FORENSIC DISTRESS EVALUATION OF CADETS BLOCK

PAF ACADEMY ASGHAR KHAN

FINAL YEAR PROJECT UG 2014

By

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Military College of Engineering, Risalpur

National University of Sciences and Technology,

Islamabad 2018

It is certified that the

Final Year Project titled

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has been accepted towards the requirements

for the undergraduate degree

in

CIVIL ENGINEERING

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ACKNOWLEDGEMENT

Prima facea, I am grateful to the God for the good health and wellbeing that were necessary to complete this document

We are highly grateful to our Project advisor Dr. Muhammad Rizwan Siddique for his continuous and effective guidance and support throughout the course of this project.

As our teacher and advisor, he has taught us more than we could ever give him credit for here. He has shown us, by his example, what a good project advisor (and person) should be.

We are highly obliged to mention Lab Engr Nadeem.

He has been a complete and efficient guide throughout our project.

Abstract

Water seepage is a potential hazard to buildings worldwide and in particular PAF Academy Asghar Khan. It has led to lots of civil actions and the Court general relies on expert opinion on the finding of facts. In establishing the cause of action, identification of the sources of water seepage is usually more important than that of the causes of water seepage. Both the external sources and the internal sources of water seepage may be identified by carryout out forensic evaluation of building. In the broad sense of the term, the common objective of forensic engineering is to diagnose problems and remedy them, making the structure sound and serviceable. In the literal sense of the term, the primary objective of forensic engineering is to identify the source of the noted problem and assign responsibility for the failure. In the Code written in 1780 B.C.E. by Hammurabi, the ruler of Babylon, it states ***"If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then that builder shall be put to death."*** Clearly, the need to determine the causes of building failures is a longstanding one with serious, sometimes dire, consequences. In daily practice, the forensic engineer's understanding of design and detailing practices, material properties, investigative techniques and construction practices dictate his or her ability to comprehend and properly diagnose problems.

Forensic building is needed to examine the affected building structure components to assess the structural integrity. This paper highlights some of the studies involved on affected concrete structures in various building types where the non-destructive test (NDT). The structural integrity can be evaluated based on the extent of deterioration from the experimental results. Nondestructive test methods (NDT) are available for the assessment of many types of defects in existing structures including: the evaluation of reinforcing steel corrosion, determination of defect location, accurate assessment of the member sizes, and reinforcement locations. By not carrying out unnecessary and/or unreliable tests, overall cost and time can be reduced. This may ultimately assist the public to resolve the problem of water seepage in buildings.

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CHAPTER 1

INTRODUCTION

1. **Infrastructural & Structural Life in Pakistan.** Infrastructures/Structures are the central prerequisite in the working of any nation. In the present current period, we require infrastructures and substantial structures to live, we require schools, health centers, colleges and huge structures for the smooth working of society/nation. We require power to light our homes and industry. We require highways to transport merchandise from one place to the next and after that ports and air terminals to send out our modern items to outside exchange accomplices. Thus, an advanced country requires powerful water and sanitation to enhance and manage the wellbeing and cleanliness of its people. In all circumstances, structures/infrastructures are such some necessities, to the point that it influences the lives of each and every person on this planet. Absence of legitimate infrastructural and structural buildings causes disorder, disorganization and devastation in our lives. It likewise causes obstruction in the smooth working of the economy.

Pakistan's infrastructural circumstance is generally poor by universal benchmarks and international standards and this intense effects on the lives of each in the nation. As far se the basic existence of the structures in Pakistan is concerned, it doesn't have a relatively good reputation in light of the fact that they are not up to the international standards. We have seen structural buildings collapsing very often. The Government of Pakistan and its people confront a hard struggle against poor infrastructures and structural standards and it appears like the Government of Pakistan is on the losing side. The advancement and development of building structures is essential for sustaining and boosting social

development and economic improvement of Pakistan and to enhance the personal satisfaction and quality of life.

2. <u>Structural Health Monitoring</u>. It defines as

"The process of implementing a damage detection and characterization strategy for engineering structures".

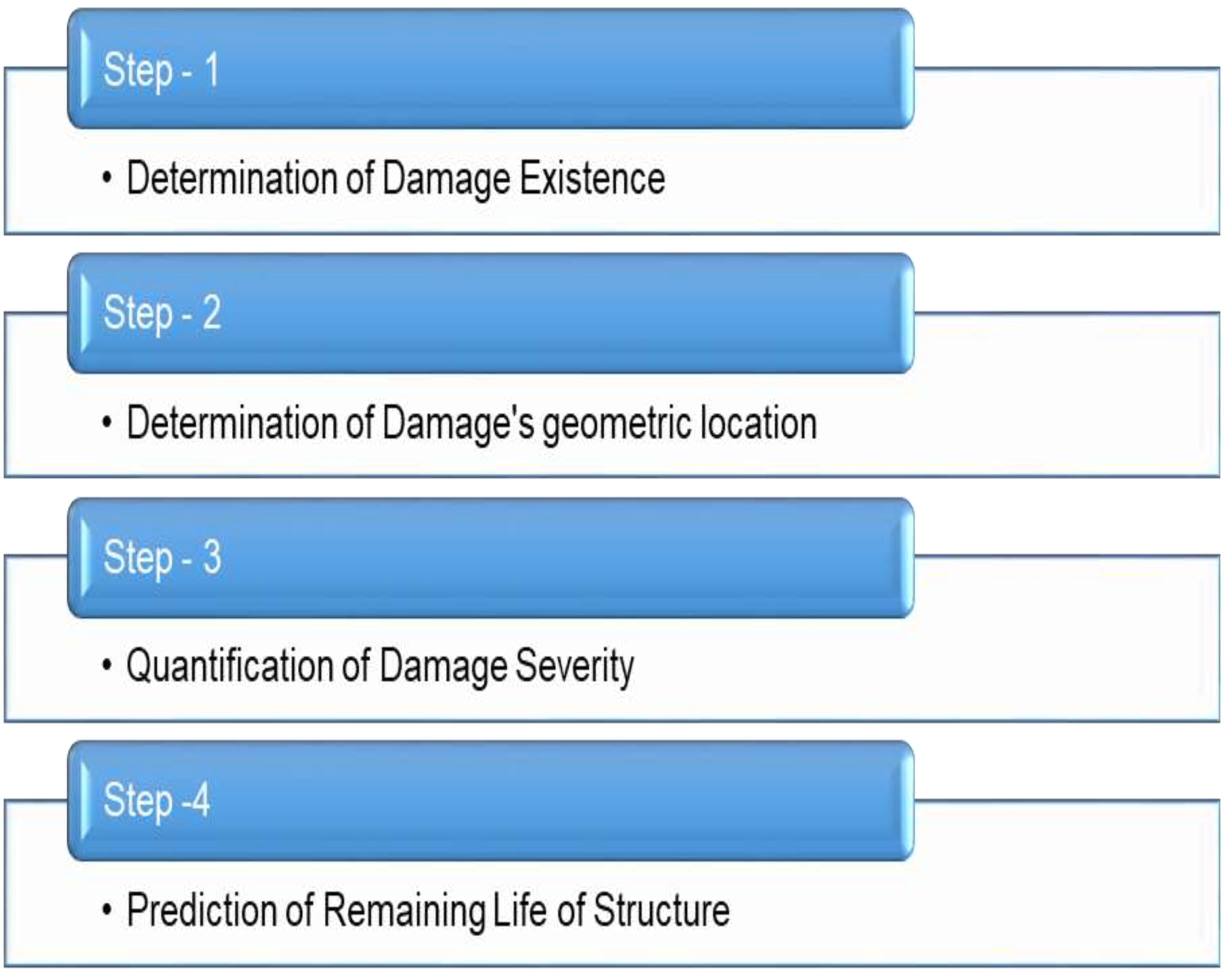
There is a transitional period in the life of a structure that need Structural Health Monitoring i.e. between the finish of the construction procedures and the start of the operational stage, for specific structures, a considerable number of handling and transportation operations happens. Structural Health Monitoring (SHM) plans to give, at each stage during the structural life of a building, a finding of the "state" of the constituent materials, of the distinctive parts, and of the combination of these parts constituting the structure all in all. The condition of the structure must stay in the area as indicated in the outline design given by architect/firm, in spite of the fact that this can be changed with the passage of time because of utilization, by the activity of the nature, and by incidental/accidentals occasions. On account of the time-measurement of observing, which makes it conceivable to consider the full history database of the structure, and with the assistance of Usage Monitoring, it can likewise give an anticipation (advancement of distresses, remaining life, and so on.). In the event that we consider just the main operation, the diagnosis, we could appraise that Structural Health Monitoring is as good as ever approach to make a Non-Destructive Evaluation. This is incompletely valid, yet SHM is significantly more. It includes the incorporation of sensors, perhaps agile materials, information transmission, computational power, and preparing capacity inside the structures. It makes it conceivable to reexamine the plan of the structure and the full administration of the structure itself and of the structure considered as a part of more extensive frameworks. SHM includes

- Health Monitoring
- Operational Evaluation
- Data Feature Extraction
- Statistical Models Development

2.1. <u>Objectives of SHM</u>

- Performance enhancement of a current structure
- Supervision of structures influenced by external factors
- Gives assessment to improve future design based on experience
- Evaluation of post-seismic structural integrity
- Reduces construction needs and increases maintenance needs
- The move towards performance-based design philosophy

2.2. <u>Steps for SHM</u>



2.3. Why to Use SHM. Following parameters can be measured

- Deflections
- Strain
- Rotation
- Temperature
- Acceleration
- Corrosion
- Pre-stressing Force

SHM is a system including an arrangement of methodology to decide the state of a common structure giving dimensional and quantitative data about basic structural damage. The capacity to consistently supervise the trustworthiness of building structures offers the chance to lessen repair and investigation costs and guarantee a more dependable examination than conventional procedures. Debasement of information because of test vulnerabilities, characterization of environment, dependable scientific models or effect of minor distresses in the beginning must be in this manner be considered.

3. Service Life of Structures. Building design and its performance is based upon on the durability of materials which are used during the construction phase and its products. Durability of building is greatly affected by how the materials are selected and used during construction. Materials used during the construction are frequent encountered the wind and rain which ultimately affect the life of a building. There is countless representation of chemical and natural elements which can influence the service life of a material or product. The persistence of a material or segment will be influenced by a few, or a mix of, these variables. Following are included in this list as

- Moisture
- Humidity
- Temperature
- Driving wind and rain
- Chemical pollutants

- Solar radiation
- Site conditions

End of service life can be controlled by various variables including changes of utilization and financial matters. Subsequently, various elective kinds of service life have been characterized as defined below:

3.1 **Service Life Required**. The least duration for which the whole structure or a predefined member of structure should achieve its design purpose to meet the clients' prerequisites.

3.2 **Design (service) life**. The time of proposed use by the designer.

3.3 **Technical (service) life**. The actual time in service until a defined minimum acceptable state is reached.

3.4 **Functional (service) life**. When the structure become obsolete although the structure is within the service life.

3.5 **Economic (service) life**. The duration during the service life of structure when the replacement of any member or part is more economical then its regular maintenance.

The main purpose of these definitions is to evaluate the performances of structures, materials used during construction and their members, from the point of view of various shareholders who have any concern regarding the structure. For example, the owner or client of the building may just be worried about the required service life as this portrays the period for which the building should perform to the client's prerequisites. Then again, the technical service life may just be the worry of the owner and the offices group as they should pay for and deal with any maintenance issues in non-domestic structures. In conclusion, the economic service life is one of the primary worries of the building owner. Different members of structures have their independent different service lives. Different members of the structures should be designed so that they should perform their intended functions at least for their expected service life because they are very difficult to repaired or replaced while the replacement of non – structural members is made possible. While evaluating the structure's service life for which it is to design or its component, it is important to know what is the main reason behind the end of the structure's service life. It also one of the fact that most of the buildings are declared dangerous buildings and are unfit for utilization even within their service lives. Purpose of the structure and the client's requirements are the factors which govern the service life of a building and is usually decided during the design stage.

3.6 **<u>Impacts if a Building doesn't complete its Designed Life</u>**: - Major damage impacts depend mainly on the use into which the building has been put but a few common impacts relevant to all structures are as under

3.6.1 **<u>Economic Impacts</u>**. If a building does not complete its designed life, the economic considerations, on which building was designed, are not fulfilled. In under developed and developing countries like Pakistan, combined effect of such practices puts, already disturbed economy, under further stress. For example; if a bridge which was initially planned for a period of 30 years, collapses after 10 years, it will require reconstruction which will put an extra burden on economy.

3.6.2 **<u>Disturbance to Users</u>**; Consumers / Users of the damaged structure / Building have to be relocated which creates disturbance among the users. Relocation will most likely be of temporary nature which will not be able to provide them the desired level of comfort and mental satisfaction, which they were in, before the damage of the structure. For Example, if a bridge gets collapsed, it will require time for reconstruction. During the construction time, users will have to be either diverted to other road (which may not be having adequate capacity to take extra traffic) or a temporary diversion will be required to facilitate crossing.

3.6.3 **<u>Bad Name to Industry</u>**; If most of the buildings in a country or a region are not able to complete their designed life, it will bring a bad name to construction industry of that country. This will ultimately cause furtherance to economic problems of a country.

4. Building Structural Testing. Structural testing is one of the most important part of the modern construction industry, regardless of whether it be demonstrating single member or materials are fit for purpose or existing structures. Structural testing should be possible to develop some certain standards for buildings to show their necessary performance or can be more altered. Here are a few examples of tests that we do on structures.

- Load testing
- Impact testing
- Tensile testing
- Exposure site testing
- Strength testing
- Weather ability
- Durability
- Settlement
- Fatigue
- Cable loading on support systems
- Air tightness
- Water tightness
- Light reflectance value testing
- Slip resistance testing
- Chemical testing.

4.1 Purpose

The purpose for the structural tests is to give a kind of assurance to the owner of the buildings and the one which are using it that the building or the structure is built according to desire standards and fulfill the structure design requirements. These tests and assessments are for quality assurance audits and their implementation does not ease the contractors or subcontractors of their obligation regarding quality control of the work and any design for which they are responsible.

