CHAPTER 1
CONCRETE AS A CONSTRUCTION MATERIAL

1.1 Introduction

Concrete is the most widely used man-made construction material in the world (see Table 1-1). It is obtained by mixing cementing materials, water and aggregates, and sometimes admixtures, (shown in Fig. 1.1), in the required proportions. The mixture when placed in forms and allowed to cure hardens into a rock-like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time, and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of larger particles (coarse aggregate) are filled by the smaller particles (fine aggregate) and the voids of fine aggregates are filled with cement. In a concrete mix the cementing material and water form a paste called cement-water paste, see Table 1.1, which in addition to filling the voids of fine aggregate, coats the surface of fine and coarse aggregates and binds them together as it cures, thereby cementing the particles of the aggregates together in a compact mass. The *strength*, *durability* and other characteristics of concrete depend upon the properties of its ingredients, on the proportions of mix, the method of compaction and other controls during placing, compaction and curing. The popularity of the concrete is due to the fact that, from the common ingredients, it is possible to tailor the properties of concrete to meet the demands of any particular situation. The photos in Fig. 1.2 illustrate the mould ability and the structural use of concrete to execute the required architectural forms. The advances in concrete technology have paved the way to make the best use of locally available materials by judicious mix proportioning and proper workmanship, so as to produce concrete satisfying performance requirements.

Table (1-1) Definitions for Concrete

Concrete	= **Filler** + **Binder**
Portland cement concrete	=Aggregate (Fine + Coarse) +Portland cement paste
Mortar	= Fine aggregate + Paste
Paste	= Cement + Water

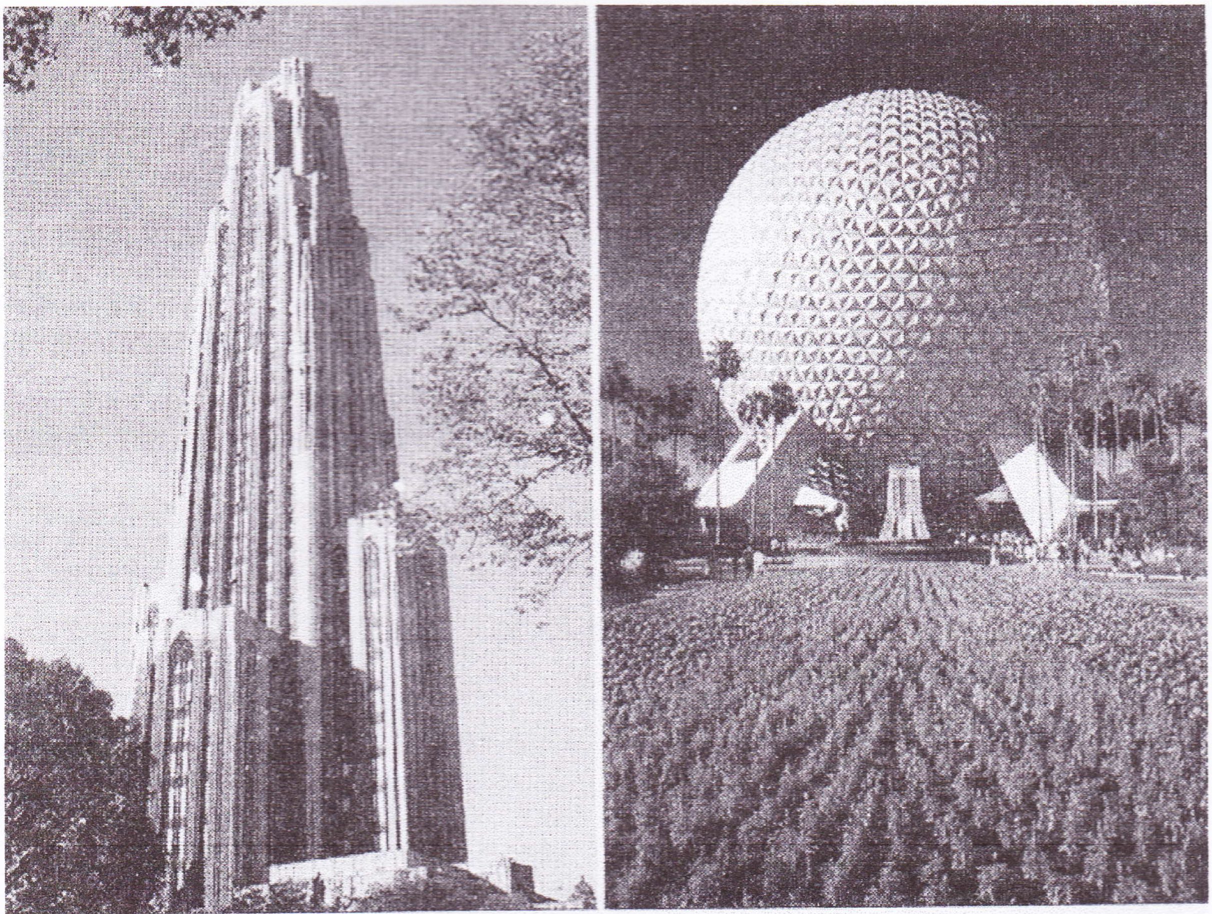
The key to producing a *strong*, *durable* and *uniform* concrete, i.e. *high performance concrete*, lies in the careful control of its basic and process components' These are the following:

