Vulnerability of RC Structure and Quality Control

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Abstract - Quality of construction materials as well as construction process directly influences strength, durability parameters and vulnerability of structure. IS 456 2000 regulates the quality as well as construction standards for construction materials (i.e. concrete, reinforcing steel, etc.) and construction process (i.e. shuttering of RC members, concreting, cover to reinforcement and curing of concrete).Ensuring desired strength of structural elements while construction, is very important step to make overall structure safe. Under gravity loading, normally structure becomes safe due to structural redundancy, safety factors and loading less than anticipated. Though structure may stand by overcoming all deficiencies, but earthquake exposes all errors in construction and may results in life-threatening damage to structure. Present work devoted to study the deficiencies in RC structure due to poor quality control and the evidence of failure from past earthquake studies. Comparative photos of some defects and failure due to similar deficiencies has been incorporated to visuals its importance. Quality control gives second chance to strengthen the weaknesses as well as correcting or repairing examined deficiencies. This is an effort to highlight importance of quality control during RC construction, deficiencies arises during construction and susceptibility towards failure.

Keywords: Durability parameters, Vulnerability of structure, Deficiencies.

I. INTRODUCTION

Reinforced Concrete (RC) construction is common construction practice in India. Though steel structures having huge advantageous over RC structures like light in weight, easy as well as fast construction, easy rehabilitation and mainly having scrap value after demolition. Along with this, steel is factory rolled material passing through keen observations and testing creates outstanding quality of construction. However this method of construction is not much suitable and efficient in Indian circumstances. Less but skilled labors, advanced equipment and expertise are crucial requirements of steel construction. On the other hand RC construction requires huge but less skilled labours, basic construction equipment's and basic technical support for construction which matches the sub-continental circumstance. As concrete is heterogeneous material and quality of same varies with batch to batch, site to site and region to region. Therefore to achieve desired strength of structure keen quality control and testing is necessary. Quality control is defined as 'The process of setting standards and testing to make sure something, like a product or service, is done correctly'. The system by which goods are checked at different stages in the production process in order to make sure that there are no defects and that the goods meet all necessary specifications. In all construction projects proper inspection and quality control plays important role to insure good and safe structure. Otherwise well-designed structure can be spoiled by careless execution work. A study done by IIT Roorkee in Noida[1] indicate that the deficiency in building crops up at different stage of planning, design and construction, and these deficiencies impart drastic reduction in seismic behaviour of structure. These deficiencies can be classified in three categories[1]:

a. Configurationally deficiencies (at planning stage)

b. Design and detailing deficiency (at analysis and design stage)

c. Constructional deficiencies (at actual construction stage)

II. EVIDENCE OF FAILURE

During Bhuj earthquake Goel R. K. (2001)[2] observed that, in few cases, out of several identical multi-storey buildings only one or two buildings collapsed in same apartment complex and other suffered with significant damage but did not collapsed. This type of failure pointed question mark on quality of material in collapsed buildings. Arslan and Korkmazalso (2006)[3]also state that, lack of supervision and poor quality control during construction are some observed reasons for seismic collapse of building. Study conducted by Pribadiet al. (2008)[4] on recent Indonesian earthquakes also found that poor quality of material and non-uniformity in construction process is the major reason of high vulnerability of structure. Nienhuys S. (2010)[5]reported that those structure designed and constructed according to minimum specifications of code survive in earthquakes of a magnitude 7 on the Richter scale. Kaplan et al. (2010)[6] also stated that many of the collapses of reinforced concrete structures during the earthquake could be attributed to the poor quality construction. Present work devoted to study the deficiencies in structure arises due to poor quality control

and the evidence of failure from past earthquake studies. Comparative study has been done to validate the effects of poor quality control and failure of structure.

