Building crack evaluation program for the identification of its causes

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Abstract: Cracking has become a standard type of problem in all buildings. The reason behind the cause of the crack in every component of building should be necessarily understood. Though the occurrence of crack in the building cannot be nullified but can be controlled and even prevented. Every individual has a wish for a house which is structurally sound and safe coupled with good aesthetics. This is becoming really hard nowadays. This research focuses on the development of an evaluation program for the identification of the crack causes which can be even used by a novice. The evaluation program consists of a separate user-form for all building components. The user-form has simple yes/no questions and photographs to help the user in answering the questions. Along with the causes, the Health Index was also evaluated.

Keywords: cracks; health index; user interface; forward chaining; concrete building.

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1 Introduction

Cracking is a common occurrence in the building, but sometimes it is misunderstood. When a house owner/asset manager notices a crack in the wall of the building, more so in a newly constructed building, conclude that there is something wrong in the building strength or safety. But it is not so (Thagunna, 2015). In ACI 302.1-04 (2004), it was addressed on cracking as

> "Even with the best floor designs and proper construction, it is unrealistic to expect crack-free and curl-free floors. Consequently, every owner should be advised by both designer and contractor that it is normal to expect some amount of cracking and curling on every project and that such occurrence doesn't necessarily reflect adversely on either the adequacy of the floor's design or quality of its construction".

The crack can be classified based on its activeness, time of occurrence, width and component in which it occurs. Here in this research, the cracks are classified based on the element in which it occurs (Jayaram, 2016).

The proposed program had a set of queries about the concerned problem and based on the response of the user; it provides appropriate advice based on the knowledge stored. The knowledge uses to make up for either rules or experience information about the behaviour of column that it of a particular subject domain. Such systems are designed for specific hardware and software configurations.

1.1 Roof slab crack

If there is a crack in roof slab, it will create a feeling of unsafe to the occupants. Some of the reasons for appearance of crack may be

- a particular area of slab subjected to high temperature and humidity difference
- improper placement of floor and roof slab joints
- poor construction practice during plastering
- foundation movement due to poor soil compaction/presence of reactive clay/water movement/flood.

Some of the configuration of cracks that occur in roof slab are spider web cracks, vertical cracks, bowed ceiling cracks and horizontal cracks (A Report, Gypsum Association, 2014).

1.2 Wall crack

It is a most commonly occurring crack in new and old buildings. They are mostly non-structural cracks, and they are due to poor construction practice. Some of the reasons for wall cracks are.

- roof slab deflection/movement
- temperature differences in some areas
- improper construction
- foundation settlement.

Wall cracks are categorised as horizontal, vertical and stair step. Horizontal cracks occur due to soil movement. Vertical cracks occur due to the settlement of foundation. Stair-step crack usually appears in masonry walls and foundation walls (Almherigh, 2014).

1.3 Column crack

Column crack is usually a structural crack. They are divided into horizontal, diagonal and bond cracks. The reason for crack occurrence are

- corrosion of reinforcement
- crushing of column due to increased load
- settlement of foundation below leading to 'hanging' of column causing a tensile horizontal crack (Nama et al., 2015).

1.4 Beam crack

Beam cracks are also structural cracks. The types of cracks occur in the beam are flexural, shear-flexural, torsional, bond slip, sliding. Usually, the crack occurs at the maximum moment area. These cracks appear as single/in groups (theconstructor.org). The main causes of cracks are

- corrosion/insufficient concrete cover
- increased flexural stress
- increased shear stress
- compressive failure
- sliding failure
- temperature variation.

2 Past research work

Van Balen (1996, 2001) developed a system for diagnosing damages in masonry due to air pollution and named it as masonry damage diagnostic system (MDDS). The limitation in MDDS is that it uses decision tables and not the production rules. The main advantages of MDDS are the possibility of online actualisation and the recommendation of further tests to improve the diagnosis.

