

**ON GOING RESEARCH PROJECT
UNDER
STRUCTURAL ENGINEERING & CONSTRUCTION DIVISION (SECD)**

**1. Study of Salinity Effects on Concrete Structures in Coastal
Region**

1. Background:

One of the major issues in coastal region is salinity. Due to the presence of salinity the major source for drinking water is groundwater. The sea water can also seep in and affect the coastal structures. Through pores water can leach in the concrete structure and make its way to the reinforcement and deteriorate it. Also in coastal areas there is scarcity of fresh water and thus using saline water which is present in abundance can also be a solution. The presence of sulphate salts at high rates negatively affects the hardened cement paste due to the formation of additional quantities of Ettringite where a large volume increase in the hardened cement paste leads to internal stresses causing cracks in the concrete mass affecting the resistance.

The number of marine concrete structures in Bangladesh is increasing every year. However, it was found that the marine concrete structures in Bangladesh are subjected to severe deterioration after a short period of exposure which results in significant loss of national revenue of the country. Therefore, this research study is crucial to overcome the loss of coastal establishments from chloride induced corrosion.



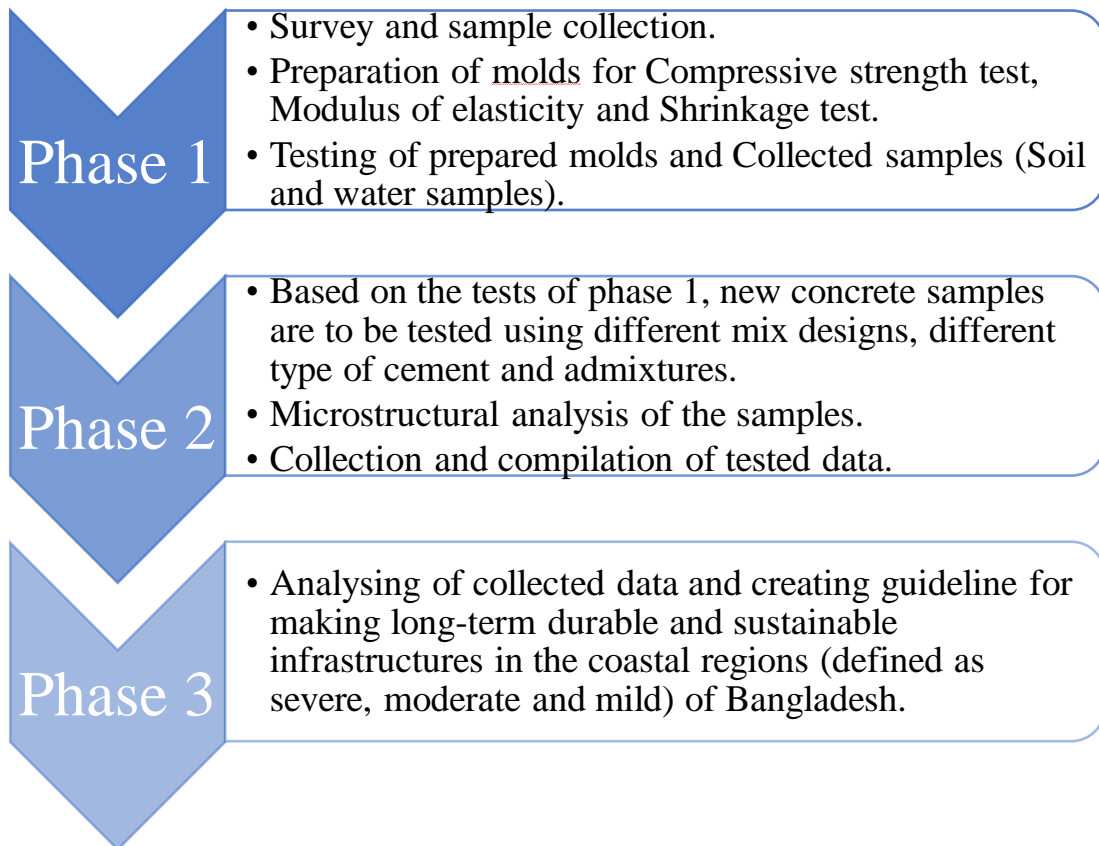
2. Objectives of the Research:

- To study the effects of salinity on concrete comprising coastal structures.
- To observe the lifetime of coastal RCC structures.
- To study the effects of using saline water as an alternative to fresh water.
- To study methods to protect steel structures from saline water.

3. Scope of the Research:

- To understand the cause of deterioration in coastal structures.
- To find alternative solutions and how they are affected by the salt water.
- To understand the effect of salt water on concrete properties when used instead of fresh water.
- To observe the lifetime of coastal RCC structures.
- Development of seawater resilient and sustainable infrastructure will help toward achievement of several Sustainable Development Goals (SDGs) of the United Nations, such as SDG 9 – Industry, Innovation and Infrastructure, SDG 11 – Sustainable Cities and Communities, SDG 13 – Climate Action, etc.

4. Research Methodology:



2. Experimental Study on the Behavior of RC Beam-Column Joint Retrofitted With Ferro Cement Jacket under Cyclic Loading

1. Background:

Bangladesh has already been known to be an earthquake prone area. Here, almost all residential buildings are reinforced concrete (RC) structures. In RC buildings, portions of columns that are common to beams at their intersections are called beam-column joints. Since, their constituent materials have limited strengths; the joints have limited force carrying capacity. When forces larger than these are applied during earthquakes, joints are severely damaged

Effectiveness of FRP and CFRP (carbon fibre-reinforced polymer) as a repair and retrofitting material is now well established. However, FRP/CFRP is expensive material and therefore may not be economically attractive in developing countries like Bangladesh. Low cost alternative should be sought after. Ferrocement laminates is a proven material for general purpose repair of RC structures. Over the past three decades, the use of ferrocement has gained tremendous popularity in different areas of civil engineering (e.g. masonry structures, water tanks, fluid retaining structures etc.). Therefore, the present study has been aimed at performing some experimental investigations using ferrocement as a replacement for FRP/CFRP in retrofitting/strengthening RC beam-column joints.

2. Objectives of the Research:

The objectives of the present study are as follows:

- To study the performance of RC beam-column joints retrofitted with ferrocement under cyclic loading.
- Comparative study of the bare RC beam-column joints with ferrocement jacketed joints.

3. Methodology and Scope:

The present research topic will be undertaken to study the behavior of reinforced concrete beam-column joint retrofitted with ferrocement under cyclic loading through experimental study. To study these effects four two bay two story RC frames representing beam-column joint will be constructed in the laboratory. Two of these frames will be jacketed with ferrocement and remaining two specimens will be kept as cast without jacketing and denoted as reference specimen. Cyclic load will be applied with same arrangement to all four specimens. Crack formation and propagation with deflection behavior throughout the loading period till complete failure will be studied and comparison between reference specimens and jacketed specimens will be studied. Findings will be quantified for the purpose of presenting in graphs and tabular form.

3. Comparative Study Between Concrete Block (CB) Aggregates And Other Conventional Aggregates

1. Background:

Concrete is the most widely used in the world as construction material. In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements. The usual ingredients in concrete are binding materials as cement, coarse aggregate as stone or brick chips and water. Sometimes various admixtures are used with mixing materials in concrete to reach the required mechanical properties. Aggregates impart higher volume stability and better durability than hydrated cement paste in concrete and provide around 75% of the body of concrete. Most of the country in the world, aggregates are usually made from natural sources but in regions such as Bangladesh and parts of West Bengal, India where natural rock deposits are rare, burnt-clay bricks are used as an alternative source of coarse aggregate. But burn clay is one of the most negative impact on environment. Nowadays, in the context of sustainable development and with thermal regulations, it is necessary to develop new construction materials with high thermal, mechanical performance and environment friendly.

Concrete block is one kind of environment friendly material. Concrete blocks are being very popular in construction. These blocks are being mostly used in the construction of multi storied buildings, factories and residential buildings as masonry works. These concrete blocks are commonly used in compound walls because of cheapness. Since the use of blocks is increasing day by day in Bangladesh. As a developing country, both the production and use of the block will be available in a few days as like as burn clay brick. It will be a big opportunity that if derive coarse aggregate from concrete block. It can be defined as Concrete Block Aggregate (CB aggregate).

2. Problem Statement:

Aggregates are one of the most important ingredients for concrete, which is combined with a paste of cement and water. Stone aggregate is traditional ingredient of concrete in the world and it is available foreign country. But in the region in Bangladesh stone aggregate is not available and also most expensive. In Bangladesh, Brick aggregate are easily available and much cheaper than stone aggregate as a result brick aggregate is mostly used in concrete instead stone aggregate. But Brick burning contributes to environmental pollution, ecosystem damage and also to absorption of greenhouse gases in the atmosphere in higher quantities. Brick kilns have long term and short-term impacts on the environment.