<u>*Cement*</u> Portland cement, the most widely used cementing ingredient, in present day concrete comprises phases that consist of compounds of calcium, silicon, aluminum, iron, and oxygen.

<u>*Aggregate*</u> These are primarily naturally occurring, inert granular materials such as sand, gravel, or crushed stone. However, technology is broadening to include the use of recycled materials and synthetic products.

<u>*Water*</u> The water content and the minerals and chemicals dissolved in it are crucial to achieving quality concrete.

Fig. 1.1 Constituent materials of concrete



A Cathedral Epcot

Fig. 1.2 Structural and architectural use of concrete

Chemical admixtures These are the *ingredients* in concrete other than *Portland cement*, *water*, and *aggregates* that are added to the mixture immediately before or during mixing to reduce the water requirement, *accelerate/retard* setting, or improve *specific durability* characteristics.

Supplementary cementing materials Supplementary cementing materials, also called *mineral additives*, contribute to the properties of hardened concrete through hydraulic or *pozzolanic* activity. Typical examples are natural *pozzolans*, *fly ash*, *ground granulated blast-furnace slag*, and *silica fume*. After concrete is placed, these components must be cured at satisfactory moisture content and temperature must be carefully maintained for a sufficiently long time to allow adequate development of the strength of the concrete.

The *factors affecting the performance of concrete* are shown in Fig. 1.3. The concept of *treating* concrete in its entity as a building material rather than its *ingredients* is gaining popularity. The user is now interested in the concrete having the *desired properties* without bothering about the ingredients. This concept is symbolized with the progress of *ready mixed* concrete industry where the consumer can specify the concrete of *his needs*, and further in the *pre-cast* concrete industry where the consumer obtains *finished structural components* satisfying the *performance requirements*. Concrete has *high compressive strength*, but its *tensile strength* is very low. In situations where tensile stresses are developed, the concrete is *strengthened* by steel bars or short randomly distributed *fibers* forming a composite construction called *reinforced concrete (RC)* or *fiber reinforced concrete (FRC)*. The concrete without reinforcement is termed plain concrete or simply as *concrete*. The process of making concrete is called *concreting*. Sometimes the tensile stresses are taken care of by-introducing compressive stresses in the concrete so that the initial compression neutralizes the tensile stresses. Such a construction is known as *prestressed concrete construction*.

Concrete can be cast into soaring arches and columns, complex hyperbolic shells or into massive, monolithic sections used in dams, piers and abutments, as shown in Figs 1.4 to 1.12.

