

## Sustainable RCC Building Construction and Rehabilitation in Bangladesh: The Urgent Needs

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**ABSTRACT:** In the past two and half decades, major business districts including Dhaka the capital of Bangladesh have experienced a marked growth in infrastructure, particularly in the building construction sector. However, the capital city Dhaka and its adjoining counties are gradually becoming unsustainable for living. Lack of enforcement of building codes in structural design and slack enforcement of regulations by the capital development regulatory authority (RAJUK), inadequacy of detail design drawings and poor quality of construction have already caused unbearable loss of life of factory workers. Severe injuries from building collapse have also resulted in permanent disability. In recent times (April 2013), the collapse of Rana Plaza in Dhaka have resulted in more than 1100 deaths of garment workers. It is believed that this is the largest death toll in human history in a single building collapse. Many building are even unsafe for gravity loads. In particular, there is a growing apprehension that a moderate to severe earthquake in any major city will result in devastating loss of life and property including breakdown of life line structures. In the recent past (2005 and 2006), buildings have collapsed in Dhaka city during construction due to poor subsurface investigation, poor quality of construction and poor construction practices. In this study, risk factors in the construction industry are identified qualitatively from safety considerations. Strict compliance to building development regulations and safety measures taken by the management in the RCC building construction sector are studied considering safety issues. This paper presents the outcome of those investigations and identifies the urgent need for measures to be taken for ensuring sustainable growth of RCC building construction and rehabilitation in Bangladesh.

### 1 INTRODUCTION

Rapid urbanization has been taking place in Bangladesh for the last two and half decades. A large number of industrial, commercial and high-rise apartment complex buildings have been built throughout Bangladesh during the past few decades. The building construction industry is one of the fastest growing as well as one of the largest sector in Bangladesh in terms of its contribution to the GDP. The growth rate of the sector in terms of GDP has been 6.7 percent during 1996 to 2009 (WCC, 2009). The sustained and continuing growth of this sector resulted in the overall infrastructure development of Bangladesh and its economy. Although the construction industry is growing rapidly in Bangladesh, building construction technology has not developed to the extent observed in developed countries. structural safety, occupation health and safety, and records of injury in the workplace show that it has the worst safety record when compared with other industries in Bangladesh. The dismal safety record of the building industry is comparable only to the Bangladesh garments industry. Recent building collapses under normal working loads have resulted in large number of deaths and injuries leading to disability.

For example, the deadly collapse of Rana Plaza that took more than 1100 lives (April 2013) happened due to violation of rules of the Bangladesh National Building Code (BNBC 1993) and the regulations of the City Development Authority (RAJUK) for vertical extension of buildings. In addition, faulty construction practices, lack of quality control and lack of proper supervision have resulted in the construction of unsafe structures. The tendency of non-compliance in the construction industry with regard to building codes and regulations and quality construction practices have been the primary reason for a devastating disaster in 2005, when a nine storied garment factory building at Savar, Dhaka suddenly collapsed. Another example is the collapse of a five storied building in Tejagaon industrial area, Dhaka (2006). All these collapses occurred under normal working loads. In this connection, it can be mentioned here that in the last one and a half year, the first author has extensively conducted nondestructive evaluation of columns, beams and slabs. Structural members of factory buildings including residential and commercial buildings were investigated (one Turkish carpet factory and a big hotel are included in these investigations). The strength of concrete was found to be less than 20% to 30% of the design strength for a significant number of buildings. The rules for safe building design as well as rules for safe construction are provided in detail in the BNBC. However, in many construction sites these rules are ignored due to slack enforcement as well as due to lack of trained professionals to enforce these rules.

The rapidly growing construction industry of Bangladesh urgently needs attention with regard to safety aspects. Appropriate national enforcement policies are needed to build safe and sustainable structures so that loss of life resulting from faulty design and construction practices can be prevented. Improvement of safety measures in construction sites and strict implementation of detailed design following BNBC is expected provide safer buildings. In this paper, recent major building collapses are investigated and discussed in detail. In addition, the current trend of construction practices adopted by developer companies and corporate business organizations for constructing buildings in Dhaka city are also investigated. The technology scenario regarding available safety measures in the construction sector currently used is also discussed.

