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Structural Integrity and Safety of Building: A Review

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Abstract
Understanding the integrity of critical structures has been a driving force for the development of engineering analysis methods since Galileo, in the seventeenth century, investigated the resistance of a beam subject to bending loads. Construction, process, power generation, manufacturing and transport industries need to be able to assure the safe and economies operation of their plant by relying on the integrity of appropriate structures and components. The design engineer assists in the creation of a structure or component by using analytical tools and supporting data most appropriate for the application. By comparison, the operator of the plant has to ensure that, throughout the service life, it is secure against the design intent. Both offer challenges with respect to the structural integrity diagnosis and assessment which forms an essential input to providing the necessary assurance of safe and reliable operation. In general failure of structures or components can have profound commercial and financial implications. However, there are areas where failures are completely unacceptable due to the impact on the environment and society. Those industries where this is particularly relevant are nuclear, chemical and transportation. To specify and formulate the overall strategy for safe, reliable and economic operation requires a comprehensive understanding of the capability of the plant to meet the required duty based upon a structural integrity assessment. In this overview, we consider what assessment methods designers and assessors require, the tools available and the needs of specific industries. Recent and future developments are discussed briefly.

Keywords: Structural Integrity Assessment, Service Safety Structures, Maintenance Repair Failure

I. INTRODUCTION

The city infrastructures of transportations network, systemized communication system, well channelized water supply, uninterrupted electrical power supply, employment opportunities, health care facilities and education systems are providing the higher quality of life to city people. The Mall building concept is also incorporated to city infrastructures. These buildings are offering the quality house hold materials to city people. These buildings are providing variety of shops, indoor entertainment facilities, relaxations facilities, multi cuisine facilities, product launches, promotions, festivals and multi-level parking facilities within the building premises. These facilities are attracting the younger generation in a grater way. They are using these buildings for their formal discussion and gathering. The easy accessibility of these buildings, internal air conditioning comfort and escalator facilities makes the people to spend their quantity time inside.

In weekends and all festival times these buildings are used as public gathering entertainment buildings by all age group of people. Hence Life safety has become as paramount importance in these buildings.

These multi vibrant activities, the multi storied height and the fixed glass construction for façade treatment of these buildings are required safety and security inside. It is the duty, responsibility of the architects and the construction industry professionals to assure fire safety and life safety to these buildings.

The background study was carried out from numerical dataand fire affected buildings.**Numerical Data Study**: The nineteen years (From 2001 to2018) fire accidents, property loss and lives loss numerical data werecollected and displayed in a table. From the display the highest valuesand minimum values were identified. The total values, average valueswere calculated. The Graphs were prepared. The table display and theGraphs details are as follows: **(Data Source: Tamil Nadu Fire cum RescueDepartment**)

Table 1.1 Fire Accidents Numerical Data Analysis (periodFrom 2000 TO 2018)

Year	**Number of fire Accidents**	**Property loss in Crores**	**Human loss in numbers**
2000	16987	13.64	47
2001	17697	15.79	112
2002	18264	14.10	79
2003	16109	24.57	89
2004	16136	13.07 **Minimum value**	**249 Highest value**
2005	15093 **Minimum value**	14.20	99
2006	17442	27.74	65
2007	21224	26.87	72
2008	17433	53.17	69
2009	21840	53.17	127
2010	18311	24.60	75
2011	22273	27.59	84
2012	32,273 Highest Value	27.02	87
2013	25109	42.55	75
2014	24398	46.13	70

2015	19866	22.47	38
2016	25897	43.04	72
2017	21047	97.87 Highest Value	67
2018	22601	58.83	36 Minimum Value
Total Values	3,90,000	646.42	1612
Average Values	20,526.32	34.02	84.84

