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Earthquake shocks and liquefaction threat to DHA and Clifton areas, Karachi

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Abstract:

Coastal zones are always vulnerable to natural hazards while earthquakes and resulting liquefaction remains to be the most devastating phenomenon in urban areas. The residents of Defence Housing Authority and Clifton areas, part of Karachi coast have been experiencing jolts produced due to local seismic activity.

As there are no seismographs installed, these jolts remain unrecorded and the local seismic behavior remains unexplained.

In September (2006) a water tank in DHA Karachi, vertically submerged into the ground. An investigation was made in this context; samples were collected and analyzed which revealed that liquefaction induced by local seismic activity resulted in the submergence of the tank structure. The threat of liquefaction is increasing in the coastal belt of Karachi as new buildings of ever increasing heights are being constructed recently. The threat of liquefaction can be minimized by applying geo-technical methods both by treating the soil layers and structure.

Keywords: Seismic activity, Liquefaction, Structure, DHA and Clifton Karachi

1. Introduction:

The Defence Housing Authority came into existence through presidential order No. 7 of (1980) and was later approved by the National Assembly of Pakistan .The area is spread over 8852 acres and provides civic facilities to millions of residents.

In order to provide the residents with water, water tanks had been built through out the area, one of which collapsed and sunk vertically into the ground. This tank was constructed in mid seventies, by a joint venture with a Chinese company. According to the residents of the area, subsidence of the tank took 8 minutes causing the 80 feet high tank to submerge 70 feet in the ground, the remaining 10 feet left above the surface. This event that took place on the 8th September (2006) and resulted in destruction on a small scale, in the area, as water with high velocity gusted out of the tank.

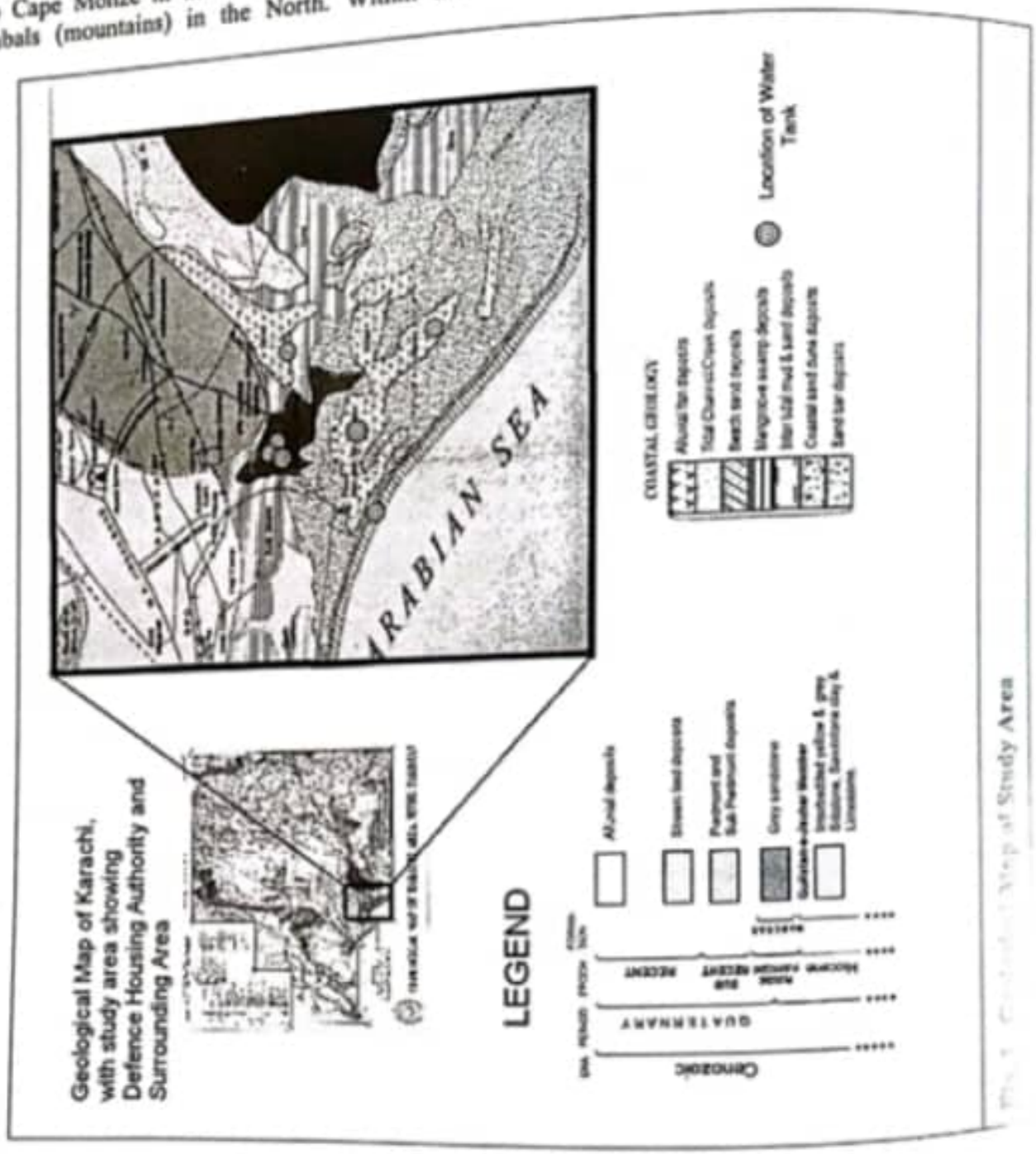
A technical investigation was made to ascertain the causes of the collapse of the structure. The studies done in this context revealed that the major cause of subsidence of the tank could be liquefaction, possibly triggered by localized shocks which result in jolts in DHA and Clifton areas. The soil of the area has high tendency to liquefy as it is rich in water with increased salinity and very poor cementation of the particles.

