SONARGAON UNIVERSITY (SU)

Project and Thesis

AGEING IMPACT AND CRACK STUDY OF UNREINFORCED BRICK MASONRY STRUCTURE AND ITS REMEDY

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A Project Submitted to the department of Civil Engineering, Sonargaon University, Dhaka in Partial fulfillment of the requirements for the degree

Of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

FALL-2019

CANDIDATE’S DECLARATION

We hereby declare that the work presented in this thesis paper has been performed by us. We also declare that neither this paper nor any complete part of it is being submitted elsewhere for any other purpose to award of any degree. Where other sources are used, appropriate references are made.

We do hereby agree to the approach and content of the present exposition.

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ACKNOWLEDGEMENT

First of all we would thanks to Almighty Allah for his gracious, unlimited kindness and with the blessing of whom the good deeds are fulfilled.

The author would like to express her deepest sincere gratitude to supervisor Hamamah Sadiqa, Lecturer, Department of Civil Engineering of Sonargaon University (SU) for giving a unique opportunity to work on such an important topic. Her continuous guidance, invaluable acumen are greatly acknowledgement. Her keen interest on the topic and enthusiastic support on her effort was a source of inspiration to carry out the study. The author considers him fortunate to work under her supervisor.

We would like to thanks our families, friends for their mental support throughout this work. We would also like to thank our University authority whose has given us the opportunity to study in such a decent environment.

APPROVAL AND CERTIFICATION

This is certify that the project on “Ageing impact and Crack study of Unreinforced brick masonry structures and Its remedy ” is the confide record of project work done by Md. Sahidul Islam, Md. Sahadat Hossen, Md. Ahashan Ullah, Rahat Akanda and Aslam Jomadder in the partial fulfillment of the requirements for the degree of B.Sc in Civil Engineering from the **Sonargaon University of Bangladesh (SU).**

This project work has been carried out under my guidance and supervision and is a record of successful work.

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ABSTRACT

Unreinforced masonry (URM) buildings represent a large portion of the buildings stock around the world and in Bangladesh. During the construction of those buildings very little or no seismic design requirements are considered. Moreover, no dynamic test on unreinforced masonry building made by Bangladeshi indigenous material is done yet. Therefore, the objective of this study is to understand the Ageing impact and Crack study of the unreinforced masonry (URM) building of Bangladesh.

In this study we visit the two sites in Old Dhaka and Narayanganj. In our visiting time we collect the different data for our thesis study. In the basis of collecting data we trying to analyzing different cracks and ageing impact of the unreinforced masonry structures. We also trying to find out causes of the cracks. After analyzing we found some specific causes of cracks.

Basis of the finding results we trying to suggest the remedy or retrofits of those cracks whose are created by different causes. We also suggest prevention and repair of the ageing impact on unreinforced brick masonry structures.

I sincerely hope that this document is an unpretentious but interesting contribution for the growing knowledge in the masonry field.

DEDICATED

TO

OUR

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CHAPTER ONE
INTRODUCTION

1.1. GENERAL

The oldest material, which is widely used in the construction industry, is masonry (Moffat, 2016). Even now a day, in different parts of the world including Bangladesh, people are constructing masonry buildings. Failure of unreinforced masonry structures is reported as one of the main causes of uneven settlement of soil and ageing of structures. Working groups were created in order to develop specific aspects related to masonry behavior such as: Serviceability of Masonry Walls, Preparation of Codes on Masonry, Historic Masonry Buildings, Seismic Design of Masonry Structures or Complex Shaped Masonry. In this respect the present work has been developed by a working group dealing with the serviceability behavior of masonry structures since the need to give more attention to these aspects and their relation with defects in masonry structures was identified. The concept of defects is quite subjective, because in building construction there is still a strong component of manual work, where workmanship is very important. This document is concerned with defects that are not simple, minor aesthetic, imperceptible or unavoidable failures, but with failures that could be considered to compromise the building behavior and might result in a claim being made. Nowadays masonry is still used in important structural and non-structural elements.

Theoretically the infilling walls have no relevant mechanical behavior, but in practice these walls have structural importance since some transference of loading can occur due to building structure interactions. These interactions, as well as other effects like dimensional changes of the walls, due to thermal or moisture movements or foundation settlement, can lead to several different defects in masonry walls in serviceability states, such as cracking, On the other hand, apart from the structural role, or not, of masonry walls, these cracking defects can affect other important functional walls requirements. According to Grimm cracks are the first cause of three occurrences. Beside the implications there is also significant damage to acoustic insulation, durability and the fire resistance of masonry.

Moreover, despite the general quality improvement expected from the profusion of codes and standards, in recent years some building masonry cracking defects are still being reported with high frequency in different countries. These defects incur costs and can involve litigation between different parties involved in the construction process. In terms of liability, which party is responsible is a relevant question. In fact, although building construction is an industrial activity, we know that buildings are still prototypes and in some areas, like masonry, the relationship between traditional technologies and local materials is relevant and important, so different practices evolve in different areas. Therefore, these aspects justify that more attention should be paid to design in order to avoid or minimize defects associated to the serviceability behavior on masonry structural.
Therefore, the objective of this research is to understand the failure mode of unreinforced masonry structures with particular material properties, aspect ratio and boundary conditions under dynamic loading.

1.2 BACKGROUND STUDY

Disaster Risk Index indicates that old Dhaka is one of the most relatively vulnerable cities in the world (Cardona et al, 1999). The city is situated near Madhupur reverse fault which is located at a depth of 10 km with 45degree dip angle and down-dip rupture width of 42 km (CDMP, 2009). At present older part of Dhaka city's old masonry structures age averagely 120 years and all of the masonry structures conditions is very dangerous.