For this reason, both brick production and use are opposed to sustainable development. So it is necessary to use of alternative aggregate in any construction site to reduce the uses of brick aggregate. Therefore, Concrete Block Aggregate (CB aggregate) can be used as coarse aggregate in Brick aggregate replacement. Because Concrete Blocks are eco-friendly and also support the sustainable development. Regular use of concrete blocks in building construction materials can automatically reduce the overall use and production of burn clay bricks and Negative effects on the world's environment can also be reduced.

3. Research Goal:

The objectives of this study are as follows:

- To know the various properties of CB aggregate and also compare the properties of Brick aggregate.
- To analyze the effect on concrete strength for the using of CB aggregate.
- Developed alternative coarse aggregate from the concrete block instead of burn clay brick aggregate.

**COMPLETED RESEARCH PROJECT
UNDER
STRUCTURAL ENGINEERING & CONSTRUCTION DIVISION (SECD)**

**Research on Structural, Electrical and Fire Safety for RMG
Factory Building in Bangladesh**

EXECUTIVE SUMMARY

The Rana Plaza incident together with Tazrin Fashion incident triggered the indication of the acute problem. As most of the RMG buildings were constructed before the enforcement of local standards and using policy guideline, an in-depth study has to be carried out so that the practical situation can be understood and the root cause of the problem has to be documented. Different initiatives like ALLIANCE, ACCORD, NTP came along to work on to solve the non-conformity issue that prevails in the RMG buildings in Bangladesh. It has been observed, there are some confusion and lack of clarification regarding RMG context. To find out the specific difference between current industry practice and available national code of practice. BGMEA requested HBRI to conduct a research work “Research on Structural, Electrical and Fire Safety for RMG Factory Building in Bangladesh”. It was decided to get field data from RMG factories on critical issues. The survey data was collected from Dhaka Metro and Dhaka District, Narayanganj District, Gazipur District, Manikganj District and Chattogram District of Dhaka and Chattogram Division.

ELECTRICAL SAFETY

Specific Scope of Research:

The scope of the research is to make statistical analysis with the field data and validation & publication of the acquired data for

- a. Minimum cross-sectional area of copper ECC's in relation to the area of
- b. Associated Phase Conductors.
- c. Minimum distance between two adjacent grounding PIT of earthing system.
- d. Space for Transformer.
- e. Space for Standby Generator.
- f. Height of Distribution Boards (incoming Circuit Breaker).

STRUCTURAL SAFETY

Specific Scope of Research:

The specific scopes for the research to make validation and publication are listed below.

- a. Load combination

- b. Occupancy group
- c. Minimum live load
- d. Impact and dynamic loads
- e. Introducing New Articles

FIRE SAFETY

Specific Scope of Research:

The scope of the research is to make statistical analysis with the field data (150 number of existing RMG buildings 16016150 square feet) and validation & publication of the acquired data for

- a. Occupancy Type (Industrial Occupancy).
- b. Vertical Shaft.
- c. Duration of Flow required for Fire Protection System.
- d. Space per Occupant.
- e. Fire Rating of Common Construction Element.
- f. Type of Construction (Steel Structure).

PART – A: RESEARCH ON ELECTRICAL SAFETY FOR RMG FACTORY BUILDING IN BANGLADESH

1.1 Background

Bangladesh, a raising developing country bordered by India and Myanmar has a population of approximately 164 million people. The economy of Bangladesh has a stable growth for the last decades and the Ready-Made Garment (RMG) industry has contributed in a leading role. Bangladesh is the world's second largest garments exporter after China. Approximately 80% of the total exports of Bangladesh are from RMG industry which propelled since its starting in 1970 with relatively small investment. This industry flourished in two phases in 1980 and 1990.

The majority of the RMG factory building was constructed in an unplanned way on a time span of last few decades in contrast of spatial planning. The Rana Plaza incident together with Tazrin Fashion incident triggered the indication of the acute problem hence stressed on the importance of safety conformity in the Structural, Electrical

and Fire attributes of a RMG building. Different initiatives like ALLIANCE, ACCORD, NTPA came along to work on to solve the non-conformity issue that prevails in the RMG buildings in Bangladesh.

During the execution of the different initiatives, lack of code reference and inconsistency in many aspects of the development of a RMG building came out. Some guidelines are prepared but the integration of all aspects is missed as a result the holistic approach to the solution of the problem is under question. As most of the RMG buildings were constructed under the local standards and policy guideline, an in-depth study has to be carried out so that the practical situation can be understood and the root cause of the problem has to be documented. This study came to the existence by the initiative of BGMEA. BGMEA requested HBRI to conduct a research work “Research on Structural, Electrical and Fire Safety for RMG Factory Building in Bangladesh”.

1.2 Objective

The specific objectives of the consultancy are to:

- a. Review available literatures to understand the concurrent practice related to RMG sector.
- b. Study the current scenario of building assessment under different initiatives locally and internationally.
- c. Prepare a formulation of code supplementary (Electrical safety) for RMG factories
- d. in Bangladesh and recommend updating for Bangladesh National Building Code
- e. (BNBC) in next revision.

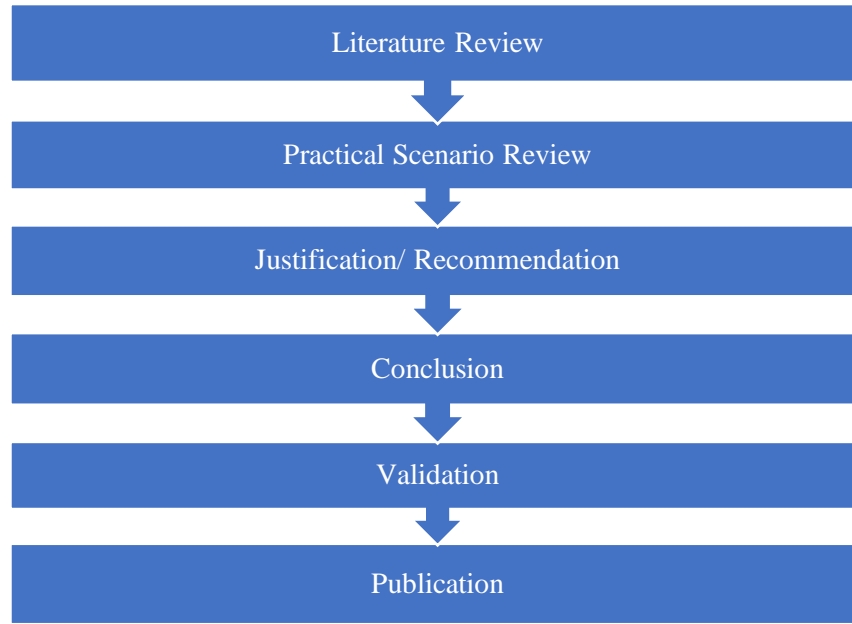
1.3 Scope

The scope of the research is to make statistical analysis with the field data and validation & publication of the acquired data for

- a. Minimum cross-sectional area of copper ECC's in relation to the area of Associated Phase Conductors.
- b. Minimum distance between two adjacent grounding PIT of earthing system.
- c. Space for Transformer.
- d. Space for Standby Generator.
- e. Height of Distribution Boards (incoming Circuit Breaker).

1.4 Methodology

This research was designed for scope centric assessment of concurrent local and international code of practice and standards. Field data has been collected based on requirements.



2.0 Recommendation:

The survey results pointed out that the requirements in BNBC 2020 for the following issues are widely accepted by the RMG sector and most of the industries comply these requirements. The issues are

- a. Minimum cross-sectional area of copper ECC's in relation to the area of Associated Phase Conductors.
- b. Minimum distance between two adjacent grounding PIT of earthing system.
- c. Height of Distribution Boards (incoming Main Circuit Breaker).

So, there is no need to adopt new requirement in BNBC 2020 for these issues.

However, some major deviations have been found for the following issues.

- a. Space for Transformer.
- b. Space for Standby Generator.

The requirements set in the BNBC 2020 are not followed in many of the industries for these two matters. The literature survey about these topics pointed out that there are scopes of revisions and the requirements can be relaxed a bit for the existing buildings. So, it is recommended that the space requirements for the transformer and generator

can be studied more details and the requirement set in NEC or Vietnam standard can be followed for the existing buildings.

