Diagnosis of Preliminary Failures in Concrete Structures Using Basic Artificial Intelligence

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Abstract: The (Reinforced Cement Concrete) RCC structures have definite life span and are prone to damage, which may further lead to failure of the structure. It is of great concern to engineering Professionals to monitor the structure at various stages of life span to maintain its utility value and repair requirement .This paper is output of the research work of M.Tech dissertation to develop Artificial Intelligence tools and techniques to diagnose the preliminary failure from symptoms observed and to suggest most appropriate solution to fix the failure condition. Typical civil structures such as Pavements , Buildings etc. were identified and selected for the study. Preliminary failures related data and information was gathered. Civil Engineering Experts from filed were consulted and human experience and intelligence has been the base for evolving model/software .The outcome of Artificial Intelligence based software is presented. Based on the findings of Artificial Intelligence the remedial measures for fixing the preliminary failures are suggested.

Keywords: The RCC structures Artificial Intelligence in Civil Engineering, Causes of Structural Failure, Failure Diagnosis, Repair of Preliminary Failure.

I. INTRODUCTION

Concrete structures are designed for specific purpose and for specific life span. The life span of these structures gets varied according to the utility of these structures. During the service period, the structures are exposed to typical conditions and varied environment, the variation in environmental conditions results in deterioration of concrete. Thus, they demonstrate failure at different stage of life. The diagnosis of failure is quite important at their preliminary stage prior they lead to catastrophic failure. Conventionally, these diagnoses are based on human experience and intelligence. Based on the knowledge the decisions are taken for the repair and rehabilitation of failures in concrete structures. But due to interventions of Information and Communication Technology (ICT) and advancement of Artificial Intelligence (AI), these diagnoses can be done using Artificial Intelligence and machine languages also. In these technologies the knowledge based programing is developed, in which can be further changes can be done. The application of AI in civil engineering has been well proven and successful.

Artificial Intelligence is the science and engineering concerned with making machines especially computers think like human. AI focuses on developing computer programs which is associated with human intelligence of reasoning and complex problem solving. The aim of AI is to create expert system with intelligent behaviour to demonstrate, explain and give advice to its users.
AI emerges as separate field of research in 1940-50s. In 1950 Alan Turing introduces Turing Test and published the first paper on Computing Machinery and Intelligence. In same year, Claude Shannon published Detailed Analysis of Chess playing.

In 1956 the term Artificial Intelligence was first introduced in conference. In 1989 the first Journal, on civil/ structural Engineering applications of neural network was published by Adeli and Yeh. Due to extensive use of ICT and impact of computer
Artificial Intelligence in Civil Engineering: With the advancement of AI in solving engineering problems, the same is being used in various aspects of Civil Engineering in particular. Broad applications of AI in Civil Engineering are:

Artificial Intelligence in Structural Analysis: Artificial Intelligence is used for designing the structures using Designing Software. Designing the software using algorithmic analysis is done. Hi-Rise, an expert system based software is useful in addressing preliminary structure design. SANCON is another expert system which address some aspects of automated consultant to advice non-expert engineers the use of FEM.
Artificial Intelligence in Construction Management: AI expert system HOWSAFE is suitable for evaluating safety aspect of site practices. Another expert system, SAVOIR is suitable for selecting material handling equipment for concrete frame buildings. AI is suitably used for project monitoring, cost and time controlling, inventory control.
Artificial Intelligence in Environmental Engineering: Hazard Ranking System (HRS) is expert system based software developed for ranking hazardous waste. AI is also applicable for landfill sites for disposal of waste, by assessing ground water contamination potential by organic chemical.
Artificial Intelligence in Geotechnical Engineering: AI system is used for site characterization including, density, stiffness, strength has been developed. Software such as SITECHAR, interprets geotechnical site characteristics. WADI is applicable for failure diagnosis in retaining wall. Another expert system CONE is intended to check raw cone penetration data validity, classify the soil and infer design parameters.