Old urban settlements of older part of Dhaka city was built during the Mughal period (1526-1707) and the later part of the British rule (1757-1947). Most of these masonry structures have been constructed without following any ageing impacts, cracking other failure reasons resistance guidelines. Over the years many unplanned modifications took places which are serious threats for the houses from structural considerations. Moreover, these old vulnerable structures are situated in the most densely populated area in the city.

This type of old masonry structures consists approximately 18 percent of total buildings of in the city. Most of the buildings were built during Mughal period and British rule, having unique architectural style constructed by brick masonry with lime mortar. Over the years many unplanned modifications took place which is a serious threat for the houses.

Most of these old masonry buildings have bearing walls consist of clay brick masonry with lime mortar. Floor and roof framing consist of straight or diagonal lumber sheathing supported by wood joists, on posts and timbers. The diaphragms are flexible relative to the walls. Ties between the walls and diaphragms consist of bent steel plates or anchors set in the mortar joints and attached to framing. Foundations consist of inclined brick that act like an arc or concrete spread footings. In most of the houses, an open veranda encloses the court approximately in the middle of the linear plan. Very narrow stairways exist in almost every building. One of the most important structural features of this building is arch lintel. These arrangements of masonry unit function as a header to carry the load above the opening to either side. [LISBOA 2012]

Old masonry structures in old Dhaka City is at the highest relative earthquake disaster risk as expressed by local experts, as the phenomenal urbanization, high density of population. Although no moderate to large environmental disaster has struck in older part of Dhaka city in historical past (Khan, 2004). The physical characteristic of the region made the community more vulnerable to this type of masonry structure. Some buildings in older part of Dhaka city collapsed even without any disaster only for ageing impact (Jahan, 2011), so it is beyond imagination what will happen when create cracks and other failure for ageing impact. In June 2004 a five storied building collapsed in Sakhari bazaar which killed 19 people and injured several others among its 30 inhabitants.

1.3 OBJECTIVES

This study is performed to satisfy following purposes:

1. Analysis ageing impact on brick masonry structure.
2. Crack study of these structures.
3. Crack analysis to identify the causes of crack.
4. Determine risk level of masonry structure considering its age and deterioration.
5. Remedy of the crack/renovation of structure.
6. Marking the around masonry structure.

1.4 Activity

To accomplish this study, we got involved with following activities

1. Cracks and fault analysis.
2. Aging effect study for various structure.
3. Ageing effect of masonry structure.

1.5 Scope of the Study

The purpose of the study writes down below.

1. Cracks analysis of masonry structures.
2. Analyzing the reasons of creating cracks on masonry structures.
3. Risk analysis of masonry structure used for more than design period of buildings.
4. Suggestion/Renovation of masonry structures.

CHAPTER TWO

LITERATURE REVIEW

David A.Waddicor, ElenaFuentes, LauraSisó, JaumeSalom, BérengerFavre and ChristelJiménez said in “Climate change and building ageing impact on building energy performance and mitigation measures application: A case study in Turin, northern Italy” that, they used a building energy performance simulation to investigate the impact of predicted climate warming and the additional issue of building ageing on the energy performance for a library in Turin, Italy. The climate and ageing factors were modelled individually and then integrated together for several decades. Results from the climate-only simulation showed a decrease in the building heating energy usage which outweighed the increase in the on-site cooling energy demand occurring in a warming scenario. The study revealed a high sensitivity of energy performance to building ageing, in particular due to HVAC (Heating, Ventilation and Air Conditioning) equipment efficiency degradation. Building ageing was seen to negatively affect the energy performance as it induced a further increase of the cooling energy usage in a warming climate, while it also counteracted the reduction of the heating energy usage resulting from warming.

Jamal idris ,Thierry Verdel Marwan Al-Heib said in **“**Numerical modelling and mechanical behaviour analysis of ancient tunnel masonry structures**”** As with all older construction, ancient tunnels feature particular characteristics, especially as regards past construction methods, geometrical design considerations and the set of construction materials used. Old tunnels usually display a unique vaulted section shape built with masonry. The present paper proposes two numerical models of an old tunnel supported by masonry; these models were developed by the well-known Universal Distinct Element Code (UDEC). A masonry mechanical behaviour analysis and numerical simulation of the masonry ageing phenomenon will also be addressed by means of an experimental design to study the influence of masonry block physical properties on the mechanical behaviour of masonry structures in old tunnels.

Tatyana Micic and Milos Asenov said in “Probabilistic Model for Ageing Masonry Walls” considered a probabilistic model of masonry wall capable to take into account uncertainties caused by ageing and site specific parameters. We define masonry wall uncertainties using random variable representation for geometric, load and mechanical properties and then by introducing specific probabilistic deterioration model. Subsequently, we use probabilistic analysis in ANSYS (APDL) using Monte Carlo simulation method and Latin Hypercube sampling technique with aim to approximate the cumulative distribution function for the von Mises stress and displacement at particular location. It is demonstrated that the likelihood of exceedance of critical parameters such as displacements and von Mises stresses due to ageing could be quantified.

Masonry structures represent a traditional and historically widely used type of construction. Therefore, ageing of masonry structures brings formidable challenges to many infrastructure owners. As a consequence of high variation in quality of masonry between sites, unevenness in mortar joints between and within sites, Josipovic and Stewart (2015), but also environmental effects, damage and deterioration over the life cycle, there is a significant uncertainty in ageing of components. Therefore, models for quantification of site. specific uncertainties and ageing process would be very useful.