In general practice in Bangladesh, when fire trigger in an industry or building, utility authority cutoff all utility supply in that area. So, there found difficult to run Fire Fighting equipment. This has been found that there is no emergency power distribution system plan for fire incident. It requires to run Fire Pump system, Fire Lift (if any) during fire incident. Hence, its being proposed to design an emergency power supply to fire equipment.

3.1 Limitations:

The research faced some limitations as below:

- i. The scopes of this research were limited. Area of evaluation was concentrated on selected topics. There are some other area which need to be reviewed.
- ii. Validation of Design and/or information shared by factory management was not part of this project.
- iii. Maintenance policy or guideline not reviewed.
- iv. The research was offer when the globe was suffering with COVID-19 situation. The research work suspended various time due to lockdown. It hampered physical data collection process.
- v. Time Limits: The timeline for this research was constraint. This should have some more timeline. Moreover, Due to country wide lock down, project timeline has been lost.
- vi. Sample Data Size: Targeted physical data collection was not possible due to pandemic lockdown. In some cases, could not get data on physical visit.

3.2 Conclusions:

It has been found, for electrical safety, RMG sector is maintaining code in some cases within the scope. In some cases, like transformer and generator its need to be more vigilant to maintain the code. Other international standards may be reviewed and absorbed in our code. It may be proposed to create a professional body for electrical design and implementation supervision. It may be included review maintenance schedule and audit periodically. Create an emergency power system for fire incident support. To review above, its need to research further.

PART – B: RESEARCH ON STRUCTURAL SAFETY FOR RMG FACTORY BUILDING IN BANGLADESH

1.1 Background

Bangladesh, a raising developing country bordered by India and Myanmar has a population of approximately 164 million people. The economy of Bangladesh has a stable growth for the last decades and the Ready-Made Garment (RMG) industry has contributed in a leading role. Bangladesh is the world's second largest garments exporter after China. Approximately 80% of the total exports of Bangladesh are from RMG industry which propelled since its starting in 1970 with relatively small investment. This industry flourished in two phases in 1980 and 1990.

The majority of the RMG factory building was constructed in an unplanned way on a time span of last few decades in contrast of spatial planning. The Rana Plaza incident together with Tazrin Fashion incident triggered the indication of the acute problem hence stressed on the importance of safety conformity in the Structural, Electrical and Fire attributes of a RMG building. Different initiatives like ALLIANCE, ACCORD, NTPA came along to work on to solve the non-conformity issue that prevails in the RMG buildings in Bangladesh.

During the execution of the different initiatives, lack of code reference and inconsistency in many aspects of the development of a RMG building came out. Some guidelines are prepared but the integration of all aspects is missed as a result the holistic approach to the solution of the problem is under question. As most of the RMG buildings were constructed under the local standards and policy guideline, an in-depth study has to be carried out so that the practical situation can be understood and the root cause of the problem has to be documented. This study came to the existence by the initiative of BGMEA. BGMEA requested HBRI to conduct a research work "Research on Structural, Electrical and Fire Safety for RMG Factory Building in Bangladesh".

1.2 Objective

The specific objectives of the consultancy are to:

- a. Review available literatures to understand the concurrent practice.
- b. Study the current scenario of building assessment under different initiatives locally and internationally.
- c. Prepare a formulation of code supplementary (Fire, Electrical and Structural safety) for RMG factories in Bangladesh and recommend some up gradation for practicing codes.

1.3 Scope

The scope of the research are,

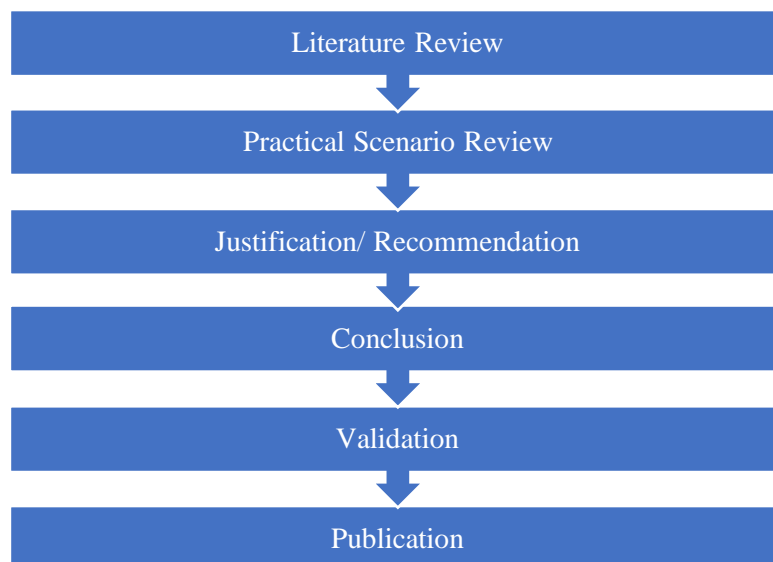
- a. To convey field survey for the specific structural design criteria
- b. To make a statistical analysis with the field data.
- c. Validation and publication of the acquired data.

The specific scopes for the research to make validation and publication are listed below.

- Load combination
- Occupancy group
- Minimum live load
- Impact and dynamic loads
- Introducing New Articles

1.4 Methodology

Appropriate literature is selected based on the research area and scope. Several national and international building codes such as BNBC 2020, BNBC 2006, Indian National Building Code 2016, IBC 2018, ASCE 7-05/10/16, ACI 318-14 are to be studied. These are taken as a reference to summarize and conclude to a comparatively considerable and implementable building code to a middle income country. For practical scenery review some field data has to be collected to recommend revised scopes. Statistical analysis has to be carried out for result generation from field data. From existing building data recommendation for new building would be suggested. The whole research shall be go through some validation process.



2.0 Recommendation:

Load Combination:

The load combination is reviewed and compared to other international codes BNBC 2020 is already similar to ACI, ASCE and IBC for load combination. Which are

1. $1.4D$
2. $1.2D + 1.6L + 0.5Lr$
3. $1.2D + 1.6Lr + (L \text{ or } 0.8W)$
4. $1.2D + 1.6W + 1.0L + 0.5Lr$
5. $1.2D + 1.0E + 1.0L$
6. $0.9D + 1.6W$
7. $0.9D + 1.0E$

In Indian national building code, factor for dead load, earthquake and wind load is more than that of BNBC 2020.

Occupancy group:

The occupancy category table in BNBC 2020 has been updated following ASCE7-10 and occupancy category for garments manufacturing industry has been added. Occupancy: I, II, III, IV is comparable with other building codes.

Minimum live load:

BNBC 2020 recommended live load 2.4 KN/m^2 for office space and for store 6 kKN/m^2 . These are found to be okay from the field data.

From field data, the recommended live load for cutting, finishing canteen, prayer, sewing rooms are 3 KN/m^2 . BNBC 2020 recommended live load 4 KN/m^2 for the above areas.

Impact and dynamic loads:

The values of acceleration for dynamic loads generated from the sewing floors are less than the harmful level of motion for human. For this reason, the effect of dynamic load in design of sewing floors may be omitted.

Introducing new article (Industrial Racking):

For design, maintenance and usage ANSI code is included here. Other international codes may be consulted for more references.

Further research is needed to make more economic design recommendation for RMG sector in Bangladesh.

3.1 Limitations:

The research faced some limitations as below:

- The scope of this research was predefined. This was some selected part from National Building Code.
- Pandemic Situation: The research was offer when the globe was suffering with COVID-19 situation. The research work suspended various time due to lockdown. It hampered physical data collection process.
- For occupancy group importance factors couldn't be changed as there needs do a vast research for changing this scope.
- These scopes are applicable for new constructions. For constructions earlier than 2021 NTPA guideline should be followed.
- For impact and dynamic loads only sewing floor is recommended for not implementing live load increment. More research needs to be done to get findings for other machine operated floors.
- Time Limits: The timeline for this research was constraint. This should have some more timeline. Moreover, Due to country wide lock down, project timeline has been lost.
- Sample Data Size: Targeted physical data collection was not possible due to pandemic lockdown. In some cases, could not get data on physical visit.
- For some cases difficulties has been found to have access in field.

3.2 Conclusions:

After going through the codes, it seems that ASCE, ACI and IBC are quite similar to each other. Sometimes these are making reference to each other. For some areas BNBC is also conveys similar data. This research implies optimized design factors for those scopes. Further research is needed to make more economic design recommendation for RMG sector. Other industries can be developed by more research works.

PART – C: RESEARCH ON FIRE SAFETY FOR RMG FACTORY BUILDING IN BANGLADESH

1.1 Background

Bangladesh is a developing country bordered by India and Myanmar has a population of approximately 164 million people. The economy of Bangladesh has a stable growth for the last decades and the Ready-Made Garment (RMG) industry has contributed in a leading role. Bangladesh is the world's second largest garments exporter after China. Around 80% of the total exports of Bangladesh are from RMG industry which propelled since its starting in 1970 with relatively small investment. This industry flourished in two phases in 1980 and 1990.