II. Related Review Work

Following few researches of previous works are:

Kajol Mevawala et al. (2016) studied latest techniques, material and requirement for repairing work to check for deterioration which was essential and economical for reconstruction. Different methods to repair distress, includes, shotcrete, sealing, epoxy injection [1].

H. Naderpour et al. (2016) applied Fuzzy Logic theory to solve and simplify RCC problems such as, crack diagnosis, evaluation of concrete durability, strength prediction in FRP reinforced concrete beam. Results obtained are more reliable and accurate to answer human logics [2].

Grishma Thagunna (2015) this work deals with crack problem in concrete based on different observational methods obtained using different instruments. Different causes of cracks and remedial measures have been discussed [3].

Lam Siu- Shu Eddie et al. (2015) identified the water seepage problem. Different methods to investigate the cause and source of seepage are investigated. Different methods such as, dye test, protimeter measurement, infrared thermography are used for identification [4].

Mohammed Abd Elmoneam Zaky (2013) investigate different repair, strengthening and retrofit techniques for RCC beam. Different methods that were studied include, unbound type strengthening, section enlargement, concrete repair. It was concluded that over corroded reinforcement, cracks should not be sealed without encasing the bar [5].

F. Moodi (2009) developed DEMAREC-Expert, which involve material failure analysis, condition assessment, material selection, rehabilitation. Different standards were used to acquire knowledge, which is further used to provide rapid method to make decisions from assessment of concrete impairment [6].

Based on the researches on AI in civil Engineering this research is proposed to develop basic Artificial Intelligence based software to diagnosis the preliminary failure in RCC structures. This research is confined to the analysis of three typical structure, bridge, building and rigid pavement, further the work can be carried on different structures also.

III. RESEARCH OBJECTIVE

Major research objectives of the study were:

1. Development of basic AI system for preliminary failure of selected RCC structure matched with human knowledge.
2. Analysis of RCC structure for preliminary failure using developed AI software as pilot try out.

IV. MAJOR STEPS OF RESEARCH

A. Selection of typical RCC structure

RCC structures available in Bhopal region were surveyed for the selection of suitable structure for diagnosis of preliminary failures. These structures are

a) Bridge
b) Building
c) Rigid Pavement

B. Eliciting of information on RCC failure using human experts/ knowledge:

In view of gathering information about preliminary failures and its causes, a detailed survey cum discussion was carried out and experts were approached to collect the required knowledge;

Bridge structures:

As mentioned below, Nine (09) Preliminary failure symptoms observed in bridge is due to both exposed environmental conditions and vibrations due to moving vehicles; the symptoms observed are:

1. Cracks in deck: Failure symptom observed due excessive traffic vibrations or environmental factor of thermal variation cause cracks in riding surface.
2. Delamination: When the vibrations are induced on over bridge, due to repetitive stress, leads to delamination of the structure. Variable impact load also causes delamination.
3. Spalling: Repetitive freeze and thaw cycle cause corrosion in imbedded reinforcement causing spalling of concrete.
4. Opening of joints: Improper bonding, traffic vibrations leads to joint opening.
5. Corrosion of reinforcement: Structures subjected to moist environment leads to corrosion in exposed reinforcement.
6. Accumulation of water: Improper slope causing ponding of water on abutment seats, which further deteriorate the bridge.
7. Surface deterioration: Another common failure symptom observed is surface deterioration, which is caused due to repetitive loading and over stresses.
8. Flaking of parapet plaster: Due to improper traffic causing collision of vehicles from parapet, or vibrations induced due to moving vehicles lead to flaking of plaster from parapet. Other causes include, weathering effect, rusting due to seepage may also results in flaking of plaster.
9. Corrosion in parapet: Paint and corrosion protective film gets eroded due to rainwater which erodes the metal of parapet.