Moodi and Knapton (2003) developed a system for repairing concrete structures and named it as repair of concrete (REPCON). REPCON aimed for offering a repairing solution for damages in concrete elements. The knowledge-base is structured in13 decision tables, and only one is dedicated to diagnosis. The main advantage is that REPCON can evolve with the knowledge of the users.

Zhao and Chen (2002) proposed diagnosis synthesis (DIASYN) for maintenance of the concrete bridge. Murlidharan et al. (1997) developed a system for evaluating damage to buildings from cyclones. Lu and Simmonds (1997) developed a system for diagnosing framed reinforced concrete structures. Anumba and Scout (2001) proposed subsidence case management system (SCAMS) for evaluation of pathologies due to soil settlement

3 Development of the program interface

The program provides communication with the system developer and the eventual user of the system. It also controls the dialogue with the user in a form consistent with the user's understanding of the task being dealt with. This may be an explanation module which provides the user with information about questions asked, and decisions made, by the inference engine.

This program interface identifies the cause of crack in building components. The data for crack causes are taken from codes and through internet. The coding has been done using visual basic in MS-Excel and its very user-friendly so that even a novice can use the program to detect the cause of crack. The interface performs a forward chaining to arrive at the inference.

3.1 Forward chaining

In a forward chaining strategy, the inference engine cycles through the rules testing the truth of each rule's' condition component against any existing information. It is known as the recognised act cycle. The existing information consists of data supplied by the user, data from an external devices and also information that has been inferred by the system during an earlier cycle of the inference engine. From those rules whose condition components are true the inference engine selects one rule to 'fire' a conflict resolution strategy (Ramsey et al., 1986).

3.2 Sample segments

To build and to program the interface knowledge net shown in Figure 1 is developed and used. Sample segments of inference engine are given below.

Sample 1

IF Crack appears along the edges of roof slab.

AND Settlement observed in the building.

AND Building age is more than 5 years.

AND Dampness or Peeling of paint occurred in the roof slab

THEN The crack may be due to loss of strength in foundation and water logging effect in roof slab.

Sample 2

IF there is inclined/diagonal crack in beam

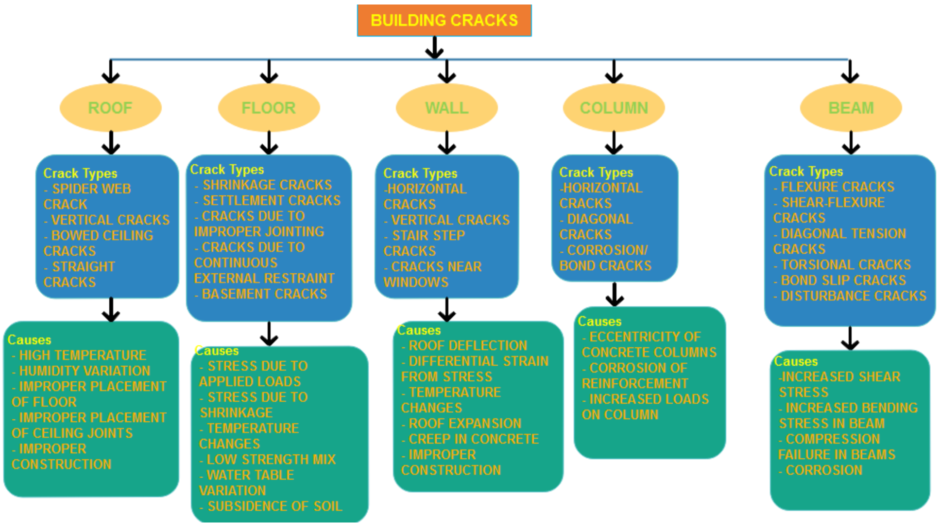
AND if they run from soffit to top of beam

AND if the crack have split ends

AND if the crack appears near support

THEN The crack may be due to combination of bending stress, compression failure and shear stress.