The majority of the RMG factory building was constructed in an unplanned way on a time span of last few decades in contrast of spatial planning. The Rana Plaza incident together with Tazrin Fashion incident triggered the indication of the acute problem hence stressed on the importance of safety conformity in the Structural, Electrical and Fire attributes of a RMG building. Different initiatives like ALLIANCE, ACCORD, NTP came along to work on to solve the non-conformity issue that prevails in the RMG buildings in Bangladesh.

During the execution of the different initiatives, some gaps and inconsistency in many aspects of the development of a RMG building came out. Some guidelines are prepared but the integration of all aspects wasn't possible for various reasons. As a result, the holistic approach to the solution of the problem is under question. As most of the RMG buildings were constructed under the local standards and policy guideline, an in-depth study has to be carried out so that the practical situation can be understood and the root cause of the issues have to be documented. Beside these, the research will make some recommendations against these issues.

This study came to the existence by the initiative of BGMEA. BGMEA requested HBRI to conduct a research work "Research on Fire Safety for RMG Factory Building in Bangladesh". Upon formal process, HBRI has selected Auspicious and Advisors as a consulting partner to conduct this research.

1.2 Objective

The specific objectives of the proposed consultancy are to:

- a. Review available literatures to understand the concurrent practice.
- b. Study the current scenario of building assessment under different initiatives locally and internationally.
- c. Prepare a recommendation (Fire safety) for RMG factories in Bangladesh and for future up gradation of BNBC, this research work also can be used.

1.3 Scope

The scope of the research are,

1.0 Occupancy Type (Industrial Occupancy)

- 1.1 Fire rating of Vertical Shaft
- 1.2 Duration of Flow Required for Fire Protection System (Capacity of water reservoir)
- 1.3 Space per Occupant
- 1.4 Fire Rating of Common Construction Element
- 1.5 Type of Construction (Steel Structure)

In order to select the above mentioned scopes; we have studied over 200 initial inspection reports and follow up reports by different foreign (ACCORD and ALLIANCE) initiatives and local (NTP- RCC) initiatives. Initially, we also have visited 20 factory buildings and interviewed factory compliance personnel about the most critical issues regarding fire safety which is hard to comply with codes. Afterwards, with the concern of Advisor Prof Dr. Maksud Helali, BGMEA and HBRI these scopes are selected and validated with 150 numbers of factory buildings.

1.4 Methodology



2.0 Recommendation

2.1 Recommendation for Type of Industrial Occupancy

As in different international codes (NFPA, National Building code of India & Vietnam), Industrial occupancy is subdivided into 3 or more groups. So, Industrial occupancy (230 types of production unit) can be divided into 3 or 4 subdivisions like G1, G2, and G3 and so on.

RMG need to be defined as “specialized occupancy” considering hazard, dense population and multi occupancy. Performance based design need to be implemented for this specialized occupancy. So that passive fire protection system, egress components, fire detection and alarm system and fire protection system of a building can be designed according to its merit.

In order to answer the question “How RMG can be subdivided into occupancy G1 or G2”, Fire load need to be quantified from the content of building. Smoke production rate and toxicity of gases occurs during fire incident need to be quantified for hazard calculation. A range can be defined as per Vietnam code for smoke production rate and toxicity of fumes.

Recommendation:

Occupancy Type	Symbol	Fire Load Density
Low Hazard Industry	G1	1 MJ/m ² to 180 MJ/m ²
Moderate Hazard-1 Industry	G2	181 MJ/m ² to 1400 MJ/m ²
Moderate Hazard-2 Industry	G3	1401 MJ/m ² to 2200 MJ/m ²
High Hazard Industry	G4	Greater than 2200 MJ/m ²

Conditions:

- In a building, the floor containing the higher fire load density will be considered.
- In a building, if any portion of floor has higher fire load density and area of that portion is less than 10%, it can be considered as accessory occupancy.
- If content of building has a quantity hazardous materials greater than exempted amount mentioned in Table 3.2.5a, BNBC (ed.2020). Then it will classified as “J”.

2.2 Recommendation for Vertical Shaft

Number of Storey		Fire Rating of Shaft Enclosure	Fire Rating of Opening Protective in Shaft Enclosure	Landing door of Lift Core	Opening Protective of Plumbing Shaft
Fire Rating of Shaft enclosure connecting 4 stories or more	New Building	2.0 hour As per BNBC 2020	1.5 hour As per BNBC 2020	1.5 hour	1.5 hour
	Existing Building	1.0 hour	1.0 hour	1.5 hour	0.5 hour
Fire Rating of Shaft enclosure connecting less than 4 stories	New Building	2.0 hour As per BNBC 2020	1.5 hour As per BNBC 2020	1.5 hour	1.5 hour
	Existing Building	1.0 hour	1.0 hour	1.5 hour	0.5 hour

- 1 Fire Rating of Shaft enclosure and its opening protective
- 2 Defining penetration as per NFPA & IBC. For penetration, shaft enclosure is not required. For small floor opening (1 sft or less) smoke enclosure (0.5 hour fire rating) is recommended.
- 3 Extent of shaft enclosure should be as per BNBC 2020.
- 4 For opening protective, different construction elements fire rating can be adopted from IBC 2018 Table 721.1 along with BNBC 2020.

- 5 Any connecting opening with the exterior vertical utility shaft need not to be fire resistant.
 - a. Scenario-1: Interior side of vertical shaft has proper fire resistance rating & Annular space around penetration are fire retardant materials.
 - b. Scenario-2: Interior side of vertical shaft has proper fire resistance rating and vertical riser are covered with open type shaft on exterior side.
- 6 Lift core and stair sharing same lobby shall be protected by 2.0 hour enclosure and 1.5 hour opening protective. Individual opening protective for lift and stair is not required.

2.3 Recommendation for Vertical Shaft

Firstly, For New Building, Capacity of Water Reservoir = 75 minutes of flow for fire-fighting (as per BNBC2020)

Secondly, For Existing Building, Capacity of Water Reservoir = 60 minutes of flow for fire-fighting

Thirdly, Capacity of Fire Water Reservoir = Capacity of Underground water tank + Capacity of Overhead water tank + Capacity of natural sources (ponds/ lake/ wells/ swimming pools etc) + Amount of Water continuously added to reservoir (It will be applicable if arrangement is done to connect all the sources and feed the firefighting system)

Fourthly, multiple buildings which are closely located can be provided with single hydrant system (single reservoir and single set of pump which can provide sufficient flow and pressure of water in required locations considering the critical condition)

2.4 Recommendation for Space per Occupant

RMG is classified as occupancy “G” in BNBC 2020. If RMG is subjected to G1 occupancy, then this 9.5 Cu.m per occupant is not applied. So, for each occupant 9.5 cu.m air volume may be adopted for both G1 and G2.

In Bangladesh, there are many existing RMG buildings which are small in area and occupant load is less than 150. For ensuring workers health and safety, 9.5 cubic meter of air volume for each worker should be ensured. For existing RMG building containing occupant load less than 150; space per occupant should be equal to or greater than 4.0 sqm.

In dining section and finished goods store, people stay for temporary period of time. So, management of people indifferent slot of time can ensure space per occupant requirement specified by BNBC 2020.

2.5 Recommendation for Fire Rating of Common Construction Element

1. For calculating fire resistance rating of column, beam, slab and concrete wall we should consider topping (overlay) materials and protective cover of reinforcement along with thickness/ dimension of the elements itself. BNBC 2020 refer to ASCE 29, where details are provided for calculating fire resistance rating in more efficient way.
2. For New and Existing Building, Fire Rating of Solid Brick of Clay or Shale need to be included in BNBC 2020.
 - 69mm thick brick = 1.0 hour
 - 97mm thick brick = 2.0 hour
 - 125mm thick brick = 3.0 hour
 - 152mm thick brick = 4.0 hour
3. Fire door assemblies ASTM E 152 is replaced by ASTM E2074 and Fire windows and fire shutters ASTM E 163 is replaced by ASTM E 2010 -01. These should be included in BNBC 2020.
4. ASTM E 814 (Fire Stop System for Penetration) or ANSI/UL 1479 and ASTM E 2393 (Fire Resistance of Building Joint Systems) or ANSI/UL 2079 or ASTM E 1966 should be included for testing Methods for Fire Stop System for Penetration and Fire Resistance of Building Joint Systems respectively.
5. For New and Existing Building, ANSI UL and FM Approval may be adopted for testing standards along with ASTM. BSTI (Bangladesh Standards and Testing Institution) should be enforced as the national standard.
6. Fire rating of other different materials can be adopted from IBC 2018. (See Annex D1)

2.6 Recommendation for Types of Construction (Steel Structure)

1. Unprotected Steel Structure
 - For Moderate Hazard:**
 - Maximum 3 storey with fire hydrant system.
 - Maximum 2 storey without fire hydrant system.
 - For Low Hazard:**
 - Maximum 4 storey with sprinklered system.
 - Maximum 3 storey without fire hydrant system.
2. The steel sections for columns and beams/girders should be relatively thick so that W/D ratio increases and required fire protection coating thickness decreases and overall cost of steel members along with protective measures is economical. Cost of steel structure and effectiveness of fire protection measures should be optimized.