2. Geological setting:

The Karachi city and its surroundings have diverse geological conditions, with deformed Kirthar foothills in the North; Pab and More ranges in the West, Indus Delta in the East and Arabian Sea in the South. Rocks ranging in age from Eocene to Recent, deposited under hallow marine to deltaic conditions, are exposed.

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Karachi is a part of major synclinorium stretching from the Ranpathani River in the East to Cape Monze in the West, Mehar and Mol Jabals (mountains) in the North. Within the synclinorium a number of structures as Pipri, Gulistan-e-Jauhar, Pir Mango and Cape Monze are exposed (Quraishi *et al.*, 2001).



Defence Housing Authority is part of Southern coastal strip of Karachi **(Fig.1)**, covering an area of 8852 acres, with Arabian Sea in the South and South West, Gizri Creek in the East and South East, and Karachi Harbor and Clifton in the West. The topography of the area is flat with very low relief. Exposures of inter-bedded yellow and grey sandstone limestone (Gulistan-e-Jouhar member Formation, Miocene) and Grey sand (Manchar Formation, Pliocene) are pres the Northern part. Structurally this Southern most extremity of a low angled known as the Gulistan-e-Jouhar anticline.

The Southern part of DHA is influenced by Coastal geology with Beach Sand Deposits (Qbs) found along the Arabian Sea. The Sand Bar Deposits (Qsb) and Coastal Sand Dune Deposits (Qcsd) are widely distributed through out the area, while the Mangrove Swamp Deposits (Qms) in the North East. The details of these deposits are:

Beach Sand Deposits

These are medium to coarse grained, unconsolidated sand with pebbles and broken shells. These have been marked but keep on shifting by wind into small coastal dunes.

Sand Bar Deposits

These consist of medium to coarse grain sand, micaceous and shifting sand dunes.

Coastal Sand Dune Deposits

These consist of sand and gravel deposits within a marine beach system, including, but not limited to, beach, frontal dunes, dune ridges, back dunes and other sand and gravel areas deposited by wave or wind action.

Mangrove Swamp Deposits

These deposits cover natural mangrove forests exposed in low tides between creeks and contain silt, clay with abundant organic material.

Several water tanks have been constructed in the area, the sub surface geology is mainly influenced by recent coastal deposits, details of the sub surface geology of each tank and location is given in **Table 1.**

Table 1. Locations of water tanks and the sub surface lithology.

Serial	Co-ordinates	Location & Remarks	Subsurface Lithology
1	N24°47.886,E67°48.387	Phase 5 Extension *The collapsed tank*	Beach sand deposits ,Sand bar deposits
2	N24°48.199,E67°03.732	Phase 6	Coastal Sand dune deposits ,Sand bar deposits
3	N24°49.120,E67°03.180	Phase 5	Manchar formation ,mangrove swamp deposits
4a	N24°49.128,E67°03.172	Phase 5	Manchar formation ,mangrove swamp deposits
4b	N24°49.128,E67°03.172	Phase 5	Manchar formation ,mangrove swamp deposits
5	N24°.49.552,E67°04.166	Phase 7	Gaj formation, Mangrove swamp deposits.
6	N24°50.537,E67°03.432	Adjacent to Phase 2 and 1.	Gaj Formation
7	N24°47.610,E67°04.092	Phase 6, Ittehad	Coastal sand dune deposits ,Sand bar deposits

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3. Materials and methods

Sediment samples were collected from the tank site located using Global Positioning System (GPS), from a depth of 3 feet. These samples were analyzed in the laboratory for the following parameters.