## 2. RECENT MAJOR COLLAPSE OF INDUSTRIAL BUILDINGS

Some incidents of recent building collapse under working load (gravity) can illustrate the severity and magnitude of disaster scenario, which can occur in a post earthquake situation in major cities of Bangladesh. Some happenings of recent collapses during 2005 to 2013 are shown in the following

### 2.1 *Deadly Collapse of Rana Plaza Building*

In April 2013, a nine-storied commercial building “Rana Plaza” at Savar County, close to Dhaka, collapsed (Figure 1). The collapse of “Rana Plaza” is being considered as the most destructive building collapse in human history. As shown in Table 1, this deadly collapse took more than 1100 lives. More than 2400 people were rescued alive from the wreckage. More than 1500 were badly injured. Although this building was designed as a 5-storied commercial building, it was built up to 9 Storey and was being used for industrial purposes. It had garment factories in several floors. According to media reports, cracks were seen in the building the day before the accident. However, the factories remained open to meet supply. This resulted in a tragedy. During investigation, violation of rules and regulations was observed at every step of the construction of this building. The following violations were noted:



Rana Plaza building, the day before collapse

Wreckage of ill fated Rana Plaza building

Figure 1: Deadly Collapse of Rana Plaza Building at Savar County, Dhaka

- It is mandatory to take approval of plan from Capital Development Authority (RAJUK) in order to construct any building in Dhaka City (including Savar County). Rana Plaza was constructed without permission from RAJUK. The revised plan for vertical extension (5 storied to 9 storied) was approved by the local council without considering the original structural designs

-An architect was involved for the preparation of the 5-storied building plan. However, no registered structural engineer was engaged for structural analysis and design checking for possible vertical extension with appropriate strengthening or retrofitting technologies. The building was vertically extended upto 9 storied without considering the capacity of the pile foundation to take additional loads

- Poor quality of concrete used in the columns is the main reason for the collapse of the building. The coarse aggregate made from locally burnt bricks were used. Such aggregates absorb too much water and produce very low strength concrete. The total construction was supervised by the owner himself who had no technical capacity for quality construction

- In Bangladesh National Building Code (BNBC), a structural importance factor is included for different types of super structure. This was totally ignored for the case of Rana Plaza.

- Sewing machineries and the generators for the factories were placed in the upper floors. BNBC does not approve generators in upper floors. Vibration of the generators accelerated the gradual weakening of the poor concrete which, finally resulted the collapse of the building.

Table 1. Post Disaster Rescue Operation Scenario

Rescued as alive	2438
Rescued as death	1115
Death in hospital	12
Total death	1127
Unidentified body	293
Treatment in hospital	More than 1500
Missing	More than 50

## 2.2 Spectrum Building

In 2005, a nine storied garment factory building at Savar, Dhaka suddenly collapsed due to gravity load for poor design and construction materials. In this incident, about 70 workers were

killed and about 90 workers were injured. It took more than a month to clean the debris from the site even though this building (Figure 2) is located in relatively open space compared to other densely populated locations and structures in Dhaka city. Investigation on this collapse revealed that the discontinuity in the pile foundation and the respective column resulted progressive collapse of the structure. Although initially the start of progressive failure was reported, no measures were taken by the concerned authority before the sudden collapse.

### 2.3 Warehouse Building

In February 2006, a five storied building undergoing remodeling construction for floors space-use collapsed without warning at the Tejgaon industrial area of Dhaka city, killing about 20 people and injuring about 40 (Figure 2). It is reported that this building, initially used as warehouse for factory machines and equipments was being built as a 500 bed specialized hospital in joint collaboration with Mount Elizabeth Hospital, Singapore. The probable cause identified as that pile up floor tiles on a floor by the labors that increased concentrated vertical load. These collapses indicate lack of continuous supervision and inadequate knowledge of the project supervisor. These are examples of vulnerable buildings that have failed under normal loading condition without an earthquake. In this respect, a moderate to severe earthquake can cause unbearable devastation and pose risk to lives of people and their assets, as well as the basic infrastructure of the country.