Figure 1 Knowledge net used for developing evaluation program interface (see online version for colours)



3.3 Health index

In addition to the cause of crack, the Health Index of the components is also calculated depending on the type of crack/damage occurring on the components. For calculating Health Index, each query posted in user-form are assigned with a particular importance factor (I). The answer Yes or No of each query is also assigned a rating factor (x). Once evaluation is completed the Health Index is evaluated as (Chen et al., 2016)

$$\text{HealthIndex HI} = \frac{\sum xI}{I} \tag{1}$$

4 Mechanism of the program

The program is query based which follows the If –then rules these rules are called as productive rules as they give a product/result at the end. In Figure 2 the basic structure of the program is mentioned clearly each black represents a separate user-form sheets in the program. In Figure 3 the working of the beam user-form is mentioned in the flowchart, this itself is the database for the beam user-form.

Figure 2 Flowchart describing the basic architecture of the program

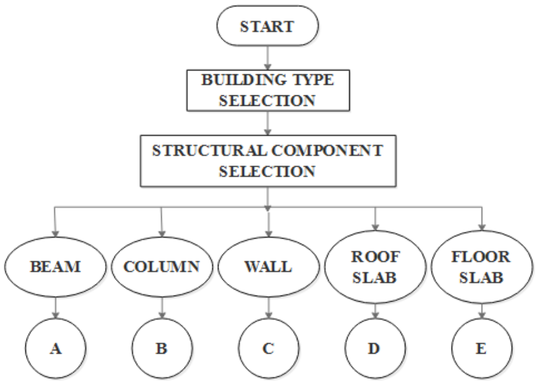
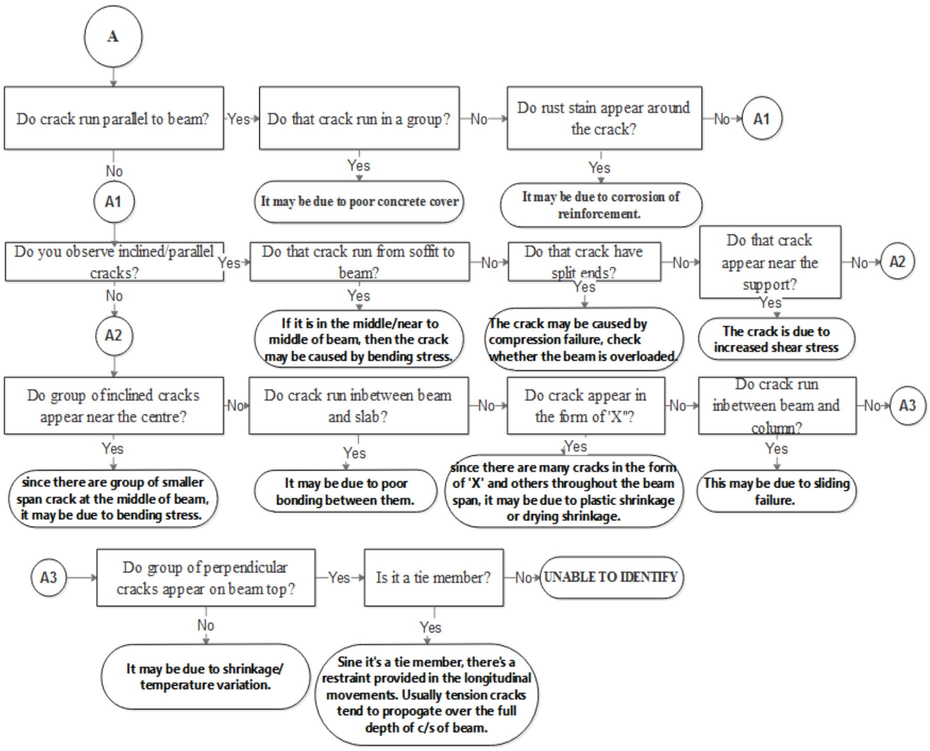


Figure 3 Mechanism of beam user-form



5 A session of building crack evaluation program

The program is a query session, it starts with the selection of masonry building/framed structure for the evaluation by the user, refer Figure 2. After selection of type of building the user is instructed to select the building component whose crack evaluation has to be done, see Figure 3. Then in the selected building component user-form the user are asked to answer the yes/no query format. To get better clarity of crack the user is provided with appropriate photographs for reference. Figures 4–9 shows typical query session for four building components with crack namely Roof slab, Beam, Column and Wall.