II. SIGNIFICANCE OF STRUCTURAL INTEGRITY ASSESSMENT

A historical preview of the development of engineering structures can help to get an impression on the significance of structural integrity assessment. For a long time objects are constructed regardless of operation life, in accordance with available knowledge, materials and experience. When more complex and sophisticated structures had been designed, following more and more strict requirements and applying materials of improved properties, using more improved technology, the failures became more and more important and solutions for extended operability were necessary. However, fast unpredictable progress in science and technology offers non-expectable capabilities in design and manufacture, but also, when required, new procedures on how to treat structural integrity and life. It is to underline that this development has involved new serious problems, closely connected with environmental protection, from two essential reasons. The first is environ-mental pollution through the operation of industrial plants and all participating sectors in human community, like traffic. The second one is related to failures of pressurised equipment, often with catastrophic consequences. It became clear that knowledge and experience in the time of design and manufacture of machines and equipment were insuffi-cient to satisfy all needs. The development of materials was behind the design requirements in many senses. The experi-ence how to use new products in an economic, safe and reliable way was poor. One may claim that in spite of the huge progress of engineering, the situation is still similar to that from the early beginning of industrialisation, because each new development opened new problems, which could not be understood due to lack of knowledge. In this way a specific spiral in competition of knowledge and imagined design is created. Available knowledge enables realisation of colossal objects as huge buildings, large ships, airplanes of unbelievable size, thousands kilometres of long pipelines, and on the opposite size scale, microprocessors, nanostruc-tures and related products, still under intensive develop-ment. But it is likely that there are no limits in knowledge and development. Although there is no end in the size of super large and super small products, on either side the necessary knowledge and skill must be under steady progress. Structural integrity is a common denominator for both classes, large and nano structures.

Examples of objects with global structural integrity saved for centuries have shown that small deterioration could be neglected or repaired. Also these objects can be restored in a convenient way or even redesigned if required, not affecting global structural integrity.

Several failure examples from service are presented and fracture as crack propagation is discussed, based on fracture mechanics approach. Developed procedures for structural integrity assessment in presented cases are capable to predict crack initiation and behaviour during fracture, e.g. to evaluate the reliability of the structure under the applied load in a different environment. This evaluation is based on a conservative model, convenient to cover possible uncer-tainties of different nature, but also to cover critical unex-pected events. Case studies of experienced failures had to be followed by experimental tests, theoretical and numeri-cal analysis. Sometimes previously unknown material prop-erties /2/ and structures had to be additionally included in the analysis, and the structure had to be re-designed in order to improve its functionality, reliability and safety in service.

The significance of welded joints for the integrity assess-ment of structures is that they present the critical location. The shape of welding joint represents the source of stress concentration. And this is not the end with problems induced in welded joints. Different types of cracks can be formed in the welding procedure (crystallization, cold or reheating cracks, lamellar tearing). Additional problems are cracks that are not detected in inspection, and after some operating time they can initiate and grow by different mechanisms (corrosion, creep, fatigue, stress corrosion).

III. PROGRAMS FOR STRUCTURAL INTEGRITY ASSESS-MENT

More detailed structural integrity assessment is enabled after a developed theoretical background. It is recognised that the crack, the most dangerous defect in a structure, can be an initiation of fracture and for the integrity assessment of cracked component, the formulation and determination of crack parameters is a pre-requisite. Anyhow, significant efforts had been involved to describe the crack behaviour in a loaded structure.

Several programs for structural integrity assessment are developed and practically accepted. Probably more extended is the European procedure SINTAP (Structural INTegrity Assessment Procedure for European Industry), /50/. The project SINTAP included the experience of practical direc-tives for use, explained in PD 6493:1991 (replaced by BS 7910:2005: Guide on methods for assessing the acceptabil-ity of flaws in metallic structures), as a simplified treatment of use of fracture mechanics methods to establish accep-tance levels based on fitness for purpose, on fracture mechanics analyses and experience with cracks in welded structure. It offers varying levels of complexity in order to allow maximum flexibility gained from the application of existing procedures and has comprised activities such as collation of published information, assessment of material behaviour, optimisation of industrial procedures and the derivation of methods for treating assessment methodolo-gies, all with specified limits for application.

