Assessment and Thorough Analysis of the Impact due to Earthquake on Industrial Structures in Bangladesh

Md Abdul Wahed[1], and Md. Arifujjaman[2]

***Abstract*—** Bangladesh is one of the populous countries in the world having large number of poorly constructed industrial structures in the outskirts of the capital, Dhaka city. During the incidents of last Nepal earthquake, there has been severe damage on some of the industrial buildings in Bangladesh. An extensive analysis had been conducted on a three storied industrial frame structured building which is situated at 24-26 Dighi Borabo, Tarabo, Rupgonj, Narayangonj, Bangladesh. In this paper, the test results of concrete core samples have been highlighted which were performed at the laboratory of Housing and Building Research Institute, Dhaka, Bangladesh.

***Keywords*—** RCC, DEA, BNBC, STAAD Pro.

I. Introduction

MAX Sweater (Bd) Ltd entrusted the team of experts for assessing the structural condition of their two buildings. The team comprising of experienced structural engineers who visited Max Sweater (Bd)'s two buildings located at 24, 26 Dighi Borabo, Tarabo, Rupgonj, Narayangonj, Bangladesh. This paper will present the Detail Engineering Assessment (DEA) of building number 02. This company has two buildings in a large campus. The building was constructed in the year of 2000-2002. The building has 3 stories and the structural form of the building is framed type. The building is reinforced cement concrete framed structure. Floors are of beam and slab systems. There are 38 nos. of columns of different sizes ranging from 25"x25" to 60"x36" in building #02. The building is more or less regular in plan and elevation. There are 2 nos. staircases and but no lift or lift core exist in the building. Beams are mostly 12"X24" sizes and slab thickness is 5". Assessment of structural condition of the building was performed to document the general condition of the building emphasizing the following.

- Study of existing Architectural and Structural layout plan of the buildings. Check for available test reports like soil test, material test etc.
- Details visual observation of the building to check any cracks in walls, any sort of distress in the beams, corrosion in the steel structure, water seepage etc.
- Check for the type of the occupancy and corresponding occupancy load.
- Check for any alteration and addition done in the building.

Some features of the building have been given below-

TABLE I
SOME FEATURES OF THE BUILDING

Features		**Building number-02**
Construction period		2000-2002
No. of Stories		3 Nos.
Structural type		Framed Structure
Occupancy Type	Ground Floor	One part for official purpose and another part for lightweight storage
	1st Floor	Lightweight knitting machine
	2nd Floor	Lightweight knitting machine
Floor Area		2547 sqm per floor
No. of workers		2500 nos. (Appr.)
Presence of joints		Not present
Presence of lift or lift core		Neither is present
No. of Staircase		2 nos.
Presence of basement		Not present
Overhead water tank at roof		Very lightweight Plastic Tank
Lime terracing		Finished as per guidance of engineer in charge.
Slab thickness		6"
Presence of Grade beam		Present
Footing type		Some are combined and some are isolated column footing

II. Methodology

The expert team visually inspected the building several occasions along with concern personal. All accessible building structural elements available and visible at the time of the site visit were inspected for evidence of structural integrity, damage, degradation and repairs. Representative photographs were taken to describe structural elements of the building. Building finishes were removed to reveal concealed conditions. Information was also gathered from available personnel by verbal interrogation. During inspection of the site available documents were collected for review. Cores were taken from existing structural elements at the top floor of the building for tests to authenticate the intention of structural design and drawings. Excavations were made at the base of footing to check their physical conditions (size, thickness, no. of reinforcement etc.). Total 2 excavations were done for this building to cover all types of the footing. Scanning of structural members like beam, column, slab etc. at various

Md Abdul Wahed and Md. Arifujjaman are with the Housing and Building Research Institute, Dhaka, Bangladesh (Phone: +88-02-8034095, +8801718632068 email: emawhbri@yahoo.com, islam.badol@yahoo.com)

representative locations of all floors of the building was done by using sophisticated digital rebar scanner. Non destructive hammer test was performed at the ground floor of the building to check the concrete compressive strength. Load carrying capacity of columns were calculated then it was compared to the load that actually coming on it. The adequacy of the footing and slab of the building were also checked. Structural analyses have also been carried out using available information. Computer aided modeling and design techniques were used as analyses tools. The computer software used for modeling and analysis is STAAD.Pro-Version–6. Manual calculation has also been performed to compare with computer model outcome and found similar.

