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Unexpectedly two storied tin shed collapse: A case study of urban hazard in Dhaka city, Bangladesh

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ABSTRACT

The study has been carried out for an urban hazard analyses to find out the engineering geological characteristics of subsurface sediments and causes of two storied tin shed unexpectedly and suddenly collapsed and submerged in Rampura valley, Dhaka city, Bangladesh on the 15 April, 2015. Total 12 people were spot died due to collapsed tin shed. The area is covered by valley and this valley is composed of organic material, clayey silt, silty sand and sandy silt. Atterberg limit test indicates that the sediments are slightly plastic and low compressibility inorganic silts. Specific gravity of the sediments varies from 2.66 to 2.68, natural moisture content about 34.5%, dry density about 1.37 gm/cc, wet density about 1.84 gm/cc and unconfined compression strength about 45.9 Kpa. From this result, it reveals that shallow foundation is not suitable for the study area but deep foundation particularly pile foundation would be required. Five major possible causes have been identified for this incident, these are (1) presence of a valley and valley deposits, (2) very soft organic clay and soft slightly plastic clayey silt, (3) poor quality construction materials of shed and shallow foundation pillar, (4) overloaded by inhabitants with their usable items, and (5) filled up asides of the valley by filling materials which pressurized the pillar of the shed. Due to push or additional side pressure by filling materials to the foundation pillar, the pillar was moved and imbalanced the total shed and finally shed was suddenly subsided and collapsed by uniform settlement. Finally, it can be concluded that geological and engineering - geological study must be carried out for an urban hazard analyses in Rampura valley area as well as other valley areas in Dhaka city for future plan of urbanization and avoiding this type of urban hazard.

Keywords: Urban hazard, Uniform settlement, Urbanization, Engineering geology, Tin shed, Rampura valley

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INTRODUCTION

A two storied tin shed was unexpectedly and suddenly collapsed and submerged in Rampura Jheel, Dhaka city, Bangladesh at 2:45 PM on the 15 April, 2015. It has been reported in several electronic media on the same date and also reported in national news papers on the following day. The pillars of house have been subsided in the mud of the Rampura Jheel. Lower storey/first floor was fully and upper storey/second floor was partially submerged and damaged (Fig. 1). Total 12 people were died. Twenty garment workers/low income families were lived in the shed. Due to incident, they lost their family members as well as daily useable items such as fridge, television, furniture, etc. The shed was made by tin, corrugated iron sheet, bamboo poles and concrete pillar. Length and width of the shed was 50 and 20 feet, respectively and number of rooms was 20 and 10 rooms on each floor. Concrete with rod and bamboo poles was used as pillar. Corrugated iron sheet was used for fence frame, floor and roof platform. Tin was used for fence and roof. The shed was made up of two feet above on water level, where depth of water was about 10 to 12 feet. The bridge was constructed by bamboo for communication between road and shed. The shed was so fragile that it would shake when someone walked. The inhabitants of the shed were very scared during storm. The incident happened in the afternoon, when most of the dwellers left for work after lunch. Otherwise, a lot of people would have died due to collapsing. Fire service was conducted for the rescue operations and they recovered dead bodies from collapsing shed. They also rescued a number of survivors and sent them to hospital. Rescuers tried to remove the tin ceilings from the mud by cutting off the bamboo poles but failed. Later they used cranes to remove the frame of the house, which was floating.

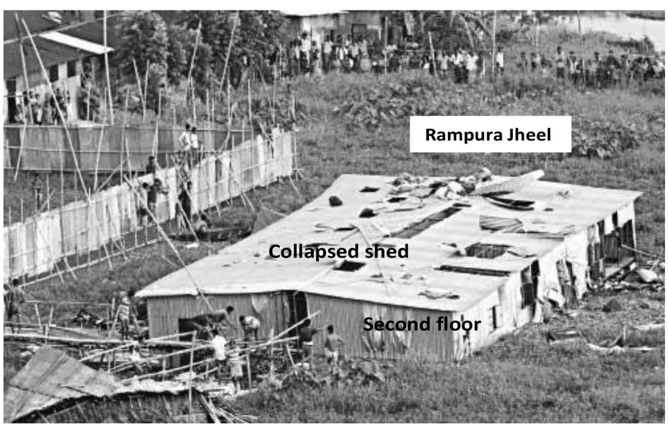

Fig. 1: The first floor of two storied tin shed submerged at bottom of Rampura Jheel, Dhaka city due to subsidence