1.2 Classification of Concrete

As mentioned earlier the main ingredients of concrete are cement, fine aggregate (sand) and coarse aggregate (gravel or crushed rocks). It is usual to specify a particular concrete by the proportions of these constituents and their characteristics, for example, a l:2:4 concrete refers to a particular concrete manufactured by mixing cement, sand and crushed stone in a 1:2:4 ratio by volume (with a specified type of cement, water-cement ratio, maximum size of aggregate, etc.). This classification specifying the proportions of constituents and their characteristics is termed as *prescriptive specifications* and is based on the hope that adherence to such perspective specifications will result in satisfactory performance. Alternatively, the specifications specifying the requirements of the *desirable properties* of concrete such as *strength*, workability, etc. are stipulated, and these are termed *performance-oriented specifications*. Based on these considerations, concrete can be classified either as *nominal* mix concrete or *designed* mix concrete. Sometimes concrete is classified into *controlled* concrete and *ordinary* concrete, depending upon the levels of control exercised in the works and the method of proportioning concrete mixes. Accordingly, a concrete with ingredient proportions *fixed* by designing the concrete mixes with *preliminary tests* are called *controlled concrete*, whereas *ordinary concrete* is one where *nominal mixes* are adopted. Proper workmanship in batching, mixing, transportation, placing, compaction and curing, coupled with necessary checks and tests are essential for quality acceptance.

