ON GOING PROJECT

1. Assessing the Impact of Salinity on Concrete Structures in Coastal Regions: A Comprehensive Survey

1. Background:

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. Most widespread & common form of chemical attack is Sulphate attack which causes volume expansion. In many cases, cement paste undergoes significant softening and disintegration. The consequences of sulphate present in sea water causes expansion, cracking, loss of strength due to the loss of cohesion in the cement paste and its bond with aggregate, damage usually starts at edges and corners followed by progressive cracking and spalling which reduce the concrete to a friable or even soft state. Also, thumasite formation is also an effect of sulphate attack which is not immune sulphate resisting cement. Salinity in water can also cause damage to concrete through the development of crystal growth pressure Chlorine is also responsible for the deterioration of concrete. It is mainly responsible for the initiation of steel corrosion. The use of ground water in many constructions also effect the use of fresh water. Salinity intrusion caused by the sea level rise augmented by climatic variation is imposing increasing threat to the potable water sources in the coastal area. Thus, safe drinking water scarcity is an acute problem in the coastal regions of Bangladesh. Using fresh water sources for construction will only add up to this problem. Therefore, this research study is crucial to understand the loss of coastal establishments from saline induced corrosion.

2. Objectives of the Research:

- Study of effects of salinity on concrete and steel of RCC.
- Study the condition of structures and environment of coastal region.

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 and Scope of the Work:

Survey of coastal structures to determine damage due to salinity

1. Site selection of survey. Minimum of 4 sites to be selected.

2. Selection of coastal building in each site for survey.

3. To conduct preliminary and detailed condition survey on coastal concrete structures in the different exposure conditions of coastal regions to understand the main causes of deterioration of marine concrete structures. List of tests:

• Core cutting

• Rebound hammer test

• Ferro scanner

• Water quality test

• Soil quality test

4. Data collection and compilation for the final report.

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 impacts 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.

4. Recycling of Demolished Concrete Waste for Sustainable Concrete Production

Introduction:

Concrete was discovered by the Minoan civilization over 2000 BC. In the previous phases of the Roman Empire about 300 BC, the Romans found that mixing a sandy volcanic ash with lime mortar produced a hard water resistance material which we know as concrete. Concrete is considered as the second most consumed material after water. Worldwide consumption of concrete is estimated at 20 billion tons. To produce such a huge volume of concrete, we need 14 billion tons of natural aggregate. As urbanization is increasing over time, the demand for new buildings and infrastructure has sharply risen. With the steep increase in new construction the demand on natural aggregates has also risen. This leads to increased quarrying and subsequent depletion of natural aggregates. The demand on stones and sand for concrete production has increased to such an extent that it is posing serious environmental threats. Hence it is very necessary to control the rate of extraction of these resources.
Demolished concrete is produced when structure made up of concrete is demolished and the amount of waste concrete left after demolition is named as demolished concrete. When the beneficial life of any structure is over it will be demolished. Besides the existing old buildings are demolished to make way for new modern ones based on the need. Large quantities of construction and demolition wastes are continuously being generated which are just being dumped in landfills. This requires large areas of land which is becoming difficult to find. So it is very important that the construction wastes are accounted properly. One of the best solutions to both the problems would be to recycle and reuse the demolished concrete as aggregates in new concrete. This will ensure sustainability in construction. This will not only provide for protecting the environment from depletion of natural aggregates but also will account for the problem of dealing with the construction wastes.
In developing countries like Bangladesh, because of population growth and innovation of new design and technologies old structures are being knocked down and new structures are constructed as a replacement. The debris from demolished buildings results in a plethora of waste concrete. Expanding urbanization and enormous construction activities related with fast economic development has produced a huge amount of C&D waste in Bangladesh, which sequentially has triggered a severe degradation of the environment. Roughly 1.28 million tons (0.149 construction and 1.139 demolitions) waste were produced in Dhaka city in 2016, of which the three significant extents were concrete (60%), brick/block (21%), and mortar (9%), all dumped in landfills or at unauthorized places (Islam et al., 2019).
The idea of recycling demolition waste was first introduced in Germany. After that, many countries have been researching about the properties of recycled aggregates and applying the recycled aggregate to produce new concrete. Although most of the research was conducted on the properties of recycled concrete, still the number of researches is not quite enough specially in Bangladesh only a limited number of researches available in the existing literature. Therefore, for practical application users may get limited information about recycled aggregate concrete in context of Bangladesh construction industry. Therefore, research on the utilization of recycled aggregate has become necessary for the construction sector.