C. Tedeschi, A. Kwiecień, M. R. Valluzzi, B. Zając, E. Garbin and L. Binda said in **"**Effect of thermal ageing and salt decay on bond between FRP and masonry**"** Thermal cycles and salt crystallization test were carried out on solid brick samples and small masonry assemblages, using bricks and mortars produced in Italy and in Poland. The specimens were strengthened with CFRP textiles or laminates in different configurations. To perform thermal accelerated ageing tests, specimens were subjected to a temperature variation ranging between −10 and +70 °C, applied cyclically. The procedure was validated during testing. The results showed the influence of the properties of the adhesive and of the strength of the brick in the failure of specimens. As for salt decay tests, a RILEM pre-standard procedure was followed to evaluate the resistance of tested materials to sulfates. Damage evolution was monitored by visual observation and by quantification, at each 4-week cycle, of material loss by a laser profilometer. The results showed the rising of salt from the uncovered surface as from the first week of observation, and also a concentration of stresses underneath the fibers. The pull-off test was chosen as reference test, in order to the loss of bond. The durability was also checked on reference unreinforced specimens. Pull off tests were carried out on the surviving specimens at the end of the tests. The results among the various series of specimens are compared. This costly repair technique can show adhesion problems.

J.Galvão , I Flores-Colen , J.de Brito and M.R.Veiga has said in "Variability of in-situ testing on rendered walls in natural ageing conditions Rebound hammer and ultrasound techniques" the first barrier against degradation agents and their performance affects directly that of building façades. During the life cycle of renders there is a progressive reduction of their performance until they are no longer able to fulfil their required functions, such as protection of walls and finishing of surfaces. The evaluation to understand how a render performs over time is a complex activity, not only due to the multiple factors concerning its exposition, but also to the difficulty in assessing the in-service behaviour. The use of in-situ techniques gives the possibility of obtaining the information about in-service performance of renders. Discusses the use of ultrasound and pendulum rebound hammer techniques for assessing the mechanical performance of rendered walls under natural ageing conditions. The results of ultrasound pulse velocity and rebound hammer index, in conventional and industrial renders, allowed identifying some of the main influencing factors, related both to the rendering-wall system (characteristics and degradation) and the inspection conditions and procedures. This study has confirmed the usefulness of these in-situ tests to evaluate the mechanical performance of rendered walls, despite their variability in natural ageing conditions.

Elena Mastrapostoli , Matthaios Santamouris, Dionysia Kolokotsa, Perdikatsis Vassilis, Danae Venieri and Kostas Gompakis said in "On the ageing of cool roofs: Measure of the optical degradation, chemical and biological analysis and assessment of the energy impact" The use of cool materials for heat island mitigation has gained a lot of interest during the past few years. Cool materials are characterized by high solar reflectance and infrared emittance values. To maximize cooling energy savings, high albedo roof coatings should maintain the above properties for the service life of the coating. The aim of the present paper is to analyze the weatherization of the cool roofs in two buildings in Athens Greece. The optical properties of the aged and new cool roofs are measured and compared. The impact of ageing in the two buildings'_energy performance is estimated. A mineralogical analysis is performed in order to quantify the deposition of pollutants on the cool roofs' surface. In addition, a series of microbiological tests are implemented to reveal the impact of ageing and weatherization in health. In both school roofs the surface temperature has a significant decrease between the part of the existing cool coating and the application of the new part with a temperature difference reached reaching 7–12 K.

Fritz Wenzel and Helmut Maus said in " Repair of Masonry Structures" Besides the traditional repair techniques of craftsmen for masonry structures, engineering methods and procedures such as grouting and reinforcing of old masonry are available. These technical measures can help to save the monumental value of historically important buildings more effectively than the procedure of dismantling and rebuilding; and, as a rule, they are distinctly less costly. Nevertheless, too much technical aid can destroy what is meant to be preserved. For that reason the investigations described in this paper on both improvement and development of engineer-like repair techniques have been focused on the goal of minimizing interventions and modern additions as far as possible.

Fausto Mistretta,FlavioStochino and MauroSassu said in " Structural and thermal retrofitting of masonry walls: An integrated cost-analysis approach for the Italian context" Constructions ageing is a relevant problem in developed country like Italy. In particular, in case of existing masonry buildings, retrofitting interventions aimed at improving structural and thermal performances represents an obvious need. At the same time, sustainability awareness of buildings life-cycle has grown in the last years. Consequently, the whole life-cycle of constructions should be analyzed and assessed during the design of retrofitting interventions. In order to take into account these aspects new design and planning methods are necessary. This paper presents an integrated approach to evaluate structural and thermal retrofitting strategies for masonry walls. Economic and ecological costs of each examined retrofitting solution are compared, taking into account thermal and seismic capacity demand of the construction site. Given the *economic cost*, a set of retrofitting solutions for masonry panels have been mapped with a couple of parameters (structural strength Vs thermal insulation). An analogous mapping, considering the *ecological cost* due to equivalent CO2 production, have been performed. A methodology to find the best solution among a set of retrofitting solutions is presented, depending on the location of the building and its seismic and thermal characteristics. Examples, based on six retrofitting techniques located in four different sites in Italy, are analyzed to explain the effectiveness and the feasibility of the proposed method. The comparison between ecological and economical cost allowed to highlight the characteristics of the different interventions. Thermal performance proved to be more important in cold weather conditions while structural retrofitting is preferable in high seismic risk areas.

CHAPTER THREE
METHODOLOGY

3.1 SITE SELECTION

3.1.1 SITE AT OLD DHAKA CITY

Dhaka is the Capital city of Bangladesh selected as the location of the study. The Dhaka city become the 7th most populous city in the world and considered as the world's most densely mega-city). Old Dhaka is located on the banks of the Buriganga river and southern part of Dhaka south city corporation with a population density of 14,608 persons per sq. (Banglapedia, 2008).

