposed methods for liquefaction evaluation. These works, along with research, have laid a strong foundation for understanding and mitigating liquefaction risks in Bangladesh[13-17]. Building on these efforts, this paper aims to review and synthesize existing research, with a particular focus on reclaimed areas, and to highlight the importance of integrating advanced methods for assessing liquefaction potential in the local context.

2. 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[18,19]. However, below the clay layer, medium to coarse grained formation exist.

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 and surface geology of Dhaka with minor anthropogenic modifications[20]. 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.

Alluvial Silt and Clay: Medium to dark grey Silt to Clay; Colour is darker as amount of organic an material 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.

3. 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 and other factors, 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 1** 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 1** 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[21].

Fault zone	Earthquake events	Estimated magnitude, mw
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)[22]

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	

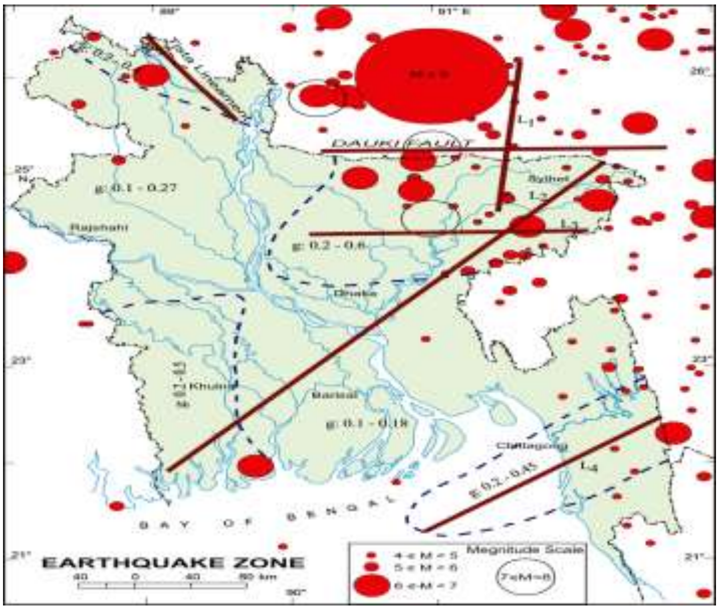

Figure 1. Seismo-tectonic lineaments capable of producing damaging earthquakes (Source: www.banglapedia.com).

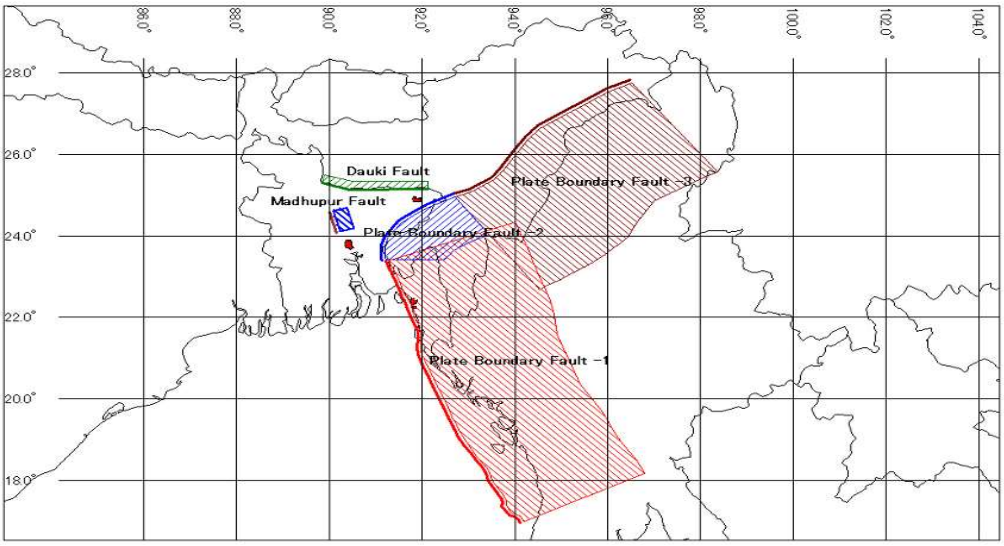

Figure 2. The major fault lines which affect seismicity in Bangladesh (CDMP,2009).

4. Liquefaction and its significance

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

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 3** 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.

