Discussion Forum

Partial collapse of a multi-storeyed concrete structure

I have carefully gone through the paper by D.S. Prakash Rao and K. Sridevi, published in the January 2005 issue of ICJ, Vol. 79, No. 1, pp. 40-46. Both the authors deserve high appreciation for a worthwhile paper. After a long time, collapse of a structure has been discussed and analysed. Such information provides much more educative value in understanding engineering and materials than any other method of education. Such papers need to be read again and again so that sufficient understanding about the subject is developed with respect to serviceability, performance and durability.

I have few doubts which the authors are requested to enlighten.

(i) When did the collapse occur? How far was it away from occupation, timewise?

(ii) Please provide details about columns below plinth and plinth beam cross sectional provisions.

(iii) The paper does not touch upon the adequacy of the foundation, that is, founding strata and safe bearing capacity. That could be a cause of "triggering" — imbalance, mechanism — collapse due to a "partial localised settlement".

(iv) What about the stability of the balance structure? It is implied that it has the same congenital defect.

(v) Was there any change in cross sectional provisions of columns below plinth?

(vi) How much time did it take since observing signs of instability, that is, commencement of part spalling, wide cracking, member loss of profile and elemental collapse till "actual mechanism was formed" and location area where the collapse may have been initiated? It is the most probable expert guess work which at times may suggest location of "trigger" mechanism and in turn to understand the structure better.

(vii) Collapse profile before demolition may suggest a lot of relevant information. This could be commented upon.

(viii) Authors have presumed concrete strength of 20 MPa — based on Schmidt hammer test results. Which was the test sample relied upon and from where was it taken? Did the authors rely upon the sample from portion of the structure, that is, undisturbed or it was from damaged portion? Was it an average figure or a specific value of the sample?

For such a collapsed structure, 20 MPa appears to be good quality concrete and indirectly implies reasonable technical supervision and basic quality control. Therefore, I want to understand more about the type of impact hammer used by the authors — whether it was calibrated, make and type P or N? These factors may vary the results. In many locations, was the hammer used and what is the procedure for averaging to arrive at the figure of 20 MPa.

(This question is not intended to point out the limitations in the tests. However, the entire findings and related deficiency is based on 20 MPa; hence the need for clarity).

(ix) Why was core extraction the not resorted to from the remaining upright structure? This may have

given some additional authentic information.

(x) There appears to be few more vulnerable areas in the surviving structure. Was any malfunctioning observed at such location?

(xi) Was any damage in the adjoining structure retained beyond the collapsed structure due to "sympathy".

Trust, the authors would respond to the above queries.

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Authors' reply

The authors thank Er. R. N. Raikar for his keen interest in the paper, and for his appreciative comments. The queries raised are highly pertinent to the causes leading to the unfortunate collapse. The point-by-point reply to Er. Raikar's comments is as given below

(i) The collapse occurred even before the structure was inhabited; all the partition walls were built, most of the inner walls plastered and even the water tank over the staircase was filled with water. The constant groaning noises appear to have slowed down the work, and may have prevented the owners from occupying the flats.

(ii) The structure was not provided with plinth beams, and the columns were not tied in any way at the footing level.

(iii) The site offered favourable conditions for construction, with hard soil of safe bearing capacity 350.0 kPa at 1.5 m depth (determined after the collapse). The ground floor columns were 2.2 m above the ground floor level with a total height of about 3.0 m above the footings. The estimated load on the foundation was 325.1 kPa under H 5, the column suspected to have triggered the collapse (for a factored column load of 1.58 MN excluding live load, and footing size of 1.8 × 1.8 m).

However, because of the favourable foundation conditions, and the inadequacy of the columns to sustain the axial loads at the time of collapse, the authors are inclined to eliminate foundation problems.

(iv) The remaining structure too can be expected to have the same congenital deficiencies. The slabs were generally adequate for the design loads, while some of the beams were deficient, as discussed in the paper, possibly due to underestimated partition wall loads.

(v) The column section was constant above the footings.

(vi) The neighbours mentioned that some of the columns showed signs of distress (visible cracks and groaning sounds) at least a month before the collapse. It is likely that the completion of partition walls and filling of water tank imposed loads beyond the capacity of the columns. Surprisingly, the columns in the surviving part of the structure did not show visible signs of distress.

(vii) Unfortunately, the authors were not aware of the demolition plans and schedule, and did not visit the structure during demolition. Apparently, the demolition did not present any problems.

(viii) The strength of 20.0 MPa adopted in the analysis is based more on conjecture, and less on actual test results, since some concrete in the collapsed part of the structure crumbled under finger pressure. The tests on two cores of 38 mm diameter taken from the collapsed part of the structure indicated a mean strength of 12.0 MPa; the equivalent cube strength may be taken as 15.0 MPa.

A further factor of 0.85 (Cl. 16.2.3 of IS 456 : 1978 or Cl. 17.4.3 of IS 456 : 2000) would indicate a cube strength of 17.6 MPa. The test results on steel bars, collected from the collapsed segments, indicated poor quality (*Table* 1 of the paper).

(ix) The tests on the ground floor columns of the surviving part of the structure with Schmidt rebound hammer (type N, Indian make) indicated a strength of about 20.0 MPa. The mean value of the readings on vertical columns faces at mid-height levels was adopted. The authors agree with Er. Raikar that the value indicates good quality concrete for a collapsed structure.

(x) Unfortunately, cores were not taken from the surviving part of the structure, and only two cores could be extracted from the collapsed segments. The first author collected all the details possible in the fortnight after the collapse during the investigations; the authors did not have the authority afterwards to gather any samples or take measurements.

(xi) It is likely that the surviving part of the structure has regions of poor concrete as well. However, location of weak and vulnerable regions would require a more detailed tests using thermography or Ground Penetrating Radar (GPR) than just two cores and a Schmidt Rebound Hammer.

(xii) Fortunately, the structure collapsed inwards, and was bounded by roads on two sides. The structures on the other two sides did not show distress.

The investigations could not be as comprehensive as they should be on the entire structure, partly due to the lack of sophisticated equipment. The under estimation of the partition wall loads was not obvious in the first instance, and could be determined much later after several repeated analyses.

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