We choose old Dhaka because, has many brick masonry structures, oldest masonry structures, has huge number of emperor masonry structures, easy to visit and collect information.

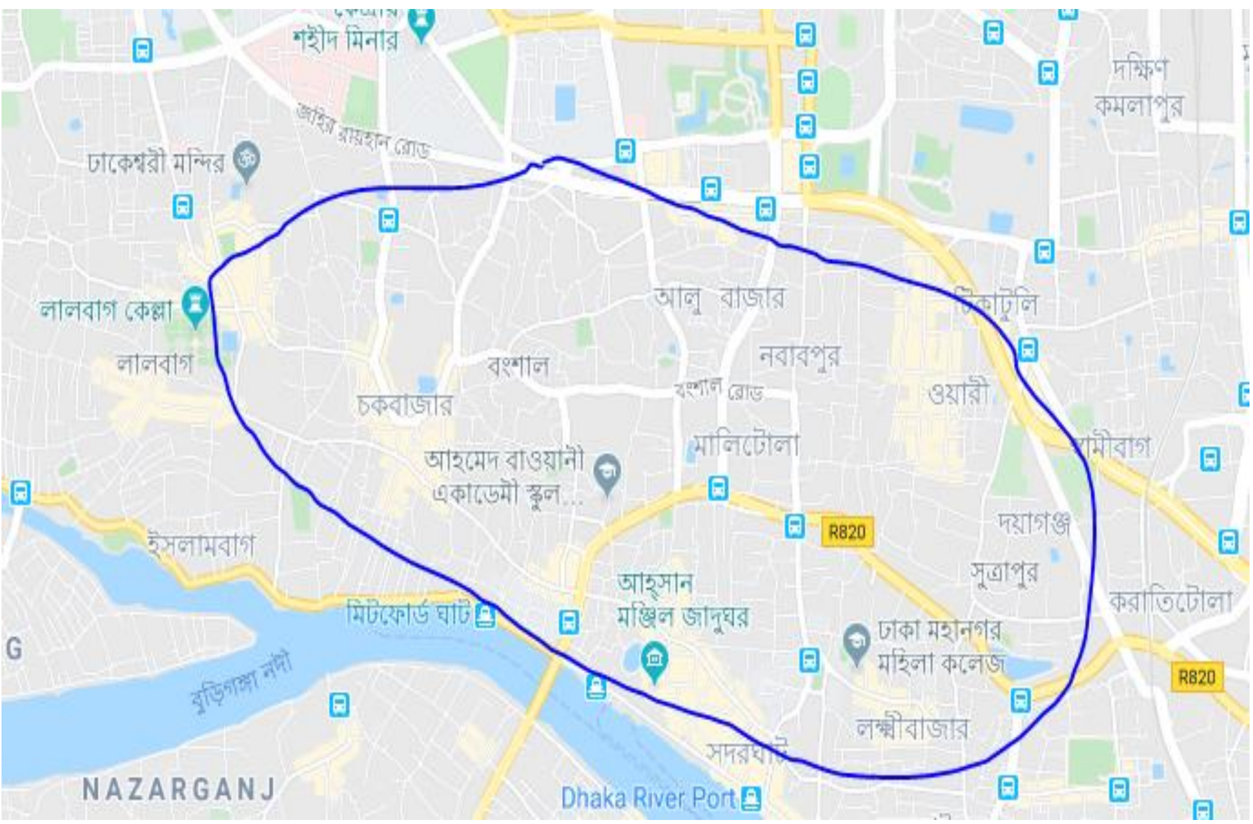

Figure 2.1: Location map of old Dhaka.

3.1.2 SITE AT NARAYANGANJ CITY

Narayanganj is a city in central of Bangladesh. Narayanganj district, near the capital city of Dhaka and has a population of about 2.2 million. It is the third-largest city in Bangladesh (Banglapedia 2015). Murapara, Rupganj is the Thana of Narayanganj near the bank of the Shitalakshya River.

We choose to Narayanganj because of this place near to Dhaka, Different masonry structures, has many masonry structures in a close area, various cracks and failure, oldest emperor masonry structures , easy to talking local people .