During analyzation, we have three test to consider.

4.1.1 Test through Visual Inspection. Before you go hardcore and set the proper milestones of testing, the construction should be visualized in order to:

1. Defects in the structure should be identified
2. Any sign of deterioration to materials should be recognized
3. Any deformation or distress in the structure must be identified
4. Recognize any overloading caused by maintenance or repair

4.1.2 Non-Destructive (NDT) and Destructive Testing (DT). These tests are of great importance in order to determine the strength and quality of concrete, to determine the damage to construction structures subjected to corrosion, chemical attack, fire or other reasons.

4.1.3 Concrete strength test.

1. **Rebound Hammer Test.** to measure surface hardness of concrete
2. **Ultrasonic Pulse Velocity Test.** to assess homogeneity of concrete, to assess strength of concrete qualitatively, to determine structural integrity
3. **Core Sampling and Testing.** to measure strength, permeability, density of concrete
4. **Permeability Test**. to assess whether concrete is permeable or not.

4.1.4 Core Testing. In this method, cylindrical core samples are taken from existing structures. The cores are visually inspected and tested in laboratory to check its compressive strength.

Despite the fact that this sort of testing will give an immediate measure of a structure's ability to maintain weight, the building may support physical harm because of the over the top pressure. Along these lines, very few choose this sort of confirmation.

5. <u>Forensic Distress Evaluation</u>. Given that solid masonry work dividers are relied upon to encounter shrinkage along with warm contraction / expansion (depending upon weather conditions), and at times even carbonation, all through their service life, cracking is not out of the ordinary. Nonetheless, after masonry work and walls have been put into use, initially foreseen and accounted splitting is frequently misdiagnosed as an imperfection. Such misdiagnoses frequently result in or are utilized to help cause. This paper starts by discussing the reasons and kinds of foreseen cracking inside masonry structures followed by an exchange on the procedures and investigations that exists for legitimately assessing them and their centrality. From here, the paper at that point displays an instance of misdiagnosed concrete work breaking and the imperfect rationale utilized to help prosecution.

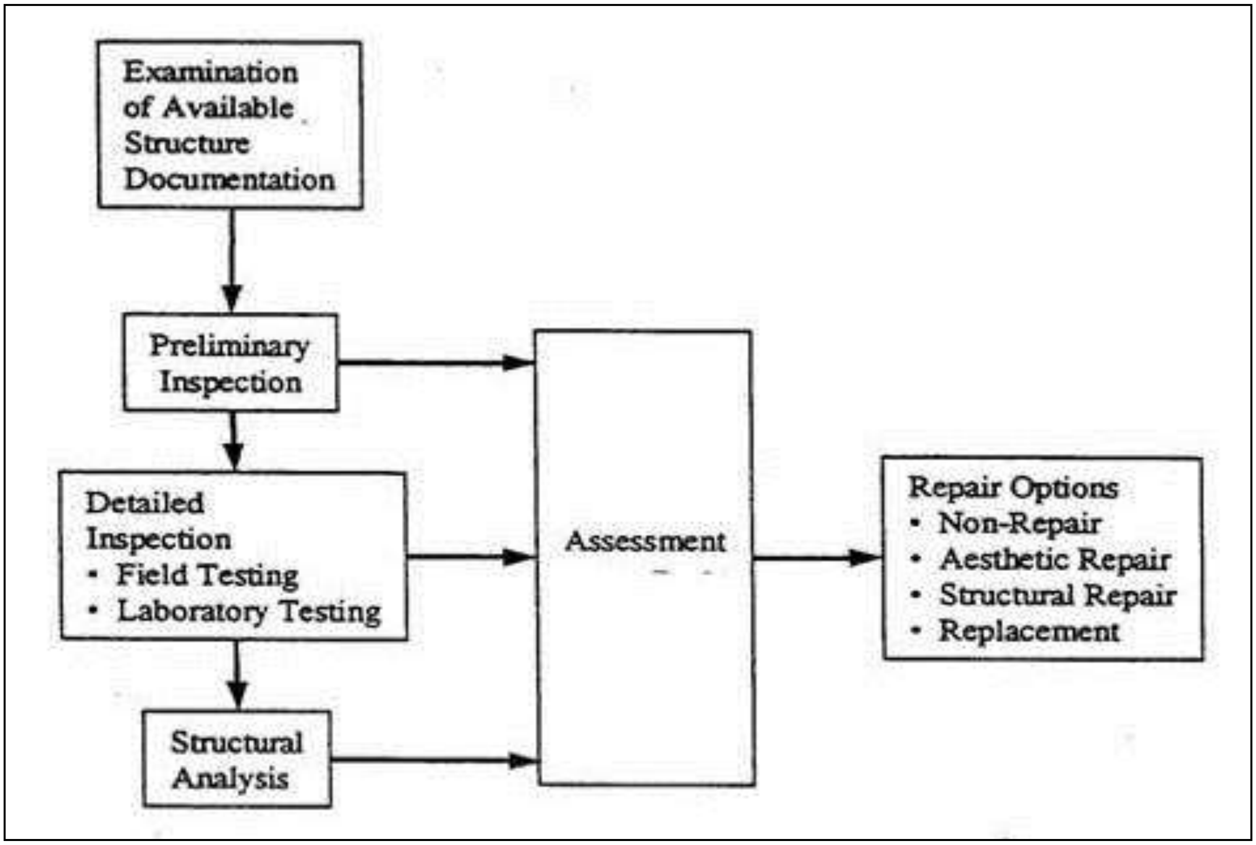
Forensic engineering has been defined as ***"the investigation of failures - ranging from serviceability to catastrophic - which may lead to legal activity, including both civil and criminal"****.* It therefore includes the examination of materials, items, structures or parts that come up short or don't work or capacity as expected, causing individual damage, harm to property or economic loss. The consequences of failure may give rise to action under either criminal or civil law including but not limited to health and safety legislation, the laws of contract and/or product liability and the laws of tort. The field also deals with retracing processes and procedures leading to accidents in operation of vehicles or machinery. By and large, the reason for a legal designing examination is to find cause or reasons for failure with a view to enhance performance or life of a segment, or to help a court in deciding the actualities of a mischance. It can likewise include examination of licensed innovation claims, particularly patents.

Crucial to the field of forensic engineering is the way towards exploring and gathering information related to the materials, items, structures or parts/components that fail. This includes examinations, gathering proof, estimations, creating models, acquiring model items, and performing tests. Regularly testing and estimations are carried out in a neutral testing lab or other independent and unprejudiced lab.

Forensic Distress Evaluation is branch of Forensic Engineering which deals investigation of failures and distress in structures which are ascribed to supporting soil, basic structure design, material qualities, and quality control and so on. The assessment notwithstanding these additionally covers legitimate and authoritative perspectives. The failures in structures because of characteristic dangers including seismic harms likewise go under this domain. The generally received standard strategies of testing, investigation, outline, and development may not be sufficient for forensic distress evaluation. Hence, in the forensic distress Evaluation, each small scale part of the design, maintaining and construction activities are contemplated in detail to break down what, when, how, and why something turned out badly and all the more imperatively, who is responsible of it. This method aids cases, as well as aides in enhancing the principles of practices received amid execution of a project

With a specific end goal to conveniently examine the causes that lay the format for a distress in buildings, thereby recognizing the segments included and accountability of each, one may contend that forensic engineers are a focal topic. This is due to the reason that they exhibit not just a comprehension of loads, strength and stability, yet additionally aptitude of how working business and practices of the outline procedure and the latter's development may take after.

Key aptitudes develop which will recommend where, when, how, why and by whom reasons for distress happened. Briefly, forensic engineers address the subject of how to direct the examination/investigation applicable to each case; they should be additionally acquainted with the examination approach adopted. Since about every single basic lack posture claims, yearn debate and require legitimate snares, measurable architects should know about the important lawful process, in addition knowing previously how to successfully manage lawyers. Subsequently, it could be contended that profundity skill of the nature and outcomes rose because of the heaps, notwithstanding the key highlights that check vulnerabilities.



Forensic Analysis Process

Keeping in mind the end goal to conveniently examine the causes that actually foundation the failure, thereby recognizing the segments included and every responsibility, one may contend that forensic engineers are a focal subject. This is due to the reason that they show not just a comprehension of loads, strength and stability, yet in addition aptitude of how working business and practices of the design procedure and the latter's construction may take place. Key skills develop which propose where, when, how, why and by whom reasons for failure might have happened. We can say that, forensic engineers address the topic of how to direct the examination pertinent to each case; they should be additionally well conversant with the examination approach adopted. Since nearly all structural deficiencies pose claims, aspire disputes and require legal entanglements, forensic engineers should know about the pertinent lawful process, also knowing in advance how to adequately manage lawyers. Hence, it could be argued that depth mastery of the nature and outcomes developed because of the loads, in addition to the key highlights that stamp vulnerabilities of the structures, is vital, if not the key determinant

6. Problem Statement

Pakistan is one of the developing countries. Buildings are normally designed here by giving due consideration to economic aspects which, many a times overrides the design standards. This approach of designing gives rise to a considerable Risk factor. The main causes of building defects in buildings particularly in Pakistan are as shrinkage, thermal expansion & contraction, seepage, salinity issues (particularly in central Punjab & few areas of KPK), carbonation, cracking owing to use of substandard materials etc. Mostly residential buildings in Pakistan are designed for a period of 30 years (maximum). The project understudy aims at analyzing the defects in Cadets block which will further lead to remedial measures to overcome the problem.

7. Explaining the Project

PAF Academy Asghar Khan is a premier training institution of Pakistan in general and PAF in particular. Cadet’s block is frequently visited by dignitaries, not only from Pakistan but from allied countries as well. Thus, marks the importance of building under study. Seepage problems of buildings in PAF Academy Asghar Khan had been a much talked about phenomenon quite since long. Stereotype practices to resolve the issue have been implemented quite a few times but nothing has worked so far properly. Buildings of Cadets blocks were constructed by Construction Works Organization in 1984. Since the year 2002, Academy is facing ever increasing problems of damages in the buildings, especially in the Cadets bock; the problem is much aggravated and is mainly attributed to the seepage issue.

Main Tenants of Project			
Ser	Query	Answer	Remarks
1.	Nature of the problem	Seepage, Corrosion, Staining, Spalling	-
2.	Type of problem	Leakage and seepage leading to corrosion	-
3.	Location of Problem	Cadets Blocks (PAF Academy Asghar Khan)	-
4.	Duration since problem being faced	Since 2002, (18 years after construction of building, seepage was first observed)	-
5.	Peak occurrences	During Monsoons	Corrosion remains a problem throughout the year
6.	Department involved	Structural Dept MCE	-
7.	Main Equipment used	Schmidt Hammer Testing, Pundit, Radon Scanner	NDT
8.	Duration of problem Study	8 months	-

8. **Methodology Adopted.** The outcome of this report has been notched by resorting to the sequence as under:

8.1 **Secondary Sources**

Different publications, for instance books, specialized papers and reports and web journals are fundamentally inspected for this examination to distinguish the examination techniques and reasons for the failure arisen in structures in place. The implications of these examinations on the predominant conditions in Risalpur were kept under consideration.

8.2 Gathering Information

Establishments for instance, MES PAF and Academy Administration were approached, trailed by directing meetings with the organizations which did treatment after the issue was taken note. The primary concern of these meetings looked for seeking the systems/methods embraced to cure the damage occurred to existing structure in the buildings understudy.

8.3 Analysis of Data

Required information was collected to evaluate the causes and the severe deformation of structure.

- **Establishing a Forensic Framework**

  In light of the accessible information and according to measures and rules, a legal structure was created which comprised mainly of NDT and modern Equipment like Radon Scanner.

- **Authentication of the Developed Structure**

  The methodology developed in the forensic evaluation of the building understudy was verified by applying comparative analysis with similar Projects.

8.4 Conclusions & Recommendations

To the finish of this examination, conclusions are made combined with suggestions/recommendations being made which call attention to a few comments on the best way to address the issue.

CHAPTER 2

LITERATURE REVIEW

9. Forensic Engineering

Forensic engineering may be interpreted as the application of engineering sciences applied to the investigations of failures and/or performance issues.

As needs be, such building is an exceedingly particular field esteemed fundamental to accomplish skill as well as learning of the legal methodology. In this vein, scientific basic or potentially affable architects have the sole part of working out 'dissections' upon members and additionally full-sized structures, for instance structures and other designed built offices/framework trying to reveal insight into the causes that commute the distresses.

As explained above, it addresses from one perspective how the distresses happen, for instance, in structures, offices and other significant buildings frameworks. On the other, from a legitimate point of view, scientific building could be a reality discovering mission important to distinguish the importance that causes the distresses. At the end of the day, legitimate angle rotates around realities that hone its point of view.

Keeping in mind the ultimate goal to conveniently explore the causes that lay the layout for some distresses, in this way recognizing the stakeholders involved and every obligation, one may contend that forensic designers are a focal topic. This is on account of the show not just a comprehension of loads, quality and durability, yet additionally mastery of how design procedures and methods are being practiced and the last's building structure may take after. Quickly, scientific architects show the subject of how to lead the examination important to every situation; they should be likewise acquainted with the examination approach embraced. About every structural insufficiency posture claims, aim question and require lawful snares, forensic designers should know about the pertinent legal process, notwithstanding knowing in advance how to successfully manage lawyers. Consequently, it could be contended that mastery skill of the nature and outcomes rose because of the loads, notwithstanding the key highlights that check structure’s vulnerabilities, is critical, if not the key determinant.

10. Non-destructive Testing. NDT are basically carried out to make an approximate idea of the problem.

10.1 Why to go for non-destructive testing

When the desire strength of concrete is achieved it is important to go for testing of concrete structures that if the concrete structure is suitable for its intended purpose for which it is designed. In a today's world, such testing should be done without damaging the structure. In today era, the tests which are used for testing structure range from the non – destructive testing, which is not detrimental to the structure, to those which is somewhat detrimental to the structures, i.e. is destructive testing, for example, core cutting tests, repaired of the surfaces is usually done after the testing is completed. There are many properties which can be analyzed by using the above-mentioned testing such as thickness, elastic modulus and quality and additionally surface hardness and surface ingestion, and fortification area, size and separation from the surface. At times, it is additionally advisable to check the how workmanship is done and structural uprightness of the structure by the ability to recognize voids, splitting, delamination etc.