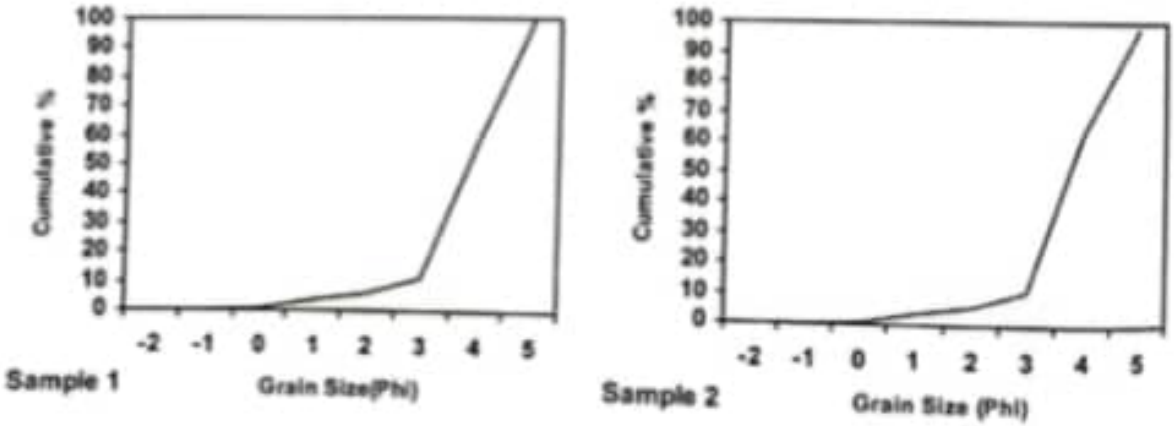
Grain Size

200 grams of each sample was taken for sieving using the sieve shaker set. The grain size data obtained is given in **Table 2.** The cumulative curves drawn from this data are illustrated in **(Fig.2).**

Table 2. Result of Grain size analysis

Grain Size		Sample 1			Sample 2		
Φ	Mesh #	Weight (gm)	Weight %	Cumulative %	Weight (gm)	Weight %	Cumulative %
-2	5	0	0.0	0.0	0	0.0	0.0
-1	10	0.2	0.1	0.1	0.2	0.1	0.1
0.0	18	1.2	0.6	0.7	0.9	0.45	0.55
1	35	5.4	2.7	3.4	6.4	3.2	3.75
2	60	5	2.5	5.9	4.8	2.4	6.15
3	120	11.2	5.6	11.5	9.5	4.75	10.9
4	230	91.3	45.65	57.15	103.4	51.7	62.6
5	Pan	84.7	42.35	99.5	70.7	35.35	97.95

Fig. 2, Cumulative grain size data



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Sorting

The samples were found to be moderately sorted, it was determined by the formula

$(\Phi 84 - \Phi 16)/4 + (\Phi 95 - \Phi 5)/6.6$ (Folk, 1980)

The Standard Deviation determined is 0.84 Φ.

Water content

10 grams of each sample was taken after coning and quartering, and was placed over night in an electric oven at 100°C. The difference in the weight revealed that the average water content present is 17.85%.

Clay Content

10 grams of each sample was taken and 100 ml of water was added, the sand was allowed to settle and was separated by decantation process, the remaining solution was dried in the oven. After the water had evaporated the clay left was weighed which was found to be 0.1% to 0.2 % in mass.

Mineralogy

The samples were observed under a binocular microscope, the major mineral observed was quartz with subordinate amounts micas and some calcareous grains. The grains were moderately to well rounded, poorly packed with cementation almost absent.

