1.1.2 Objectives of the Design of Reinforced Concrete Structures

Every structure has got its form, function and aesthetics. Normally, we consider that the architects will take care of them and the structural engineers will be solely responsible for the strength and safety of the structure. However, the roles of architects and structural engineers are very much interactive and a unified approach of both will only result in an "Integrated" structure, where every material of the total structure takes part effectively for form, function, aesthetics, strength as well as safety and durability. This is possible when architects have some basic understanding of structural design and the structural engineers also have the basic knowledge of architectural requirements.

Both the engineer and the architect should realize that the skeletal structure without architecture is barren and mere architecture without the structural strength and safety is disastrous. Safety, here, includes consideration of reserve strength, limited deformation and durability. However, some basic knowledge of architectural and structural requirements would facilitate to appreciate the possibilities and limitations of exploiting the reinforced concrete material for the design of innovative structures.

Before proceeding to the design, one should know the objectives of the design of concrete structures. The objectives of the design are as follows:

1.1.2.1 The structures so designed should have an acceptable probability of performing satisfactorily during their intended life.

This objective does not include a guarantee that every structure must perform satisfactorily during its intended life. There are uncertainties in the design process both in the estimation of the loads likely to be applied on the structure and in the strength of the material. Moreover, full guarantee would only involve more cost. Thus, there is an acceptable probability of performance of structures as given in standard codes of practices of different countries.

1.1.2.2 The designed structure should sustain all loads and deform within limits for construction and use.

Anim. 1.1.2	Anim. 1.1.3	Anim. 1.1.4

Adequate strengths and limited deformations are the two requirements of the designed structure. The structure should have sufficient strength and the deformations must be within prescribed limits due to all loads during construction and use as seen in Anim. 1.1.2. Animation 1.1.3 shows the structure having insufficient strength of concrete which fails in bending compression with the increase of load, though the deformation of the structure is not alarming. On the other hand, Anim. 1.1.4 shows another situation where the structure, having sufficient strength, deforms excessively. Both are undesirable during normal construction and use.

However, sometimes structures are heavily loaded beyond control. The structural engineer is not responsible to ensure the strength and deformation within limit under such situation. The staircases in residential buildings during festival like marriage etc., roof of the structures during flood in the adjoining area or for buildings near some stadium during cricket or football matches are some of the examples when structures get overloaded. Though, the structural designer is not responsible for the strength and deformations under these situations, he, however, has to ensure that the failure of the structures should give sufficient time for the occupants to vacate. The structures, thus, should give sufficient warning to the occupants and must not fail suddenly.

1.1.2.3 The designed structures should be durable.

The materials of reinforced concrete structures get affected by the environmental conditions. Thus, structures having sufficient strength and permissible deformations may have lower strength and exhibit excessive deformations in the long run. The designed structures, therefore, must be checked for durability. Separate checks for durability are needed for the steel reinforcement and concrete. This will avoid problems of frequent repairing of the structure.

1.1.2.4 The designed structures should adequately resist to the effects of misuse and fire.

Structures may be misused to prepare fire works, store fire works, gas and other highly inflammable and/or explosive chemicals. Fire may also take place as accidents or as secondary effects during earthquake by overturning kerosene stoves or lantern, electrical short circuiting etc. Properly designed structures should allow sufficient time and safe route for the persons inside to vacate the structures before they actually collapse.

How to fulfill the objectives?

All the above objectives can be fulfilled by understanding the strength and deformation characteristics of the materials used in the design as also their deterioration under hostile exposure. Out of the two basic materials concrete and steel, the steel is produced in industries. Further, it is available in form of standard bars and rods of specific diameters. However, sample testing and checking are important to ensure the quality of these steel bars or rods. The concrete, on the other hand, is prepared from several materials (cement, sand,

coarse aggregate, water and admixtures, if any). Therefore, it is important to know the characteristic properties of each of the materials used to prepare concrete. These materials and the concrete after its preparation are also to be tested and checked to ensure the quality. The necessary information regarding the properties and characteristic strength of these materials are available in the standard codes of practices of different countries. It is necessary to follow these
clearly defined standards for materials, production, workmanship and maintenance, and the performance of structures in service.

1.1.3 Method of Design

Three methods of design are accepted in cl. 18.2 of IS 456:2000 (Indian Standard Plain and Reinforced Concrete - Code of Practice, published by the Bureau of Indian Standards, New Delhi). They are as follows:

1.1.3.1 Limit state method

The term “Limit states” is of continental origin where there are three limit states - serviceability / crack opening / collapse. For reasons not very clear, in English literature limit state of collapse is termed as limit state.

As mentioned in sec. 1.1.1, the semi-empirical limit state method of design has been found to be the best for the design of reinforced concrete members. More details of this method are explained in Module 3 (Lesson 4). However, because of its superiority to other two methods (see sections 2.3.2 and 2.3.3 of Lesson 3), IS 456:2000 has been thoroughly updated in its fourth revision in 2000 taking into consideration the rapid development in the field of concrete technology and incorporating important aspects like durability etc. This standard has put greater emphasis to limit state method of design by presenting it in a full section (section 5), while the working stress method has been given in Annex B of the same standard. Accordingly, structures or structural elements shall normally be designed by limit state method.

1.1.3.2 Working stress method

This method of design, considered as the method of earlier times, has several limitations. However, in situations where limit state method cannot be conveniently applied, working stress method can be employed as an alternative. It is expected that in the near future the working stress method will be completely replaced by the limit state method. Presently, this method is put in Annex B of IS 456:2000.

1.1.3.3 Method based on experimental approach

The designer may perform experimental investigations on models or full size structures or elements and accordingly design the structures or elements. However, the four objectives of the structural design (sec. 1.1.2) must be satisfied when designed by employing this approach. Moreover, the engineer-in- charge has to approve the experimental details and the analysis connected therewith.

Though the choice of the method of design is still left to the designer as per cl. 18.2 of IS 456:2000, the superiority of the limit state method is evident from the emphasis given to this method by presenting it in a full section (Section 5), while accommodating the working stress method in Annex B of IS 456:2000, from its earlier place of section 6 in IS 456:1978. It is expected that a gradual change over to the limit state method of design will take place in the near future after overcoming the inconveniences of adopting this method in some situations.

1.1.4 Analysis of Structures

Structures when subjected to external loads (actions) have internal reactions in the form of bending moment, shear force, axial thrust and torsion in individual members. As a result, the structures develop internal stresses and undergo deformations. Essentially, we analyse a structure elastically replacing each member by a line (with EI values) and then design the section using concepts of limit state of collapse. Figure 1.1.1 explains the internal and external reactions of a simply supported beam under external loads. The external loads to be applied on the structures are the design loads and the analyses of structures are based on linear elastic theory (vide cl. 22 of IS 456:2000).

1.1.5 Design Loads

The design loads are determined separately for the two methods of design as mentioned below after determining the combination of different loads.

1.1.5.1 In the limit state method, the design load is the characteristic load with appropriate partial safety factor (vide sec. 2.3.2.3 for partial safety factors).