Structural integrity assessment is of special importance in component operation when decisions depend on whether a damaged component should be used, and if so, under which conditions. The decision for further use is reached as based on state evaluation and the adopted term is “Fitness-For-Purpose” (FFP). Two effects are significant in FFP assessments. The first is the choice of an applicable proce-dure for defect awareness and integrity assessment of a damaged structure. The other is in determining defect type, its size and location within the structure. Accuracy of fitness assessment depends on the exactness of defect data. This is why methods for detecting defects and their charac-terization are intensively developed with the idea of effi-cient tracking of detected flaws in service.

Stress and strain analyses stipulates knowledge of loading and its accurately defined characteristics and operating conditions, also taking into account impacts of the operat-ing environment. Having in mind the

problem nature, development of probability methods, their excellent knowl-edge and conditions of use are relevant for efficient FFP assessments. All of these details are a prerequisite for the use of developed procedures for determining the signifi-cance of damage. This relates to corrosion damage assess-ment procedures, material fatigue, fracture appearance and development, and to high temperature influence and creep. A considerable part of these procedures is included in SINTAP at a practical level.
A request for data on defects needs to be added to all of this that should be accurate with a description of character-istics, sizes and defect locations.
Just to mention some other programs: R5; R6; API 579; API 1104. The selection of an appropriate procedure depends on the mode of failure (fracture, fatigue, creep or corro-sion), type of component, service temperature and user's experience. Some of the above procedures are specific to a certain industry, such as R54 or R65, developed for the nuclear industry, whereas others such as BS 7910 have more general applications. Most interesting programs are for mechanical and civil engineering, related to the built environment (as bridges, foundations, offshore structures, pipelines, power stations, process plants, boilers and pres-sure vessels, water and wastewater infrastructure) and the variety of mechanical (moveable) structures (airframes and fuselages, coachworks and carriages, cranes, elevators, excavators, marine vessels, and hulls). The design of static structures assumes they always have the same geometry (in fact, so-called static structures can move significantly, and structural engineering design must take this into account), but the design of moveable or moving structures must account for fatigue, variation in the method in which the load is resisted and significant deflections in structures.

IV. APPLICATION OF INFORMATION TECHNOLOGY STANDARDS IN STRUCTURAL INTEGRITY OF BUILDINGS

Important aspects of modelling are already introduced in standards, /53, 54, 55/. Precise determination of causes for potential failure and the assessment of structural life in civil engineering requires documented history with detailed building data. The needed documentation is diverse and consists of many paper or electronic documents included in the history during phases of conceiving, design, construction, exploitation, maintenance and restoration. Building records and surveys showed that almost 80% of failures that critically affect the lifecycle come from misconceptions in con-ceiving and design. The remainder results from errors in production and maintenance.

Object oriented modelling enables rapid and reliable development of complex systems for Building Information Model (BIM), (Fig. 36). It is standard in the software indus-try, for modelling all pursuits of information technologies in all branches of human life, /54, 55/. The basis of the electronic building model development interoperability are data models as the extensible markup language (XML) and Industry Foundation Classes (IFC). Similarly, the IFC Bridge model is intended to manage the entire lifecycle of the bridge construction. BIM improves building planning, design, construction, operation, and maintenance by enabling all participants in the process to exchange and share building information using a same standardized data model. The benefits are:

- reduced loss of information during data ownership take-over from the various disciplines involved in the process;
- reduced errors because data are entered only once, after-ward used and modified by all participants in the process;
- Early conflict detection among building elements or functions which reduces all costs.

V. Conclusion

Although structural integrity assessment is well defined, accepted and adopted for practical application, there are still regions in which its application is questionable due to shortage in knowledge and experience. Hence, the problem of structural integrity needs to be opened in order to follow further developments in science and engineering.This research finding reveals the passive measures condition of mall buildings in the study area. These buildings are existing with adequate measures and inadequate measures (not existing measures).

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