Both new and old concrete structures can be analyzed by using the nondestructive testing. For new structures, the important parameters are the quality control during construction and to determine the nature of material used and the quality of workmanship. We can analyze the structural integrity and its adequacy of structure by non- destructive testing of existing structures. In any case, if we just perform destructive testing, for example, by just cutting core for performing only the compression test, the cost required for cutting coring and then its testing may just limit us to perform moderate number of tests to be completed on a huge structure which might mislead us. To ensure that cutting core is essential we firstly go for nondestructive testing to make sure that from where the coring is essential.

10.2 **Non-Destructive Testing of concrete**. Nondestructive Testing of concrete should be done by following method

- On site Visual inspection, which is an important component to any intended non-destructive test. By just seeing the damaged structure or its part an experience civil engineer or forensic designer analyze the type of non – destructive testing used for testing.
- Corrosion of steel by electric potential method
- Analyzing surface hardness by Schmidt hammer.
- Checking the depth of Seepage whether it affected the steel bars or not by Carbonation Depth Test
- Checking the rate of flow of water in the concrete structures by permeability test
- Penetration resistance used to measure surface hardness and hence the strength of the surface and near surface layers of the concrete.
- Checking the location of steel bars in the concrete structures with the help of cover meter
- Checking the voids in the concrete by Radiographic test.
- Measuring the compressive strength of concrete by performing the Pulse Velocity test (PUNDIT).
- Detecting voids in the concrete by impact testing
- Locating the position of steel bars using GPR

11. Strength of Concrete. The strength of concrete is judged to a great extent on the quality of that concrete. Methods and procedures are constantly being modernized, testing techniques are enhanced, and methods for interpreting and analyzing test data are ending up more advanced. Preceding the 2008 release of the ACI 318 Standard, we depended solely on the quality of 6-by-12-inch cylinders, made on the jobsite and tried in compressive test at 28 days age for evaluation and assessment of concrete. The utilization of 4-by-8-inch cylinders for quality assessment was first tended to in ACI 318-08.

11.1 The Importance of Strength

Clearly, the quality/strength of any structure, or part of a structure, is essential the level of significance relying upon the area of the structural member under thought. The column member of first floor of a high-rise structure, for instance, are more critical than a wall having no loads or stress. Loading/Stress is more important in the concrete structure, failing to achieve the desired strength can result in valuable and difficult maintenance and repairs or, even under the least favorable conditions, a wondrous disaster.

We can accept or reject any concrete structure based upon the strength of the concrete which a structure has. There are many publications and codes which have given the desired compressive strength of some of the members of concrete structures. When any of the specimen is fail to achieve the desired strength of the concrete as mentioned in the code, it is essential to resort to additional testing of concrete. This may include core cutting test from the concrete or performing nondestructive testing that is used measure the surface hardness of concrete.

Few details allow a little measure of disagreement provided if it isn't not of some serious nature and may punish the contractor by deducting from the structure's payment due for the failure in not achieving the desire concrete strength. Concrete strength is essential when figuring a proposed blend for concrete, as the different proportion of mixtures depend on the properties of the constituents which are essential for concrete strength.

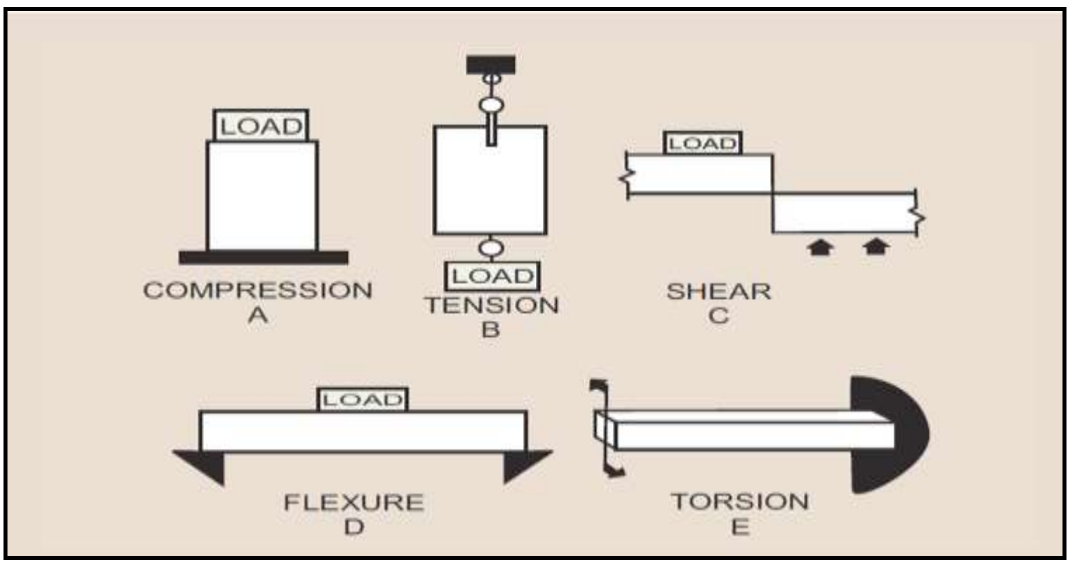
11.2 Strength Level Required

The required quality or the strength of concrete basic consideration on which design is made by the structural engineer and that must be accomplished and verified by the various test results as indicated. A few structural engineers determine strength of concrete of 5000 to 6000 psi, or considerably higher in certain basic members of concrete. Specific strength in the range of 15,000 to 20,000 psi have been created for ground floor column members of tall structures. A high level of quality control is required to produce high strength concrete. Note that the ACI 318 Standard (Section 19.2.1.1) shows that 2500 psi is the minimum specified strength of concrete which should be achieved. Basically expressed, no concrete structural member can be specified with a compressive strength under 2500 psi. Various properties of the concrete can be important for the structure or its any of member exposed freezing and thawing conditions, exposure to sulfate and chloride. Concrete's quality is the basis on which strength of concrete is determined. Concrete strength is linked with many properties of concrete because it enhances durability of concrete.

STRENGTH REQUIREMENTS	
TYPE OR LOCATION OF CONCRETE CONSTRUCTION	SPECIFIED COMPRESSIVE STRENGTH, PSI
Concrete fill	Below 2000
Basement and foundation walls and slabs, walks, patios, steps and stairs	2500–3500
Driveways, garage and industrial floor slabs	3000–4000
Reinforced concrete beams, slabs, columns and walls	3000–7000
Precast and prestressed concrete	4000–7000
High-rise buildings (columns)	10,000–15,000

11.3 Types of Strength.

For the most part, when strength of concrete is under discussion, it is expected that there is a study going on the compressive strength of concrete. There are, many others various strength of concrete which should be considered other than compressive, depending upon that what type of loading a structure is exposed to. Shear, Torsion, Flexure and Bending are the other strength which a structure may encountered and the concrete and its reinforcing steel bars should able to resist them. Fundamental tests used for testing concrete in compression and in flexure are applied consistently as control tests during the stage of construction. Laboratory data and their procedures can be applied for examining shear and torsion of concrete but such tests are neither pragmatic nor essential for control, as the structural engineer can assess such loadings as far as compression, flexure or tension.



12. Likely Distresses in Concrete Structure

Weakening of concrete is of very complex nature. It is shortsighted to recommend that it will be conceivable to recognize a particular, single reason for weakening for each side effect identified amid an assessment of a structure. Much of the time, the damage detected would not be because of one mechanism, it is link with many others. For instance, corrosion of strengthening steel may have cracks or faults that permit Seepage more prominent access to the inside of the structural concrete. This Seepage could prompt extra damage by the process of freezing and thawing. Regardless of the multifaceted nature of a few causes working all the while, given a fundamental comprehension of the different mechanism which cause damage to concrete, it ought to be conceivable, to decide the essential primary reason for the distresses seen on a specific structure and to settle on inventive decisions concerning choice of repair materials and procedures.

Once the assessment phase of the structure is completed, the following stage is to set up the reason or reasons for the damage that has been recognized. Since a large number of the side effects might be caused by not a single mechanism acting on the structure concrete, it is important to have a comprehension of the fundamental hidden reasons for distresses and damage. Deterioration of concrete can have a number of causes and the damage to concrete will result from combination of many factors. The accompanying addresses about potential reasons for solid bothers and the variables that impact them.

- **Corrosion of Reinforcement.** One of the major cause of distresses in concrete in the corrosion of steel and other embedded metals. The rust from the corroded steel occupies a greater volume in the steel. This expansion will result in generation of stresses due to tension in the concrete, due to which cracking of concrete, delamination and appalling of concrete occur.
- **Inadequate Reinforcement**. Concrete does not have enough reinforcement will likely to fail under tension and its strength will reduce.
- **Wrong Placement of Concrete**. If the reinforcement is not placed at correct location it will also affect the concrete and cause reduction in strength
- **Damage or Distress Freezing and Thawing**. Water expands when it freezes and when it freezes in moist concrete, it will result in formation of voids and pores in the concrete. If the stresses/pressure in these pores will more than its tensile strength it will cause rupture of concrete. Expansion of concrete,

cracking of concrete spalling and maybe corrosion are the result from freeze and thaw cycle in the concrete.

- **Poor Construction Techniques**. Cracking of concrete may be caused by poor construction techniques adopted in concrete structures. One of the most important is the addition of water to concrete to improve workability. Extra water has the effect of reducing strength, increasing settlement, and increasing drying shrinkage. Cracking in concrete structure may be resulted from the lack of curing. When we stop curing of concrete early then required it will increase the shrinkage of concrete at a time when the strength of concrete is low.
- **Spalling**. Due to Seepage concrete strength is reduced such that bond between reinforcement and mortar gets weaker due to which concrete tends to fall from towards the ground because of low concrete strength
- **Aggregate Expansion**. Much of the water is absorbed by the aggregates to a critical level that it cannot sustain the expansion due to increase in volume of water due to freezing of water in the voids. Due to which volume of the aggregate increases and the homogeneity of concrete gets disturbed. Examples are the protruding of concrete surface at some places.
- **Honey combing**. When mortar is not able to completely bond different mix proportion of concrete, some voids left between the coarse aggregates this result in honey combing of concrete. Too many thick reinforcement, weak bond between different particles, and lesser quantity of fine aggregates can add to honeycombing. Vibration during placing of concrete and increase slump of concrete may help in counteracting this type of distresses by increasing the concrete’s flow ability.
- **Delamination**. When the mortar surface is too dense that it traps the air and some of the drain water delamination occur to the concrete. They are very hard to recognize or determined during the completion phase and become visible and obvious after the drying of concrete surface and the delaminated zone is crushed under movement. Blister is one of the examples of delamination.

CHAPTER 3

TESTING

13. Pundit

13.1. Fundamental principle

Electro – acoustical transducer produces longitudinal vibrations in the form of pulse, which is in contact with the surface of the concrete required to be testing. At the point when the liquid coupling material such as grease or oil is applied to the transducer which help in transmission of pulse from transducer to the testing concrete, it experiences numerous reflections at the limits of the distinctive material stages inside the concrete. An unpredictable arrangement of stress waves creates, which incorporate both longitudinal and shear waves, and engenders through the concrete. Longitudinal waves are firstly received by the transducer and then it is change over into an electrical signal by the other.

Longitudinal pulse velocity (in km/s or m/s) is given by:

$$v = L/T$$

Where

V is the longitudinal pulse velocity,

L is the path length,

T is the time taken by the pulse to traverse that length.

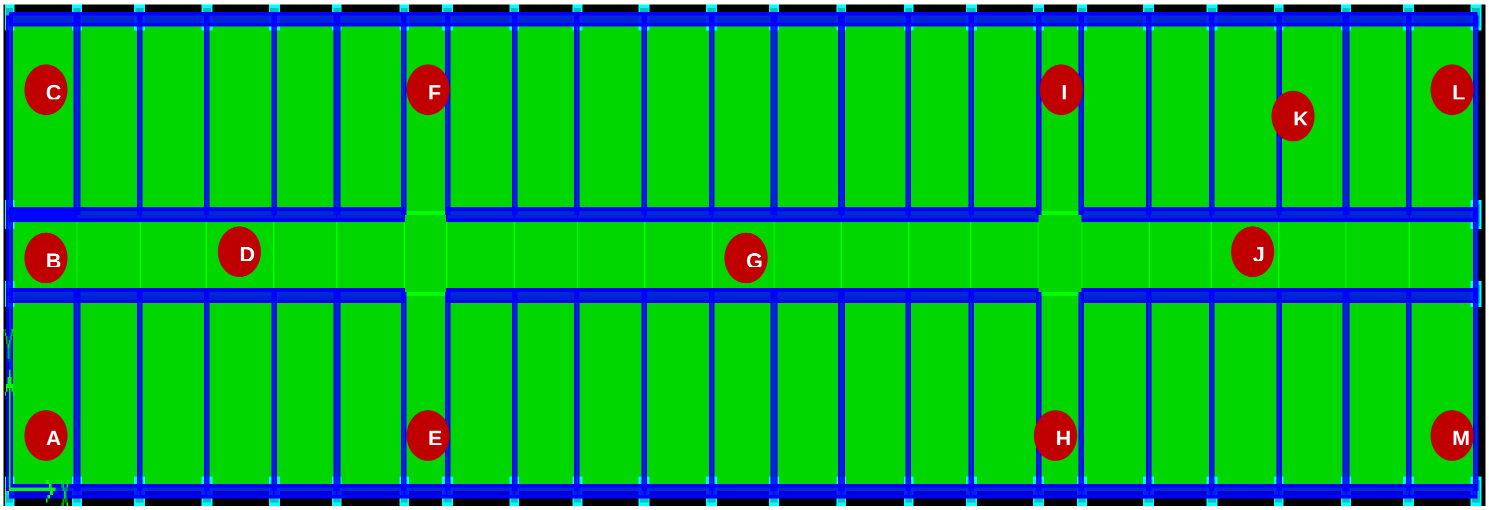
13.2. Applications.

