Building collapses and remedies

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The spate of building collapses, in the past couple of years has put question marks on the engineering practices followed in the construction of buildings. It has eroded the confidence of the common man in the engineers responsible for their construction and certainly blotted their professional reputation. "The entire system is at fault" say a lot of people. What ails the system ? Are there no solutions ? Who will take the initiative. Questions come unabated. The author, a structural engineer himself, answers a few of these. There will assuredly be a number of differing views, which is what he hopes to achieve in a broader sense — stimulate thought. For, we are all in need of a concrete solution. Now !

There have been quite a few building collapses in Mumbai, Calcutta and other metropolitan cities in the recent years resulting in loss of several human lives. These tragic incidents have severely shaken the confidence of the general public about the safety and stability of buildings, particularly of those constructed in the last twenty years or so. The professionals involved in building construction, viz. architects, structural engineers and builders, are under severe scrutiny about their roles and responsibilities in these collapses, and are being seen in poor light at present. The municipal authorities, who give approval for construction of these buildings and also monitor their safety later on, have also come under criticism about their role in these events.

Two collapsed structures are mainly reinforced concrete framed buildings used for residential and commercial purposes, developed mainly in the private sector. The aim of this article is to find the causes of these collapses in the present construction scenario, and look for remedial measures which could reduce such occurrences in future.

Stability concept

Before we discuss on the subject of collapse, it is necessary to understand the concept of stability. Stability of buildings is a fundamental engineering concept, which is rather loosely defined many a time. A stable structure can be broadly defined as one which will not cause disproportionately large displacements, deflections or stresses which would result in overall or local collapse. In order to measure the stability of a building, one must take into account the geometry and materials of the structure, subsoil, environmental effects, and consider the effect of various loads acting on them which include besides self weight, imposed vertical loads, wind loads, seismic loads, vibratory loads, explosions and impact. It is necessary to distinguish between overall instability and local instability, and draw attention to the conditions that lead to such instability.

Overall instability

It entails the complete failure and collapse of the whole of the building. These failures may arise out of:

(i) the omission or failure of a shear wall at a vital section resulting in a side-sway failure.

(ii) the local failure or dislodgement of one structural member leading to failure of the successively adjacent members and a progressive collapse of the structure.

(iii) weakness of the joints between members of self-contained unbraced frame causing frame instability and possible overall collapse. In load-bearing wall and precast-concrete construction without bracings, a similar phenomenon is sometimes referred to as a "pack-of-cards" collapse.

(iv) overstressing of the subsoil due to inadequate anchorage of the structure to the foundation leading to overturning failure.

Local instability

Local instability or failure of a component of the building does not usually lead to the complete collapse of a section of the building unless the effect is cumulative or the resultant change in the geometry of the framework is highly unfavourable. The most common local failures are:

(i) overstressing of members or components due to eccentric loading.

(ii) shear failure in concrete.

(iii) local defects or workmanship or material in isolated components of the structure.

(iv) long-term failure of a structural member caused by exposure to harmful environment, corrosion of reinforcement, sulphate attack, etc.

(v) large deflection of a suspended floor slab, particularly one which is flexible enough to vibrate in service, causing unease and discomfort to the user.

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(vi) movements such as settlement of supports, expansion and contraction of structural members and building components.

Common causes of collapse

Often, it is a combination of the instability conditions mentioned above apart from mistakes, oversights, misunderstandings, ignorance, and incompetence that can cause the collapse. The main headings under which the failures occur are:

(i) Improper and inadequate design.

(ii) Improper and inadequate detailing.

It has been customary in Mumbai to submit typical design calculations of one slab, one beam, one column and one footing to municipal authorities, irrespective of the height of the building. The design of other components and the structure as a whole, is generally not insisted upon, whether it is a two storey building or a twenty storey building. Finally what matters for the authorities is a completion certificate from the structural engineer for the building stability.

(iii) Poor materials and poor workmanship.

(iv) Improper design and inadequate bracings of temporary works.

(v) Subsidence of foundation.

(vi) Unauthorised structural alterations and abuse of the original design.

(vii) Lack of maintenance of building.

Before the actual collapse takes place, reinforced concrete buildings normally exhibit signs of distress such as cracking and spalling of concrete, corrosion of reinforcement, large deflections, movement of joints and foundation, etc. giving enough warning for a long time. Even the shear and compression failures which appear to be sudden, show these symptoms. If the appropriate structural repair is not undertaken in time, failure is inevitable.

Present construction scenario

In the present national scenario, construction of residential and commercial buildings in the private sector starts with a developer. If the developer is not a builder, he generally engages the services of small-size piece-work contractors for carrying out different works that constitute the building construction activity. The developer engages the services of an architect for getting approval of layout drawings from municipal authorities, and the services of a structural engineer for reinforced concrete designs and drawings, directly or through the architect. The architect and structural engineer are always in an ever-pressing demand for elegant low-cost solutions within a pricing system, due to which the quality of construction becomes secondary at many times. Under these conditions, the structural members designed, using usually the minimum grade of M15 concrete, are to be very thin and slender, and the reinforcement quantity has to be as minimum as possible. For commercial viability, the developer knows by a thumb-rule how much quantity of concrete and reinforcement is required per square metre of building floor area.