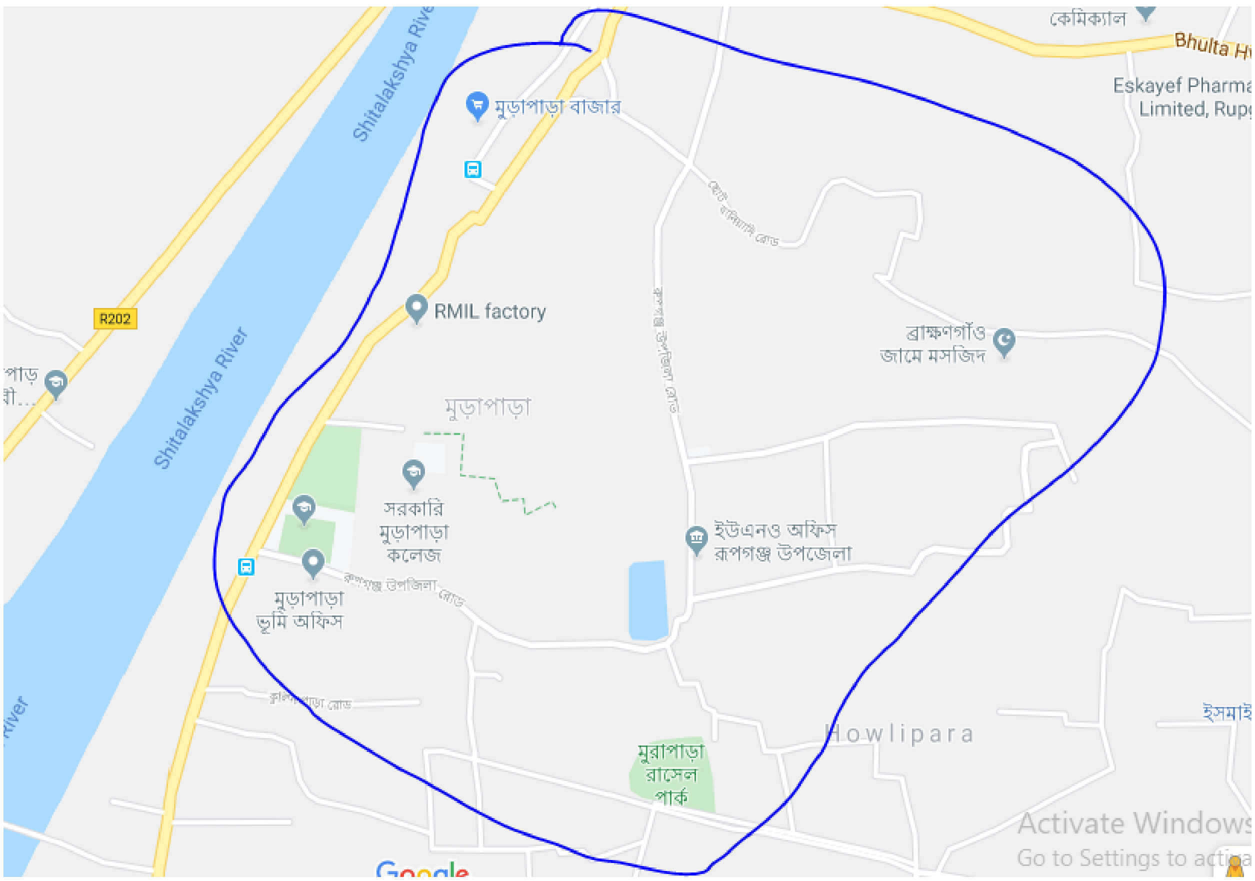

Figure 2.2: Location map Murapara, Rupganj, Narayanganj.

3.2 SITE VISIT

We visited two areas. One area was in Old Dhaka, Dhaka south city corporation, Dhaka and another one was Murapara, Rupganj Upazila, Narayanganj district. In these two areas we visited 18 brick masonry structures.

Our first visiting area was Murapara, Rupganj Upazila, Narayanganj. We observed that area in two times 4th and 7th October in 2019. In 4th October 2019, we start our visiting tour at 8:00 AM from our university campus with our group members and we reached the Murapar at 9:30 AM. After the reaching Murapara , we managed one guide. With his help we visiting three brick masonry structures, Murapra Gov't collage, Murapara Jomidar bari and an ancient building. After the visiting those structure we came back from here.

2nd day of Narayanganj visiting was 7th October 2019, we reached the Murapara at 11:00 AM. With our guide again we started visiting the masonry structures. We visited two masonry structures on that day and go back our old visited masonry structure for collecting different data and then we came to Dhaka.

Our second observation area was Old Dhaka City. We visited in 5th and 11th November 2019. First day of visit, we visited seven masonry structure at Tatibazar, Islampur, Shakharibazar English road in old Dhaka. In the afternoon ,we come back from old Dhaka. The next part of our visiting all of our group member again we came to old Dhaka for collecting data in 11th November 2019. We observing various masonry structure at Laxmibazar, Jonson road, Nababpur, Bangsal. In that day we observing six brick masonry building.

After visiting two areas we collected various data related to aging and earthquake impact on those structures.

3.3 DATA COLLECTION (Questioner Survey):

The initial data were gathered through a questionnaire survey where questions covered vulnerability to earthquake, its impacts on masonry building in old Dhaka. It is believed that closed-ended questions probably limit the responses to the topics. Thus, the questionnaire was decorated with both the closed and open-ended questions to gain the maximum possible results.

OLD DHAKA CITY:

Table. 3.3.1: Questioner Survey for Old Dhaka

SL NO.	Types of people ask for questioner	Questions				Remarks
		1	2	3	4	
1	Native old person	Building age	Causes of crack	Crack propagation	Crack age	
2	Residences of house	Crack length and depth	Changing time of crack	Crack propagation	Building age	
3	Regular visitors	Building's past and present condition	Changing time of crack	Changing time of crack	Crack propagation	
4	Permanent residences of this area	Crack age	Causes of crack	Crack propagation	Building age	
5	Young people	Causes of crack	Crack propagation	age of the crack		
6	Shopkeepers	Changing time of crack	Crack propagation	Building's past and present condition	Changing time of crack	

NARAYANGANJ CITY:

Table. 3.3.2: Questioner Survey for Narayanganj.

SL NO.	Types of people ask for questioner	Questions				Remarks
		1	2	3	4	
1	Native old person	Building age	Crack age	Crack propagation	Causes of crack	
2	Residences of house	Crack length and depth	Changing time of crack	Building age	Crack propagation	
3	Regular visitors	Building's past and present condition	Causes of crack	Changing time of crack	Crack propagation	
4	Permanent residences of this area	Crack age	Building age	Crack propagation	Causes of crack	
5	Young people	Causes of crack	Crack propagation	age of the crack	Building age	
6	Shopkeepers	Building age	Changing time of crack	Building's past and present condition	Crack propagation	

Different types of secondary data, which included the area, masonry building number and masonry building density of the corresponding areas, were gathered focusing the objective of the study. In addition, building age and their visible physical conditions in respect of areas were also collected.