Ultrasonic pulse velocity of longitudinal vibrations transmitted through the concrete is measured to gain one of the following reason:

- Uniformity of concrete member is determined
- Changes in the concrete properties with the passage of time is measured
- Quality of concrete is measured by correlating the pulse velocity and strength of concrete
- Poisson ratio and elastic modulus is also determined.

13.3. Results & Location of Test

Ser	Reading	Path length	PV	Comment	Remarks	
A	88	12	3.46	Doubtful	<2	very poor
	72	12	4.23	Good	2.0-3.0	poor
B	86	12	3.55	Good	3.0-3.5	Doubtful
	101	12	3.02	Doubtful	3.5-4.5	good
C	191	12	1.6	Very Poor	>4.5	excellent
	170	12	1.79	Very Poor		
D	128	13	2.58	Poor		
	126	13	2.62	Poor		
E	84	12	3.63	Good		
	74	12	4.12	Good		
F	91	12	3.35	Doubtful		
	92	12	3.31	Doubtful		
G	125	12	2.44	Poor		
	139	12	2.19	Poor		
H	126	12	2.42	Poor		
	132	12	2.31	Poor		
I	137	12	2.23	Poor		
	128	12	2.38	Poor		
J	106	12	2.88	Poor		
	97	12	3.14	Doubtful		
K	128	12	2.38	Poor		
	124	12	2.46	Poor		
L	91	12	3.35	Doubtful		
	87	12	3.5	Good		
M	127	12	2.4	Poor		
	133	12	2.29	Poor		


C
F
I
K
L
B
D
G
J
A
E
H
M

14. Schmidt Rebound Hammer Test

14.1 Fundamental Principle

To check the hardness of concrete surface we resort to Schmidt Rebound hammer test. It performs works on the basis that elastic mass rebound number relies upon the surface hardness against which the mass encroaches. There is minimal obvious hypothetical connection between concrete strength and the hammer's rebound number. However, within limits, empirical correlations have been established between strength properties and the rebound number.

14.2 Applications of Schmidt Rebound Hammer Test

The Schmidt hammer can be used in any of the way like horizontally, vertically upward or vertically downward as well as at any angle, provided the hammer is perpendicular to the surface under test. The position of the hammer in the vertical downward direction affects the hammer rebound number due to the effect of gravity force. Due to which vertical upward surfaces like ceiling and horizontal surfaces like walls have greater rebound number than vertical downward surfaces such as roofs. Concrete with lower compressive strength have lower rebound number while concrete with high compressive strength have higher rebound number.

15. Determination of Compressive Strength using Schmidt Hammer and Pundit

Zones	Average Rebound Value	Average Pulse Velocity		f'c psi(CA 1000)	f'c psi (CA 1200)	average f'c (psi)	f'c psi (pulse velocity +rebound hammer)
A	39	3.8	5049.654	5293.387836	3168.461662	4230.924749	3245.439174
B	29	3.3	4752.114	4290.736788	1423.681596	2857.209192	1549.579681
C	20	2.1	4038.018	2592.074353	208.7216339	1400.397993	309.3682066
D	46.5	2.35	4186.788	2879.044487	311.3760883	1595.210288	1236.922712
E	34	2.25	4127.28	2760.628755	265.3371997	1512.982977	736.3982575
F	19	2.3	4157.034	2819.214961	287.436357	1553.325659	362.6845608
G	32	2.54	4299.8532	3118.207956	421.9983773	1770.103167	919.4731342
H	42	3.7	4990.146	5075.669633	2699.984926	3887.827279	3347.05984
I	34.5	2.9	4514.082	3627.190797	750.69652	2188.943659	1411.011729
J	25	2.9	4514.082	3627.190797	750.69652	2188.943659	925.0157801
K	21	2.4	4216.542	2940.143717	337.3096897	1638.726704	459.7066889
L	22	2.3	4157.034	2819.214961	287.436357	1553.325659	439.5408383
M	44	3.4	4811.622	4474.785706	1670.70583	3072.745768	2882.839705
		Average Values	**4447.249938**	**3562.883904**	**967.9879044**	**2265.435904**	**1371.156947**

16. Conclusions from Non-Destructive Tests

- Average value of Compressive strength obtained is 1372 psi.
- From above results it was observed that the Compressive Strength obtained from Non-Destructive tests is far below the minimal Compressive strength requirements given in ACI Code i.e. 2500 psi.
- The above results indicate that the concrete has lost its strength.

17. **Soil Test**.

17.1. **Geologic & Seismic Conditions**

17.1.1. **Geologic Overview**

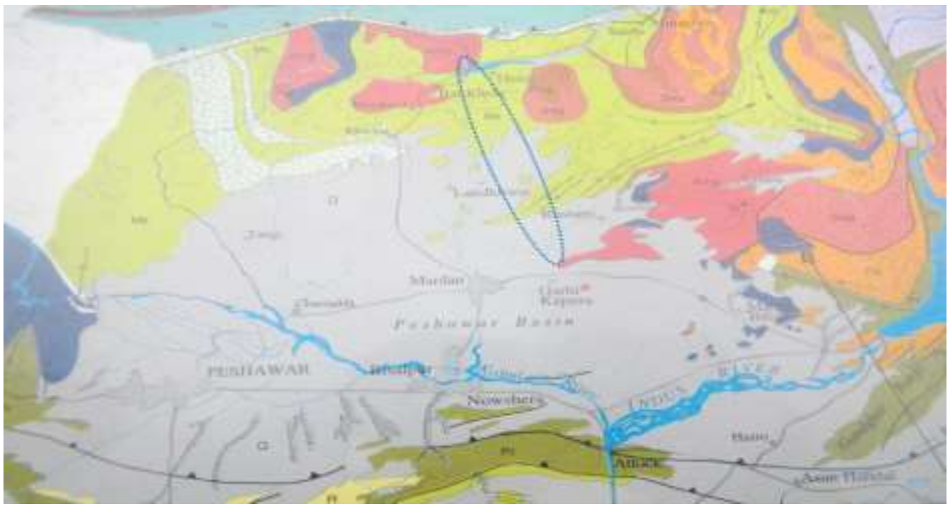


Figure: General geology of the project area (Source: Shell, ND)

17.1.2. **Seismicity**

The faults in the area are classified as thrust faults and strike-slip faults. The project is bounded by an active fault in North and South; indicated in red lines, some undifferentiated faults in red dotted lines and some lineaments shown in black (dotted) lines, Figure 1. The area is closely located near Cherat and Malakand fault.

Epicenters of the magnitude 5 to 7 earthquakes located in the vicinity of the project area are shown in red circles with block dots and earthquakes of magnitude 3 to 5 are shown in red circles, Figure 1. The depths of the historic earthquakes range from a few to 50 km, (Source: Bakr and Jackson, 1979). According to the Building Code of Pakistan 2005 (Figure 2), the project area belongs to Seismic Zones varying from 2B to 3 with Peak Horizontal acceleration ranging from 0.24g to 0.30g. From the seism tectonic viewpoint, the project site is inferred as ‘Moderate to High” seismic risk zone and therefore poses a caution on the structural design of bridges, excavations and buildings.

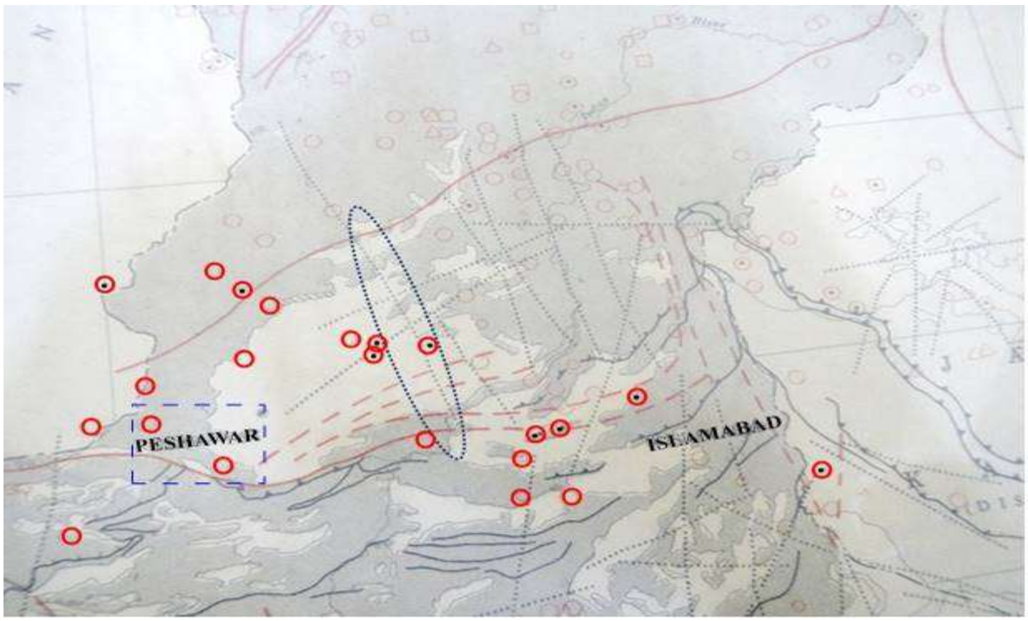


Figure1: Faults in the area (source: Bakr and Jackson,

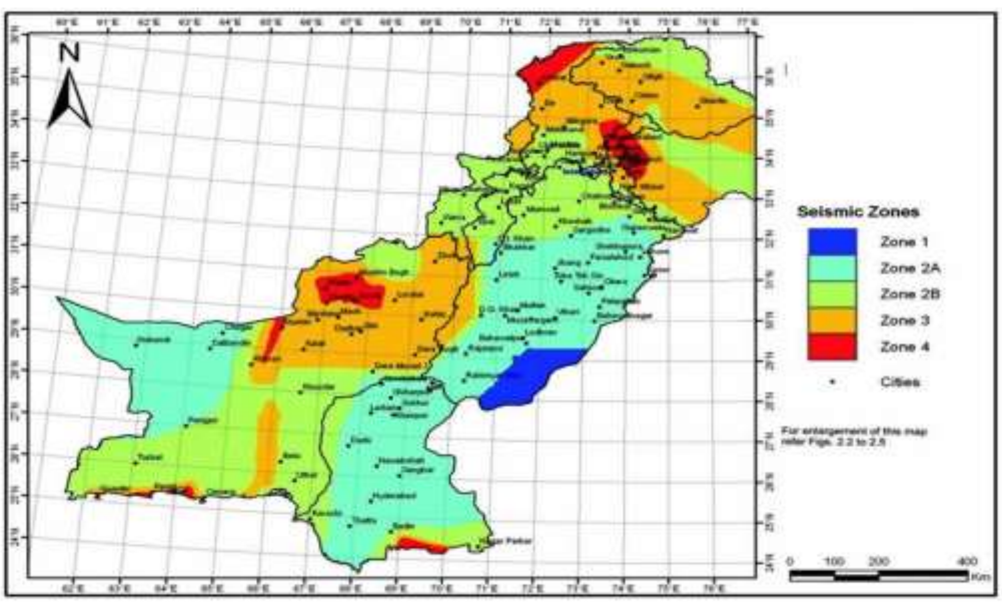


Figure2: Seismic zone of the construction site

17.2 Site Exploration & Reconnaissance

17.2.1 Exploration Program

Our field investigations were performed on 7th May 2018 and the excavation and logging of three exploratory borings up to depth of 15 ft. The boring locations selected to approximate the subsurface conditions. Our exploratory borings were advanced using a hand Augur equipped with hollow-stem augers. Soil samples were collected with split-spoon samplers driven with a 140-pound hammer repeatedly dropped from a height of 30 inches with a wire line sampling system. The samplers included the 2-inch outside diameter (OD) Standard Penetration Test sampler. The sampler types used are indicated on the boring logs at the appropriate depths. The number of hammer blows required to drive the samplers were recorded in 6-inch increments for the length of the 18-inch-long sampler barrels. The associated blow count data, which is the sum of the second and third 6-inch increment, is presented on the boring logs as sampling resistance in blows per foot. Our staff geologist logged the borings in general accordance with the Unified Soil Classification System. The stratification lines shown on the logs represent approximate boundaries between the soil materials; however, the transitions may be gradual.

17.2.2 Subsurface

Three exploratory borings were excavated in the area of the proposed building. In general, our exploratory borings encountered predominantly low plastic clay to the full depth explored of 15 feet.

17.2.3 Laboratory Test

Unconfined Compression Tests were performed on specimens obtained from Shelby tube samples obtained from 7ft depth on boreholes No.1-3 and Additionally, Unconfined Compression Tests were also performed on specimens obtained from Shelby tube samples obtained from borehole No.1, 2, 3, at 7ft depth. Summary of soil properties along with safe bearing capacities at 7ft depth as well as natural soil levels is mentioned below.

17.2.4 Groundwater

Ground water table was not encountered at this depth.

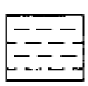
17.2.5 Analysis of Tests

Terzaghi equation for computation of allowable bearing capacity was used while considering factor of safety 3. Additionally, Unconfined Compression Tests were conducted on Shelby tube samples obtained from natural strata up 7ft depth.