Figure 4 Screenshot of the program showing the selection of buildings (see online version for colours)

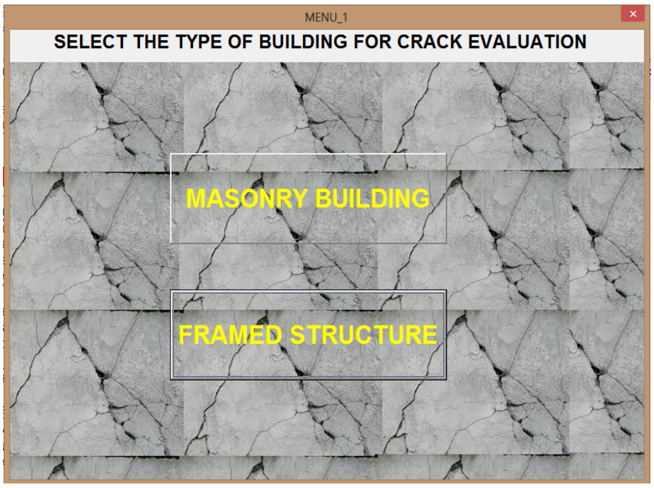


Figure 5 Screenshot of program showing components of framed building (see online version for colours)

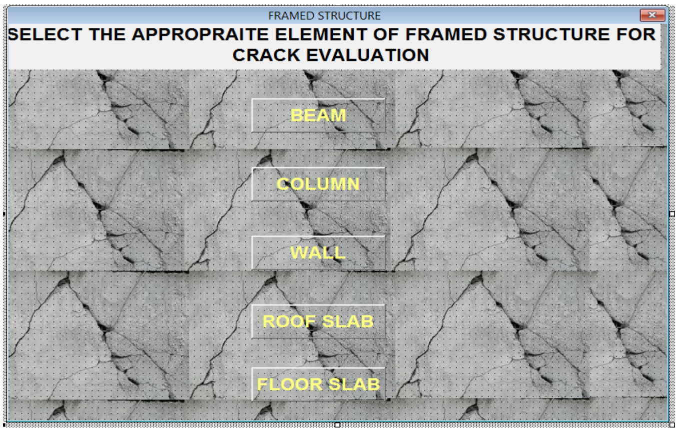


Figure 6 Screenshot of program showing roof slab user-form (see online version for colours)

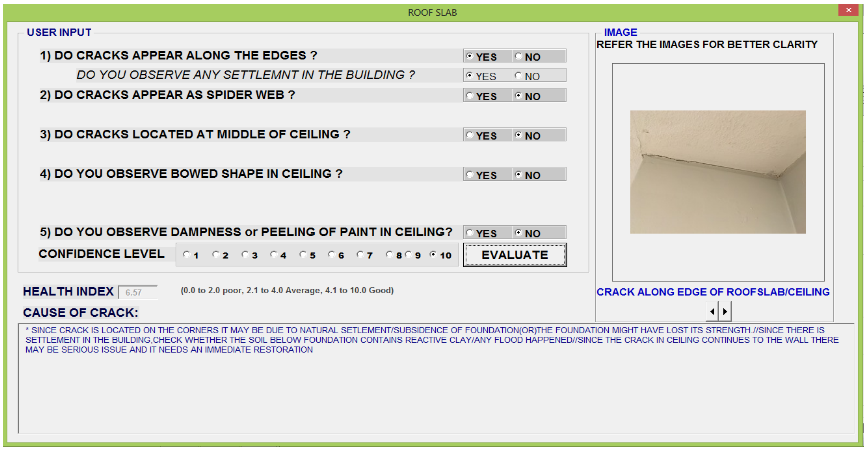


Figure 7 Screenshot of program showing beam user-form (see online version for colours)