III. QUALITY CONTROL

The responsibility of quality control should be separated from those who are entrusted with execution work. Generally every construction company have separate department for quality control which comprises of quality control engineers. Inspection, testing and sampling are the major quality control methods. Inspection involves careful examination of procured material, production process and finished goods. This is an important tool to trap visual defects in construction, so the preventive measures can be taken. Inspection detects few common imperfections like misplacement of section sizes, mistakes in placing reinforcement, insufficient anchorage length, inadequate cover to reinforcement, higher water cement ratio, substandard scaffolding and honeycomb concreting occurs before, during and after construction process. Things cannot be detected by visual inspection needs destructive and non-destructive testing for validation. Superior or inferior quality of materials, Internal defects in concrete and information about achieved strength of casted concrete cannot be decided by visual inspection and shall be interpreted by thorough testing. But when quality determination required for large group by examining a part of it and which will be representative of whole group needs sampling. Sampling is one sub step of testing and reliability of same depends on size of sampling. Size of sample for a group, testing procedure, upper and lower limits for testing results are also regulated by different codes. In simple words quality control is a verification process for construction materials, process and finished structure with some standards with the help of Inspection, Testing and Sampling to achieve desired strength.

IV. CONSTRUCTIONAL DEFICIENCIES

This heading includes different common defects found in construction and its effect on performance of structure under extreme conditions.

a) Inadequate Anchorage for reinforcement bars:

Insufficient anchorage length is common mistake observed during construction and can be identified during pre-concreting visual inspection(as shown in fig. 1). Inadequate development length results in slipping of bars, losing confinement of concrete and fallouts in failure (as shown in fig. 2). IS 456-2000 in clause number 26.2 gives minimum value of anchorage length in terms of development length of bar according to grade of concrete as well as nature. This fault can be over taken and future failure can be avoided by correcting inspected defects.

Fig. 1 Quality control inspection report, found inadequate anchorage length and lack of bends[8]

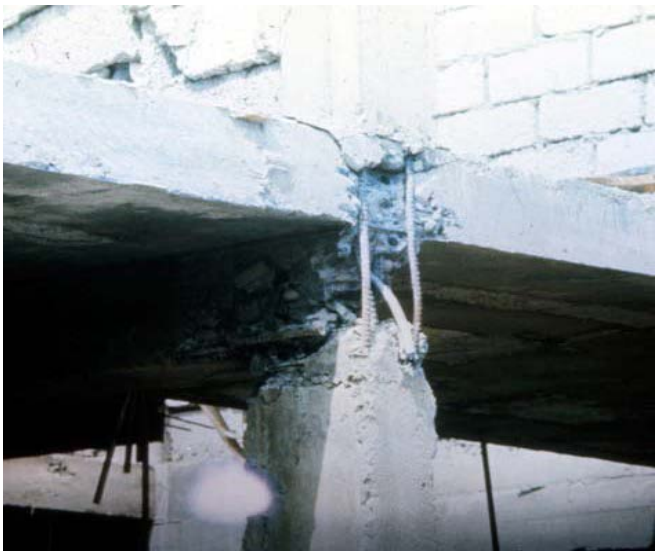

Fig. 2 Failure due to Inadequate Anchorageto reinforcing bars[5]

b) Honeycomb concreting:

Porous concrete commonly seen at many places in structure and is a result of poor workmanship. Insufficient compaction results in honeycomb concrete (as shown in fig. 3) which having poor compressive strength and poor bonding effect (as shown in fig. 4). Honeycomb concrete leads to crushing of concrete (as shown in fig. 6), slipping of bars and rusting

of reinforcing bars under extreme condition. Workmanship has been discussed in relevance with mixing, placing, compaction, durability, curing and quality assurance measures of concrete in section 2 of IS 456-2000.

Fig. 3 Quality control inspection report, found concreting

Fig. 4 Failure due to poor quality of concrete

c) Insufficient Cover to Reinforcement:

This is also common mistake found during construction and can be avoided by keen inspection (as shown in fig. 8 and 10). This is small but important thing from durability and fire resistance point of view. Cover protects reinforcement from rusting which result in desired life of structure, but in absence of same and rusting will takes place(as shown in fig. 5), which will reduce strength as well as life of structure. Many times spalling of concrete may takes place (as shown

Fig. 5 Failure caused due to porous concrete and rusting of reinforcing bars

Fig. 6 Quality control inspection report found Honeycomb concreting in beam

d) Substandard scaffolding:

Scaffolding should be sufficient as well as strong enough to sustain the dead load, live load and load of equipment comes on it during construction. Many times it is observed that the scaffolding provided to support structure during construction is not insufficient as per design (as shown in fig. 7). These props should be interconnected properly which is missing unknowingly or intentionally at many sites. This may result in partial or complete collapse of the structure during construction itself (as shown in fig. 8). Forms shall not be released until the concrete has achieved strength of at least twice the stress to which the concrete may be subjected at

the time of removal of formwork and IS code also mention some minimum period before striking formwork (IS 456-2000, Cl. No. 11.3).