## 3 STRUCTURAL SAFETY RISK SCENARIO

The safety with regard to a structure means that it would not fail in its expected life time due to the maximum load considered (from all load cases) by the designer. But as mentioned, in recent years, some building structures collapsed suddenly that resulted a huge economic loss as well as human lives. The construction process needs to be implemented in such a way that the structure attains its proper strength and does not collapse in its desired life time. To explore this possibility twenty construction sites are considered in Dhaka city (Motijheel, Paltan, Pallashi, Dhanmondi, Elephant Road, Kalabagan, Mohammadpur, Mirpur, Gulshan and Uttara). Detailed inspection on the sites (Hasan and Kundu, 2012; Uddin and Khan, 2007) identify faulty construction procedures such as inadequate clear spacing between reinforcement bars at the beam column joints, non conformation of the requirements of minimum clear cover of structural elements and water cement ratio of concrete, segregation and improper compaction of concrete. The inadequate clear cover in column may result in spall of concrete cover earlier due to water absorption and rusting of reinforcement in particular in seasonal humidly climate time. Similarly difficulty is faced during placement of fresh concrete at the joint due to lack of appropriate spacing between reinforcement bars. The concrete strength is very sensitive on the water cement ratio. However, it is observed that worker has a tendency to add more water than the requirement for their convenience of transportation and placing of concrete in the moulds of structural members. This leads to segregation as shown in Figure 3 in concrete which in turn results poor concrete strength. On the other hand improper compaction (not placing the vibrator in vertical position) as shown in Figure 3, results in porous concrete. The main causes of construction faults (clear cover and minimum spacing between bars) and poor fresh concrete preparation, transportation, placing and improper compaction are reasoned as poor inspection by the site engineer or sometimes absence of site engineer, lack of knowledge of workers on concrete strength, violation of Building Code and overall poor management of the developers, contractors.



Figure 2 (a) Collapse of Spectrum building



(b) Collapse of Phoenix Building



Figure 3 (a) Concrete mix with high W/C ratio



(b) Vibrator at inclined position

#### 4 HUMAN SAFETY RISK SCENARIO

Human life is the most valuable possession to every human being. So it is very difficult to accept death and bear its outcome in terms of social and economic implications. The economic implications include not only the total amount of lost earnings but loss of experience, insurance cost, delay in completion of work and increase in cost of work (Hinze, J: 1997). On the other hand Social implications include psychological strain to the family. This situation is severe when the worker is unmarried and aged parents have no means of earning. As mentioned earlier, twenty construction sites located in different areas of Dhaka city are inspected in detail to observe the conditions of safety measures to workers and pedestrians. The risk scenario associated in the construction sites is presented in Table 2.

Table 2. A Summary on Human Safety Risk Associated in Different Sites of Dhaka City

Sl. No.	Human Safety solutions applied by Developers	Observations/Remarks
1	Managerial Status with Regard to Human Safety	No Inspector Employed
2	Use of hand gloves, Helmets, Safety Belts etc.	65% not provided at all
3	First Aid Attainment	65% not available
4	Training and Regular Safety Practices	100% not trained
5	Precaution Signs at Sites	90% not provided
6	Boundary Fence and Hanger Net for Protection	20% not provided
7	Risky Equipments and Tools	15% to 50% risky equipments found
8	Insurance Policy for Workers	Most cases no insurance for workers
9	Compensation	About 10% no compensation provided
10	Police and Media Informed	Most of accidents are not informed