3. For calculating fire resistance protective measures, we can use the formula of ASCE29, IBC 2018, SFPE Handbook. (all of them recommend same equations)

4. Gypsum Plaster Board for Providing Fire Resistance Rating of Steel Column & Beam

25mm- 1.0 hour, 38mm- 2.0 hour.

Light-weight aggregate Gypsum Plaster for Providing Fire Resistance Rating of Steel Member

15mm-1.0 hour, 25mm-2.0 hour, 51mm- 3.0 hour.

Cement Plaster on metal lath for Providing Fire Resistance Rating of Steel Member

22mm- 1.0 hour, 64mm- 2.0 hour.

Carbonate, light weight concrete & sand light weight Providing Fire Resistance Rating of Steel Member

25mm- 2.0 hour, 38mm- 3.0 hour, 51mm- 4.0 hour.

[For detail see national building code of India and International building code.](#)

3.1 Limitations of the study:

Occupancy Type	Symbol	Fire Load Density
Low Hazard Industry	G1	1 MJ/m ² to 180 MJ/m ²
Moderate Hazard-1 Industry	G2	181 MJ/m ² to 1400 MJ/m ²
Moderate Hazard-2 Industry	G3	1401 MJ/m ² to 2200 MJ/m ²
High Hazard Industry	G4	Greater than 2200 MJ/m ²

From NFPA 557 (ed 2016) we come to know that,

$$\text{Fire Hazard} = \frac{\text{Potential Hazard}}{\text{Protective Measures}}$$

that is,

$$B = \frac{P}{N \times S \times F}$$

where

B = fire hazard

P = potential hazard

N = standard fire safety measures

S = special measures

F = fire resistance of the building

Potential hazard is provided in our recommendation. If certain limit of fire hazard can be fixed for performance based design. Then low potential hazard (G1- 1 MJ/m² to 180 MJ/m²) need less control for the building and high potential hazard (G4- greater than 2200 MJ/m²) need most control for the building.

Further research can be carried out for fixing limits for different attributes of building considering 4 number of subdivision.

1. Fire Resistance of the building
 - a. Fire resistance of Column / shear wall.
 - b. Fire resistance of beams / girders/ trusses.
 - c. Fire resistance of Slab.
 - d. Fire resistance Roof.
2. Mixed Occupancy Separation.
3. Egress Route Separation.
4. Fire Detection System.
5. Fire Protection System.

For example, if we want to fix duration of water flow for fire-fighting in a RMG building

Occupancy Type	Duration of flow for fire-fighting (Capacity of Reservoir)
Low Hazard Industry (G1)	60 minutes
Medium Hazard Industry (G2)	60 minutes
Moderate Hazard Industry (G3)	75 minutes
High Hazard Industry (G4)	90 minutes

For example, if we want to fix space per occupant in a RMG building

Occupancy Type	Space per Occupant (sqm)
Low Hazard Industry (G1)	2.3
Medium Hazard Industry (G2)	4.0
Moderate Hazard Industry (G3)	6.0
High Hazard Industry (G4)	10.0

Other managerial Constraints are given below

Pandemic Situation: The research was offer when the globe was suffering with COVID19 situation. The research work suspended various time due to lockdown. It hampered physical data collection process.

Time Limits: The timeline for this research was constraint. This should have some more timeline. Moreover, Due to country wide lock down, project timeline has been lost.

Sample Data Size: Targeted physical data collection was not possible due to pandemic lockdown. In some cases, could not get data on physical visit.

Access: It is challenging to have access in field.

3.2 Conclusions:

Performance base design is already permitted in BNBC (ed 2020), Part 4, Chapter 5. Maximum unit of RMG factory is subjected to light industry except storage and utility part. In this study 4 number of subdivision are made on the basis of fire load density which directly related with performance base design. When performance based design will be implemented, RMG building can be constructed and maintained economically. For our sustainable progress in economy we need to have safe and sound building and performance based design can ensure that.

Fire Prevention is the most important part. Vertical shafts are one of the main medium for vertical propagation of fire and smoke from one floor to another floor. So, fire rating of vertical shaft's enclosure and opening protective are most important for fire prevention (see summary of recommendation). Location of vertical shaft is also important. If lift core located in staircase and electrical / plumbing shafts are exterior then fire prevention process is easier and most of the RMG buildings will be compliant. Annular space of penetrations can also be sealed easily thus shaft enclosure can be avoided. All vertical shafts of RMG buildings can be made compliant by following the above recommendations.

In Bangladesh, public water supply system with sufficient volume and pressure for firefighting is not available yet. There are not enough space to accommodate such a large volume outside of the building and existing foundation of RMG building do not have sufficient capacity to accommodate large volume of water reservoir inside and roof top of the building. In this research study, the capacity of reservoir is so that 60 minutes of flow for fire-fighting is recommended for existing RMG building. Natural sources (ponds/ lake/ wells/ swimming pools etc.), pump stations and deep tube wells are also been counted as water source with sudden feeding system other than water reservoirs. Multiple buildings which are closely located can be provided with single hydrant system.

In order to ensure proper fire prevention measures fire protection construction or passive fire protection system is required in a building. Fire resistance rating of different materials are need to be identified correctly and accurately

for designing fire protection construction of a building. In the above literature we have tried to find out the actual fire resistance rating of different elements of building. In Bangladesh, for different construction materials we import from different countries which is referred to different testing standards of different origin and it could create confusion. Like other developed countries we should have indigenous standard for testing materials. BSTI (Bangladesh Standards and Testing Institution) should be enforced as the national standard. Different construction materials which is processed or produced in our country can be tested and certified locally by BSTI and it will help to increase number of compliant building in Bangladesh and it will also ensure the growth of different industry and thus have great economic impact.

For unprotected steel structure which is common in Bangladesh, there are contradictory statement in BNBC associated with permissible number of storey. Permissible number of storey is in our recommendation. For structural fire engineering the section, the steel sections should be relatively thick so that overall cost of steel members along with protective measures is economical. In this research study, different fire protective measures and calculations are provided by which one can design relatively safe steel structure subjected to fire exposure.

For existing building, there is no particular code of practice in Bangladesh. In our research study, we have drawn recommendations focusing most critical issues for existing RMG buildings. Continuous research process is the need of the century, by focusing all issues related to fire safety and enforcing code practices for existing building.

Preparation and Incorporation of Alternative Pavement Section (Interlocking Concrete Block Pavement) into Road Design Manual

1.1 Background of the Project:

The project is conceived from the requirement for construction of huge road length of village road of low to medium volume commercial vehicles. The traditional way of building such kind of road initially by HBB and later reconstruction brick chips of the HBB bricks in lower layer and stone chips in upper layer (base course) with seal coating with pea gravel (small stone).

HBBs are made with clay burned bricks which give severe environmental impact. Government of Bangladesh is considering to stop burning of clay to manufacture bricks. Concrete blocks are in the way of construction of insignificant number of houses at present.

Asphalt road requires different types of machineries. For most required temperature controlled liquefaction of asphalt needs equipment which is very difficult in manual method. Thus, it is technically troublesome for constructing village road with semi-skilled men with only road roller. These kinds of roads could be paved for

low and medium commercial vehicles very simply by using Concrete Blocks of appropriate strength and interlocking capacity.

Bangladesh has very little stone for use. Most of the asphalt road constructions are made with imported stones. But Bangladesh has river sand of different rivers of having different F.M. (Fineness Modulus) and to keep the rivers navigable, huge dredging works are made. Disposal of these dredged sands are making hazards to environment as well.

Prime Minister of Bangladesh gives directives to use these dredge sands in beneficial and be construction fitting way. Some of the dredged sands are used for manufacture of concrete block utilized in housing. But it is not up to significant level of construction of houses. Great shift from clay burn bricks to concrete blocks is required in the society. Some industries are making interlocking concrete blocks for industrial yard pavement. These huge dredged sands could be used in the manufacturing interlocking concrete blocks for pavement.