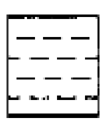
17.2.6 Conclusions and Recommendations

Keeping in view results of the field/lab tests and collapse potential of the foundation soil, it is concluded that bearing capacity of **0.50TSF** was favorable for construction of Cadets Block

Bore Hole No	1
Date of Boring	7 May 2017
Type of Boring	Auguring
Ground Water Table	Nil
Final Depth	15ft

Material Description	Classification	Sample No.	Depth (ft)	SPT Blows			N Value	Remarks
				1st 6”	2nd 6”	3rd 6”		
			2					
			3					
			4					
			5					
			6				18	
			7	8	9	9		
			8				19	
		UDS/SS	9		9	10	18	
L.L=24.2%			10	9		9		
P.L=20.0 %			11		9			
		DS /SS	12	10				
			13					
	CL-ML		14					
		DS /SS	15					

Bore Hole No	2
Date of Boring	7 May 2018
Type of Boring	Auguring
Ground Water Table	Nil
Final Depth	15ft

Material Description	Classification	Sample No.	Depth (ft)	SPT Blows			N Value	Remarks
				1^{st} 6”	2^{nd} 6”	3^{rd} 6”		
			2					
			3					
			4					
			5					
			6				19	
			7	9	9	10		
			8				23	
		UDS/SS	9		11	12		
L.L=22.0%			10	9				
P.L=19.5 %			11		14	15	29	
		DS /SS	12	10				
			13					
			14					
	CL-ML	DS /SS	15					

Bore Hole No	3
Date of Boring	7 May 2018
Type of Boring	Auguring
Ground Water Table	Nil
Final Depth	15ft

Material Description	Classification	Sample No.	Depth (ft)	SPT Blows 1st 6"	SPT Blows 2nd 6"	SPT Blows 3rd 6"	N Value	Remarks
			2					
			3					
			4					
			5					
			6					
			7	10	8	9	17	
			8					
		UDS/SS	9		12	15	27	
L.L=24.2%			10	11				
P. L=21.0 %			11		13	14	27	
		DS /SS	12	11				
			13					
			14					
	CL-ML	DS /SS	15					

BEARING CAPACITY EVALUATION

S. No	Ref/Marking	Bulk density (pcf)	M.C (%)	L.L (%)	P.L (%)	Classification of soil (Depth of 4ft)	Safe Bearing Capacity (TSF) UCC	- SPT
1	B.H 1	113.6	2.6	24.2	20.0	CL-ML	0.81	0.64
2	B.H 2	114.1	2.2	22.0	19.5	CL-ML	0.78	0.67
3	B.H-3	112.1	2.0	24.2	21.0	CL-ML	0.76	0.61

LAB RESULTS

Density by Core Cutter	**BH-1**	**BH-2**	**BH-3**
W1= wt. of core cutter + Soil (lbs)	2.026	2.031	2.013
W2= wt of core cutter (lbs)	0.981	0.981	0.981
W3= wt Soil(W1-W2) (lbs)	1.045	1.049	1.032
Vol. Of core Cutter (cft)	0.0092	0.0092	0.0092
Density= W3/Vol. lbs/cft	113.6	114.1	112.1

Moisture Content	**BH-1**	**BH-2**	**BH-3**
w1= wt of wet soil+cont. (gm)	28.20	45.40	42.60
w2= wt of dry soil +cont (gm)	27.80	44.70	42.00
w3= wt of cont. (gm)	12.65	12.90	12.30
Ww= wt of water (w1-w2) (gm)	0.40	0.70	0.60
Ws= wt of dry soil (w2-w3) (gm)	15.15	31.80	29.70
M.C= Ww/Wsx100 (%)	2.6	2.2	2.0

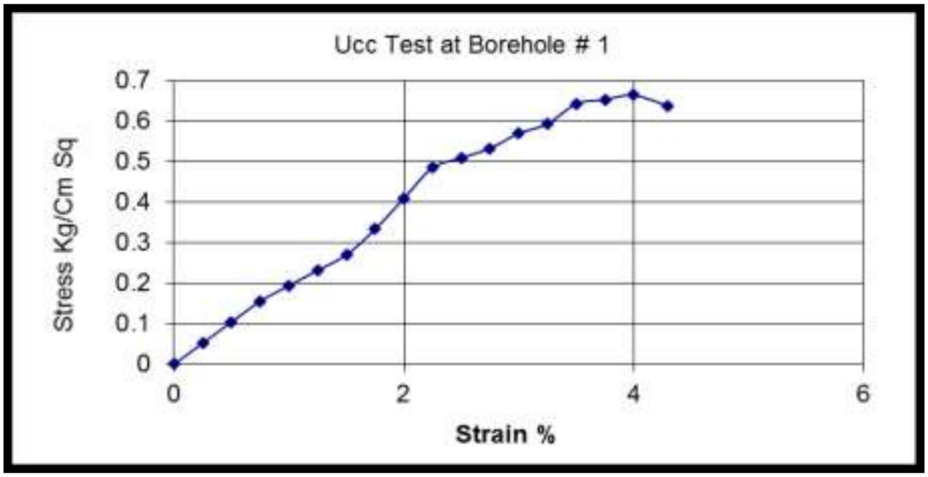
LAB RESULTS

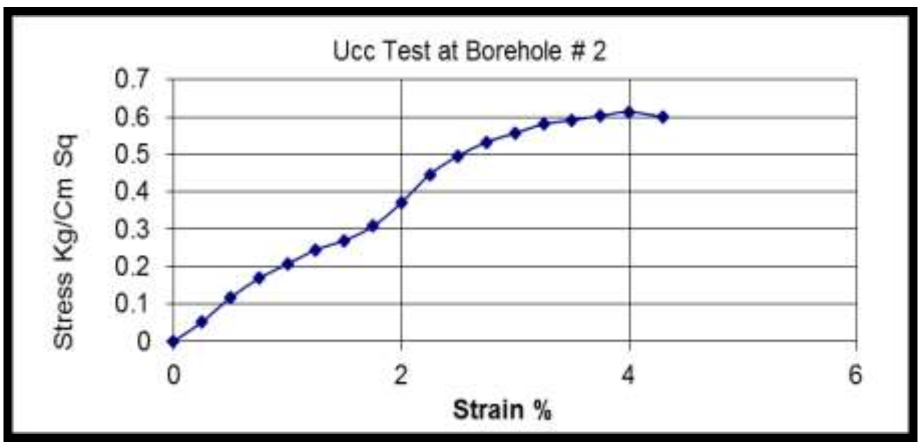
Safe Bearing Capacity By UCC	**BH-1**	**BH-2**	**BH-3**
DR=	49.0	47.0	46.0
Def=	300.0	320.0	340.0
Dia of sample= cm	5.50	5.50	5.50
Ao= Пd2/4=cm2	23.76	23.76	23.76
Lo= mm	112.0	112.0	113.0
ΔL= defx0.01	3.00	3.20	3.40
Є= ΔL/L	0.03	0.03	0.03
Ac= Ao/1- Є =cm2	24.42	24.46	24.50
Qu=0.31xDR/Ac=kg/ cm2	0.62	0.60	0.58
C= Qu/2= kg/ cm2	0.31	0.30	0.29
δn= Cx7.4+γdf=kg/ cm2	2.66	2.56	2.50
Qa= δn/3x0.9139= TSF	0.81	0.78	0.76

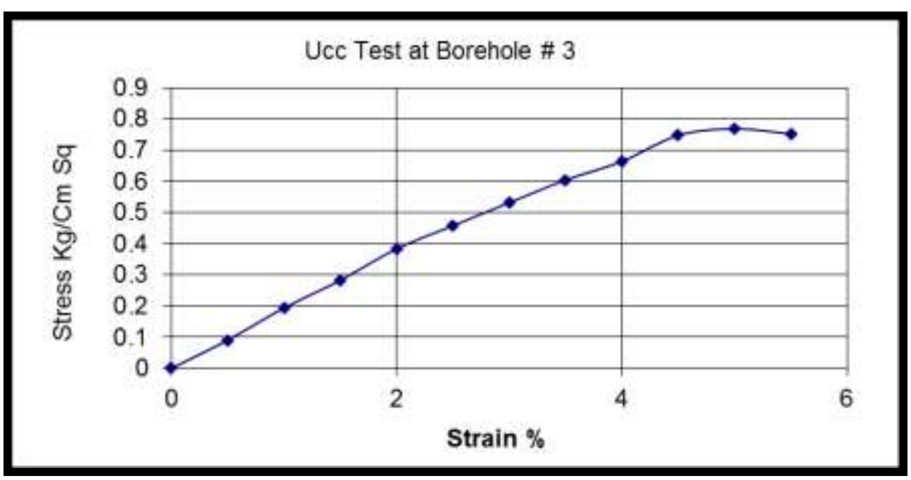
SPT

Detail	**BH-1**	**BH-2**	**BH-3**
γwet= Bulk Density lbs/cft	113.6	114.1	112.1
N= SPT No. of Blows	**18**	**19**	**17**
Df= Depth of foundation =ft	7	7	7
Po’ = γwetxdf	795.06	798.41	785.00
CN= N corrected value 2000/po’	1.59	1.58	1.60
Ń=NXCN x 0.8x 0.75	17.13	18.04	16.28
Qu= 0.25 x Ń =ksf	4.28	4.51	4.07
C= qu/2 =ksf	2.14	2.26	2.04
δn= 1.3* Cx7.6+γdf=kg/ cm2	16.64	17.49	15.84
Qa= qult X 1000/3X2240=TSF	0.64	0.67	0.61