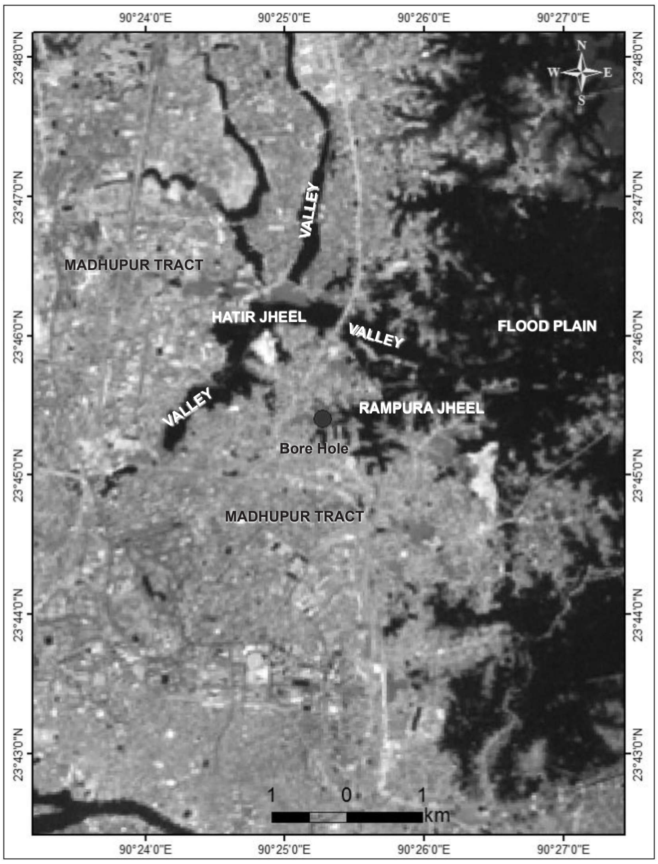

Fig. 2: Location of bore hole area as well as geomorphological units of the investigated areas shown on the Global Land Survey (GLS) Satellite image of 1991

Location and Access

The investigated area falls under Rampura area in Dhaka North City Corporation, Dhaka city, Bangladesh and is situated at the latitude 23.75680°N and longitude 90.42118°E (Fig. 2). The area is well connected with a metalled road network.

MATERIALS AND METHODS

Google Earth (image) and Global Land Survey (GLS) Satellite (1991) imagery have been studied by visual image interpretation techniques. The tone, texture, shape, size and association have been analyzed for image interpretation. The imageries of different times are combined and used to identify the changes between the present and past landforms. Drilling of 1 geotechnical borehole has been performed up to depth of 30 m below EGL at closest distance that is 15-meter far from collapsed shed where considering same geology and geomorphology. This borehole was not possible at exact location of collapsing shed due to valley and 10 to 12 feet depth of water. The Standard Penetration Test (SPT) was executed at a regular interval of 1.5 m up to a 30 m depth with collection of disturbed and undisturbed soil samples. The laboratory tests such as grain size analysis, density, moisture content, unconfined compression, Atterberg limits, specific gravity, and direct shear have been conducted. All of the findings with geotechnical laboratory data have been incorporated in this study which will be helpful to understand the causes of urban hazard. Information was collected from the local people, rescue team and journalists about past records of such incidents.

GEOMORPHOLOGY

Dhaka city lies in the extreme southern part of the Pleistocene Madhupur Tract. The overall elevation of Dhaka city is about 06 meters above mean sea level (msl), lowering gradually towards the south. A prominent north-south trending depression is situated at the eastern part of the city. The city is divided by the east-west direction abandoned channel named as Begunbari Khal. The general slope of the city is towards both east and west. A sharp boundary between Madhupur clay and recent floodplain has been observed both in the eastern and western side of the city (Asaduzzaman et al., 2014). Rashid (1977) has divided the Dhaka city and its surrounding areas into three main divisions: (a) Madhupur Tract (b) alluvial plains of the Jamuna-Ganges River system, and (c) alluvial plains of the Brahmaputra–Meghna River system. The study area is covered by broad valley and surrounded by Madhupur Tract and recent floodplains. The valley is identified by its shape. In the GLS satellite image of 1991 shows dark grey and green tone, smooth texture, elongated and wide shape in the Madhupur Terrace area (Fig. 2). The sediments are mainly of organic clay underlain by clayey silt. Organic clay is grayish black and dark grey, soft, sticky and with fully decomposed vegetal matter present. Clayey silt is mostly grey with partially decomposed root, rootlets, leaves, vegetal matter, fiber of woods, hard shell and impression of burrows present.

