Indian Journal of Design Engineering (IJDE)
ISSN: 2582-8584 (Online), Volume-2 Issue-1, February 2022

Damage Assessment of Reinforced Concrete Structures: A Review

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Abstract: ***Damage may be assessed using several damage indices with values associated with different structural damage states. The usefulness of a variety of current response-based damage indices in seismic damage assessment is addressed and critically assessed. A novel rational damage assessment method is provided, which measures the structure's physical reaction characteristics. A practical method based on various analyses is given to evaluate the damaged structures in earthquakes of different intensities. This paper provides an overview of previous research works on the damage assessment of the reinforced concrete structures. This study may be helpful for easy understanding about the damage assessment of reinforced concrete structures and reduce the impacts of disaster and surrounding structures.***

Keywords: Damage Assessment, Damage Grade, Service Life, Reinforced Cement Concrete Structures.

I.INTRODUCTION

Damage assessment is the process of assessing the magnitude and scope of a disaster's loss, suffering, and damage to the community, whether natural, unintentional or inflicted by humans. Damage assessment is a critical technique for determining the magnitude of a disaster's effect, both retrospectively and prospectively. This lays the groundwork for catastrophe preparation and prevention in the future. Detecting and "evaluating possible future occurrences that may have a detrimental effect on people, property, and the environment deciding on the acceptability of the risk-based on a risk analysis while taking into account influencing variables." Following is some of the objectives and reasons for the need for damage assessment in the reinforced concrete structures. This paper mainly focused on damage assessment of the residential building.

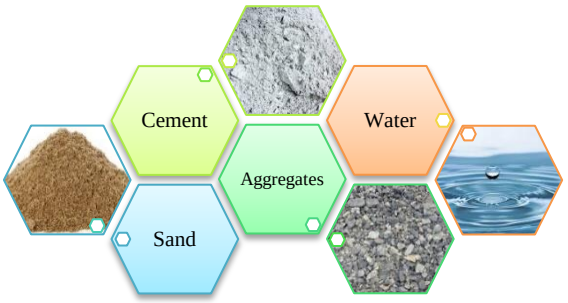

Fig.1 Materials

Manuscript received on 11 January 2022 | Revised Manuscript received on 29 January 2022 | Manuscript Accepted on 15 February 2022 | Manuscript published on 28 February 2022.
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In this mainly we used these materials for repair of the reinforced concrete structure. These are the global materials for the construction of reinforced concrete structures.

II. OBJECTIVES OF THE STUDY

Purpose of the Study

- Generally, damage assessment of structure is conducted on weaker structures. This study helps find the source of damages in reinforced concrete structures.
- In this generally, two types of investigations are there. One is rapid structural assessment, which involves less time for assessment of structure and the second one is regular assessment tests, which involves time taking procedure.
- Generally, rapid assessment tests are used for giving early conclusions to the damaged structures.

Procedure of Assessment

- First, check the entire outside of the reinforced concrete structure. Check whether any type of damages are present or not.
- Enter into the reinforced concrete structure, if the outside of the structure is safe.
- Check all the structural components in the reinforced concrete structure. Mark any damages in the structural parts, if any. Note down all the points in the documentation.
- Take photographs of damaged parts in the reinforced concrete structure, go to the laboratory, and conduct tests to identify the cause.
- After identification of all causes, the conclusion is given for reinforced concrete structure.
- If the client wants a stability certificate or certificate of occupancy, rapid structural assessment gives a quicker conclusion.