## 5 THE URGENT NEEDS FOR SUSTAINABLE GROWTH OF INFRASTRUCTURE

### 5.1 *Immediate role of the Government*

For preventing deadly collapse of existing buildings, the government should first immediately identify and then stop the illegal use of residential and commercial buildings for light industries such as garment factories. It should be mandatory for existing building owners to display approval and occupancy certificate showing the type of building with corresponding design load information. The authenticity of the certificates may be verified by contacting the building regulatory authority (RAJUK in case of Dhaka). A step by step risk assessment of buildings (Ahmed et. al., 2007; Sucuoglu and Yazgan, 2003) in different areas of major Cities needs to be carried out for designing an appropriate rehabilitation program. The concerned ministries may take necessary steps to seek support from international development partners. Educational institution buildings, emergency shelters ( during cyclones and earthquakes) public and private hospitals, clinics, government and semi-government buildings including private garment industries should be taken care of under the framework of the rehabilitation program. The Government of Bangladesh is expected to take necessary steps required to execute a program of investigation regarding the vulnerability of the infrastructure of the country's critical facilities. Above all, awareness among the general people regarding safe sustainable use of buildings and essential infrastructure should be increased. Government needs to play an important role in this connection. With regard to post-disaster management, Disaster Management Bureau may set up a command and control centre and take over the whole process. Bangladesh is the member of International Search and Rescue Advisory Group (INSARAG) which includes search wing, rescue wing, technical wing and medical wing. Government should ask help from them and coordinate the planning and management of relief and rescue operations with them. In American standard, such a team is generally a 31-man unit. It is advisable for Bangladesh to form several such working units. Some policy measures are suggested which may help to build safe and sustainable infrastructure for the future:

- Rewarding companies through tax incentives which implement earthquake resistant design and construction
- Organizing seminars and short training programs regularly on earthquake resistant design and construction at The Institution of Engineers Bangladesh (IEB), annual fair of real estate companies through Real Estates and Housing Association of Bangladesh (REHAB) etc
- Providing community based earthquake disaster preparedness program
- Undertaking programs periodically to identify vulnerability of public buildings such hospitals, schools, floods and cyclone shelters. In the event buildings are assessed to be vulnerable, initiatives may be taken for their rehabilitation

### 5.2 *Role of Garment and other Export Oriented industries*

Capacity building initiatives need to be taken for factory personnel to train them on the basic function of structural elements with regard to load carrying capacity and safe construction practices. Industry associations should encourage industry owners to take immediate action for implementing a program for assessing the vulnerability and risk assessment of their essential infrastructure and take appropriate rehabilitation measures if so required. It is the responsibility of the factory owners to ensure safe and risk free work environment of all factory workers and personnel. For financing such a program the owner may approach banking institutions, international financial organizations and donors for grants/loans if necessary.

### 5.3 *Government and Private partnership cooperation program for RCC Construction*

At present the building development regulatory authority such as RAJUK for Dhaka Capital and part of greater Dhaka has limited manpower to monitor large number of RCC buildings. With such limited manpower it is difficult to ensure the enforcement of building construction regulations (as per building code) during design and construction. A possible solution to ensure implementation of National Building Code and regulations of RAJUK is to involve various public and private consulting agencies in the process and/or to formulate a program of public private partnership (PPP). For example for a particular area RAJUK may allow a private enterprise, a public institution (for example an academic institution) or a private and government joint venture for a particular region. This entity will thoroughly check and initially approve the architectural plan, structural design including fire safety requirements for industries, commercial and residential buildings. They will then forward these documents for final approval by RAJUK. This will ensure that building code and construction practices and regulations are strictly followed for RCC building construction in the country. However RAJUK has become involved in building and infrastructure development. This severely limits its effectiveness to work as a regulatory body for planned development of the city. To overcome this problem, some leading civil engineering academics and experts have recommended the establishment of a National Building Regulatory Authority. This authority will only be involved in regulatory work.

### 5.4 *Immediate Role of International Donors*

After gaining independence in 1971, Bangladesh initiated a series of Global Assistance programs for reconstructing a war savaged nation struggling with poverty, unemployment, food and energy crisis, natural calamities and weak governance. In the last 40 years, Bangladesh has achieved significant milestones on socio-economic indicators. The uninterrupted flow of aid has remained a critical factor in sustaining its development activities. Donor organizations such as UN, World Bank, DANIDA, SIDA, SDC, CIDA, USAID, DFID, GIZ (former GTZ), NORAD, AusAID etc. have been thoroughly integrated into the development processes of the country.