Building structures

Ten (10) Failure symptoms are observed in building is basically due to design deficiency or due to improper utility; common symptoms in building super structure are:

1. Reinforcement exposure: Cover required over the reinforcement is not fulfilled, either due to design deficiency or poor workmanship. Which even gets deteriorated over time, hence reinforcement gets exposed to environment.
2. Cover deterioration: Due to weathering effect cover gets deteriorated. Also, improper sand grain particle size and sand- cement proportion leads to cover deterioration.
3. Cracks in beam/ column: Typical environmental conditions and variation in environmental and structural temperature expands and contracts the structural component hence leads to cracks in beam/ column.
4. Honeycombing: Coarse aggregate particles gets accumulated and exposed forming honeycomb structure. It is due to improper compaction, bleeding, segregation and improper mixing and placing.
5. Spalling: Due to stresses induced, large fragments of concrete get break into small pieces, known as spalling.
6. Flexural cracks: When bending of component exceeds the permissible limit, flexural failure of beam is observed.
7. Cracks in slab: When load applied exceeds the design limit then cracks are preliminary symptom observed in structural component.
8. Joint failure: When beam and column is not monolithically designed or material specification is not provided.
9. Seepage: Improper drainage and slope cause seepage in structure.
10. Flaking of wall plaster: Poor workmanship or improper cement sand proportion cause abrasion of plaster from wall.

Rigid Pavements

None (09) Failure symptoms in rigid pavement are mainly due to thermal effect or improper designing; failure symptoms observed are:

1. Durability cracks: Due to climatic variation such as freezing and thawing, cracks parallel to each other are formed. These cracks are durability/ D- cracks.
2. Spalling of joint: Joints deteriorate due to excessive compressive stress. The stress is mainly due to heavy traffic. Sometimes water gets accumulated in these joints which cause freeze and thawing effect in joint, causing spalling of joint.
3. Faulting: Erosion of soil beneath the pavement results in difference in elevation of slab near the joints, results in faulting.
4. Pavement roughness: Studded tire wear and faulting alters the pavement friction characteristics resulting in pavement roughness.
5. Shrinkage cracks: Hairline cracks in pavement of less than 2m length are shrinkage crack. Setting and curing of pavement cause such cracks.
6. Pumping effect: Expulsion of fine materials beneath the pavement along with water cause large void formation, it is mainly due to stress induced from active loading.
7. Punch out: Breakage of localised area of slab is punch out failure.

8. Longitudinal cracks: Breakage of slab into two or more fragments due to thermal gradient and moisture loading results in such cracks.
9. Slab corner break: Pumping in excessive rate removes the support present beneath the pavement, which results in corner break of the slab.

V- MAPPING OF STRUCTURAL FAILURE AND KNOWLEDGE BASE

Failure symptoms cause and repair methods are mapped. Module based on if & then is plotted.

Structure

- Bridge
- Building
- Rigid Pavement

if Bridge *then* run module for bridge
if Building *then* run module for building
if Rigid Pavement *then* run module for Rigid Pavement

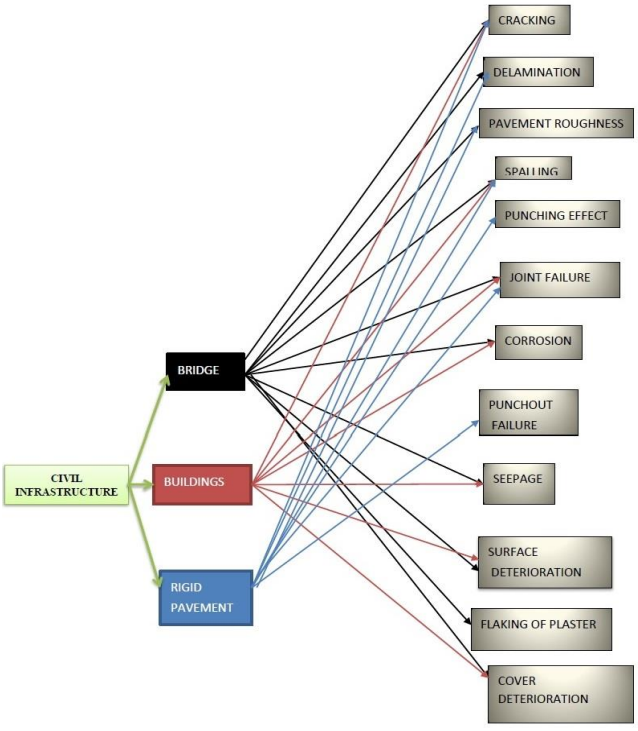

Fig 1 Mapping of structures with preliminary failure

VI- DEVELOPMENT OF ARTIFICIAL INTELLIGENCE PLATFORM FOR FAILURE DIAGNOSIS

RCC Failure Diagnosis and Repair system (RFDRS) has been developed using human knowledge/expertise.