Objectives:

The objectives of this study are;

- Sustainable use of demolished concrete waste for new construction work and evaluate its performance.
- To minimize the construction cost.

Methodology:

- **Materials Collection & Determination of Material Properties:**

Demolished concrete waste will be collected from selected site. After collecting materials, at first proper cleaning should be done. Materials are then pulverized into desired sizes. Besides, required amount of cement, sand and stone chips will be collected. After collecting all the materials, the engineering properties like specific gravity, water absorption, sieve analyses, aggregates crushing value test, aggregate impact value, Los-Angeles abrasion test and different tests of cement will be investigated and compared with the specifications.

- **Mix Proportion and Mixing of Concrete:**

Mix ratio of normal fresh concrete using brick chips will be selected using ACI mix design. Using this mix ratio required amount of specimen will be prepared for compressive and flexural test.
To investigate the strength properties of recycled concrete, 100% coarse aggregate will be replaced by recycled concrete aggregate and using the same mix ratio required amount of specimen will be prepared for compressive and flexural test.

- **Preparation of Specimen and Testing:**

To investigate the strength of recycled concrete, compressive strength test and flexural strength test will be conducted. To determine the compressive cylinder size of 100×200 mm (4”x8”) and prism size of 5’x1’x1’ will be prepared to determine the flexural strength of concrete.

- **Result Analysis:**

After conducting all the tests collected data will be assessed for final result.

5. PROPERTIES OF CONCRETE CONTAINING CERAMIC WASTE POWDER AS A PARTIAL REPLACEMENT OF CEMENT

Background:

There are 65 ceramic manufacturing companies in the country. Bangladesh's ceramic tile industry is still going strong. With an annual supply of more than 12 billion square meters, waste ceramic tiles are widely used in the construction industry. Unfortunately, the ceramic powder produced in the process of polishing tiles in an unusually large quantity, with an estimated measure of 19 kg of waste powder for each one square meter of cleaned tiles.

The disposal of this ceramic powder in landfills causes significant environmental problems. The ceramic industry has been one of the expanding manufacturing sectors of Bangladesh. The sector caters to 85% of the local demand as the country experiences steady economic growth and urbanization and progressing towards being the third largest export sector in the next five years. In the ceramic industry, about 15%-30% production goes as waste. These wastes pose a problem in present-day society, requiring a suitable form of management in order to achieve sustainable development.

However, the excess of ceramic waste powder (CWP) indicates that it may be used as a concrete remedy. A few studies have been published on the use of CWP as a binder substitute. An author explores the use of CWP as a Portland cement substitute in concrete mortars. They used two kinds of ceramic waste obtained from different sites, and the CWP was used to partially replace concrete by 10%, 20%, and 40%, respectively. Their findings revealed that CWP has pozzolanic effects, which improved the performance of the mortars studied. An experiment was conducted to see whether two types of porcelain Polishing Residue (PR) could be used as a cement substitute in mortars. So, the objective of this research is to determine the mechanical properties of concrete when a certain volume of CWP is mixed into concrete. And to determine the effective use of ceramic waste powder (CWP) as a partial replacement of cement.

Objectives:

The objective of this research is to see how Ceramic Waste Powder (CWP) affects the properties of concrete with block aggregate. The primary aim of this research is to look at the mechanical and stability properties of concrete made with CWP as a partial cement substitute. The particular goals are sketched out below:

- To determine the effective use of ceramic waste powder (CWP) as a partial replacement of cement.
- To investigate the properties of concrete formed of Portland Composite cement and partly replaced by ceramic waste powder.