Though the economic development of a country depends on its domestic effort, foreign donor organizations generally play a vital role in this case. National plans and initiatives are difficult to implement without foreign funds due to lack of adequate foreign currency reserves. Donor agencies make up this shortfall and thus assist the Bangladesh government to achieve development goals. Bangladesh has its own development agenda and policy goals. Donors contribute both financially and technically to achieve the ends of these policies wherever appropriate.

Foreign Funds are intervening major sectors which an under developed country like Bangladesh lack in areas such as Education, Health Service, Environment (Bangladesh Green Development Program; UN), Socio- Economic Development, Governance (Local Government Support Project LGSP-LIC; UN, DANIDA), Energy, Housing, Rural Development, Infrastructure Development, Disaster Management (Comprehensive Disaster Management Program; UNDP, DFID, SIDA, AusAid) and many others. For appropriate use of such funds for development of safe and sustainable RCC building construction and rehabilitation (Ahmed et. al., 2005; Dorka and Schmidt, 2002) the following suggestions are put forward:

- Research and development on safety risk assessment and rehabilitation appropriate for this country. In this regard urgent step can be taken to establish an institute such as

“Infrastructure Risk Assessment and Rehabilitation Institute” or a non profitable NGO like “Safety Concern Bangladesh”

- Dissemination of knowledge and training on reducing building collapse hazards to practicing engineers, construction managers, garments and other factory workers and owners etc, as well among the business and general people living in residential buildings and apartment complexes. Organize periodic seminars to disseminate information on gravity load and earthquake related hazards to practicing engineers, academics, real estate developer companies and the general people.
- Use of electronic and print media to disseminate information regarding possible causes of building collapse and hazards and the technology available to mitigate or prevent such collapses
- Sustainable implementation of projects in a planned way for optimum utilization of funds for achieving maximum benefit
- Collaborative research work between Bangladesh and foreign academics and technology institutions for safe sustainable buildings

#### 5.5 *Immediate Action of Media Business Owner*

Media can play a vital role towards highlighting the need to build safe buildings and to strengthen existing ones. Advertisements and broadcasting of short length documentaries in private and national TV channels can play a vital role in making people aware of the potential hazards of improperly built structures under normal circumstances and particularly during earthquakes and other natural hazards. Broadcasting post disaster scenarios of different countries such as collapse of building under gravity loads (South Korea) earthquakes (Turkey, Italy, India etc.) will generate awareness regarding the possibility of such a disaster really occurring in Bangladesh also. The present seismic scenario of Bangladesh may be described and explained, and finally the solution to the problem may be presented. The solution will include provisions for design, construction, maintenance and additional costs required to build earthquake resistant structures. People need to be convinced that such costs are justified to ensure the safety of their lives and livelihoods. Apartment buyers and house owners will not hesitate then to spend an additional amount of money to safeguard their assets. The approximate additional cost per apartment is expected to be 2% - 3% if seismic design provision is incorporated in a building. Affluent segments of the society may provide financial support for printing and distribution of leaflets and/or for sponsoring advertisements in the media sector (TV, Radio, Billboards on street sides). They can also provide research and training funds to universities as part of their social welfare undertakings and responsibilities. Advertisements made in the form of stories entertain as well as inform people. Industrialists, NGOs, corporate business organizations may undertake to sponsor these kind of programs as part of corporate social responsibility..

#### 5.6 *Role of Real Estate Developer*

Display boards may be posted at construction sites showing construction details in a simple way. Requirements for seismic or earthquake resistant design may also be displayed. This will motivate common people passing by the site to build seismically safe houses when planning to go for asset development. Systematic Quality Assurance Programs need to be implemented in the construction site. A log sheet reporting basic checks such as aggregate mixing ratio, water cement ratio, reinforcement detailing (including seismic considerations) may be filled on site by the quality assurance engineer when casting concrete. Materials Laboratories can be established at construction sites by the Real Estates and Housing Association of Bangladesh (REHAB) for training workers at these sites. This will ensure quality work.