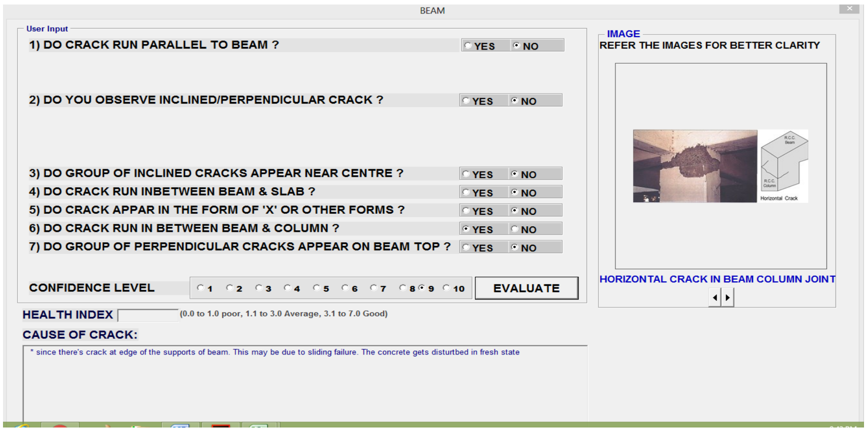


Figure 8 Screenshot of program showing wall user-form (see online version for colours)

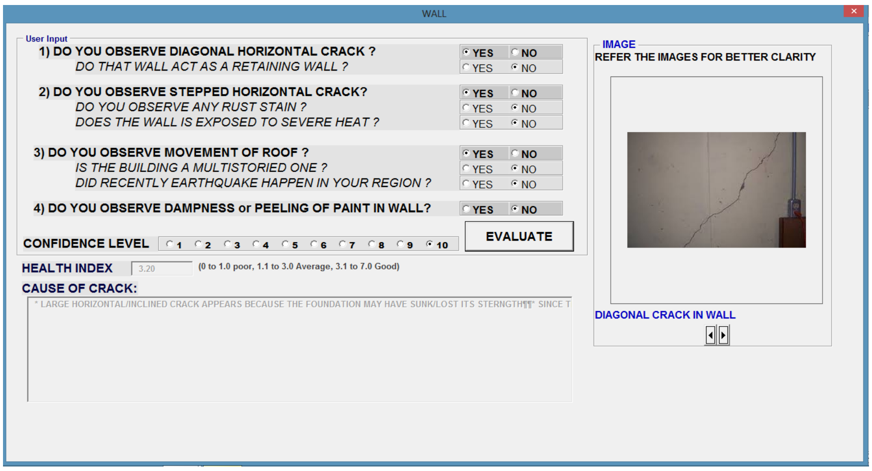
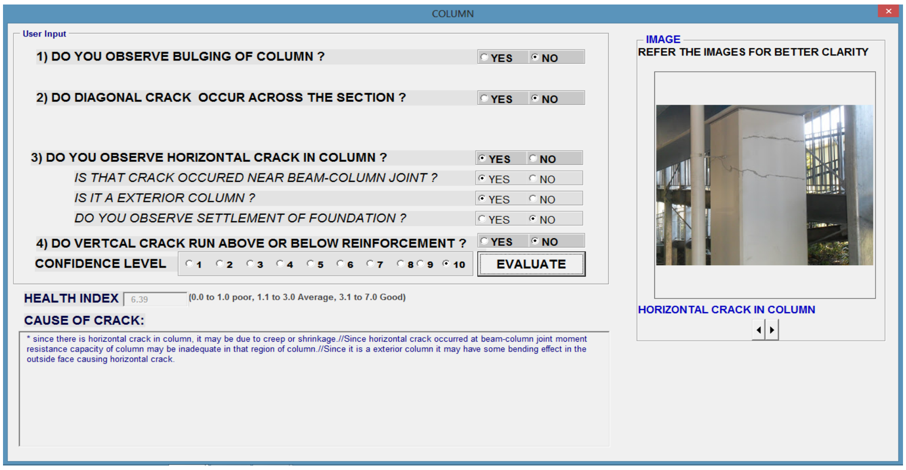