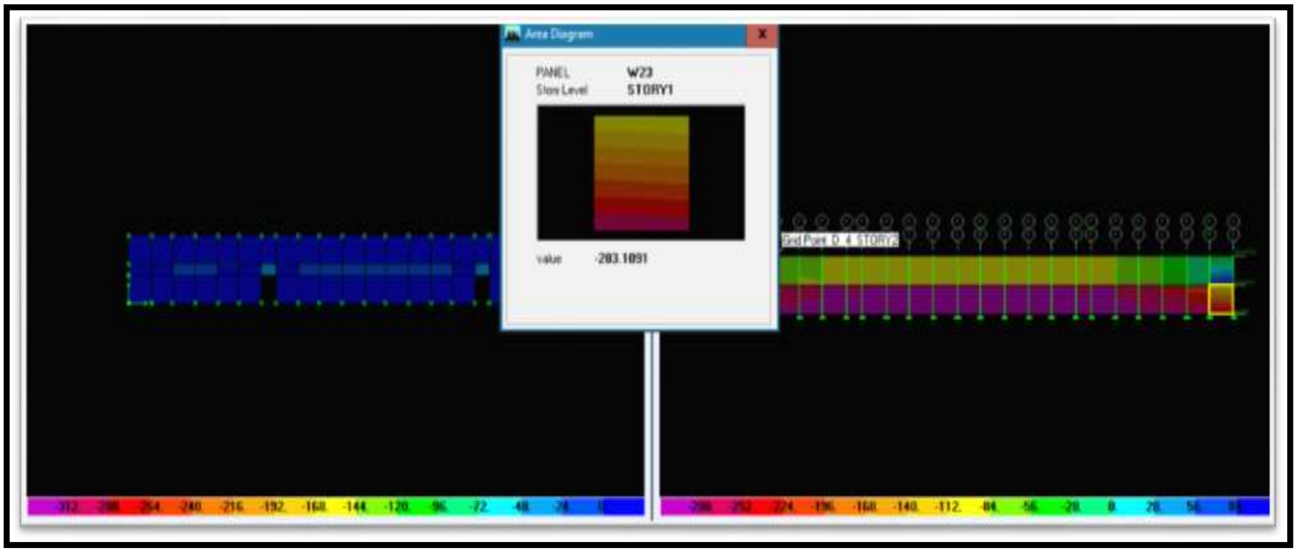
Graphs of UCC Test





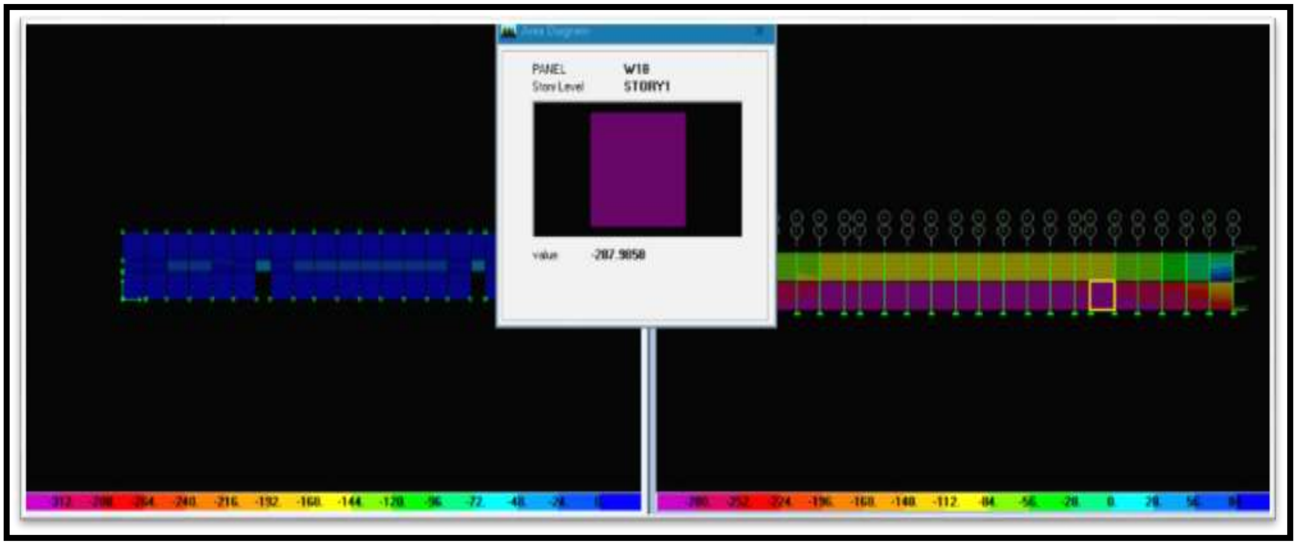


18. <u>Analysis on ETABS</u>



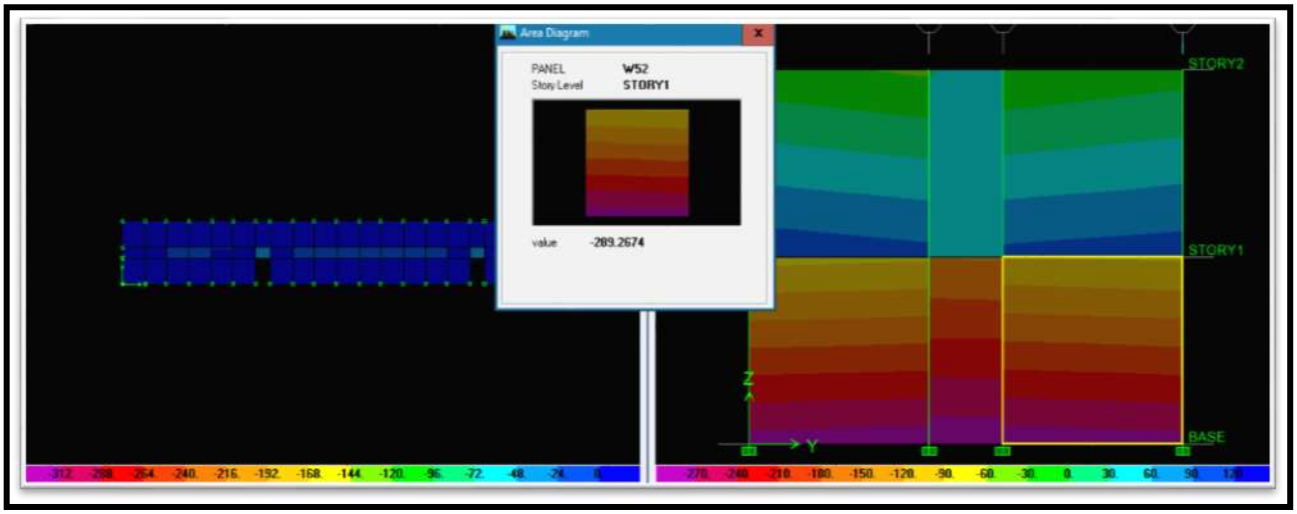
F MAX ELEV 4 (SIDE WALL) Top Floor

= 285 psi



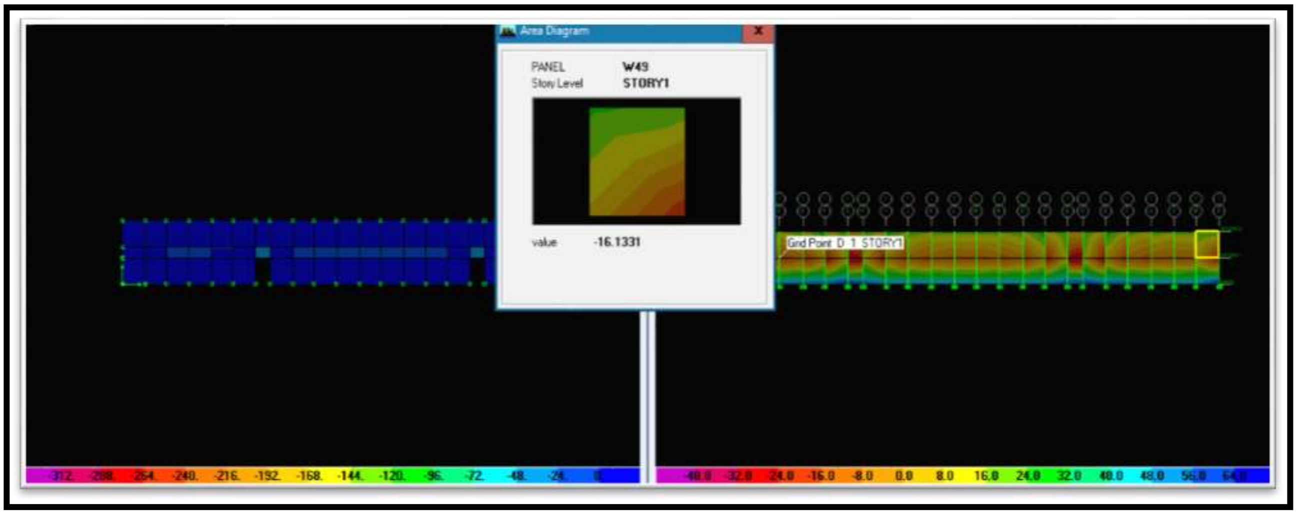
F MAX ELEV 4 (NEAR STAIRS) Top Floor

= 288 psi



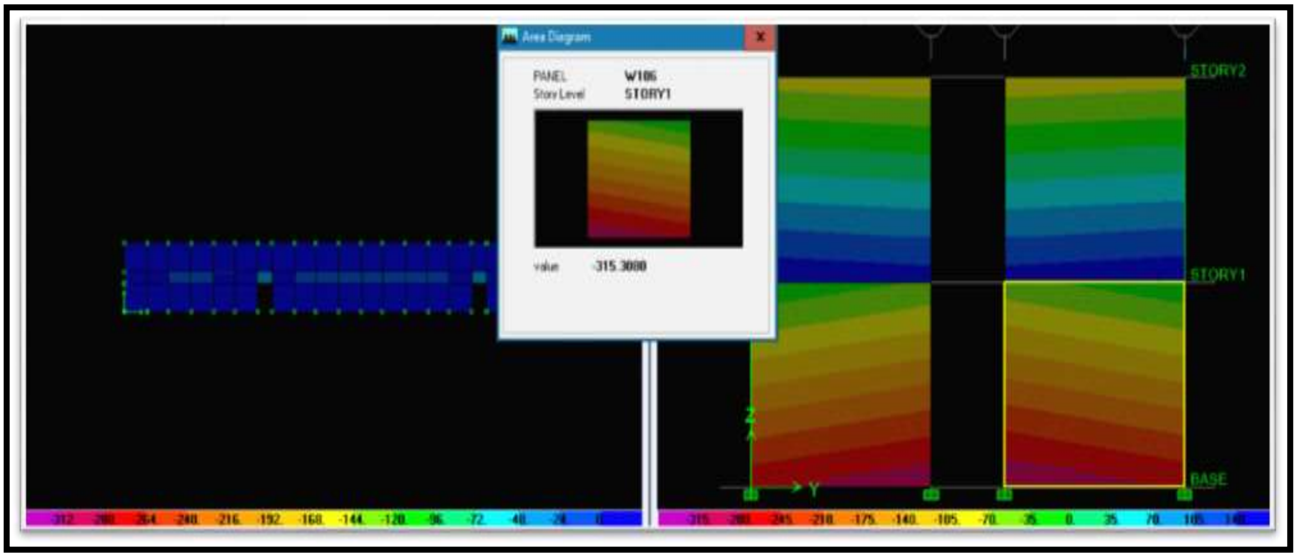
F MAX ELEV A (SIDE WALL) Ground Floor

= 290 psi



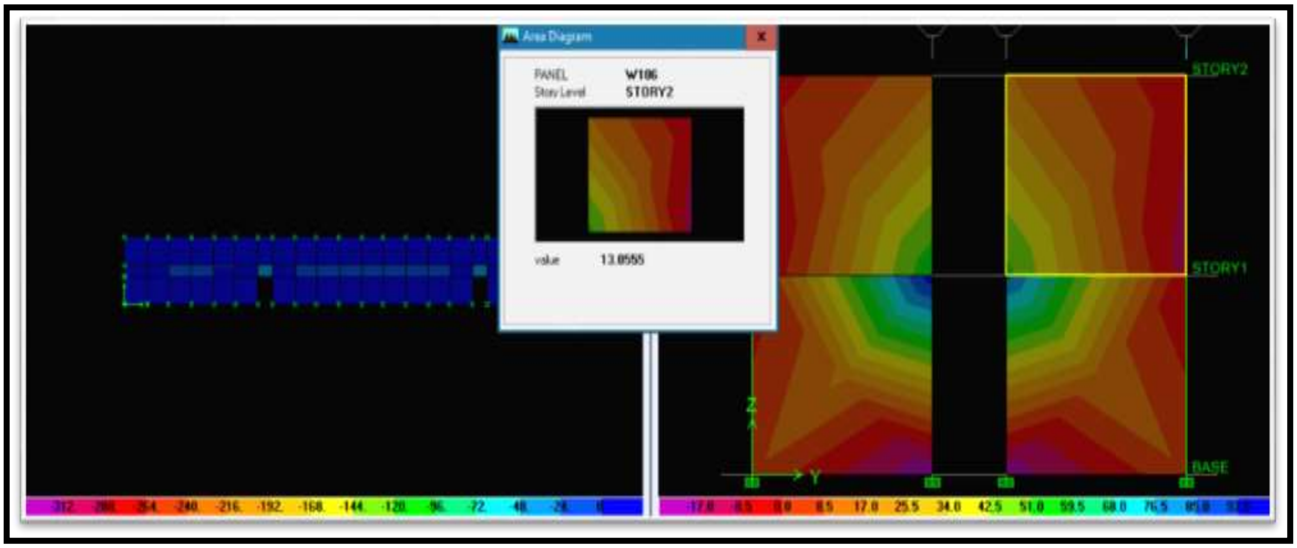
F MAX ELEV 1 (SIDE WALL) Top Floor

= 20 psi



F MAX ELEV H (NEAR STAIRS) Ground Floor

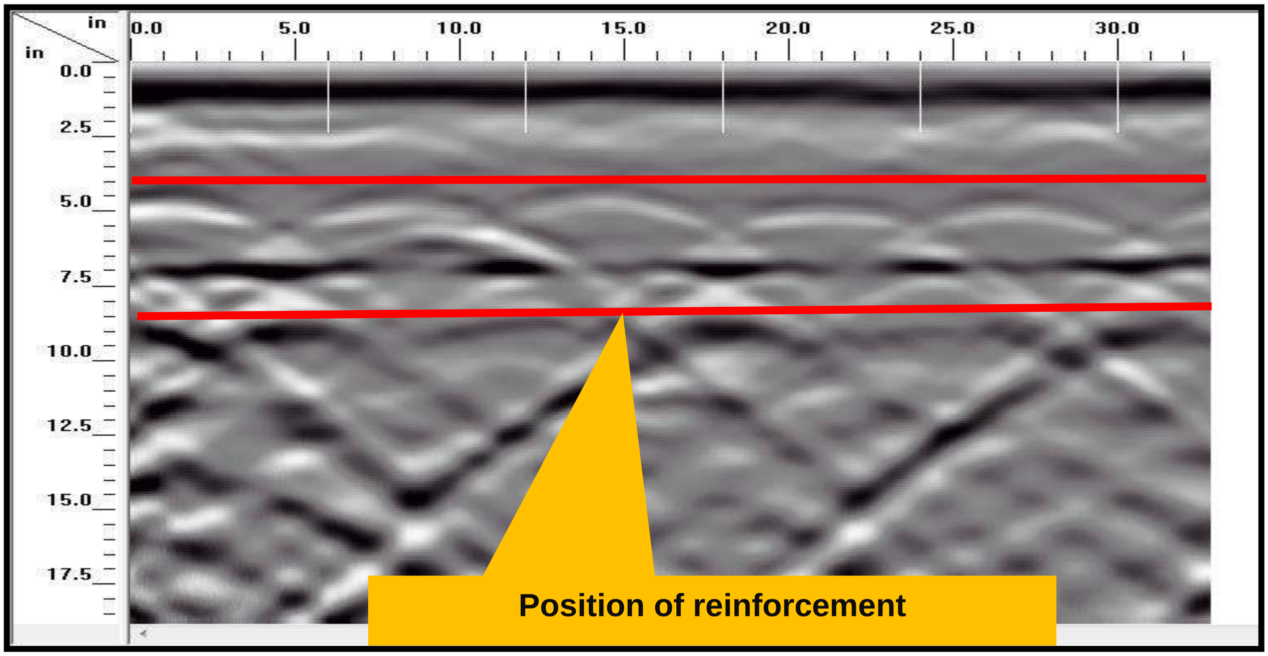
= 315 psi

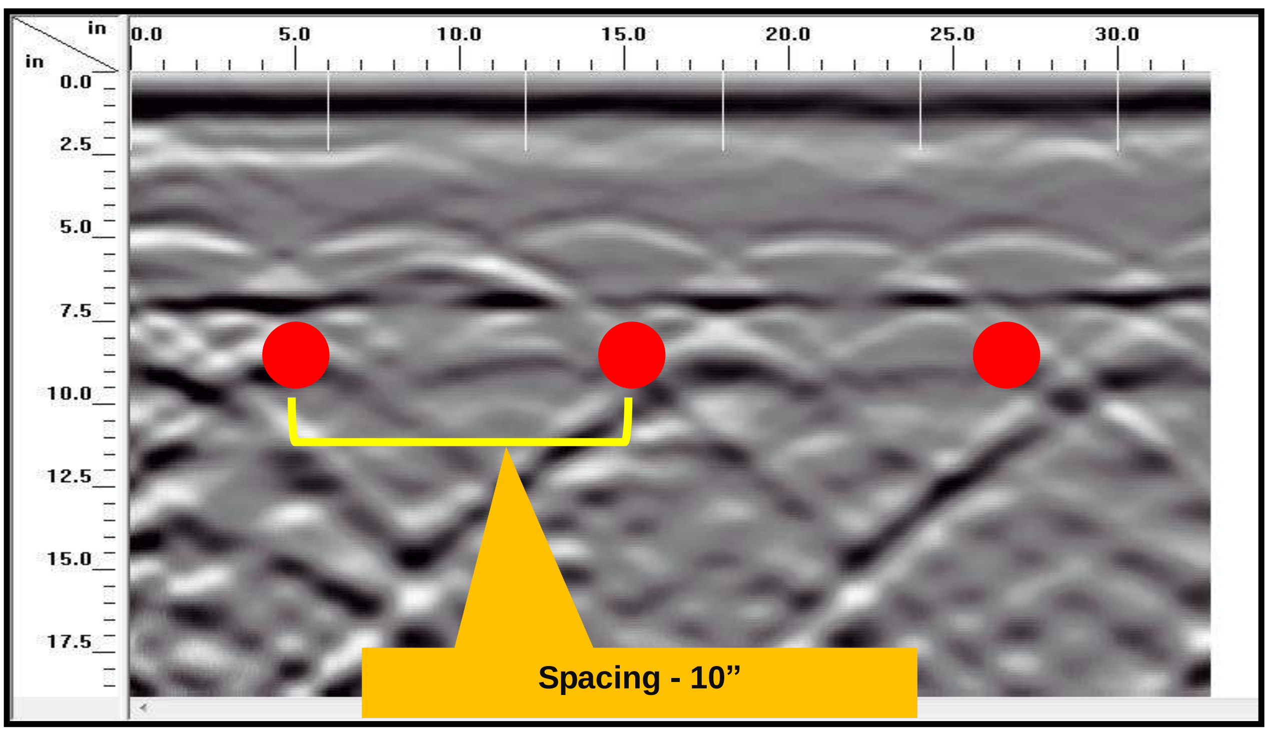


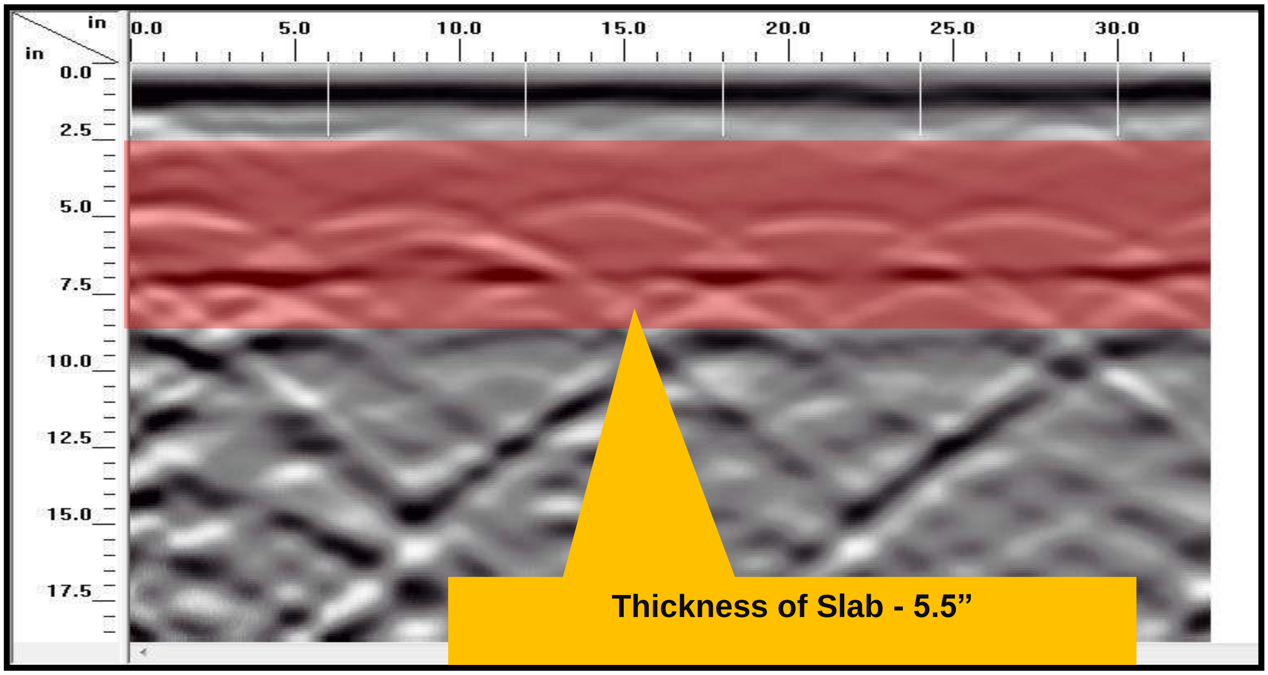
F MAX ELEV H (NEAR STAIRS) Top Floor

= 15 psi

19. **Analysis by RADON Scanner**

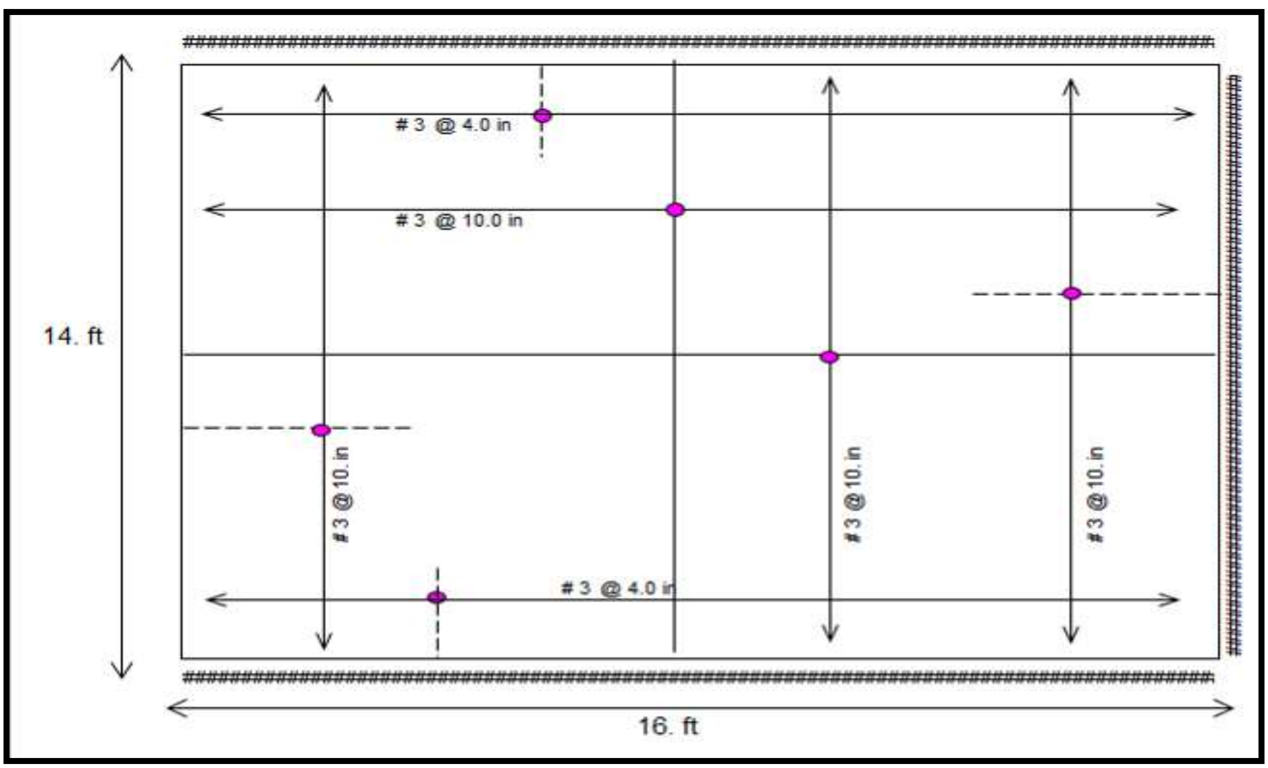






20. Conclusions from ETABS and RADON Scanner

20.1. Slab Reinforcement Calculation



20.2 Conclusions from Scanner

- By calculating slab reinforcement based on geometry, spacing of reinforcement should be 10” as verified by the scanner
- Thickness of slab is 5 “
- So no issue with the slab reinforcement
- Slab has lost his strength due to seepage problems

20.3 Analysis from Etab

- The stress on wall should not exceed its compressive stress i.e. f’m= 750 psi
- The stress found during analysis from Etab is below the max stress of walls
- There walls are stable and there is no issue with the walls in term of stresses

CHAPTER 4

DISTRESSES & CAUSES

Being dry is one of the basic criteria for a building. Ineffective design methodology, flawed construction techniques and application of faulty grade substance in a building may be major reasons of Seepage in a building. Apart from impacting building service life, it also generates unhealthy form of the construction materials to be used in building construction. **Water Proofing** is the remedy adopted to avert leakage of water from roof and **damp proofing** is carried out as to keep basement, floors and walls free from water.

21. Sources of Seepage in Cadets Block. The sources of Seepage in Cadets Block may be summarized as below:

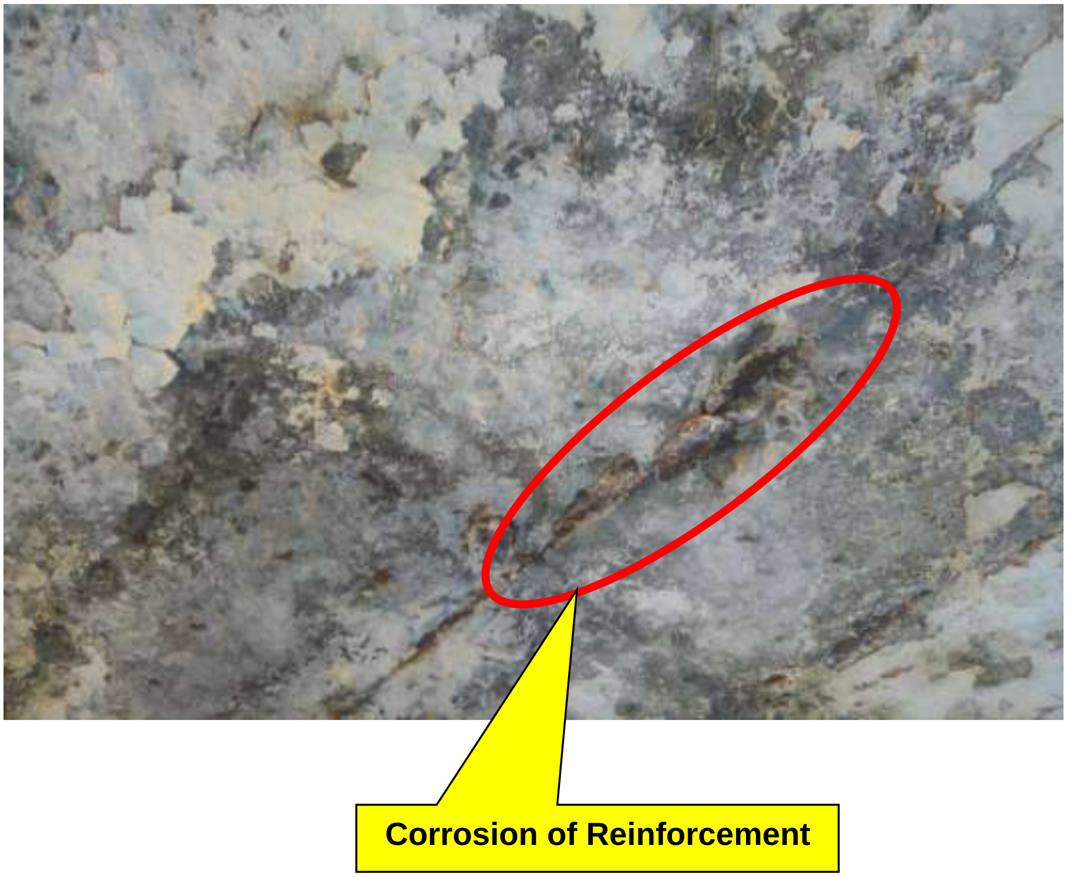
- Faulty plumbing of the fixtures in the walls is the major source. As the water of Risalpur is basically hard and containing sufficient quantity of chlorides, which is causing serious hazards to structural life and living conditions.
- As the roof is flat and roof slope is inadequate, improper rain water pipe connections and faulty junction between parapet wall and roof slab.
- Rain water penetration through unprotected walls.
- Seepage rising through the foundation walling. Moisture from wet ground may rise well above the ground level on account of capillary action.

22. Defects of Seepage in Cadets Blocks. The major flaws brought on by Seepage to Cadets Blocks are abstracted below:

- Causing efflorescence at some places which has eventually produced disintegration of bricks.
- Resulted in weakening and deteriorating of plaster.
- Spalling and blistering on the ceiling.

- It has caused fading and flaking of paint with the formation of pale patches on the ceiling.
- It has led to the corrosion of reinforcement.
- It has produced unhygienic living atmosphere for the residents.
- **<u>Other Defects:</u>**

1. Deterioration of Electrical Fittings.