III. DESIGN CONSIDERATION

A. Building Description

Occupancy Classification:
Occupancy F- Business and Mercantile Building
Subdivision F1- Offices [1]

B. Codes and Standards

- Bangladesh National Building Code-1993 (BNBC)
- Building Code Requirements for Reinforced Concrete (ACI 318-2011)
- American Society for Testing and Materials (ASTM)
- Uniform Building Code (UBC)

C. Materials

No information is available regarding the strength of concrete and reinforcing bar. Considered strength of concrete and rebar are as follows-

a) Concrete:
Compressive Strength of Concrete for RCC works
f'c = 2700 psi
b) Reinforcing bar:
Yield Strength of Reinforcing bar-
fy = 60000 psi.
Geotechnical Consideration:
Soil shear strength & settlement considered as within the allowable limit.
Dead Load:
Dead load is the vertical load due to the weight of permanent structure and non-structural component of a building e.g. walls, floors, ceilings, finishing, permanent partitions and fixed service equipments etc[2][3]. Permanent dead loads are:
a) Self weight of the structural members
b) Floor finish = 25 psf
c) Internal partition wall = 25 psf
d) Peripheral partition wall = 500 plf
Live Load:
a) Live loads based on occupancy =120 psf
b) Reduced Live Loads = 84 psf
Wind Load:
The calculation of wind loads had been also confirmed.
Where, qz = Sustained Wind Pressure at height z (kN/m2)
Cc = Velocity to pressure conversion coefficient = 47.2 × 10-6
CI = 1.0 [1]
Cz = Combined height and exposure coefficient Vb = 260 km/hr.
The design Wind Pressure Pz for a structure at any height z above mean ground level has been determined from the relation
Where, Pz = Design pressure at height z (kN/m2)
Cg = Gust coefficient [1]
Cp = Pressure coefficient for structure or components
qz = Sustained Wind Pressure as defined above.
Earthquake/Seismic Load:
The calculation of the earthquake load has been confirmed in BNBC. Dynamic Response method is adopted to calculate seismic lateral forces.
The total design base shear is calculated from the following equation.
Where, Z = 0.15 (Seismic zone coefficient) [1]
I = 1.0 (Structural Importance Coefficient) [1]
R = 8 (Response Modification Coefficient) [1]
W = Total seismic dead load in kN
C = (Numerical Coefficient)
Where, S = 1.5 (Site Coefficient for seismic lateral forces) [1]
T = Fundamental period of vibration
Basic Load Cases:

Sl. No	Load Type	Sl. No	Load Type
1	EQ-(+X)	4	EQ-(-Z)
2	EQ-(-X)	5	DL
3	EQ-(+Z)	6	LL

Combination of Load Case:

Sl. No.	Load Combination
7	DL+LL
8	1.4DL+1.7LL
9	0.9DL+1.43EQ(+X)
10	0.9DL+1.43EQ(-X)
11	0.9DL+1.43EQ(+Z)
12	0.9DL+1.43EQ(-Z)
13	0.75(1.4DL+1.87(EQ+X))
14	0.75(1.4DL+1.87(EQ-X))
15	0.75(1.4DL+1.87(EQ+Z))
16	0.75(1.4DL+1.87(EQ-Z)
17	0.75(1.4DL+1.7LL+1.87EQ(+X))
18	0.75(1.4DL+1.7LL+1.87EQ(-X))
19	0.75(1.4DL+1.7LL+1.87EQ(+Z))
20	0.75(1.4DL+1.7LL+1.87EQ(-Z))
21	1.4(DL+LL+EQ(+X)
22	1.4(DL+LL+EQ(-X))
23	1.4(DL+LL+EQ(+Z))
24	1.4(DL+LL+EQ(-Z))

Where, DL = Dead Load
LL = Live Load
EQ = Earthquake/Seismic Load

D. Design Methods

R.C Structure: Ultimate Strength Design (USD) method has been adopted for design/check of all R.C structural members / elements.