Also, LGED wants to be a pioneer in this field and wishes to pave its village roads for low to medium volume commercial roads with Interlocking Concrete Block of adequate strength i.e. 30 MPa & 35 MPa. As these dredged sands are of different F.M. and contents, for getting concrete blocks of required strengths, it needs huge research work to establish mix design criteria for achieving these set strengths. HBRI is an experienced and capable institution for this purpose.

The use of Interlocking Concrete Paving Block (ICBP) in roadway construction is worldwide. The design comprises of a simple concept of ICBPs of preselected shape, size, color, etc. Seamlessly connected over sand base and thoroughly interlocked by using jointing sand. The choice and composition of base, sub-base and subgrade materials varies according to the physical, mechanical and environmental properties as per the geographic location at which the desired road would be established. The concept of ICBP roads is ancient. It started from the early Roman Empire and got refined after World War II. The only improvements ICBP has adopted over time are being manufactured with higher quality and accuracy in placement. Currently, Europe widely constructs ICBP roads and pavements, covering millions of square meters every year. North America is also quick to follow this trend and has started on broaden its reach.

A great advantage of ICBP roads is that it can distribute dynamic loads significantly due to its divided nature and interlocking properties and these parameters become substantial under traffic loads unlike conventional flexible pavements. However, due to the similarity in withstanding loads by these two types of pavements, the structural design and construction practice of flexible pavements could be translated into the preparation of ICBP roads.

In abroad (especially in North America), the primary use of ICBP is for residential and architectural purposes by taking aesthetics into consideration, replacing the use of asphalt and plain concrete. But soon, ICBP's load carrying property is soon recognized and it is then adopted in functional aspects as well.

As it is mentioned earlier, first merit ICBP has over traditional asphalt and concrete is its diversification in size, shape, color and layout pattern which make it an ideal choice for architectural application. Also, it can be incorporated in different types of roadways, considering all geometric possibilities with visual appearance in mind.

Also, due to the highest degree of quality assurance of ICBPs, they can withstand harsh chemicals, weather conditions and point loads as they are made with high strength and low absorption concrete. Once a road surface is properly prepared, they can be readily placed over it and traffic can be allowed immediately. If there is a need to carry out utility repair under ICBP road, then blocks at the point of interest are removed and necessary adjustments are made. Then the substituted blocks are replaced again, making ICBPs reusable.

Another distinguishable feature that ICBP imparts is that it can be applied over soils with poor condition since it can handle distress better and still remain in service unlike conventional flexible pavements. Overall, ICBP pavements do have a higher life-cycle with low maintenance, making them a suitable choice for developing countries such as Bangladesh.

ICBP pavements can be used in many scenarios such as:

- Footpaths and Side-walks
- Cycle Tracks
- Residential Streets
- Car Parks
- Fuel Stations
- Rural Roads through Villages
- Highway Rest Areas
- Toll Plaza
- Bus Depots
- Approaches to Railway Level Crossings
- Intersections
- City Streets
- Truck Parking Areas
- Industrial Floors
- Urban Sections of Highways
- Road Repairs during Monsoon
- Container Depots
- Port Wharf and Roads
- Roads in High Altitude Areas

(Source: IRC: SP: 63-2004)

After considering the aforementioned factors, as per the Terms of Reference (ToR), the use of clay bricks in the construction of rural roads are discouraged by the Government of Bangladesh (GoB). GoB provided a clear rule through a notification published on 24-11-2019 under serial no: 22.00.0000.075.32.002.14 (part -3)-410, urging all to reduce the use of traditional fire-burnt clay bricks and use blocks on a periodical basis in the construction, repair and maintenance of walls, boundary walls, HBB roads and Type-B village roads. Further details of the work plan and the goal for its implementation are provided as an attachment (Annexure I) at the end of this report. Therefore, the inclusion of various alternative technologies is essential in the construction of village roads with low traffic volume and subsequently low axle loads to make these more durable, environment friendly and economic. It is also found that the use of bituminous mixture or cement concrete technology is also impractical for rural pavement design due to their lack of proper drainage system and associated higher costs. In the absence of definitive design principles, it has become difficult to incorporate Interlocking Concrete Paver Blocks (ICBP) in the context of Bangladesh, considering its numerous pavement characteristics along with social & environmental data, soil properties, etc. So, in order to mitigate the issues arising from not being able to widely use ICBP as a fundamental pavement construction method, an extensive study on existing LGED road design manuals would be carried out to get a clear understanding on road design procedures, construction practice and maintenance. Then, other national and international documents relevant to codes and standards for roadway design would be thoroughly reviewed for obtaining further knowledge regarding ICBP road design specifications. Some significant locations in Bangladesh would be visited to collect dredging sand samples to assess their potential as a raw material for the fabrication of quality ICBP and subsequently, efforts would be given in their successful inclusion into ICBP road design templates for different areas of Bangladesh. In accordance to the desire of the Client (i.e. LGED), implementation and maintenance manuals are to be prepared. Also, specification and costing would be furnished.

1.2 Objectives of the Study:

The objective of the assignment is to prepare and incorporate alternative pavement segment (Interlocking Concrete Block Pavement) into Road Design Manual of LGED. The objectives the consulting services of the assignment are:

- To develop design procedures and various design templates for the ICBP considering various dredged materials from rivers, canals, ponds, etc.
- To develop an implementation and maintenance manual including specification with costing for ICBP.

- To develop separate segment for other alternative sustainable pavement options.

1.3 Scope of Work:

The scopes of the assignment typically include, but not be limited to, the following:

- Conduct study and analysis on existing LGED road design manual.
- Collect data and information through field visit of various districts, various national and international design manual, code, journals, research papers etc. for ICBP road.
- Develop design procedures and various mix design templates for the ICBP
- Develop an implementation and maintenance manual including specification with costing for using ICBP.
- Develop a separate segment for other alternative pavement options.

1.4 Expected Outputs:

The outputs of the study that can be provided are as follows:

- Design procedures and various mix design templates for the ICBP of 30 MPa and 35 MPa from dredged sands of rivers of different locations for low & medium volume commercial vehicles.
- Implementation and Maintenance manual for using ICBP for various soil and environmental conditions.
- Separated segment for other alternative sustainable pavement options.
- Draft specification with costing.

2 Conclusions:

2.1 Summary of the Project:

This project entails the preparation and incorporation of ICBP (Interlocking Concrete Paving Block) into Road Design Manual. Under this research endeavor, numerous literatures were studied which involved national reports, international ICBP pavement manuals and international journal papers. These secondary sources revealed that dredged sand could be considered as a suitable alternative to conventional fine aggregate in the production of concrete and it could also be a sought-after way to best recycle dredged sand to promote infrastructural and socio-economic development of Bangladesh. Therefore, this study project mainly focused

on the use of utilizing dredged sediments from different locations of Bangladesh in the production of ICBPs of desired strength despite having non-compliant F.M. (in some cases) by incorporating suitable concrete mix ratio, water: cement ratio and admixture. Also, this project shed lights on the use of ICBPs in rural roads by considering light traffic.

Under the field visit, a total of 04 districts (Dhaka, Khulna, Gazipur and Narayanganj) were covered. Information related to ICBP roads comprising their lengths, widths, block dimensions, classifications based on location and vehicular composition, underlying layers thickness and overall condition were collected. Most of the existing ICBP roads observed were free from any significant deformity and almost all the paving units were intact. This further confirmed the suitability of using ICBP as a choice for roadway material. Furthermore, sand related information, mainly F.M. (Fineness Modulus), river source and sand selling marketplace were gathered from these four districts.

Method to fabricate ICBP was clearly described along with its various shapes and the corresponding performance to distribute vehicular loads with diagrammatic representations. As for the structural design considerations, IRC was selected out of 04 technical guidelines as it seemed to cover road design for light weight vehicles and complied with other factors such as climatic factors, socio-economic factors and materials availability.

Next, ICBP mix design charts were prepared, taking into account, sand F.M., location, thickness, concrete mix ratio, water: cement ratio, admixture quantity and strengths obtained at 7, 14 and 28 days. Almost all the samples achieved the desired strength of 35 MPa after 14 days of curing. Graphs of strength vs F.M. of the samples were drawn to better establish the relationship between the two parameters. It was found that ICBPs with high thickness had higher strength, there was a proportional relationship between Sand F.M. and compressive strength and early recommended strength of ICBP could be achieved by adding early strength gaining admixture with high density water reducing super plasticizer.

Under the additional aspects of ICBP, construction process, maintenance manual and technical specification were provided, and they were adopted directly from IRC guidelines for the use of ICBP in roadway construction.