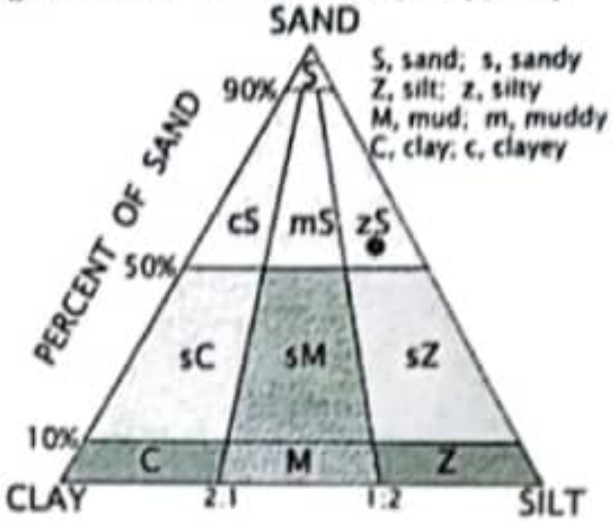
Core Density

A 2liter cylinder weighed in the laboratory was taken to the site and drawn 2 feet inside the ground, it was again weighed and the mass of the soil collected was calculated, the density of the soil was calculated to be 1.39 gm/ltr.

Soil Classification

The grain size data reveals that the samples contain an average 38.67 % Silt and 59.77 % of Sand. The samples were classified as Silty Sand, (zS) (Folk, 1980) **(Fig 3).**

Fig. 3. folk classification of soil (Folk, (1980)



PERCENTAGE OF SILT/CLAY

4. Discussion and conclusions

Different parameters and analyzed results have been discussed below which reflect the behavior of ground which includes: location of ground water table, soil type, soil relative density, particle size gradation, particle shape, depositional environment of soil, soil drainage conditions, confining pressures, aging and cementation of the soil deposits, the intensity of ground shaking and its duration.

The soil may loose its strength and liquefy due to the loss of effective stress during earthquake vibrations if it as uniformly graded with a grain size less than 0.7mm (Tony, 1994). The analyzed samples of soil revealed that 99.37 % of the grains are of the size less than 0.7mm.

Sandy and silty sands are most prone to liquefaction (Environment Canterbury fact sheet, 2006), the samples collected from the collapsed tank site are classified as Silty-sand.

The density of soil is an important factor in the evaluation of its strength. Saturated, low density soils have the highest potential to liquefy (Moffat, 2007). Poorly packed sands with low

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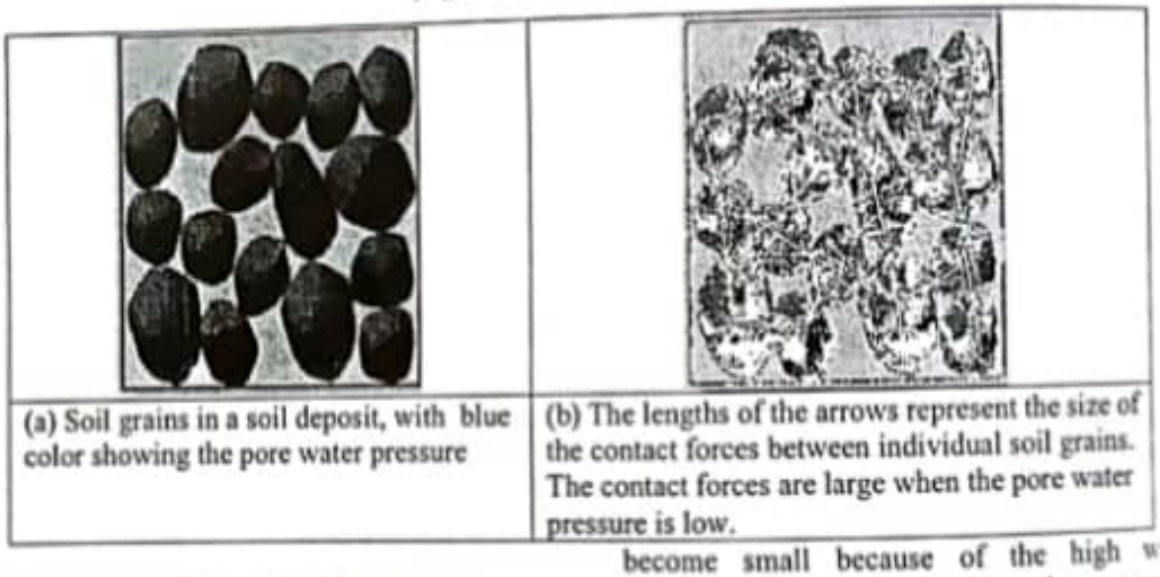
relative density are more susceptible to liquefy (Tony, 1994).The soil samples collected are saturated and have a low density i.e. 1.39 gm/lt.