GEOLOGIC SETTING

Tectonically, Bangladesh occupies the major part of the Bengal Basin and formed one of the largest delta complexes in the world. It is bounded in the east by the Indo-Burma ranges, in the west by the Indian shield, in the north by the Shillong massif and Himalayan thrust fault and in the south by the open Bay of Bengal (Alam, 1988; Alam et al., 1990). Dhaka city is situated on a complex geological region with a unique geomorphic setting. The recent sediments of this area are deposited mainly of few river systems like, Dhaleswary-Buriganga in the south, Balu-Shitalakhya in the east, Tongi Khal-Balu in the north and Turag in the west. The city area is comprised of five geological deposits such as (1) Floodplain deposits, (2) Depression deposits, (3) Natural levee deposits, (4) Gully/Narrow valley deposits, and (5) Madhupur clay deposits (Asaduzzaman et al., 2014). The study area is covered by valley fill deposits and is surrounded by the Madhupur clay and the floodplain deposits.

Sedimentological Characteristics

The surface and sub-surface data (borehole) were compiled together to build up a generalized vertical section

(Fig. 3). The sub-surface lithology is divided into four units which are (from top to bottom), respectively, (1) Organic clay unit, (2) Clayey silt unit (soft to very soft), (3) Sand unit, and (4) Sandy silt unit (stiff). From 1.05 to 3.0 m depths, the lithology contains greyish and reddish brown clayey silt. The texture and structure indicate that these are artificial filling sediments. This layer is underlain by 3 m thick greyish black to dark grey organic clay. The sediments are soft and consist of partially to fully decomposed vegetal matter. This layer was exposed for a reasonable period and deposited under back swamp environment. This layer is underlain by about 12 m thick grey to dark grey soft clayey silt layer consisting of partially decomposed vegetal matter. These sediments were possibly deposited under floodplain condition. After this layer the sediments consist of brown and yellowish brown fine- to medium- and coarse- grained sand with thin clay layers. The sands are dominated by quartz with little mica and rock fragments. These sediments were deposited as channel sand. This layer is underlain by dark grey color sandy silt layer.

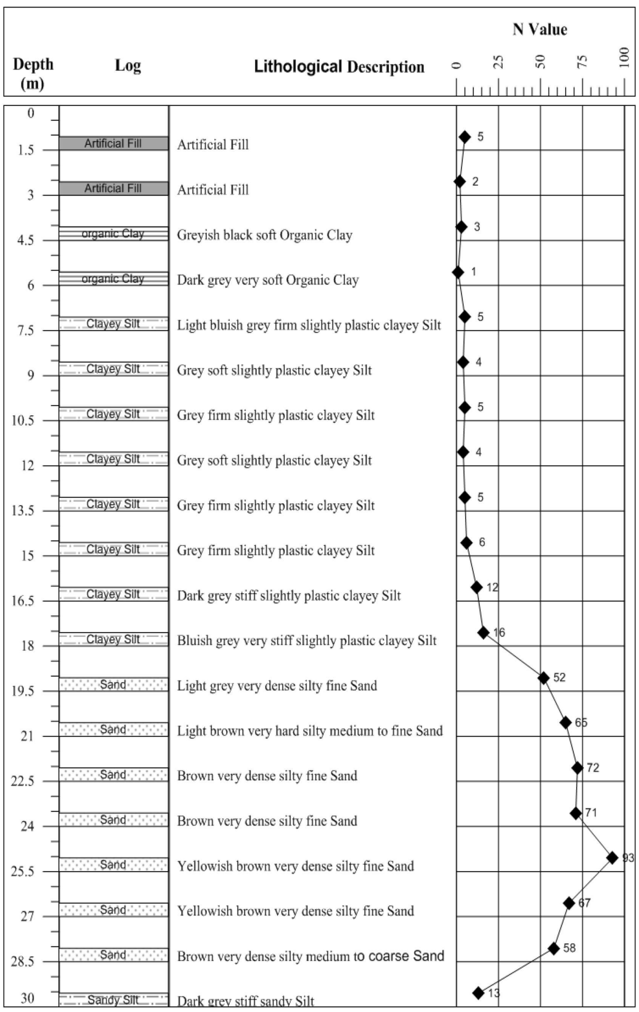

Fig. 3: Lithological descriptions with graphical representation of N values curve based on SPT

ENGINEERING GEOLOGICAL INVESTIGATION

Engineering geological investigation was conducted by several tests and analyses. The findings of these tests and analyses are explained in the subsequent sections.