The municipal authorities who give approval of drawings look into the aspects of clear space around, floor space index, minimum floor heights, lifts and staircases, fire safety, etc. as per the municipal regulations but the structural design aspects are not thoroughly looked into. It has been customary in Mumbai to submit typical design calculations of one slab, one beam, one column and one footing to municipal authorities, irrespective of the height of the building: The design of other components and the structure as a whole, is generally not insisted upon, whether it is a two storey building or a twenty storey building. Finally what matters for the authorities is a completion certificate from the structural engineer for the building stability. Similarly, for the past few years, a certificate from a licensed construction supervisor is taken by the municipal authorities to ensure quality construction. It should be mentioned at this juncture that both the structural engineer and the licensed construction supervisor are appointed and paid for by the developer only, and they are doing evaluations of their own work while giving the certificates.

Reinforcement detailing

Regarding the reinforcement details in the drawings for the building, the common practice amongst many structural engineers, is to prepare the drawings in a schedule table giving details of top and bottom bars and spacing of stirrups, etc. without showing reinforcement details in plan or elevation and sections of the structural members. The dangers of this method are that, firstly, many site engineers and steel bar benders or fixers do not know much about design aspects of the building. Secondly, the time normally devoted by a structural engineer when he visits the site to check the reinforcement that is placed, just before placing the concrete, is not sufficient to do justice to the checking work. It is not done in a systematic manner, which may lead to inadequate bar anchorages at supports, under reinforcement at places, curtailment and lapping of bars at wrong locations, etc. This method of detailing falls very much short of the standard method of detailing of reinforced concrete members as required by our own code IS:456 and other international codes.

Third party audit

It must be mentioned that if the design and construction are carried out as per the relevant Indian codes of practice, much of the above failures would not occur in reality. The main problem in the present scenario is that all aspects of the building work are carried out by people connected with or engaged by one group, that is, the builder, without having any third party check or technical audit done on the work by another agency to safeguard the interests of the society. The other serious problem that is rampant among building owners is the construction of unauthorised floors and extensions, and illegal alterations within the building, without consulting a structural engineer. If concerned authorities do not solve these problems, building collapses will continue unabated much against our wish.

It needs to be mentioned that the general public does not know the role of structural engineers in the building work. Often, advertisements are given in the newspapers seeking the services of an architect for structural repairs of buildings. Such repairs require the services of a structural engineer more than that of an architect and also of a competent contractor experienced in using special materials and techniques required for the work. Unless the municipal

authorities make it mandatory to engage structural engineers for such repair works, the present system will continue.

Remedies against collapses

The following measures can be exercised by the municipal authorities on the construction of all residential and commercial buildings of five storeys and above in the private sector to safeguard against collapses. This procedure is commonly adopted by many government and semi-government agencies for the construction of important infrastructure works, which show least casualties and collapses on record.

1 There should be a registration system with the municipal authorities for the developer and builders who must be qualified engineers or engage qualified engineers on his pay-roll. This procedure will reduce the risk of unqualified contractors doing the building work.

2 The design of the building prepared by the structural engineer appointed by the developer/builder must be proof-checked by another structural engineer appointed by the municipal authorities. As most authorities do not have sufficient staff to do the proof-checking, external structural consultants will have to be engaged for this work, as is commonly done in UK and Germany. The minimum experience of structural engineers for all the above works could be 10 years. The above procedure will reduce the risk of failures due to improper structural design.

3 Similarly, there must be separate site supervision of reinforced concrete work of the building from an external licensed supervising engineer appointed by the municipal authorities for checking quality of concrete work, placing of reinforcement, etc. The minimum experience for licensed supervising engineers could also be 10 years.

4 An expert committee could be appointed to evolve guidelines and norms to be followed by the licensed supervising engineer.

5 The cost of services rendered by the proof-checking structural engineer and the licensed supervising engineer who are appointed by the municipal authorities could be borne by the developer/builder. As this additional cost will only be a small percentage of the total cost of the building, this needs to be accepted in all fairness by those concerned.

6 The engineer-in-charge/municipal authorities must not accept reinforcement detailing drawings prepared with the present system of schedule table form. Detail drawings of various structural members as per international practices, with bar bending schedule, must be insisted upon while approving the design and drawings. A format can be evolved showing typical details for the preparation of drawings. This procedure will reduce the risk of failures due to improper detailing.

7 Soil investigation report of the site must be made mandatory which must be prepared by a recognised institute/firm/laboratory. This procedure will reduce the risk due to foundation failures.

8 It must be made mandatory that a copy of the final design calculations and all detail as-built drawings should be given to the owner or co-operative society of the building for their record and future reference, in case any structural repair or alterations are needed. It is found in practice that in majority of cases, the above details are not available from any source when it is badly required. The best people to have such a record are the owner or the co-operative society of the building.

9 For carrying out any structural alteration or structural repair work to the existing building, it must be made compulsory to engage the services of a licensed structural engineer by the owner or co-operative society of the building. For addition of new floors to the existing building, the same procedure as adopted for a new construction must be followed in regard to approval of design, drawings and supervision of work as mentioned above.

10 For buildings which are showing signs of deterioration, a "health check" should immediately be undertaken. Quite a few non-destructive techniques such as impact hammer technique, ultrasonic pulse velocity, core testing, corrosion assessing techniques, etc. are today available and a few experienced agencies/organisations are undertaking such jobs. Such agencies/organisations, which need to work in close association with structural engineers, should be engaged for the "health check" jobs.

The main problem in the present scenario is that all aspects of the building work are carried out by people connected with or engaged by one group, that is, the builder, without having any third party check or technical audit done on the work by another agency to safeguard the interests of the society. The other serious problem that is rampant among building owners is the construction of unauthorised floors and extensions, and illegal alterations within the building, without consulting a structural engineer.

The above point of view endeavours to draw attention to the major factors that cause collapse of the buildings. It is hoped that this paper will stimulate thought on how the remedies suggested can be put into practice and solve the serious problem concerning structural safety of our buildings.

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