Figure 2. Picture of liquefaction.

5. 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:

5.1. 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[23-26]. 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.

5.2. 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

Poulos's research[27] 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.

5.3. Soil type

In terms of the Soil Types most susceptible to liquefaction, Ishihara[27] 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 example Ishihara[28] describes the case of tailings derived from the industry that were essentially composed of ground-up rocks and were clasified as rock flour. Ishihara[29] 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.

Ishihara[27] stated that based on both laboratories testing and field performance, the great majority of cohesive soils will not liquefy during earthquakes. Using criteria originally stated and subsequently 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.

5.4. 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. The 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.

5.5. 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.

5.6. 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.

5.7. 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.

5.8. 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.

5.9. 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.

5.10. 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. 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.

5.11. 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. 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.

5.12. 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.

6. Problems due to liquefaction

6.1. 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.

6.2. 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.

6.3. 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.

6.4. 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 (Liquefaction Potential of UTTARA)

On the basis of soil characteristics of this locations that have been presented. Liquefaction potential based on CPT and SPT 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 4, 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.

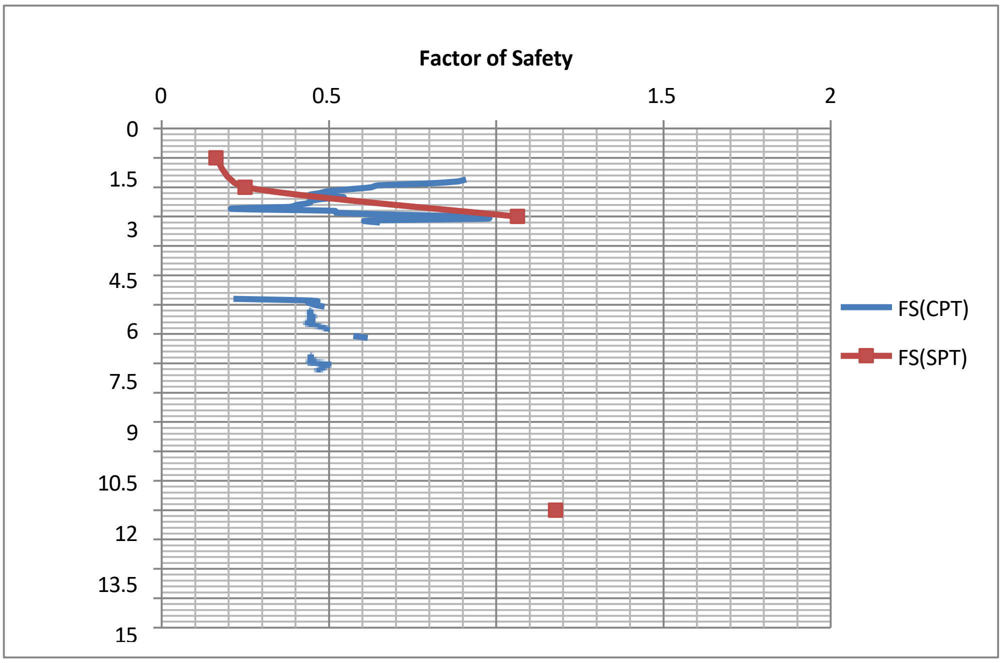

Figure 3. Depth(m) vs FS at UTTARA (Hore, 2020).

m depth if an Earthquake of sufficient energy occurs. CPT is more reliable than SPT as it is performed at each 0.1m depth.

7. Conclusions

This review highlights the liquefaction potential in reclaimed areas of Dhaka City based on analyses of SPT and CPT data from prior studies. The findings indicate that liquefaction-susceptible soils are predominantly found at shallow depths, typically within the upper 1.5 to 4.5 m of filling sand. For CPT-based assessments, the liquefaction zones vary across locations, with depths generally ranging between 2.7 to 4.8 m and 8.7 to 12.3 m, indicating multiple vulnerable layers. These risks are further amplified in areas around Dhaka City where land reclamation using loose, uncompact dredged materials is common. Such conditions heighten the probability of significant liquefaction-induced damage during seismic events. This review underscores the critical need for comprehensive geotechnical investigations and the application of advanced liquefaction assessment techniques, particularly in reclaimed urban areas, to mitigate potential risks associated with earthquakes in this high-density region.

Conflict of interest

The authors declare no conflict of interest.

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