During the visited at first, we identified the characteristics of the masonry buildings with respect to condition of the buildings. Like as poor, average, good and abended. Taking some picture of building on different angle. Also taking some snap of different cracks of masonry structures. Identifying the present conditions of masonry buildings.

We talked the local people about the masonry structure, structure life duration or approximate build year of buildings. We also talk users of buildings and collected the numbers of users of the buildings, uses duration, life duration of buildings, talk to users trying to understand situations of masonry buildings when occurred the earthquake.

In our visited structures we was found different types of cracks. Such as horizontal cracks, shear cracks, vertical cracks. We measured the reflection length and cracks depth.

3.4 CAUSE OF FAILURE MASONRY OLD STRUCTURE

- Lime mortar hydration.
- Mixture of poor mortar.
- Soil settlement.
- New structure on old one.
- Using more than design period (usually 30-40 years).
- Unplanned construction over old structure.
- One side collapse.

3.5 TYPES OF FAILURE MASONRY OLD STRUCTURE

- Shear failure
- Diagonal failure
- Bond failure
- Brick failure
- Mortar failure
- Over loading failure
- Corner/Joint failure
- 2’-0” thickness wall over hydrate

CHAPTER FOUR
DATA ANALYSIS

4.1. Murapara Gov't Collage:

Figure.4.1: Front view of the college.

4.1.1. Details of the structure

Address	: Mura para, Rupganj, Narayanganj.
Stories of Building	: 2 (Two) storied.
Established	: 1889 (Probable).
Age of Building	: 130 years (Approximate).
Residents of the Building	: Students.
Purpose of the use of the building	: College classes are held in the building.

4.1.2. Cracks of the structure

Figure. 4.2. Picture of arch crack

A roof to arch crack was observed. The crack is almost vertical along the brick sides. The crack even propagated below the arch.

Kinds of Failure: Settlement failure.

Possible Cause of Failure: Observing the crack it can be predicted that, due to the long-time perpetual loading, an uneven lime masonry settlement has been occurred. Hence a settlement failure developed.

4.2. Old Jomider Bari-1

Figure.4.3. Old Jomider bari.

4.2.1. Details of the structure

Address	: Shibganj, Rupganj, Narayanganj.
Stories of Building	: 1 (One) storied.
Established	: 1880-1900 (Probable).
Age of Building	:120-140 years (Approximate).
Residents of the Building	:1 (One) family.
Purpose of the use of the building	: One side of the building is abended other side of the building is using for residence.

4.2.2. Cracks of the structure

Figure.4.4. lintel joint crack

A roof to lintel crack was observed. The crack is almost horizontal along the concrete joint.

Kinds of Failure: Bond failure.

Possible Cause of Failure: Observing the crack probable cause of the failure due to weak bonding of lime masonry. That was the cause of bond failure.

4.3. Old Jomider Bari-2

Figure.4.5. Old jomider bari-2.

4.3.1. Details of the structure

- Address : Shibganj, Rupganj, Narayanganj.
- Stories of Building : 1 (One) story.
- Established : 1880-1900 (Probable).
- Age of Building : 120-140 years (Approximate).
- Residents of the Building : No residence
- Purpose of the use of the building: Its totally abanded building. That’s why there are no residence.

4.3.2. Crack of the structure:

Figure.4.6. Vertical crack of wall.

A vertical crack of wall was observed. The crack is almost vertical along the masonry joint.

Kinds of Failure: Settlement failure.

Possible Cause of Failure: Observing the crack probable cause of the failure due to weak lime masonry settlement. That was the cause of settlement failure.

4.4. Old House:

Figure.4.7. Front view of the building.

4.4.1. Details of the structure

Address	: Doriyakandi, Rupganj, Narayanganj.
Stories of Building	: 1 (One) storied.
Established	: 1900-1910 (Probable).
Age of Building	: 110-120 years (Approximate).
Residents of the Building	: 1 (One) family.
Purpose of the use of the building	: One side of the building is abended other side of the building is using for residence.

4.4.2. Cracks of the structure

Figure.4.8. crack on due to differential settlement of structue.

A incline/angler crack of wall was observed. The crack even propagated over the lintel.

Kinds of Failure: Settlement failure.

Possible Cause of Failure: The probable cracking defects in structural masonry seem to be associated with ground movements (settlement of soil), although defects like expansion/shrinkage of masonry materials or thermal movements can also occur.

4.5. Upozila land office, Rupganj, Narayanganj :

Figure.4.9. Front view of the building.

4.5.1. Details of the structure

Address	: Rupganj, Narayanganj.
Stories of Building	: 1 (One) storied.
Established	: 1920-1940 (Probable).
Age of Building	: 80-100 years (Approximate).
Residents of the Building	: Office.
Purpose of the use of the building	: It was reformed. After reformation, it was uses of Government office. Upolzila land office of Rupganj situated here.

4.5.2. Cracks of the structure

Figure.4.10. crack on due to settlement failure.

A incline/angler crack of wall was observed. The crack even propagated over the lintel.

Kinds of Failure: Settlement failure.

Possible Cause of Failure: The probable cause of crack due settlement of lime masonry. Probable another cause is undesired changes in the physical properties of the materials due to the presence of water/humidity.

4.6. Old Building :

Figure.4.11. Front view of the building.

4.6.1. Details of the structure

Address	: 31/1, Patuatuli, Dhaka-1100.
Stories of Building	: 3 (Three) storied.
Established	: 1920-1940 (Probable).
Age of Building	: 80-100 years (Approximate).
Residents of the Building	: Residence, Office , Shop.
Purpose of the use of the building	: It is mostly decrepit. But is uses of different shop, office, residence. There are 8-10 family lives here.