III. LITERATURE REVIEW

Author	Year	Research Findings
Yao, James TP.	**1980**	Following a hazardous event such as a strong-motion earthquake, structural engineers examine and inspect important structures regularly. Typically, such an examination yields a large amount of information. While it is relatively simple to comprehend various experimental and analytical procedures in the investigation of any given structure, for highly trained structural engineers, the complicated decision-making process that summarizes the numerous findings of such an inquiry into a concise concluding statement remains private and specialized information. As a result, an attempt is made in this research to look into the usage of fuzzy sets as an alternative, extra, or both approaches for assessing the damage state of existing structures. This suggested approach may be utilized to integrate the experience, intuition, and judgment of various specialists ready to share their essential expertise to advance the state-of-the-art in our field.
Chen, Chung.	**1996**	However, fibers are not required for the detection of fractures. Instead, the fibers act as a bridge between the fractures and as a conductor. All factors contribute to the increase in resistance. Damage assessment in real-time and dynamic load monitoring are two applications.
Johnny Vantomme	**2002**	Changes in structural system are used to identify damage has gotten a lot of press in recent years. This article provides experimental findings from constructing a health monitoring system on changes in dynamic features. Six meters in length of RC beams are exposed to progressive cracking in various stages as part of this study. According to the beam examined, Damaged components may be found in various positions. The damage evaluation entails determining the relationship between changes in the degree of fracture damage induced in the beams and its dynamic properties. According to this study, the accumulation of fractures in the beams seems to impact eigenfrequencies, and crack damage sites do not influence their evolutions; They become smaller as crack damage accumulates. Crack damage has a lower impact on the MAC factors than the eigenfrequencies, but they indicate whether the generated fracture damage is symmetrical or asymmetrical.
Koen	**2000**	EMA is performed at various degrees of damage, assuming that the structure would react linearly. According to the analysis in terms of modal curvatures, the bending stiffness of the beam is gradually reduced along the beam. As damage accumulates, the linear dynamic behaviour shows a strong amplitude dependency. The damage is used to calculate the nonlinearity. We examine and contrast the outcomes of linear and non-linear methods.
Pritam	**2020**	The multi-objective seismic damage assessment method was explored in this article, according to IS-1893-2016 (0.36 g). The Park–Ang technique was used to calculate three-dimensional DI for a four-story structure. However, As the number of stories grows. A more straightforward approach for estimating the global damage index (GDI) of structures has been suggested to minimize the complication. A four-story residential structure with plan aspect ratios of 0.5, 0.75, and 1 was studied for this purpose. The most significant factors were integrated into this research to evaluate buildings' GDI directly. According to this research, for a four-story structure. This research discovered that the bottom level suffers the most damage, while the top floor suffers minor damage in all instances. The suggested method efficiently calculates a reliable GDI that can evaluate building damage on a small to big scale.
Yi Kwei Wen	**1985**	The author proposes a technique for inspecting reinforced concrete structures for structural damage. SDF systems and typical MDF reinforced concrete structures were subjected to extensive damage investigation. Based on these findings, a direct connection is established between the destructiveness of ground movements, as measured by the "characteristic intensity," and structural damage, as measured by the "damage index." Furthermore, the suggested damage metric was calibrated using reinforced concrete structures damaged during previous earthquakes; on this basis, realistic structural damage limitations were established.
Park, Young-Ji	**1984**	The author proposes a model for determining structural damage in reinforced concrete buildings exposed to earthquakes. The maximal deformation plus the impact of repeated cyclic loadings is combined to produce damage. The statistics of the relevant parameters of the proposed model were assessed using available static (monotonic) and dynamic (cyclic) test data. As a result, a non-linear random vibration approach for collecting the response data needed for damage evaluation was devised. An intensity scale was developed to characterize the potential destructiveness of ground motion based on a thorough damage study of different reinforced concrete structures. It's a direct relationship between RMS acceleration and strong-motion duration. The suggested damage model is based on previous earthquake-related building damage. A design process is created on this foundation to keep the risk of structural damage to a minimum.
Arjun Sil	**2019**	In performance-based seismic design (PBSD), structural damage may be managed depending on the requirements for a given hazard level. Buildings subjected to significant ground motion (GM) incur moderate to severe damage, Depending on the GM's intensity. Damage assessment techniques are complex, time-consuming, and time-consuming processes that are now available. This study developed a simple empirical model that was used to compute the GDI in a single step. The proposed method produces GDI results that are similar to those of the Park-Ang model. Furthermore, a link between ground storey DI and global DI has been established. The suggested approach successfully reliable DI and may estimate seismic damage in buildings, particularly large ones.
Storer J.	**1996**	The purpose of this article is to propose a paradigm for assessing building damage caused by differential ground movement. Twenty case histories are investigated, yielding 43 special assessments using the techniques outlined in this article, and the findings compare well with real damage observations.