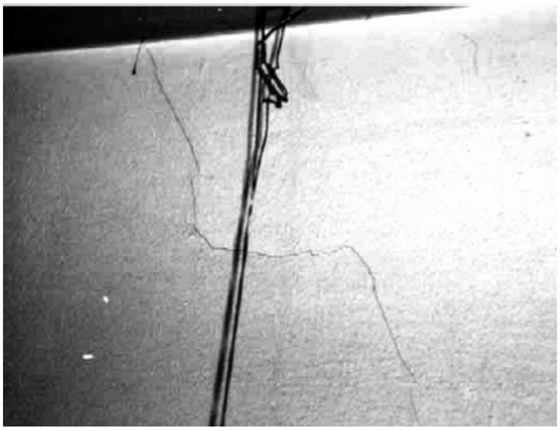
Figure 9 Screenshot of program showing column user-form (see online version for colours)



6 Result, discussion and comparison with similar expert system

The validation of the program is compared with the expert system developed by Ernest and Gil (2016), who developed an expert system for building condition assessment and named it as Doctor House (DH). In that literature work a framed reinforced concrete building that comprises four floors plus a basement level was investigated. The damage was observed in a secondary beam on the second floor and they have diagnosed that the crack have been caused by excessive shearing force. Figure 10 shows the picture of the crack diagnosed by the DH. The same damage is taken into account to prove the correctness of the proposed program.

Figure 10 A crack in the secondary beam of building



Source: Courtesy – Ernest and Gil (2016)

The diagnosis for the crack is summarised in Table 1. Once the problem is defined the building type was selected then structural element was selected (beam).

Table 1 Diagnosis summary for crack

S. No.	*Question*	*Answer*
1	Do crack run parallel to beam?$^{+}$	No
1A	Do that crack run in a group?$^{\#}$	Skipped*
1B	Do rust stain appear around the crack?$^{\#}$	Skipped*
2	Do you observe inclined/Perpendicular Cracks?$^{+}$	Yes
2A	Do cracks run from soffit to beam top?	Yes
2B	Do cracks have split ends?	No
2C	Do that crack appear near the support?	Yes
3	Do group of inclined cracks appear near centre?	No
4	Do crack run inbetween beam and slab?	No
5	Do crack appear in the form of 'X' or other form?	No
6	Do crack run inbetween beam and column?	No
7	Do group of perpendicular cracks appear on beam top?	No
7A	Is it a toe beam?	No

*The subset questions; $^{\#}$will be skipped if the main questions; $^{+}$are answered as 'No'.

Diagnosis: Since there are cracks perpendicular/inclined the crack may be due to bending/shear/compression stress. Since the crack traverse from soffit to beam top, check the location of the crack. If it is in the middle/near to middle of beam, then the crack may be caused by bending stress. Since the crack is at the supports, the crack is due to *shear stress*.

The diagnosis of crack by the program is similar to the diagnosis done by the expert system. DH proposed by Ernest and Gil (2016).

7 Conclusion

This paper presents the working of the evaluation program for diagnosing the cause of building cracks. Here the inference engine is developed using visual basic in MS-Excel. The evaluation program focuses only on the surface crack appearing on the super structure of the building. The system so developed was evaluated for its adoptability and correctness before a team of experts and it is found to be satisfactory. The program is validated by comparing it with the expert system, DH. However there is a scope for development of evaluation program for other areas like foundation cracks.

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