The liquefaction potential of soil is greatly influenced by the particle arrangement. Poorly graded, well rounded grains increases the pore water pressure which increases the susceptibility of soil to liquefy (Moffat, 2007).

The soil samples analyzed were moderately sorted , rounded to well rounded , poorly packed with cementation almost absent.

A soil deposit consists of an assemblage of individual soil particles, the weight of the overlying soil particles produce contact forces between the particles - these forces hold individual particles in place and give the soil its strength **(Fig. 4 a, b).**

(Fig. 4, (After Jorgen, 2000)



(a) Soil grains in a soil deposit, with blue color showing the pore water pressure	(b) The lengths of the arrows represent the size of the contact forces between individual soil grains. The contact forces are large when the pore water pressure is low.

Fig.4c. Arrows showing Small contact force between the grains



An increase in water pressure which reduces the contact forces between the individual soil particles, thereby softening and weakening the soil deposit. Contact forces become small because of the high wa pressure. **(Fig 4c),** in some cases, the pore wa pressure may become so high that many of soil particles lose contact with each other. soil will have very little strength, and behave more like a liquid than a (Jorgen, 2000).

The samples collected from the tank contained average 17.85 % water, with Arabian Sea coast at a distance of 300 me Saline water also plays an important role in soil behavior. The water contents are high du the close proximity of the sea as well as the water that may have also changed the salinity. The local conditions are favorable the increase in the pore water pressure .Wa table in the area is as shallow as 3-4 mete Liquefaction has been abundant in areas whe ground water lies within 10 meters of the ground surface (Hussain *et al.*, 2004).

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Reclaimed lands, wind-deposited soils, or sites comprised primarily of sedimentary deposits are all at a higher risk to liquefy. (Moffat, 2007).The Coastal zones of Karachi specially DHA and Clifton areas have been developed on reclaimed land, this un-natural process of regressing the coast is still underway with an efficient pace. Unconsolidated loose sand deposits are found to an average depth of 35 meters in these areas.

Sands may liquefy during periods of earthquake due to the propagation of seismic waves through the grains (Tony, 2002), the residents of Defence Housing Authority and Clifton have been experiencing seismic jolts in which the energy propagates from South to North, Due to un-availability of seismic stations no records are present but the residents have felt intense shaking produced due to the unknown phenomenon responsible for producing these jolts.

During an earthquake, significant damage can result due to instability of the soil in the area affected by internal seismic waves. The soil response depends on the mechanical characteristics of the soil layers, the depth of the water table and the intensities and duration of the ground shaking. If the soil consists of deposits of loose granular materials it may be compacted by the ground vibrations induced by the earthquake, resulting in large settlement and differential settlements of the ground surface. This compaction of the soil may result in the development of excess hydrostatic pore water pressures of sufficient magnitude to cause liquefaction of the soil, resulting in settlement, tilting and rupture of structures (Bertero,1997).

In recent times, shocks have been felt in the area of DHA and Clifton which seems to be responsible for causing liquefaction, synchronized with collapse of the tank. Significant damage can result due to instability of the soil in the area affected by internal seismic waves. The soil response depends on the mechanical characteristics of the soil layers, the depth of the water table and the intensities and duration of the ground shaking, as discussed above. If the soil consists of deposits of loose granular materials as of the coastal deposits it may be compacted by the ground vibrations induced by seismic shocks, resulting in large and differential settlements of the ground surface. It is concluded that the subsidence of the water tank took place due to the liquefaction which was triggered by the local seismic activity which is being felt by the residence of Defence Housing Authority and Clifton areas.

5. Recommendations:

Several hundred of thousand people live in Defence Housing Authority and Clifton areas along the coastal belt of Karachi. High rise residential buildings of Clifton and The Sea View Apartments Township are the most venerable localities to natural hazards specially to liquefaction. It is recommended that the following steps should be taken immediately.

- A network of seismographs should be installed through out the area in order to record the local seismic activity.
- Studies should be under taken in order to exploit the ground strength for various layers through out the area which should include the Standard Penetration Test (SPT), Cone Penetration Test (CPT) and a data-base should be developed for these geo-technical information which should be applied while planning the construction.
- Liquefaction hazard maps should be developed and made public.
- Standards for constructions should be designed and implemented.
- The buildings constructed in the past should be inspected and checked thoroughly for strength and the subsoil conditions, reinforcements should be applied to the buildings or the soil as necessary.
- It had been observed that old buildings and water storage tanks were fitted with advertising hoardings and cellular phone antennas which might be responsible for extra load on the structure and may become fatal.

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