- To compare the strength and cost analysis of CWP concrete and normal concrete.

Methodology:

Materials Collection & Determination of Material Properties:

Ceramic waste powder will be collected from any ceramic company. After that, required amount of others materials such as cement, sand, steel and stone chips will be collected. Following the collection of all ingredients, engineering properties such as specific gravity, bulk density, water absorption, sieve analysis, and various cement tests will be researched.

Mix proportion and mixing of concrete:

In this study, four concrete mixes with variable ceramic waste powder content were chosen to examine the qualities of concrete. The basic mix proportions were retained at 1:1.5:3 for cement, sand, and coarse aggregate, and 0.5 for w/c ratio.

Preparation of Specimen and Testing:

Compressive strength tests, flexural strength tests will be performed to assess the strength of concrete. To assess the compressive capabilities of concrete with varied replacement amounts of ceramic waste powder, cylinder sizes of 100mm×200 mm will be prepared for Compressive strength tests and beam sizes of 10'×1'×1' will be prepared for flexural strength tests.

6. Study on Performance of High Strength Steel (600 W) with Different Normal Graded Concrete

Background and Justification of the Project:

The construction industry in Bangladesh has seen significant growth over the years, driven by rapid urbanization and infrastructure development. With the increasing demand for modern, resilient, and sustainable structures, engineers and researchers are constantly exploring innovative materials and construction techniques to ensure the safety and longevity of buildings and infrastructures. One such exploration is the bonding performance between high strength steel and normal strength concrete, a critical aspect that determines the overall structural integrity of reinforced concrete structures.

Reinforced concrete, a composite material composed of concrete and steel bars, is the backbone of most construction projects worldwide. In recent years, the use of high strength steel, with yield strengths significantly higher than conventional steel, has gained attention due to its potential to enhance the performance and load-carrying capacity of structures. However, the effectiveness of high strength steel reinforcement in normal strength concrete structures is a topic that requires thorough investigation, especially in the context of Bangladesh, where environmental conditions, building codes, and construction practices may differ from other regions.

In the construction industry, the use of High Strength Steel (HSS) and Normal Graded Concrete (NGC) is common for various applications. High strength steel offers superior mechanical properties, such as increased tensile strength and yield strength, making it suitable for critical structural elements.

However, there is growing interest in exploring the bonding performance between high strength steel and normal strength concrete, especially in the context of Bangladesh. Bangladesh is a rapidly developing country with a burgeoning construction sector. As the country strives to build modern infrastructure and accommodate increasing population needs, it faces challenges in ensuring the safety, durability, and cost-effectiveness of its buildings and infrastructure projects.

The findings of this study hold significant implications for the construction industry in Bangladesh. Understanding the bond behavior between high strength steel and different graded normal strength concrete can pave the way for the design and construction of more efficient and cost-effective structures. Improved bond performance can lead to increased load-carrying capacity, enhanced structural stability, and reduced material consumption, contributing to the overall sustainability of the built environment in Bangladesh.

Objectives of this project are as follows:

- To assess the bond strength between high strength steel and normal strength concrete in Bangladesh's environmental conditions.
- To identify any potential challenges or limitations associated with the use of high strength steel in construction industry.
- To provide recommendations and guidelines for the effective utilization of high strength steel in reinforced concrete structures in Bangladesh.

Methodology:

Material Selection and Preparation - The appropriate high strength steel and normal strength concrete materials will be selected and test specimens will be prepared according to standard procedures. After collecting all the materials, the engineering properties like specific gravity, sieve analyses, aggregates crushing value test, aggregate impact value, tensile test of rebar and other tests will be investigated.

Experimental Testing - A series of experimental tests will be (Pull out test, Flexural strength test) conducted to determine the bond strength between high strength steel and normal strength concrete at different mix condition.