Fig.4 Shear Crack

We can observe that some of the walls are subjected to stains in the reinforced concrete structure. The types of stains are in green and light brown colour.

Fig.5 Stains in Structure

We can observe that some other structural elements are subjected to the hair line cracks and green colour stains in the reinforced concrete structure. In the below figure, we can see the hairline cracks and stains in the reinforced concrete structure. The number of hairline cracks is more, and stains are more in reinforced concrete structure structural elements.

Fig.6 Stains and Hairline Cracks

These types of cracks are similar to the above type of cracks. The following figure shows that the number of cracks is more, and all cracks are very small and hairline cracks in the structural elements of the reinforced concrete structure.

Fig.7 Cracks in structural elements

We can observe that some diagonal cracks are present in room number 3. Generally, these types of cracks are diagonal. In the figure below, the structural element of reinforced concrete structure is subjected to a combination of diagonal cracks and inclined cracks.

Fig.8 Diagonal Cracks

These are some types of cracks in the masonry structure. This type of crack can be observed in the steps. We can observe that the crack pattern and some interior parts are exposed due to damage to the exterior part. This is one irregular pattern of the crack in the structure.

Fig.9 Masonry Cracks

We can observe that some potholes are present in the verandah. These types of holes are generally seen on the outside of structures. This may cause leads to the occurrence of a small number of cracks and extension of cracks in the structure.

Retrieval Number:100.1/ijde.B8004081221
DOI: 10.54105/ijde.B8004.021322
Journal Website: www.ijde.latticescipub.com

Published By:
Lattice Science Publication (LSP)

Fig.10 Pot Holes in Floor

In this, we can observe that several small holes are present in the structure. We can observe that stains are also present in this structure.

Fig.11 Small Holes in Wall

In this, we can observe that vertical cracks in room number four of the reinforced concrete structure. This type of crack is generally seen in the combination of structures. That means the construction of new structures with the old structure. So the damages in the old structure will reflect on the new structure. We can observe that in the below figure combination of the new and old structures.

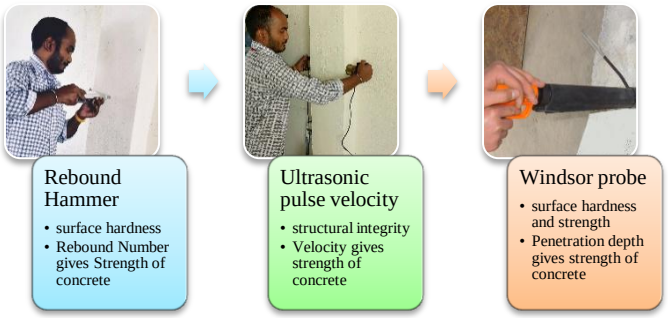
Fig.12 Crack on Joints

We can observe that some of the cracks are nearly vertical in room number four. This type of crack is due to the effect of flexure in the reinforced concrete structure.

Fig.13 Crack on Structure

V. TESTS & RESULTS

In this, we can conduct three important tests Non-destructive tests. In which we conducted these tests on hardened concrete. We have followed the testing procedure as per the Indian standard code.