Standard Penetration Test (SPT)

On the basis of N-values, the cohesive soils can be correlated with consistency and unconfined compressive strength in tons per square feet and non-cohesive soils can be correlated with the relative density of soil formation (Terzaghi and Peck, 1948; Peck, 1974). In the study area greyish black and dark grey organic clay are found at the depth from 3.0 to 6.0 m. N value of this layer is 1–3 (Fig. 3) that indicates consistency of the clay is very soft to soft and unconfined compressive strength is 0.024 to 0.048 MPa (<0.25 to 0.50 tons per sq. ft.). Organic clay layer is geo-technically very vulnerable for any civil infra-structural constructions (Asaduzzaman et al., 2014). Soft to very stiff clayey silt is found at 6.0 to 18.0 m depths. N value of this layer is 4–16 that also indicates that the consistency of this layer is soft to very stiff and unconfined compressive strength is 0.024 to 0.38 MPa (0.25 to 4.0 tons per sq. ft.). N value increases towards deeper depth at this layer. Very dense sand is found at 18.0 to 28.5 m depths. If submerged sand is very loose, a sudden shock may transform it temporarily into a sand suspension with the properties of a thick viscous liquid. In a dense state the same sand is insensitive to shock and is perfectly suitable as a base for even very heavy structures. The relative density of sand strata has a decisive influence on the angle of internal friction of the sand, on the ultimate bearing capacity and on the settlement of footings resting on the sand. N value of the sediments ranges from 52 to 93. This value indicates that the relative density of sediments is very dense (Craig, 2004). Stiff clayey silt is found at 28.5 to 30.0 m depths. N values of the sediments are 13 that indicate that consistency of sediments is stiff and unconfined compressive strength is 0.096 to 0.192 MPa (1.0 to 2.0 in tons per sq. ft.).

The overall field SPT (N) values were corrected due to the effect of the overburden pressure at the different layers of conducted borehole. Allowable skin friction is 1.07 ton/m2 and allowable end bearing is 213 ton/m2 for bored cast in situ piles at 18.0 to 28.5 m depths. Deep foundation particularly pile foundation would be required. Pile foundation is overcoming difficulties associated with foundations on weak soils. Piles transmit the loads to the deeper layers, which generally offer a higher bearing capacity, smaller settlements and especially smaller differential settlements (Zaruba and Mencl, 1976). The size, length and capacity of pile would be selected and calculated by the design engineer. Geological investigation suggests that dense sand layer is suitable for foundation layer, and in this case, pile must be penetrated below 20 meter depth where dense sand layer exists.

Grain size analysis

Nineteen representative samples were collected from different depths of conducted borehole. The results of grain size

Table 1: Grain size distribution and distribution parameters of sediment samples collected from conducted borehole

Sample no.	Sample depth	% of sand	% of silt	% of clay	Effective size	Uniformity coefficient,	Grade	Unified Classification of soil
D-2	3.0	4	76	20	0	0.05	Poorly graded	Clayey Silt
D-3	4.5	1	79	20	0	0.03	Poorly graded	Clayey Silt
D-4	6.0	10	76	14	0	0.045	Poorly graded	Clayey Silt
D-5	7.5	5	89	6	0.006	0.04	Poorly graded	Clayey Silt
D-6	9.0	3	87	10	0.002	0.04	Poorly graded	Clayey Silt
D-7	10.5	4	87	9	0.0025	0.05	Poorly graded	Clayey Silt
D-8	12.0	4	86	10	0.002	0.05	Poorly graded	Clayey Silt
D-9	13.5	4	87	9	0.0025	0.06	Poorly graded	Clayey Silt
D-10	15.0	3	86	11	0.002	0.05	Poorly graded	Clayey Silt
D-11	16.5	6	84	10	0.002	0.08	Poorly graded	Clayey Silt
D-12	18.0	8	85	7	0.003	0.08	Poorly graded	Clayey Silt
D-13	19.5	66	31	3	0.008	0.16	Well graded	Silty Sand
D-14	21.0	84	16	0	0.09	0.36	Well graded	Silty Sand
D-15	22.5	73	27	0	0	0.13	Well graded	Silty Sand
D-16	24.0	69	31	0	0	0.14	Well graded	Silty Sand
D-17	25.5	63	37	0	0	0.12	Well graded	Silty Sand
D-18	27.0	65	35	0	0	0.13	Well graded	Silty Sand
D-19	28.5	55	43	2	0.006	0.12	Well graded	Silty Sand
D-20	30.0	18	76	6	0.004	0.08	Poorly graded	Sandy Silt

analysis from the borehole samples indicate that clayey silt is found at 0 to 18.0 m depths, silty sand at 18.0 to 28.5 m depths and sandy silt at 30.0 m depths, respectively (Table 1).