2. Promoting the growth of termites to wooden fixtures.
3. Prominently reduced the life of the Structure.


Corrosion of Reinforcement


Flaking of Paints

Blistering & Flaking of Paints with Staining

23. **<u>Causes of defects in Cadets Blocks:</u>**

Moisture concentration in the building materials is one of the chief sources of Seepage. Generally, materials used in building of granular nature, so the moisture has looked up for an easy penetration into the voids and this phenomenon has been truly backed by capillary action, which has helped the moisture to drift in vulnerable directions. Thus, either on the basis of defective structural design or unskilled labor or by use of flawed structures or by application of substandard building material, moisture has found its course on the interior of the block chiefly through roof and walls due to poor plumbing.

23.1 **<u>Corrosion of Reinforcements:</u>** Due to excessive seepage and moisture percolation the reinforcements have corroded. The bond between plaster and steel has weakened. Resultantly, plaster is coming off from the ceiling especially from the areas where the reinforcements have corroded. As the temperature and humidity levels are comparatively high in Risalpur, this gives an added disadvantage to the corrosion process.

23.2 **Weakening and Deterioration of Plaster:** Due to long lasting presence of moisture in the Block's roof and walls, the plaster is continuously losing its strength and has started to deteriorate. The bond between the particles has weakened and has chipped off almost in all the rooms of the first floor. The reinforcements have corroded in areas more exposed to Seepage and the plaster is not holding its grip against the rebars in that particular area.

23.3 **Blistering and Flaking of Paint:** As the ceiling and walls of the rooms have become wet due to faulty plumbing and seepage of water from the roof has caused the paint to form bubbles. Also, the alternate wetting and drying of plaster makes it into powder form which is not capable of holding the paint thus sheets of paints are coming off from the ceiling and walls.

23.4 **Efflorescence:** There are many causes which may have led to efflorescence in bricks. Efflorescence may have been caused by water soluble salts, its upward movement and capillary action of groundwater into the walls of the buildings. Other reason may be the use of local water for the purpose of wetting the bricks and in preparation of mortar.

The bricks and building materials used such as sand and gravel may have been collected from a source prone to salt bearing water causing efflorescence. Rationally, efflorescence has not resulted into structural declination of brick masonry, it has garbled the aesthetic view of the Cadets Block.

23.5 **Formation of Colored patches:** Colored patches have been formed on the ceiling and walls of the rooms of the first floor giving a shabby look and an unattractive odor. Improper ventilation of the water has caused this effect to increase in the washrooms.

24. Retrofitting Measures:

Following measures can be adopted to overcome the above-mentioned sources of Seepage and their causes can be reduced to eventually enhance the structural life and living conditions in the Cadets Block.