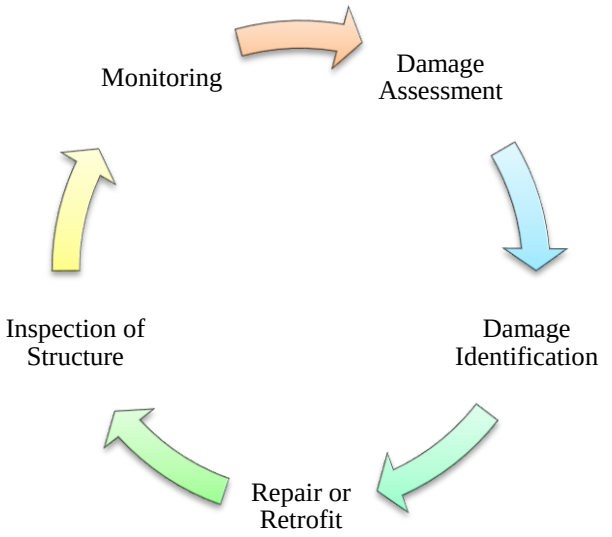


Specification	Specification No.	Required readings
Indian Standard	IS: 13311 (Part 2): 1992	6
British Standard	BS: 4408; Part 4: 1971	9
ASTM	C805	10
CPWD	CPWD - 2002	12

Table. Recommended Solutions

Room No.	*Crack Type*	*Reason*	*Solution*
1	Flexure	Overloading, Bending moment, Moving loads.	Increase Compressive Strength of concrete, Providing Steel bars, Proper Detailing.
2	Shear	Shear forces, Detailing Issues, Issues in Placement of Bars in Compressive Zone.	Proper Shear reinforcement, Proper Detailing.
3	Diagonal	Combination of loading, Shrinkage,Settlement.	Proper Mix Design, Water cement ratio.
4	Joint	Bonding Issues	Bonding Agents, Grouting, Shotcrete, Sealants.
Exterior Parts of Structure	Stains	Discolouration, Effect of $CaCl_2$, Chemical Reaction.	Avoid $CaCl_2$, Surface paints, Use of Pressure washers.
	Holes and Potholes	Cyclic loading, Wear and Tear	Use of Sealants, Bonding material.
	Hairline	Leakages, Water cement ratio, Poor Mix.	Grouting, Sealers, Bonding Agents.

Role Of Engineer



As a Structural Engineer or Consultant Engineer, first, you have to investigate the reinforced concrete structure. The primary investigation is to conducting rapid assessment tests on the reinforced concrete structure. The rapid assessment test consists of testing all the exterior parts of the reinforced concrete structure. And analyze the situation whether it is safe or not to enter into the reinforced concrete structures. If the structure is safe, then only enter into the reinforced concrete structure. After that, see any damages are present in the inside parts in the members of concrete. Notice if any damages are present and write them down in documentation. If any severe damages are present, try to stick signs in that part and make a note on Dangerous or Don't Come or Hazardous like, etc. use special paints on the damaged parts and highlight it and note down in the documentation. If any additional damages are present, take a photo with the camera and examine that after going to the laboratory. After the final review of the reinforced concrete structure, only give the right conclusion for the reinforced concrete structures.

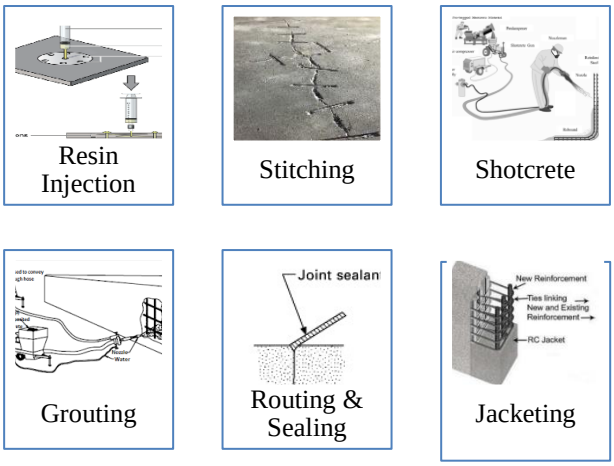


Fig.14 Recommended Methods for Strengthening

VI. CONCLUSION

After studying various research papers on the considerations of damage assessment for reinforced concrete structures, the primary conclusion of this paper is necessary, which are very helpful in finding the cause of damage and the extent of the damage in the RC structures. One of the essential things is to increase the service life of the RC structures by using various suitable repair and retrofitting techniques. Which are plays a good role in the strengthening of the reinforced concrete structures.

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AUTHOR'S PROFILE

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