Numerical Analysis - The experimental data will be supplemented with numerical simulations using advanced software tools to further explore the bond behavior and validate the experimental results.

Data Analysis and Interpretation - The collected data will be analyzed and interpreted to draw meaningful conclusions regarding the bonding performance between high strength steel and normal strength concrete in the context of Bangladesh.

7. Comparative Study among the different Conventional Roof Treatment Methods in Bangladesh

Background and Justification of the Project:

Roof treatment methods are integral components of building construction and maintenance, playing a crucial role in protecting structures from the adverse effects of climatic conditions and environmental factors. In the context of Bangladesh, a country characterized by its diverse climate and architectural heritage, the selection of appropriate roof treatment methods holds significant importance. The effectiveness of roof treatments in addressing challenges such as moisture infiltration, heat insulation, and cultural preservation has a direct impact on the longevity and performance of buildings.

Bangladesh experiences a tropical monsoon climate, marked by hot and humid summers followed by a rainy season with heavy downpours. These climatic conditions pose challenges to the durability and integrity of roofing materials. Excessive moisture and high temperatures can lead to the deterioration of roof structures, resulting in leaks, water damage, and compromised thermal performance. As a response to these challenges, a variety of conventional roof treatment methods have been developed over time to safeguard buildings and enhance their longevity.

Historically, traditional methods of roof treatment have been prevalent in the region, rooted in local knowledge and materials. Techniques such as applying lime wash to terracotta tiles and utilizing natural resins for waterproofing have been practiced for generations. However, with advancements in technology and the availability of new construction materials, modern treatments such as bituminous coatings and chemical sealants have also become common.

The rapid urbanization and changing socio-economic landscape in Bangladesh have led to a mix of traditional and modern construction practices. This dynamic has raised questions about the effectiveness, sustainability, and cultural relevance of various roof treatment methods. As the country strives for development, it is essential to assess these methods in a comprehensive manner, considering factors such as their performance, cost-effectiveness, environmental impact, and alignment with local architectural traditions.

This research aims to bridge the gap in understanding by conducting a comparative study of different conventional roof treatment methods in Bangladesh. By analyzing the technical attributes, cultural significance, and overall performance of these methods, the research seeks to provide valuable insights for architects, engineers, builders, and policymakers. The goal is to facilitate informed decision-making regarding roof treatments that are resilient, sustainable, and in harmony with both the climatic conditions and cultural heritage of Bangladesh.

Objectives of the Project:

The objectives of this study are;

- ❖ To study the performance of the various types of roof treatment method.
- ❖ To find a sustainable & economic roof treatment method.

8. An Experimental Study on the Feasibility of Fine-Crushed Stone Dust as a Partial Replacement for Cement in Concrete

Background and Justification of the Project:

Concrete is one of the most widely used construction materials in the world, owing to its exceptional durability, strength, and versatility. However, the production of conventional concrete is associated with several environmental and economic challenges, primarily stemming from the substantial use of cement as a binding agent. Cement manufacturing is an energy-intensive process and a significant contributor to carbon dioxide emissions, making it a major concern in the context of sustainability and climate change. This has led to a growing interest in exploring alternative materials that can reduce the reliance on cement while maintaining or even enhancing the performance of concrete.

One promising solution to address these concerns is the incorporation of supplementary cementing materials (SCMs) as partial replacements for cement. SCMs, such as fly ash, slag, and silica fume, have been successfully utilized in concrete mix designs to improve various properties, reduce the carbon footprint, and extend the lifespan of structures. These materials are often waste products from other industries, making them sustainable alternatives to traditional cement.

Fine-crushed stone dust, also known as quarry dust or stone fines, is another potential SCM with great promise in the construction industry. Fine-crushed stone dust is generated during the crushing of quarried stone to produce aggregates for construction. Typically, it is considered a waste product and disposed of in landfills, contributing to environmental concerns. However, researchers have recognized its potential as a valuable resource in concrete production.
The use of fine-crushed stone dust in concrete offers several advantages:

Sustainability: Utilizing stone dust as a partial replacement for cement helps reduce the demand for cement, thus decreasing carbon emissions associated with its production. This aligns with global efforts to minimize the environmental impact of construction materials.