Programing pattern developed for the software is elaborated below:

```
<html>
 <head>
<title>Welcome </title>
 </head> <p align="center">
<img  src="images/MAIN TITLE.jpg" ></img>
</p>
<hr> <form action="infra.php" method="POST" >
<h3 align="center"><u>CIVIL INFRASTRUCTURE FAILURE DIAGNOSIS-
USING AI</u></h3>
 <td><b>TYPE OF CIVIL INFRASTRUCTURE</b></td>
<tr>   <td align="right">Bridge</td>
<td><input type="radio" name="type" value="bridge"></td>
</tr>
 <tr>
<td align="right">Building </td>
  <td><input type="radio" name="type" value="building"></td>
 <td align="right">Rigid Pavement</td>
<td><input type="radio" name="type" value="rigid pavement"></td>
 </tr>
<td><input type="Submit" value="Submit"></td>
<td><input type="reset" value="Reset"></td>
</tr> </table>
</form>
</html>
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Developed Software

RCC Failure Diagnosis and Repair System is developed to diagnose the failure from the observed symptoms. At the beginning the user must select the Civil Infrastructure of which the diagnosis has to be done.

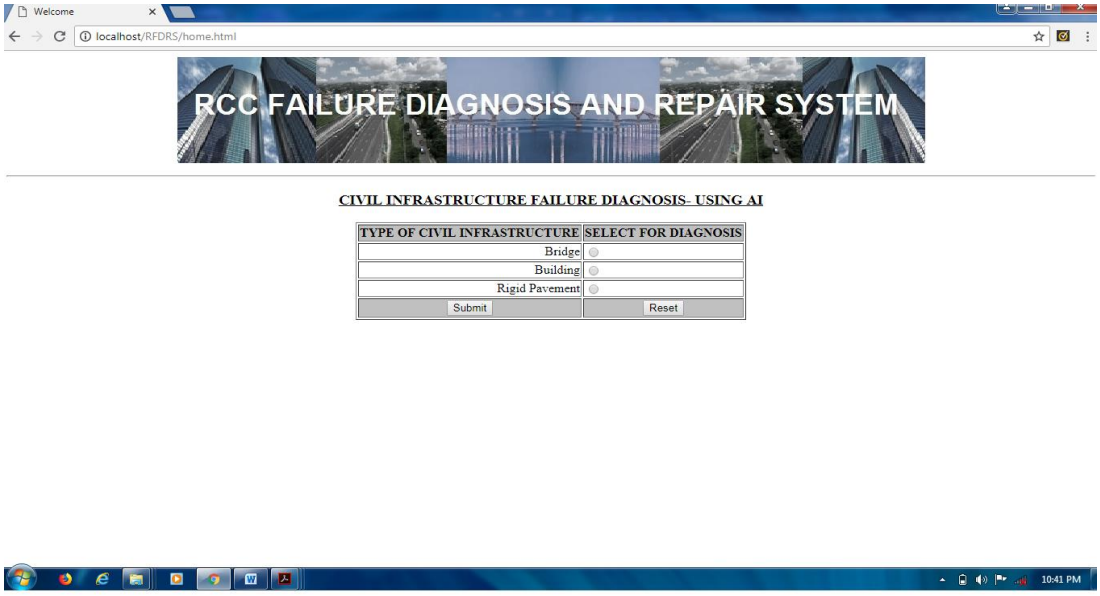

Fig 2 Main screen for structure selection

Then on the second module the user have to mention all the relevant details regarding the structure and must choose the failure symptom observed.

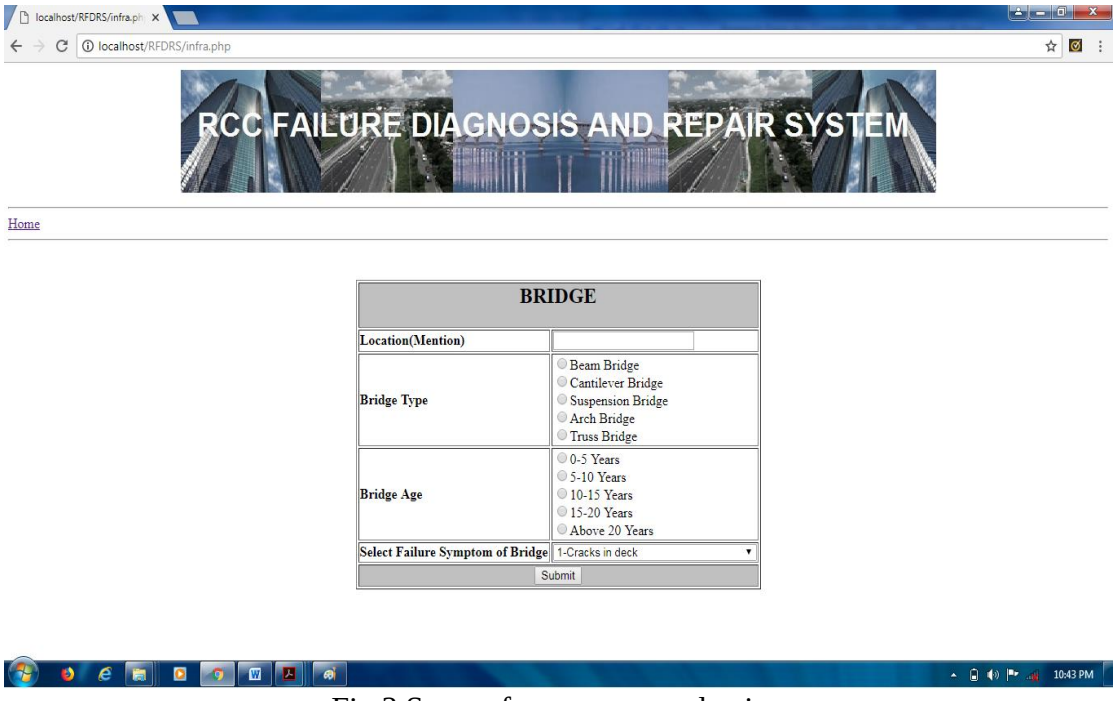

Fig 3 Screen for symptom selection

The third module gives the cause of the preliminary failure symptom and suggests the appropriate remedial method.

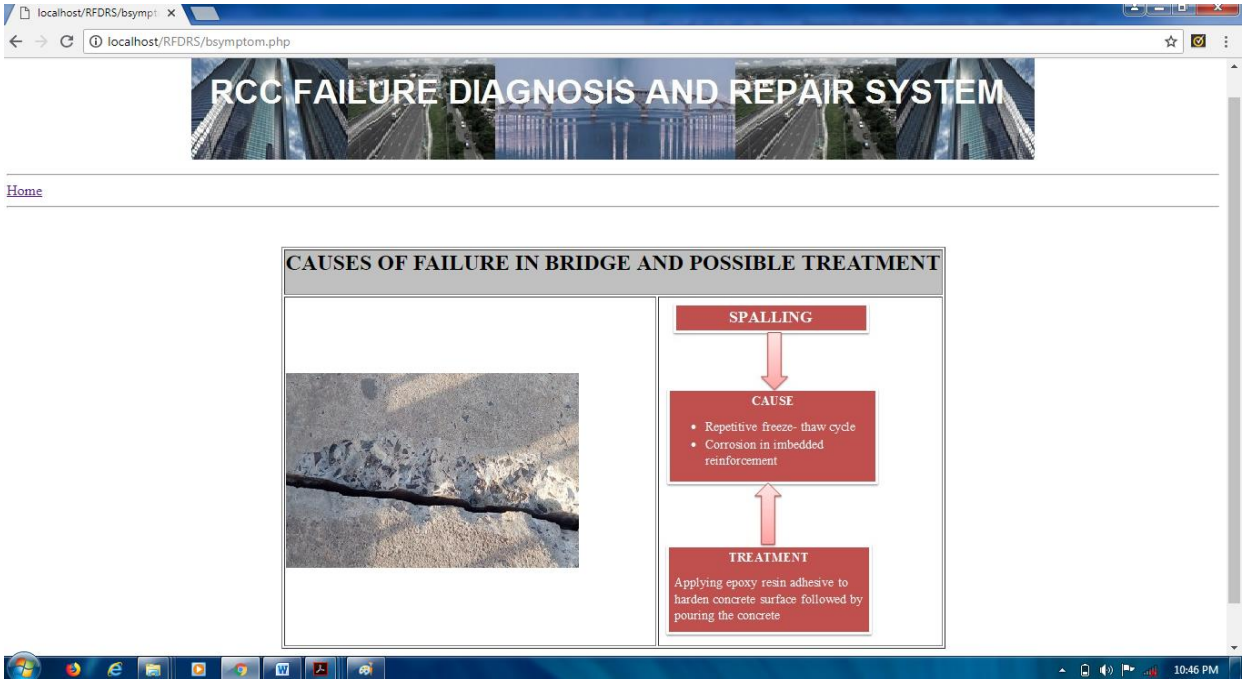

Fig 4 Cause and treatment method for symptom

The fourth module is the report generated for the selected structure with the failure symptom, its cause and remedial measure.

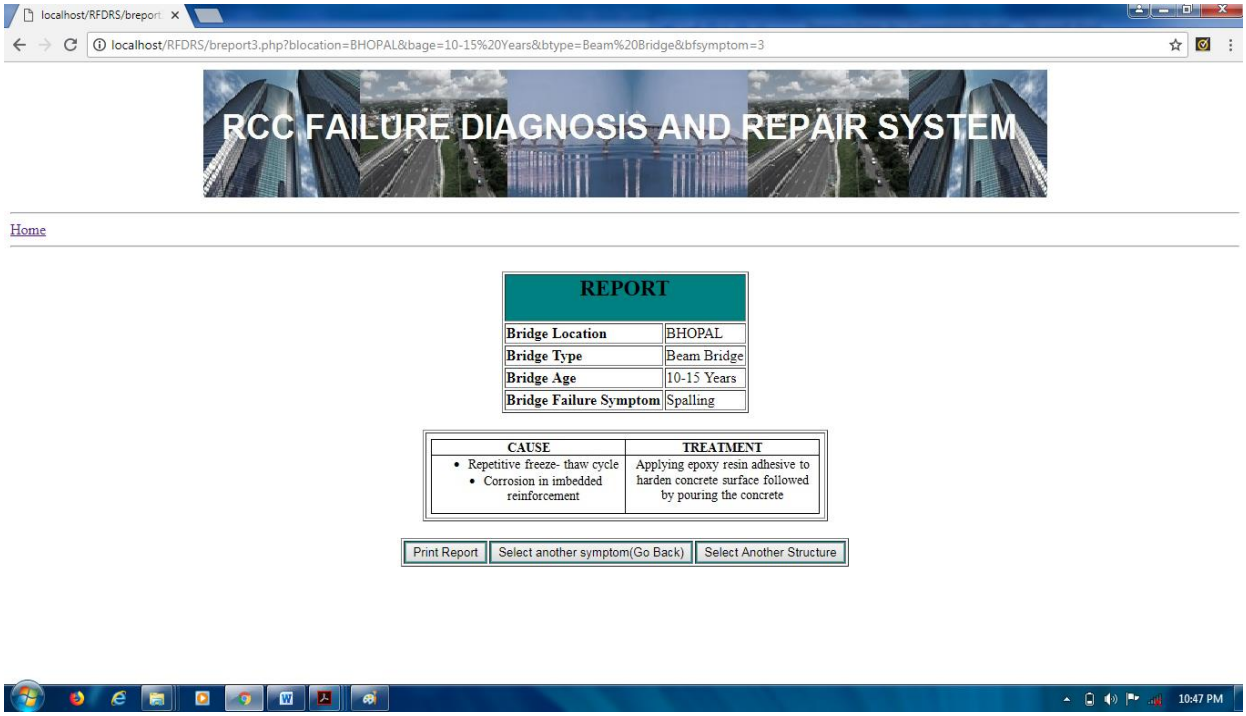

Fig 5 Report for selected symptom

TABLE I MODULE OF PROPOSED AI SOFTWARE

Module	Function
Civil Infrastructure Module	This module asks the user to select the structure to diagnose the failure.
Bridge Module	Asks the details of bridge and selection of observed symptom is done under this module