E. Software and computer program

STAADPro-Version-6 has been used for analyzing Structure.

IV. Major Findings

Available documents have been reviewed thoroughly and findings are as below:

- Building was constructed in the year of 2000-02.
- Shape of the building is more or less regular.
- Five inch thick slab seemed safe to carry the load comes on it.
- No lift or lift core were present.
- Some footings were combined and some were isolated column footing.
- 19 nos. of old columns were jacketed to enhance column capacity.

External conditions of the building are impressive. Most of the column size seems to be satisfactory. Five inches reinforced floor slab apparently satisfactory for surcharged load. Appearance of beams and slabs at different floors are acceptable. Maintenance of the functional floors found satisfactory though some hair cracks were visible on some beams near the support.

Concrete cores were taken from some columns and various locations of slab and were tested for compressive strength. Extensive rebound hammer test has been done at the ground floors of the building. Detailed structural analyses have been carried out using available information. Computer aided modeling and design techniques were used as analyses tools. The computer software used for modeling and analysis is STAAD.Pro-Version–6.

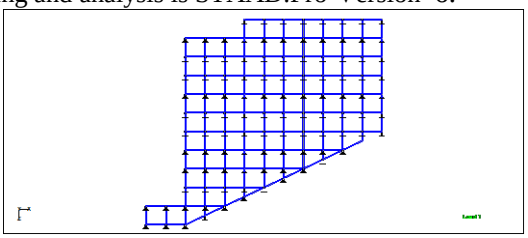

Fig. 3: Isometric 2D view of building (Taken from STAAD pro Model)

Manual calculations have also been performed to authenticate computer software output.

V. Discussion

Results of core tests conform to the assumptions of structural design. Our research includes core tests results. This assessment also includes random evaluation of the condition of column. It has been showed the column reaction due to load from the structure. It is found that column capacities are more than the load from super structure. From above analyses, it appears that the building is structurally capable to function as commercial entity. However factor of safety of structural elements of the building seems to be non-uniform. Similarly the lateral displacements of the building (bare frame) of the building have been analyzed and checked for Dead Load, Live Load and Earthquake Load. The lateral displacements in both long and short directions have been found to exceed the acceptable limit (Height of the Building/500) due to Earthquake Load. However, considering slab as diaphragm and infill walls, displacement reduces to the limiting values.

VI. Conclusions

It has been assessed for the structural integrity based on the available information and the following conclusion may be drawn from this evaluation:

- Field observation reveals no significant indication of distress in the building structure.
- The analysis of the building shows that it is safe considering present occupancy as business and mercantile.
- Foundation and columns are safe considering both vertical and horizontal loading.
- The building shows torsion irregularities within the allowable limit due to lateral loads.
- All the floor slabs have adequate thickness and reinforcement.

Based on extensive field investigation, in-situ material strength, analysis results and available design/drawing as mention above, the building structure can be recommended as safe to take care of loads coming from both vertical and horizontal directions. The lateral displacement of the building is within the acceptable limit due to earthquake loads.

References

[1] http://pwd.gov.bd/document/library/BNBC_Part01.pdf

[2] Chang Hai Zhai, Zhi Zheng, Shuang Li, Li Li Xie ;Seismic analyses of a RCC building under mainshock–aftershock seismic sequences; Journal of soil dynamics and earthquake, Volume 74, Page 46-55, July 2015.

[3] Y M Parulekar, G R Reddy, KKVaze, A K Ghosh, HS Kushwaha, R Ramesh Babu; *Seismic response analysis of RCC structure with yielding dampers using linearization techniques*; Journal of Nuclear Engineering and design, Volume 239, Issue 12, Page 3054-3061, December 2009.

Md Abdul Wahed is the principal research engineer at Structural Engineering & Construction Division in Housing and Building Research Institute, Dhaka, Bangladesh. He completed his bachelor from Bangladesh University of Engineering and Technology (BUET).

Md. Arifujjaman is working as research engineer at Structural Engineering & Construction Division in Housing and Building Research Institute, Dhaka, Bangladesh.