Economic Benefits: Quarry dust is often readily available at or near construction sites, reducing transportation costs and raw material expenses. This can make construction projects more cost-effective.

Improved Workability: The fine particles of stone dust can fill the gaps between larger aggregate particles, improving the workability and cohesiveness of concrete mixes. This can lead to better finishing and reduced water requirements.

Strength and Durability: Previous studies have suggested that the use of stone dust in concrete may enhance its mechanical properties, such as compressive strength, while potentially improving resistance to cracking and durability.

However, the successful incorporation of fine-crushed stone dust into concrete mixtures depends on various factors, including the particle size distribution, chemical composition, and the replacement level of cement. The feasibility of using stone dust as an SCM in concrete has not been comprehensively studied, and its impact on the long-term performance of concrete structures remains uncertain.

This research aims to bridge this knowledge gap by conducting an experimental study to assess the feasibility of fine-crushed stone dust as a partial replacement for cement in concrete. The research will investigate the effects of different replacement levels, particle sizes, and mix designs on the fresh and hardened properties of concrete, including workability, strength, durability, and sustainability aspects. The findings of this study will contribute to the growing body of knowledge regarding alternative materials in concrete production and may have significant implications for the construction industry, with the potential to promote more sustainable and cost-effective building practices.

Objectives of the Project:

The objectives of this study are;

- **To Determine Optimal Replacement Percentage:** The primary objective of the study is to identify the most suitable percentage of cement replacement with stone dust that maximizes the compressive strength without compromising other essential properties of the Concrete.

- To assess the physical and chemical properties of fine-crushed stone dust.

- To evaluate the mechanical and durability properties of concrete with stone dust.

- To determine the cost-effectiveness of using fine-crushed stone dust in concrete production.

COMPLETED PROJECT

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 ALLIENCE, 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 ALLIENCE, 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.

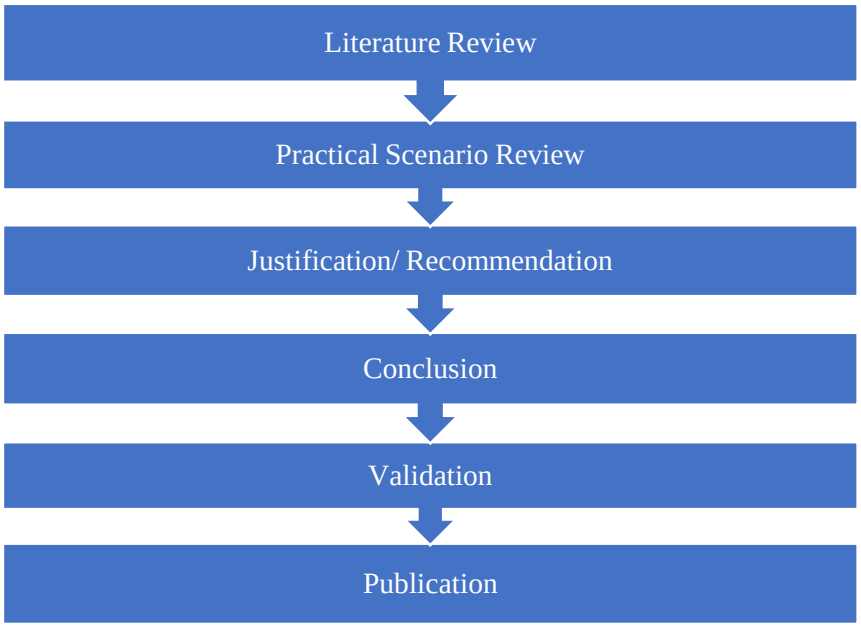
1.3 Scope

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 ALLIENCE, 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,