2.2 Limitation of the Project:

- As for the review of the existing literatures, focus was mainly put on journal papers concerning the utilization of dredging sand for the manufacture of ICBP but further studies could not be conducted on the actual design of ICBP road section due to budget and time constraints.
- Not all the districts of Bangladesh were possible to be covered in order to assess existing road conditions due to the ongoing COVID-19 pandemic and imposed lockdown by the government.

- Water Absorption Test and Efflorescence Test of ICBPs could not be done to comply with the client's wish to finish the project within the time frame.
- Tensile strength of ICBP could not be carried out as this test is currently not available at HBRI.
- Under structural design consideration, only four international design guidelines were referred to and the most suitable one was chosen.
- Implementation manual (i.e., construction process), maintenance manual and technical specification of ICBP were mostly taken from IRC and these sections could not be adjusted further in the context of Bangladesh by referring to additional journal papers/guidelines for construction and maintenance of ICBP, etc.
- Other manufacturers of ICBP were only willing to share information regarding the dimension of ICBPs they produced along with their expected strength. But they did not supply HBRI with other vital information related to admixture type and amount, concrete mix ratio, etc. chiefly due to their confidential nature and privacy concern. Therefore, technical specification of admixtures and other aspects in the fabrication of ICBPs could not be provided to draw a comparative analysis.
- COVID-19 situation in Bangladesh put a hindrance for HBRI to conduct social survey with the stakeholders and road users of existing ICBP roads, covering the discussion and comments.

2.3 Recommendation:

- By using dredged sands, ICBP could be prepared with desired strength of 30-35 MPa. So, these blocks could be used in the design and construction of ICBP pavements.
- Block manufacturers of Bangladesh should be notified of the research project by taking initiative from both government and non-government levels and encourage them to chiefly adopt dredging sand in the fabrication of ICBP.
- Design templates (for silt and clay) in the project are made on ad hoc basis. So, further research and evaluation by field testing should be done to assess their suitability.
- The road design templates provided by BRTC, BUET contain bituminous layers. But those templates could also be used by using ICBP section instead of bituminous layer.

2.4 Selected Photographs depicting Project Related Activities:

HBRI Laboratory visited by LGED Representatives



Dredging Sand Collected by HBRI from Different Locations of Bangladesh



Block Manufacturing Process Carried out at HBRI Plant



Technical Development to Upgrade Structural Integrity of Buildings in Densely Populated Urban Areas and Its Strategic Implementation Towards Resilient Cities in Bangladesh (TSUIB)

Background:

Bangladesh is one of the most earthquake prone countries in the world. Specialists are expecting a severe earthquake in this area in near future, which will cause a serious human casualty, damages of infrastructure and other losses due to its vulnerability and poor emergency response and recovery capability. The loss of life and property can be reduced to a considerable degree by the adaptation and implementation of proper planning, improved, structural design and construction procedures. Geologically Bangladesh is vulnerable to earthquake. In north of Bangladesh, there is a joining point of two plates- Indian plate Eurasian plate. In each of Bangladesh, there is a joining point of two plates- Barmiz plate and Indian plate. Indian plate is moving in north east direction and Barmiz plate is moving in north–west direction. So, the tectonic evaluation of Bangladesh can explain as a result of collision of the north moving Indian plate with the Eurasian plate. The whole Indian subcontinent is situated on the junction of these two plates. There are several fault zones active in this junction area, which are the sources of earthquake. During the last 150 years, seven major earthquakes (with M 7) have affected Bangladesh. The Bangladesh National Building Code (commonly referred to as BNBC 93) includes some guidelines for earthquake resistant design of concrete and steel structures, it is only recently (November, 2006) that steps have been taken by the government to officially enforce the code (GOB, 2006). But still this enforcement, quality control and supervision are not yet ensured in large number of buildings being constructed in urban areas of Bangladesh. Moreover, significant progress has been made in earthquake resistant design of structures in different parts of the world. These have led to revisions of code in other countries. Some of the provisions of BNBC also need to be updated by incorporating the recent developments in technology. Effective techniques for retrofitting of existing structures, which do not have adequate seismic resistance, need to be developed for improving the capacity of the structure. Above all strategic urban planning is very important for minimizing the earthquake induce losses in terms of human lives as well as economy of the country.

Justification:

The purpose of the Project is to reduce disaster risk and promote urban safety of Dhaka which shall be achieved through accomplishing four outputs; i) understanding of building characteristics governing its performance, ii) performance evaluation methodology of buildings against collapse, iii) retrofit schemes for buildings with low performance and iv) effective urban planning strategies for sustainable and resilient cities. It is envisaged that such technology should be widely used in Bangladesh. In addition, the Project is expected to contribute to the capacity development as well as the advancement of research for both Bangladeshi and Japanese research institute involved in the Project.

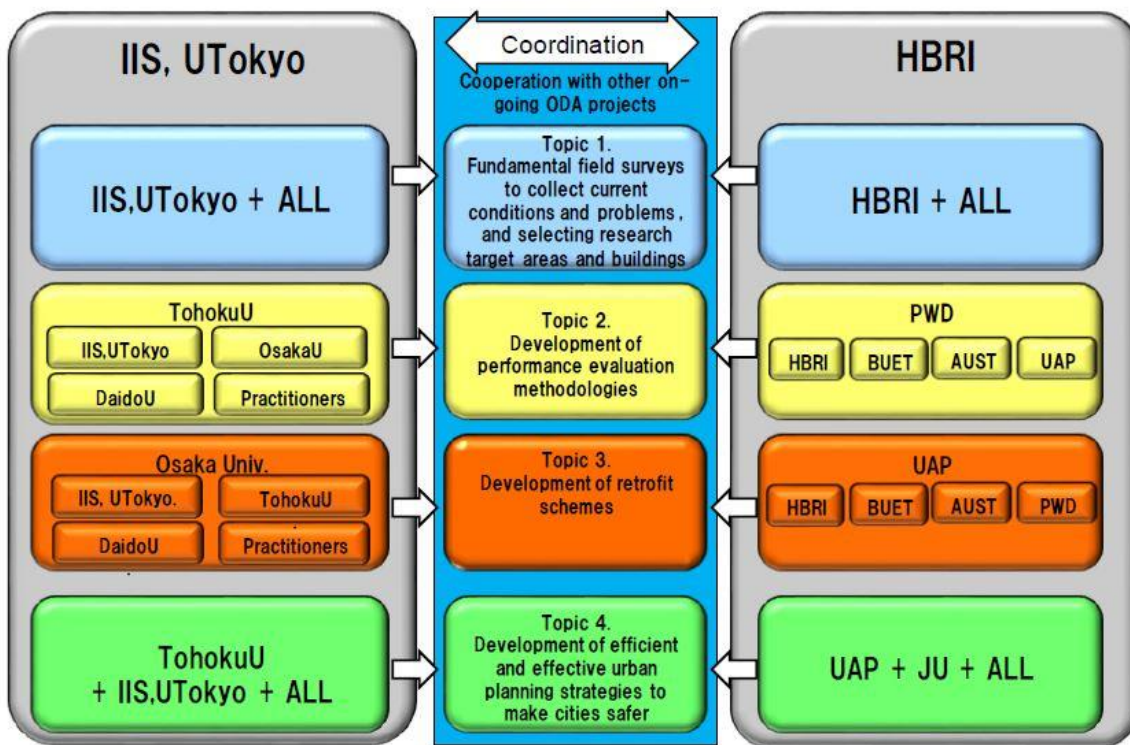


Fig. Implementation structure of TSUIB

Objectives:

- ❖ To improve the safety condition of Bangladesh people by increasing the capacity of earthquake.
- ❖ To minimizing the disaster resulting by the action of gravity load within the buildings.

- ❖ To develop customized retrofitting technologies and simplified seismic evolution methods that will be appropriate for Bangladesh, considering socio-economic condition and low-quality construction practice, by conducting research.
- ❖ To enhance the relevant knowledge through education, training and research.

Impact of the project:

Direct

Research capacity of the researchers and faculty members of four universities of Bangladesh (BUET, AUST, UAP, JU) were enhanced.

Indirect

The tools and techniques for seismic assessment and retrofit of existing vulnerable buildings, developed through this project are available now for the engineers and academicians of Bangladesh

Outcome of the project:

- ❖ Human Resource Development: Capacity of Bangladeshi researchers has been developed in conducting research works in the field of seismic assessment and retrofitting of existing buildings.
- ❖ Development of Experimental laboratory Infrastructure: Structural Testing rigs and facilities has been installed at HBRI and BUET laboratories. The researchers were trained to operate those equipment's during conducting the experiments.
- ❖ Development of Technical manuals and Guidelines: The following five Manuals/ Technical Guidelines were developed and published:
 - i. Users' Manual on Visual Rating (VR) Method for Potential Seismic Vulnerability Assessment of Existing Reinforced Concrete Buildings in Bangladesh.
 - ii. Technical Guidelines for Seismic Evaluation of Existing Reinforced Concrete Buildings in Bangladesh.
 - iii. Technical Guidelines for Seismic Retrofit Design of Existing RC Buildings in Bangladesh.