Atterberg limit test

Fine-grained sediments were tested to determine the liquid and plastic limits. The latter are moisture contents that define boundaries between material consistency states. Twelve sediments samples were collected from different depths of conducted borehole. Liquid limit of the sediments varies from 36% to 47% and plastic limit varies from 25% to 29% (Table 2). Plasticity index varies between 11% and 18% (Table 2). The result implies that the sediments are slightly plastic and low compressibility inorganic silts.

Specific gravity

Specific gravity of soil particles is defined as the ratio of the mass of given volume of soil particles to the mass of an equal volume of water at 40C. Specific gravity of the investigated soil varies from 2.66 to 2.68.

Other properties

One undisturbed soil sample was collected from 8.10 to 8.55 m. depth for analysis of different geotechnical properties. This sample was clay layer of cohesive soil. Natural moisture content of the sediments is 34.5%, dry density is 1.37 gm/cc, wet density is 1.84 gm/cc and unconfined compression strength is 45.9 KPa.

POSSIBLE CAUSES OF COLLAPSING HOUSE

Field investigation and other studies indicate that the two-storied tin shed collapsed in this area were due to following reasons:

1. Presence of a valley and valley deposits.
2. Presence of very soft organic clay and soft slightly plastic clayey silt in the subsurface.
3. Poor quality construction materials of shed and shallow foundation pillar,
4. Overloaded by inhabitants with their useable items.
5. Filled up asides of the valley by filling materials which pressurized the pillar of the shed. Due to push or additional side pressure by filling materials to the foundation pillar, the pillar was moved and imbalanced the total shed and finally shed was suddenly subsided and collapsed by uniform settlement.

Table 2: Atterberg limits of representative samples

Sample no.	Sample depth (m)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	Plasticity	Type of soil
D-2	3.0	43	26	17	Slightly plastic	Inorganic silts
D-3	4.5	47	29	18	Slightly plastic	Inorganic silts
D-4	6.0	45	27	18	Slightly plastic	Inorganic silts
D-5	7.5	39	27	12	Slightly plastic	Inorganic silts
D-6	9.0	40	29	11	Slightly plastic	Inorganic silts
D-7	10.5	42	27	15	Slightly plastic	Inorganic silts
D-8	12.0	44	28	16	Slightly plastic	Inorganic silts
D-9	13.5	42	28	14	Slightly plastic	Inorganic silts
D-10	15.0	42	25	17	Slightly plastic	Inorganic silts
D-11	16.5	40	25	15	Slightly plastic	Inorganic silts
D-12	18.0	36	25	11	Slightly plastic	Inorganic silts
D-20	30.0	39	27	12	Slightly plastic	Inorganic silts

CONCLUSIONS

The collapsed two-storied shed was made by tin, corrugated iron sheets, bamboo poles and concrete pillars. The shed was made up of two feet above on water level, where depth of water was about 3.05 to 3.66 meters. The shed was so flimsy that it would shake when someone walked. At least 40 people were lived in the shed and most of the inhabitants were garment workers. Total 12 people were died due to collapse.

The area is covered by broad valley and is surrounded by Pleistocene Madhupur Terrace and recent floodplains. The sub-surface sediments are composed of clayey sandy silt and sand. Organic clay is soft to very soft. Clayey silt is soft. Sand is brown to yellowish brown and fine- to coarse-grained. Sandy silt is dark grey and stiff.

The borehole samples at different depths are: clayey silt (0 to 18.0 m depths), silty sand (18.0 to 28.5 m) and sandy silt (30.0 m). Liquid limit of the sediments in the area varies from 36% to 47%. Plastic limit varies from 25% to 29% and plasticity index varies from 11% to 18%. The sediments are slightly plastic and low compressibility inorganic silts. Specific gravity of the sediments varies from 2.66 to 2.68. Natural moisture content of the clay sediments of the cohesive soil has been found 34.5%, dry density is 1.37 gm/cc, wet density is 1.84 gm/cc and unconfined compression strength of the same sediments is 45.9 Kpa.

Engineering geological study suggests that shallow foundation is not suitable for building construction. Deep foundation particularly pile foundation would be required. The size, length and capacity of pile would be selected and calculated by the design engineer. Geological investigation suggests that dense sand layer suitable for foundation layer and in this case, pile must be penetrate below 20 meter depth where dense sand layer exists.

Based on field investigation and laboratory test results, the following measures are recommended to reduce this type of hazards.

1. Valley should be totally avoided without geological and engineering geological investigation for any type of construction for accommodation.

2. Floating shed and house construction should be totally avoided in the Jheel area.

3. If shed and building construction is necessary in Jheel area, it would be filled in the Jheel area above flood level or ground level with geological and engineering geological study.

4. Proper valley fill techniques should be used.

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