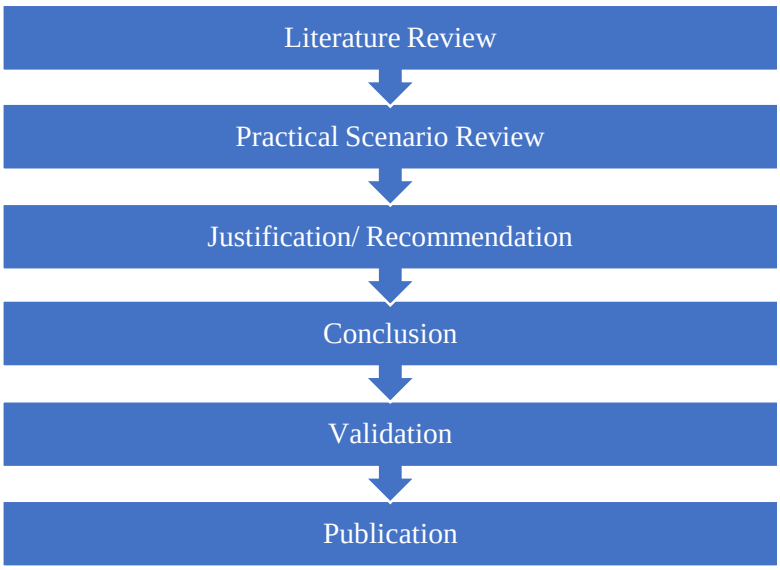
a. To convey field survey for the specific structural design criteria
b. To make a statistical analysis with the field data.
c. Validation and publication of the acquired data.

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 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/m2for office space and for store 6kKN/m2. 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/m2.BNBC 2020 recommended live load 4 KN/m2 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.

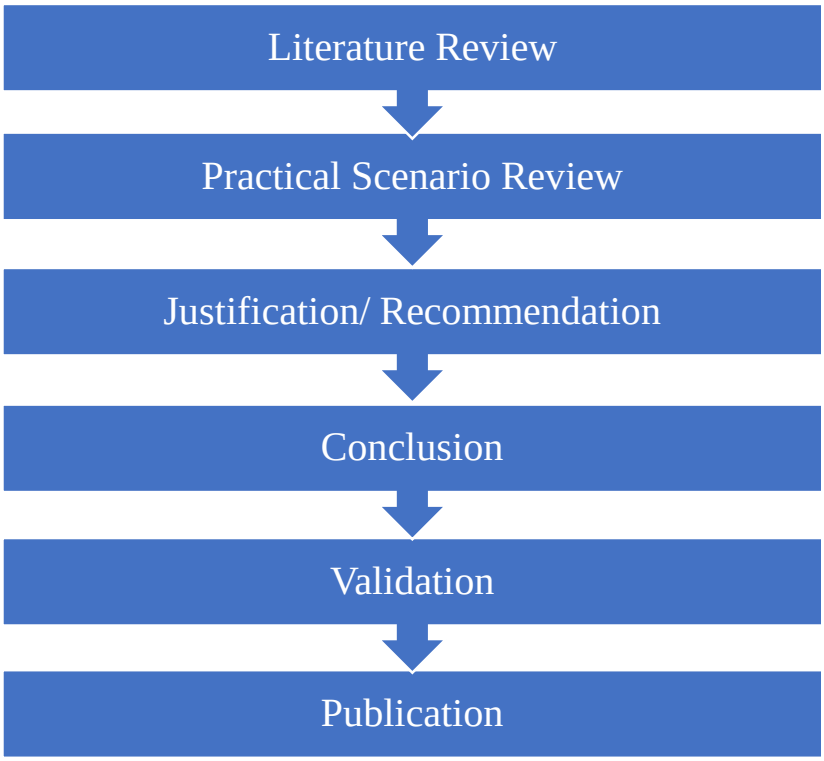
1.3 Scope

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

1 Fire Rating of Shaft enclosure and its opening protective

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**

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/m^2 to 180 MJ/m^2) 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 axel 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.