- iv. Guidebook on Towards Urban Resilience of Dhaka City: An Urban Planning Perspective.
- v. Users' manual on Seismic Assessment of Existing Unreinforced masonry (URM) Buildings in Bangladesh.



Figure. Technical manuals and Guidelines

BNBC 2020

In order to provide safe and healthy habitat, all activities related to building construction such as planning, design and construction needs to be regulated properly. Technological and socio-economic developments in recent times have led to remarkable increase in demand for more and more sophistication in buildings resulting in ever increasing complexity. Buildings are products of a multi-disciplinary profession involving specialized professional inputs from disciplines like Architecture, Fire prevention, Materials science, Structural engineering, Geotechnical engineering Construction technology, Electrical engineering, Mechanical engineering, Acoustics, Sanitation and plumbing technology, Chemical engineering, Law, etc. It is therefore imperative that a uniform standard of practice covering all aspects of planning, design and construction of buildings, including the service facilities provided in them such as electrical, mechanical, sanitary and other services, be followed to ensure safety, minimization of wastage in construction and optimum return for the user. In the Building code each of the above aspects is addressed adequately by professionals specializing in the relevant disciplines to ensure safety and comfort of the users of the buildings.

In order to regulate the technical details of building construction and to maintain the standard of construction the Bangladesh National Building Code (BNBC) was first published in 1993. It was a 1000-page detailed document specifying safe and acceptable practices in all aspects of building design and construction.

The building construction sector was first brought into a legal framework through enactment of Building Construction Act 1952. By the power given by the Act, the Government of Bangladesh has promulgated regulations which were amended from time to time. In 2006 the Building Construction Act was amended to include a new Section 18A empowering the Government to promulgate the Building Code as a legally binding document as BNBC 2006.

However, since its publication, significant changes and developments have taken place in both building technology and material properties requiring the use of the present state of the art knowledge and practices in building planning, design and construction. To keep pace with the changed circumstances, it is a routine practice to update codes.

After introduction of the BNBC in 1993, the technology of building construction in Bangladesh remained almost the same for quite some time as was in practice before its publication. The lack of legal provisions in enforcing its use has been the main reason behind it. In the meantime growing demand for home, scarcity of land and the upward trend in the land prices in the urban areas

brought in the culture of construction of moderate to high rise structures and changed the prevailing culture of planning, design and construction of buildings in the private sector. Gradually, the urban dwellers began to accept the concept of living in high rise apartment buildings and investment in the housing sector turned out to be a profitable business. As a result, building construction activities were taken up by real-estate developers following which new trends developed in building planning and construction. Some real-estate developers engaged professional people such as Architects, Engineers, Planners to make their buildings more attractive to the buyers and the code started finding its use among the professionals. However, some owners and developers retained the habit of the old method of construction giving rise to unplanned growth of structures in the urban areas. During this time some high rise structures failed to perform satisfactorily due to structural failure/fire hazard which caused alarm among the urban dwellers as well as the policy makers. The policy makers, therefore felt the urgency of updating the BNBC 1993 to make its contents time worthy and also to bring it under strict legal coverage to make its provisions binding to all involved in the planning, design, construction and use.

Since its publication in 1993, BNBC has been referred to and consulted by the professionals and designers in the field of building design and construction. After the endowment of legal status, importance of the BNBC 2006 has further enhanced. However, unlike other building codes available in the world, the Bangladesh National Building Code has not yet been formally reviewed and updated since it was drafted in 1993. Neither any feedback of the professionals regarding the document has been taken into formal consideration. In the last twenty-two years, new materials have been introduced, new scientific methods have emerged, new technologies have evolved and both design of structures and construction practices have gone through enormous changes. Researchers, engineers and academics in Bangladesh have also conducted new studies which enriched our knowledge about planning, design, construction and sustainability of buildings.

Ministry of Housing and Public Works formed a steering committee with the responsibility of Updating BNBC by a G.O. having circular no. Section 8/IM-5/93(part) 812 (28) date: 15.09.2008. The Steering Committee comprises representatives from relevant government agencies, universities and professional societies. The Housing and Building Research Institute (HBRI) has been entrusted with the task of providing secretarial service to the Steering Committee and managing the implementation of the project. According to an agreement between HBRI and Bureau of Research Testing and Consultancy (BRTC), Bangladesh University of Engineering and

Technology (BUET), for the purpose of reviewing and updating the Bangladesh National Building Code 2006, BRTC, BUET deputed leading experts in all relevant fields among academics and professionals. Finally, the updated code is available both in printed form and on website.

The updated BNBC has 10 parts with a total of 49 chapters. Some parts contain a number of appendices wherein sample calculations, design tables, graphs etc. are provided for use by the readers for important analysis and designs. Part-6 Structural Design has 13 chapters which is the maximum among all the parts.

In the contents of the Updated Code, almost all of the topics of BNBC 2006 have been retained. Moreover, some of these have been elaborated to accommodate the changes identified during review of the BNBC 2006 and the various codes and documents collected to make their scope wider, up to date and user friendly.

Part-6 “Structural Design” in the Updated Code include two new chapters, one on Bamboo Structure and the other on Steel-Concrete Composite Structures. The former is intended for use in the rural areas. The use of well-designed and economic bamboo structures is expected to be attractive to the rural people. The Steel Concrete composite structures are expected to be widely used in the industries. In urban areas this type of structure is expected to find application in high rise construction.

Contrary to the presentation of Geotechnical engineering in BNBC 2006 wherein it has been treated as “Foundation” having limited scope, in the Updated code the chapter on geotechnical engineering has been re-named as “Soils and Foundations.” The scope of the proposed “Soils and Foundations” chapter has been made wider by including topics such as ground improvement, geotextiles, soil reinforcement, slope stability, foundation on problematic soils and sanitary landfills, dewatering, evaluation of liquefaction potential of soils. The new scope of the “Soils and Foundations” chapter is in line with the codes reviewed and requirements of the Geotechnical professionals of the country.

Depletion of energy resources and environmental changes is a major concern worldwide. Bangladesh is no exception to it. Keeping these aspects in mind, changes and modifications have been suggested in BNBC 2006 for use of energy saving appliances, non-conventional fuels etc. in buildings. The updated BNBC contains chapters addressing the issues of energy conservation, rainwater harvesting and distribution mechanisms in buildings.

In Part 3, “General Building Requirements, Control and Regulation” a new Chapter titled, “Energy Efficiency and Sustainability” has been included giving minimum code requirements for achieving the efficiency.

To reduce energy consumption in building provisions for use of variable refrigeration system in HVAC applications, Variable Voltage, Variable frequency drives in elevator applications has been included in Chapter-2 “Air Conditioning, Heating and Ventilation” of Part-8 “Building Services”. Energy conservation in lighting using energy saving lamps, Fluorescent lamps and GLS lamps has also been proposed in Chapter-1, “Electrical and Electronics Engineering Services for Buildings” of the same part.

To augment water supply in Buildings, Chapter-8, “Rainwater Management” in Part-8 “Building Services” has been included in the Updated Code containing specific guidelines for harvesting, storage and distribution of rainwater.

Contents of the chapters already existing in BNBC 2006, have been thoroughly revised in the updated version. In some cases, new concepts have been included. For example, In Chapter-7 “Masonry structures” of Part 6, the concept of ‘Confined Masonry’ is introduced and guidelines for design and detailing are provided.

In general, up to date information and standards are included in the updated Code in a way which is practicable by designers and professionals involved in building construction. Provisions of various recognized codes and standards are adopted in the present code after a thorough review. In Part 2, a practical approach is delineated in administering and enforcement of the Code; which is expected to pave the way in actually implementing the Code provisions and ensuring safer building construction in Bangladesh.

Contributions of members of the Steering Committee and the Editorial Committees are gratefully acknowledged for their active participation and guidance in updating the building code. The process of updating has undergone a rigorous and time-consuming review exercise. Diligence and cooperation of the authors during the exhaustive process are deeply appreciated. Final editing of this huge document has been extremely tedious and tried to be presented in a uniform format. To enhance readability, many figures of the previous version of the code have been redrawn and

improved. However, we regret any unintentional editorial or typographical mistakes that may still exist in the code.



BNBC 2020