### 5.7 *Role of Academics and Practicing Engineer*

Academics of universities may undertake collaborative research and training programs with similar institutions of foreign countries that have experienced major earthquakes. It is suggested that initially collaborative research programs be undertaken with Istanbul Technical University, Swiss Federal Laboratories for Material Science and Technology (EMPA) and Swiss Federal Institute of Technology to develop and upgrade the training curriculum for training different target groups. These may include quality assurance engineers at the site as well as construction workers especially construction managers. This program may include exchange of academics and professionals between Bangladesh and universities of Europe to conduct joint research that upgrade knowledge of academics and trainers with regard to safe building design, construction and retrofitting of existing vulnerable structures. A postgraduate course on Risk Assessment and Rehabilitation may be introduced at BUET and other technical universities of the country. Customized detailing for additional seismic reinforcement and anchoring for continuity with existing structural members, appropriate scaffolding and shuttering systems for site rehabilitation has to be developed. Periodic workshops can be held at the universities, Institute of Engineers Bangladesh and Real Estate and Housing Association Bangladesh etc. for training of different professional groups including field level engineers, skilled and semi-skilled workers. Such workshops may play a vital role in transfer of technology, development of appropriate and inexpensive local rehabilitation technologies, etc required for initiating a step by step risk assessment and rehabilitation program in the country. Upgrading of structural and geotechnical laboratory facilities of the universities for seismic evaluation and testing may also be undertaken. Financial support for upgrading laboratories may be sought from international donors under the framework of international cooperation between institutions of higher education.

## 6 CONCLUDING REMARKS

The recent deadly collapse of nine storey Rana Plaza building along with the collapse of the Spectrum Garments building in 2006 have been reported in this study. The probable causes for these failures have been identified. It has been observed that the Bangladesh National Building Code (BNBC) was not followed during design and construction of buildings and related infrastructure. The rules of the Building Regulation Authority were also ignored. This incompliance eventually resulted in complete and sudden collapse of the Rana Plaza building and the Spectrum Garment building. The owners of these buildings did not take any pre-emptive measures as progressive cracks developed in the columns even after being informed by the workers. Investigations carried out in construction sites indicate that a lack of quality supervision exists in most cases. In addition, the building code is not strictly adhered to during construction of industrial buildings. Construction workers as well as site engineers are not properly trained and sensitized with regard to the paramount importance of human safety and the devastating economic effect of loss of life and services in case of collapse of a building due to faulty construction. Such training of construction workers, site supervisors and site engineers is essential to ensure quality of construction. Quality of construction is of paramount importance to ensure safe and sustainable buildings and infrastructure. On the other hand owners of garment industries, commercial buildings and developers of apartment complexes are not sensitized to the issue of the safety of the lives of workers, residents or even about the real possibility of the loss of their own property and livelihoods. Many owners and developers want to maximize profit by disregarding the building code and the regulations of building development authorities. In most construction sites, workers are not aware or conscious of the need to protect themselves from possible injuries. These sorts of risk can be mitigated through periodic training of owners, workers and managerial personnel on both occupational health and safety practices and by strict

monitoring and enforcement of the law by the regulatory agencies. In this regard, donors may come forward to play an important role. They may finance the establishment of training institutes to train workers and engineers on good construction practices, as well as on risk assessment and rehabilitation of existing vulnerable buildings. In this context it may be mentioned here that the success in sustainable development in the Water and Sanitation sector has been achieved nationwide in Bangladesh through grants from Donors especially by DANIDA (Denmark). Similar remarkable developments in rural road communication network have been achieved by the Local Government Engineering Department with major support from SIDA (Sweden), JICA (Japan), GIZ (Germany) etc. SDC (Switzerland) is now working towards human aid and disaster risk reduction (cyclones affected districts). Universal female education and female empowerment at the grass root level has been achieved through e-media broadcasting. A documentary mini-series named "MINA" popularizing female education and empowerment is funded by UN. This advertisement is very popular and still running in local media channels. The media should continue to play a vital role on this issue considering it as a part of their contribution on corporate social responsibility. It is strongly believed by the authors that appropriate steps taken now will ensure sustainable and safe infrastructure for all in the future.

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