Building Module	Asks the details of building and selection of observed symptom is done under this module
Rigid Pavement Module	Asks the details of rigid pavement and selection of observed symptom is done under this module
Cause and treatment Module	Gives the cause of preliminary symptom observed and suggests the possible treatment method.
Report Module	Generate the report of selected failure symptom with all the details specified.

VII- PILOT IMPLEMENTATION

The developed Artificial Intelligence platform is tested on identified structure. The structure details are:

TABLE III CASE STUDY SITE DETAILS

Site Location	Bhopal
Structure Type	Commercial Building
Location	GTB Complex
Latitude	$23^0$14’11.421”
Longitude	$77^0$23’54.621”
Structure Age	Above 20 years

Preliminary failure symptoms observed in the structure are:
1. Reinforcement exposure
2. Cracks in slab
3. Flexural cracks
4. Cracks in column

Reports from the developed software were generated for the preliminary failure symptoms observed in the selected structure, which proves that the developed software performs well for failure diagnosis.

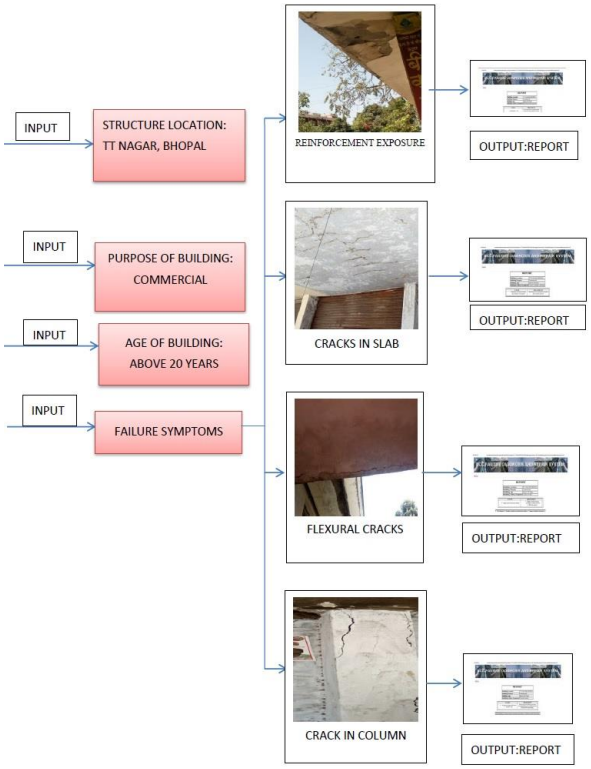

Fig. 6 Working of developed AI System

VIII-CONCLUSION

The human intelligence and knowledge on the diagnosis of failure is converted into Artificial Intelligence, and AI based platform/ system is developed. Knowledge from experts is acquired on concrete structure failure and based on elicited information; the Artificial Intelligence system was developed. Using the developed software a pilot try out is carried out on the existing structure of building and it was proved and found that the developed AI system performs well for the diagnosis of failure in concrete structure. In the research work, the problem of diagnosis of preliminary failure in concrete structure is addressed, analysed and assessed which has been the concern of Engineering Professionals .

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