4.6.2. Cracks of the structure

Figure.4.12. Crack on due to ageing impact/ settlement failure.

Observed an incline/angler crack of wall. The crack is almost 45 degree with respect horizontal axis.

Kinds of Failure: Ageing impact /settlement failure.

Possible Cause of Failure: The probable cracking defects in structural masonry due to ageing impact / settlement of masonry. Other Probable cause of the crack due to build new structure over the old structure. Another cause of failure, Ageing and degradation of the materials, in particular rendering systems, due to continuous exposure in the environment.

4.7. Sir Solimullah medical collage stuff quarter:

Figure.4.13. Front view of the building.

4.7.1. Details of the structure

Address	: Midford road, Dhaka-1100.
Stories of Building	: 2 (Two) storied.
Established	: 1920-1940 (Probable).
Age of Building	: 80-100 years (Approximate).
Residents of the Building	: Residence.
Purpose of the use of the building	: Hospital's 4th class employer's stuff quarter. There are almost 20-25 family lives hare.

4.7.2. Cracks of the structure

Figure.4.14. Crack on due to settlement failure.

An incline crack of wall was seen. The crack is over the lintel.

Kinds of Failure: Masonry settlement failure.

Possible Cause of Failure: The probable cause of crack due uneven settlement of masonry. Probable another cause is undesired changes in the physical properties of the materials due to the presence of water/humidity.

4.8. Tajmahal House:

Figure.4.15. Front view of the building.

4.8.1. Details of the structure

Address	: 24 no. koilash ghosh lane, Dhaka-1100.
Stories of Building	: 2 (Two) storied.
Established	: 1910-1920 (Probable).
Age of Building	: 90-100 years (Approximate).
Residents of the Building	: Residence.
Purpose of the use of the building	: There are four family lives in the building. But the building almost decrepit.

4.8.2. Cracks of the structure

Figure.4.16. Crack on due to the deformation of support.

A horizontal crack was observed. The crack developed for uneven settle of foundation.

Kinds of Failure: Settlement failure.

Possible Cause of Failure: The probable cause of crack due uneven settlement of brick masonry or soil. Another probable cause is the presence of door and window openings in near the crack.

4.9. Redwan Vila:

Figure.4.17. Front side view of the building.

4.9.1. Details of the structure

Address	: 6/1, Koilash ghosh lane, Dhaka-1100.
Stories of Building	: 2 (Two) storied.
Established	: 1900-1920 (Probable).
Age of Building	: 100-120 years (Approximate).
Residents of the Building	: Residence.
Purpose of the use of the building	: There are 5 family lives in the building. But the building is very oldest building.

4.9.2. Cracks of the structure

Figure.4.18. Crack on due to the masonry settlement.

Observed an incline/angler crack of wall. The crack is almost 45 degree with respect to horizontal axis.

Kinds of Failure: Masonry settlement failure.

Possible Cause of Failure: The probable cracking defects in structural due to masonry settlement. Other Probable cause of the crack due to build new structure over the old structure. Another cause of failure, Ageing and degradation of the materials, in particular rendering systems, due to continuous exposure in the environment.

4.10. Barmibas Baban:

Figure.4.19. Front side view of the building.

4.10.1. Details of the structure

Address	: 20 no. court house street, Dhaka-1100.
Stories of Building	: 2 (Two) storied.
Established	: 1950.
Age of Building	: 70 years.
Residents of the Building	: Residence, Shop, office.
Purpose of the use of the building	: Two family lives in 1st floor. In ground floor there is a one shop and one office.

4.10.2. Cracks of the structure

Figure.4.20. Crack on due to the Joint failure/share failure.

Observed joint crack in masonry column and bean.

Kinds of Failure Joint failure/share failure.

Possible Cause of Failure: The probable cause of crack due to weak bonding of mortar in the joint. Other Probable cause of the crack due to design over load on the structure.

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1. Repair/Remedy Strategies for Cracking in Masonry Structures:

The cracking of masonry structures results when quality standards or serviceability requirements are unsatisfactorily complied with. The selection of repair strategies is conditioned by the type of defect, its causes and the features that are intended to be improved (stability, structural and fire safety, thermal and acoustic comfort, energy efficiency, water-tightness, or others). There are two main strategies to repair masonry structures; they can be used alternatively or combined:

- Repair, locally, any single defect with a specific technique.
- Global improvement of masonry performance, with an extended and multi-purpose repairing technique.

Choosing one or both of these strategies depends on several factors:

- The number and spatial distribution of the defects in the structures.
- The diversity of defects observed;
- The existence of a multi-purpose repairing technique, for the multiplicity of defects, compatible with the construction of the masonry, its coating and finishing solution.

The most frequent groups of defects are cracking, water penetration, ageing and local degradation. The structural stability is only affected in a few cases of cracking but, when it happens, it is the most important factor concerning the repairing strategy and the repairing techniques. For all the defects not having structural consequences, there are several approaches that can be taken together to obtain a more durable versus economic solution: suppression of the defect, replacement of the affected materials, concealing or hiding of the defects, protection against aggressive agents, elimination of causes and upgrading of specific features. Soft techniques, such as repairing coatings and finishing - like thin reinforced mortar layers elastic and water tight paints coats are used when the main defects affect all of the wall but only its external surface (cracking, humidity, ageing, etc.). They are often used as supplementary corrective action after the local repairing of cracks using wall ties, embedded steel bars, anchors, etc. Considering structural walls, the selected repairing techniques must re-establish the continuity that allows the correct (and, if possible, the original) transmission of compressive, tensile, shear and flexural forces, without exceeding masonry strength and avoiding local stress concentration under the expected loads and imposed deformation, although an upgrading of strength cannot be neglected if the actions responsible for the previous failure are not reduced and will remain effective. In these situations, the repairing strategy should involve construction components related to the masonry walls, such of slabs, beams and foundations. For non-structural walls, if their stability is guaranteed, cracking repair should achieve the repair of other wall features such as aesthetics. The correct selection of repairing techniques for cracking of masonry walls should be supported by a correct diagnosis, an extended identification and characterization of the cracks (their thickness, length, pattern, age, etc.) and also should be based on their expected development. Many authors have established a check list for assessing masonry cracking in order to assure an accurate diagnosis and repairing strategy. A main cause of masonry cracking is thermal movement and the stresses it induces. This behaviour will be both cyclical and seasonal. Whatever the cause, cracks constitute involuntary expansion joints. In fact, most masonry cracks change over time, for a variety of reasons:

- The crack reflects natural movements of the wall caused by temperature and humidity variation.
- The crack is cyclic or acts randomly over time.
- The crack is permanent, persistent or increases over time.
- The edges of the crack are progressively destroyed by erosion or other physical or chemical actions;
- The crack is progressively filled with particles, dust, salts, detritus etc.
- The repair techniques for this situation are often aligned with one of these principles or strategies.
- If there is a high level of internal thermal or moisture induced stress, the formal creation of an expansion joint, instead of cracking repair, should be considered.
- If the transmission of forces and movements between crack sides is relevant,
- fixing anchors or embedded steels bars should cross the crack. if the expected movements are reduced and become innocuous, but can affect the in a coating, a non-bonded strip repair should be used.

A clear situation for cracking repair occurs when the water tightness of the wall should be restored. It is often necessary to enlarge the crack in order to get the ideal shape to install a water barrier, before repairing the crack. It is essential to remember that the accuracy needed for the initial estimation of crack width is much lower than when it is required for monitoring its evolution. Firstly, a thorough visual inspection can distinguish between thin cracks (under 0.5 mm) and medium (up to 2 mm) or large cracks, but their evolution cannot in general, be observed without precision equipment, able to detect and record 0.01 mm movements

5.2. Method of Repair/Remedy:

Deciding how the repair should be done depends on the cause of the problem and its implications. The problem may be aesthetic or it could point to a serious structural impairment. In any case, a well monitored inspection is required to stabilize the problem. Having confirmed the stabilization, according to three repair methods can be chosen, summarized in 5.1. Note that these methods can be used together depending on the problem at hand.

Table 5.1. Repair Methods

Method	Applicability	Observations
Raking and Re-pointing	Usually applied to cracks localized in the mortar joints. Effective for cosmetic reasons only. Requires a skilled bricklayer and correct specification of a compatible mortar.	Difficulty to completely fill the joint. Long term shrinkage of fresh mortar can cause cracking to re-appear at the same interface. The use of a polymer modified cement mortar can allow better penetration and bonding characteristics. Special care should be taken with facing brick masonry in order to preserve aesthetics
Re-construction of Selected Areas	Usually applied to restore structural integrity, including demolition and re-building of the damaged area. Also requires skilled tradesmen and the correct specification of materials.	Difficult to guarantee bond between new and old masonry unless a control joint is provided. The use of a new reinforced coating, when possible, is recommendable.
Resin injection	Usually applied to cracks in masonry units and to mortar joints. Requires specialized equipment and personnel.	Epoxy infection, despite the extra cost compared with conventional methods, provides mostly full penetration and effective bond. The resin must have compatible stiffness to the repaired material, to avoid local stress concentrations under future movements. Exposed resin must be resilient

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

6.1. Conclusion:

From the issues exposed and presented some general suggestions can be include in the conclusion.

- Masonry walls perform several roles in buildings: they can be structural or infilling, enclosure or partition, they can have different finishes or be the final finish and they may contribute to other functional requirements.
- The control of all functional requirements and the behaviour of masonry walls is yet far from being perfect, taking into account the relevance of materials properties and workmanship.
- The influence of regional practices, materials, and architectural solution increases the difficulty of global approaches common for other building components.
- Codes and standards, despite the important improvements made in recent years, have few guidance on how to minimize serviceability problems such as cracking.
- Among structural and non-structural solutions in a building, masonry is possibly the one that is given less attention in undergraduate courses in architecture and engineering despite its economic and functional importance.
- Probably the most common masonry defect is cracking. This defect has different manifestations, between those that must be considered as unavoidable and only with aesthetic implications, to those that are clearly unacceptable for aesthetic and functional reasons. The range of accepted cracking defects is very different in different cultures.
- Cracking repair depends on a correct diagnosis of the source of the movements producing the cracks and if this movement is stabilized or not.
- Cracking repair is frequently not efficient. To achieve the repair objective a strategic approach, methodology and technique should be adopted.
- It is important to consider that, due to the development of steel and concrete, reinforced concrete structures are increasingly flexibility. This leads to an increase in deflections and, therefore, an increase in cracking.
- Practices such as walls bearing on thin slabs, exclusion of mortar in vertical joints, use of 10 mm thick mortar rendering and the use of brittle materials such as rendering also have contributed to the appearance of problems with partition and enclosure walls.
- A better understanding of masonry service behaviour and the capacity for preventing defects needs more research - mainly experimental.

6.2. Recommendation:

The prevention of problems is concerned with design, construction and workmanship control procedures which are given in this manual. Repair must always be based on a correct diagnosis of the real causes of each problem seen. The aim should always be to restore the structure to its original condition. No repair process should ever merely conceal or cover up the original problems since in time this might lead to a lack of structural safety or stability.

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