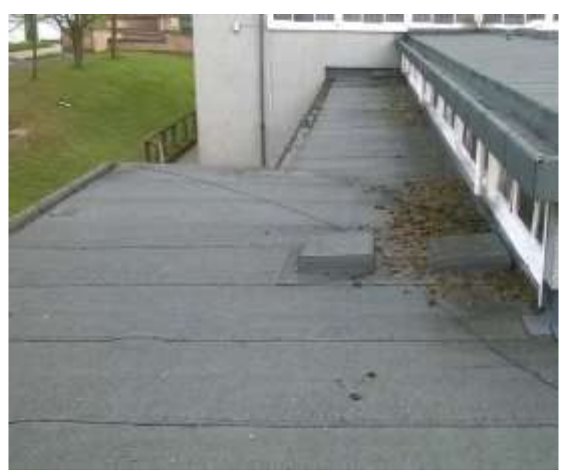
24.1 Fixing the Plumbing Leaks

Remove the affected areas of the wall around the shower, basins and toilet. Repair the damaged pipes and properly seal all the joints between the pipes to ensure no water leakage should happen.

The pipe connections from the water tank should be tighten to stop the accumulation of water on the roof.

24.2 Laying Bitumen on the Roof.

A coating of bitumen should be laid on the roof to cover all micro pores and cracks that have developed over time due to water seepage and deterioration of building materials.



24.3 Sloping of Roof.

Roof slope should be made adequate as to direct rain water and overflowing water from water tanks into the roof drains. When proper sloping is carried out water will not be able to stay on the roof.

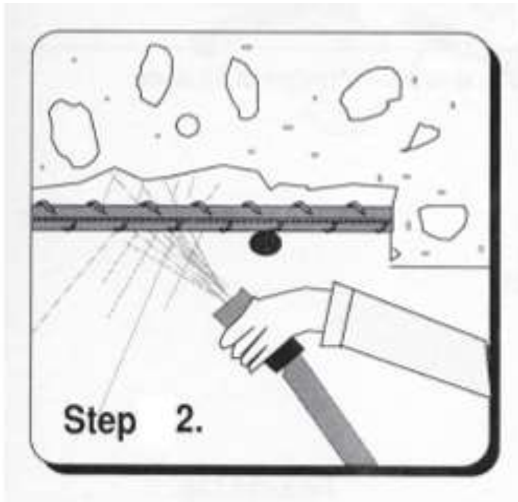
24.4 Repair of Damage with Exposed Steel Reinforcements.

Firstly, the broken and loose pieces of concrete to be removed keeping in mind the structural stability of the structure, then the solid concrete and corroded steel rods completely uncovered. By scrubbing or grinding rust should be removed from the steel, depending on the extent and level of corrosion. Next, anti-corrosive epoxy primer or cement based anti-corrosive coating to be applied on the exposed steel bars in order to protect them from further corrosion.

Subsequently, the peeled area will be repaired by the application of high performance patching mortar, in order to restore the monolithic nature and strength of the damaged structural element.

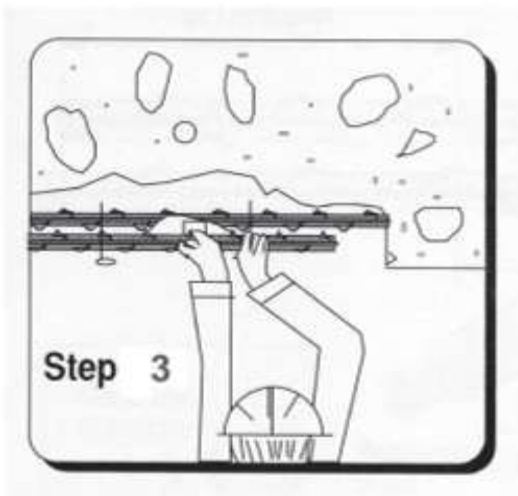
STEP 1

Removal of broken and loose pieces of Concrete and uncovering the corroded Steel bars



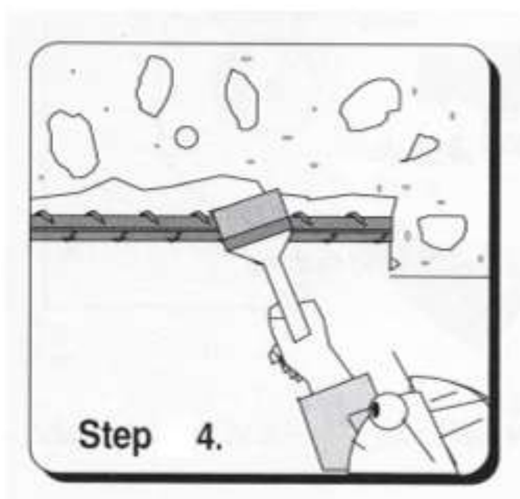
STEP 2

Scrubbing and Grinding to remove Rust



STEP 3

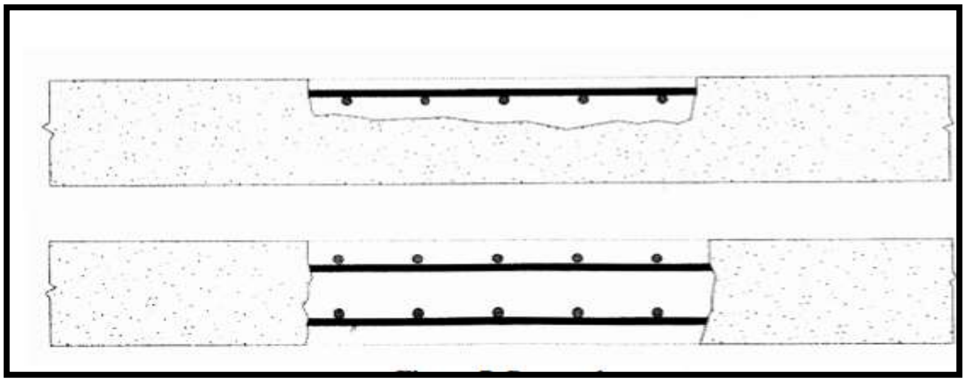
Applying anti-corrosive epoxy primer or anti-corrosive coating on exposed bars



STEP 4

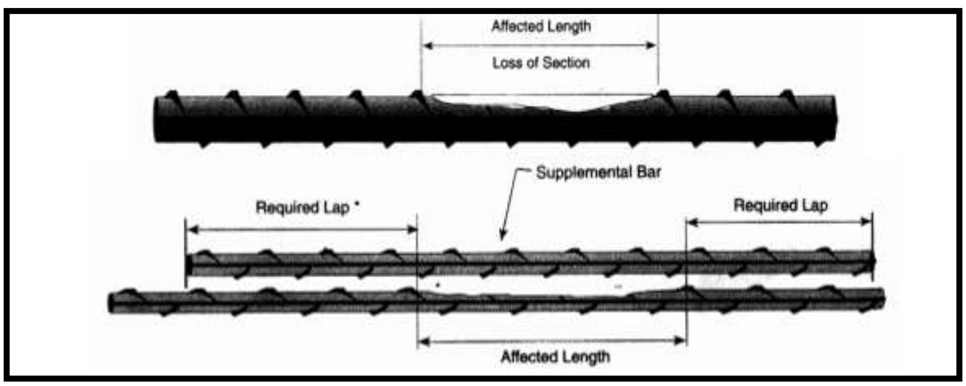
Application of high performance patching mortar

24.5 Replacement of Corrosive Reinforcement



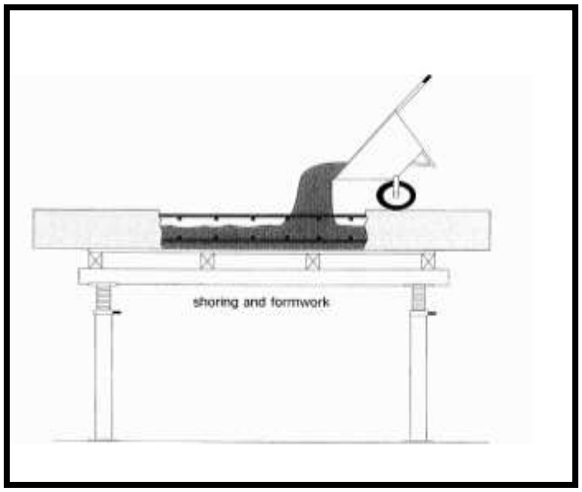
STEP 1

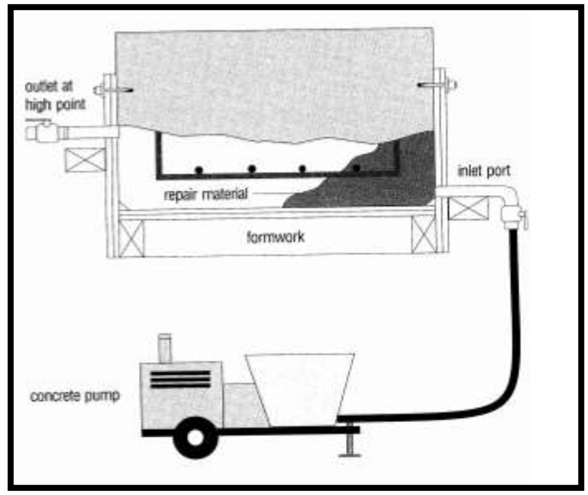
Remove the porous or damaged concrete around the corroded reinforcement



STEP 2

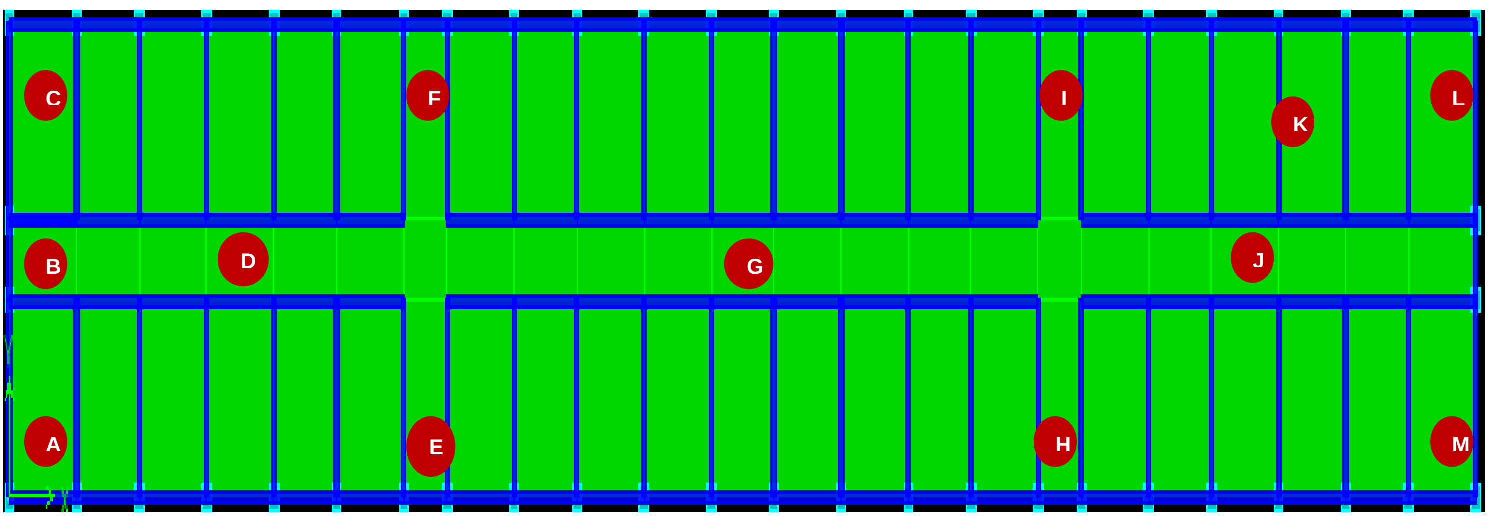
Replace the complete bar or portion of the bar by cutting the affected length with new bars





STEP 3

Pouring of concrete to cover replaced reinforcements



24.6 Plastering of Walls.

The outside walls mostly have plastered off and at the junction of walls and slab there are cracks from where rain water percolates into the walls. These walls should be plastered completely after removing the old plaster and cracks be covered or filled.

24.6 Removal of Blisters and Flaking of Paint.

After complete elimination of the source of water seepage, remove paint blisters by scraping and apply primer coat first before applying a good quality paint. Considerable drying time should be given.

24.7 Brushing to remove Efflorescence.

Dry brushing may be carried out as it is simple and quick method to remove Efflorescence.

25. Conclusions & Recommendations

25.1. Low Quality Concrete

Results from PUNDIT & Schmitt Hammer test showed that strength of concrete at present is reduced to 1372 psi. The value is far less then even Low strength concrete (2500psi). It leads us to the fact that concrete used at the time of Construction was also of low quality that is why it has further reduced to such low value.

25.2. Seepage

Seepage from the building was main cause of distress. Seepage was initially reported back in 2002 (18 years after construction of the block understudy). Issue was not rectified at that time which kept on increasing with the passage of time.

25.3. Poor Plumbing

Poor plumbing caused a reasonable increase in the seepage which added to distress of the building. Slope of the roof was also not suited to the requirement which used to increase seepage especially during rainy season

25.4. Lack of Focused Repair

Periodic inspections were not carried out by the authorities concerned. Although repairs were carried out 3 times spending about 15 Mn rupees but this was just a waste of monetary resources. If expert were consulted and focused approach towards repair would have been carried out, the same could be rectified with much less funds and for the rest of the designed life of the block.

26. Recommendations

26.1. Replacement of Corrosive Steel Reinforcement

Corrosive steel reinforcement bars may be replaced by new bars and short Crete process may be resorted to. This will not only address the issue of seepage and other defects but will also prevent the block from further damage.

26.2. Periodic Inspection of Buildings

Periodic inspection of buildings be carried out and expert advice be taken to address any such issue. Stereotype and non-engineering practices, which are non-permanent remedial measures, may be done away with, as they lead to wastage of economic resources and don't add to long term solution.

26.3. Readjustment of Roof Slope & Fixing Plumbing Issues

Roof slope be adjusted so that rain water doesn’t accumulate on the roof. All Plumbing fixtures be checked and defected/leaked ones be replaced at priority. These actions will stop the further damage to building.