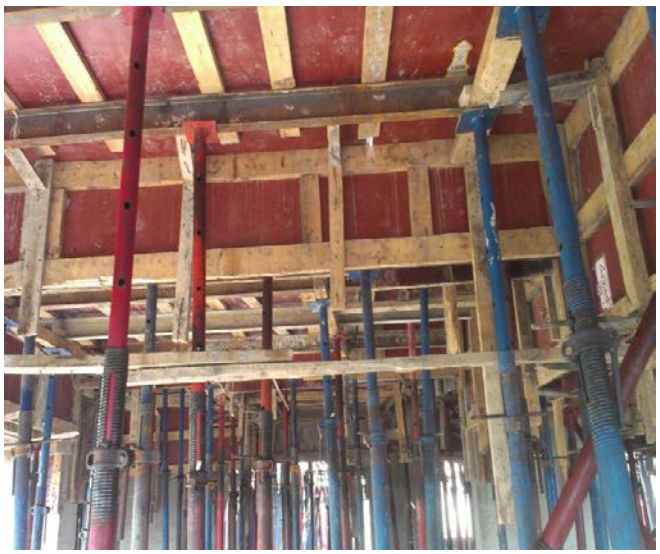

Fig. 7 Quality control inspection report, extra gap found in props than desire and props are not interconnected.

Fig 8 Failure of under construction structure due to insufficient props.

e) Inadequate curing:

Hardening of cement aggregate matrix is an exothermic chemical reaction. So arrangement of frequent curing should be done and many time found eliminated on many site (as shown in fig 9). If proper curing is not done results in inferior strength of concrete. Inferior grade or low grade of concrete has also one reason of failure (as shown in fig. 9). Curing directly influences the durability of structure as well as load carrying capacity of material. As per IS 456-2000 concrete of Ordinary Portland cement needs at least 10days curing (Cl. No. 13.5.1).

Fig. 9 Quality control inspection report, Cloth wrapping is not done for curing

Fig. 10 Failure due to wide spacing of lateral ties as well as low quality of concrete

V. TESTING AND SAMPLING

Quality of procured material, internal defects in structure, quality of casted concrete and achieved strength cannot be predicted by visual inspection. In such case standard requirements are cross verified by destructive as well as non-destructive testing. Testing is important tool of quality control and IS 456-2000 regulates some sampling, testing specifications and acceptance criteria guidelines in clause number 17 of section 2. Many times test results of small set represents large group, in such case sampling plays

important role and reliability of result depends on size of sample. Sampling is one sub step of testing; such testing should be performing after certain interval. Frequency of testing is also regulated by various codes and it varies according to material or construction type. If material used for construction is not fitting quality requirements then irrespective of workmanship and other parameters structure shows drastic reduction in capacity, which increases chances of failure of structure. In post-earthquake study of turkey earthquake, it was found that complete collapse of building (as shown in fig.1) happened due to poor quality of material used for construction[3]

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VI. CONCLUSION

Every constructional deficiency increases vulnerability of structure and directly or indirectly governs the strength as well as durability. The evidence of failure in past earthquake highlighted the importance of quality control in construction, which will help to prevent constructional deficiencies and resulting loss of life as well as property. Quality checks assure engineers and users about strength as well as durability of structure. Quality control will support to eliminate defects by pre-concreting inspection as well as testing and taking preventive measure after concreting inspection as well as testing. This study helps to create awareness in construction industry about importance of quality control.

VII. FUTURE SCOPES

Comparative photos of some defects and failure due to similar deficiencies has been incorporated to visuals its importance. Quality control gives second chance to strengthen the weaknesses as well as correcting or repairing examined deficiencies. This is an effort to highlight importance of quality control during RC construction, deficiencies arises during construction and susceptibility towards failure.

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