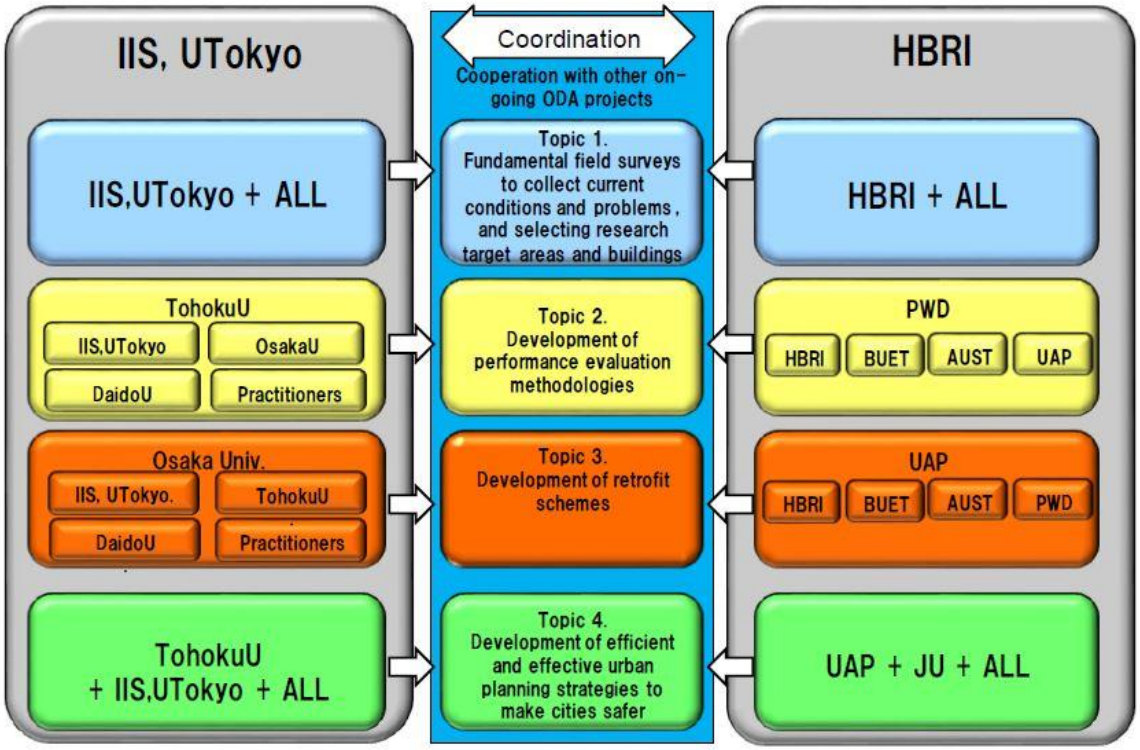


Fig. Implementation structure of TSUIB

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 researhers 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 equipments 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.

Fig. Technical manuals and Guidelines

Research Report on Study of Salinity Effects on Concrete

Abstract:
Salinity poses a significant challenge in coastal areas, impacting various aspects of the environment and infrastructure. In these regions, groundwater serves as a vital source of drinking water due to the presence of salinity. However, the ingress of seawater can infiltrate coastal structures, leading to detrimental effects. Water can permeate through the concrete structure via its pores, eventually reaching the reinforcement and causing its deterioration. The utilization of groundwater in numerous construction activities further exacerbates the scarcity of fresh water. The intrusion of salinity, intensified by rising sea levels and climate fluctuations, poses a growing menace to the availability of potable water sources in coastal areas. Consequently, the coastal regions of Bangladesh face a pressing issue of limited access to safe drinking water. Opting to use fresh water sources for construction purposes will only contribute to the exacerbation of this problem. This study provides an analysis of the effect of salinity if it replaces fresh water in both casting and curing. The study also discusses about the effect of manual mixing and consolidation and compares with the mechanical process.

Keyword:
Salinity, Concrete, Chlorine attack, Cylinder, Compression Test, Sieve Analysis, Water quality test.