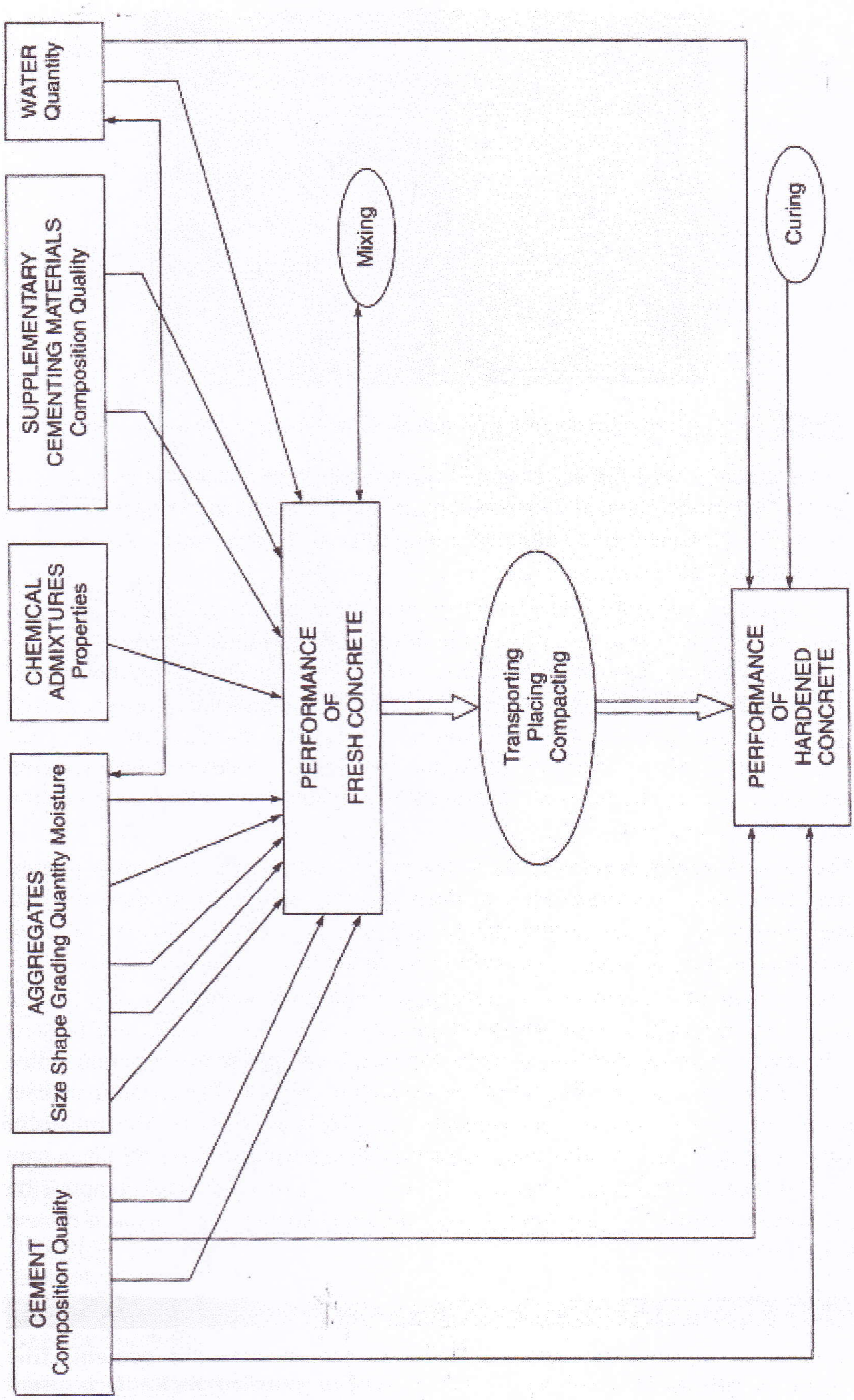


Fig. 1.3 Factors affecting performance of concrete

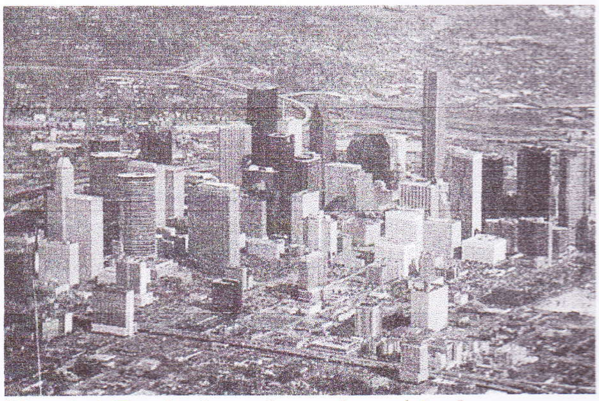


Fig. 1.4 Typical modern city with skyscrapers –looks like a concrete jungle

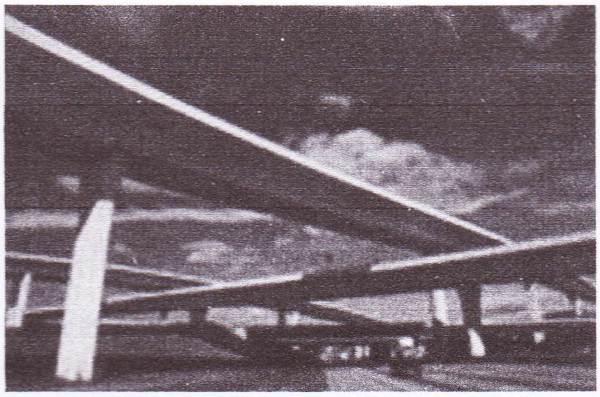


Fig. 1.5 Typical RC superhighways with over passes – smooth and efficient traffic movement saves energy

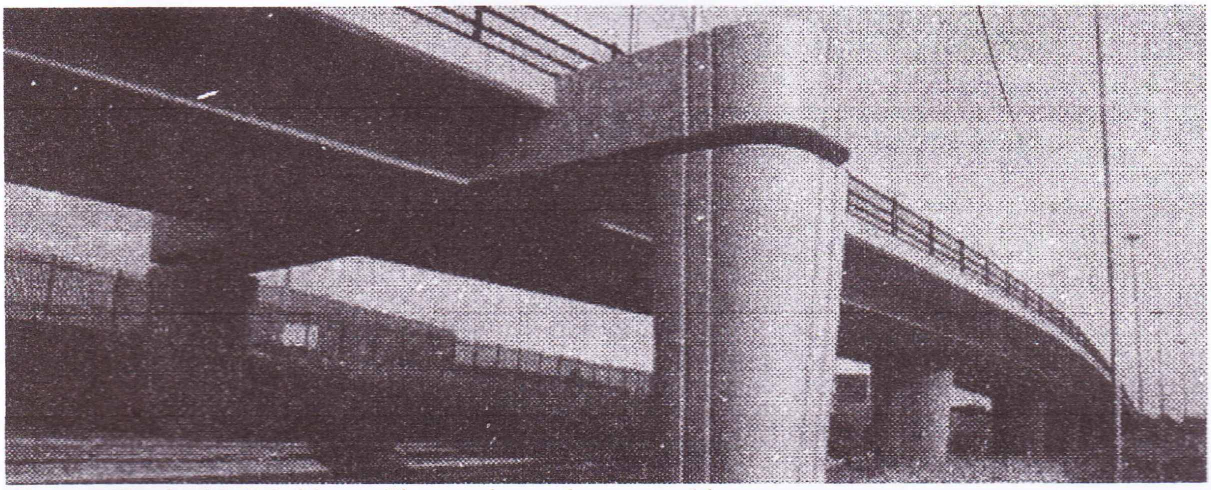


Fig. 1.6 Typical RC bridge with massive columns and beams

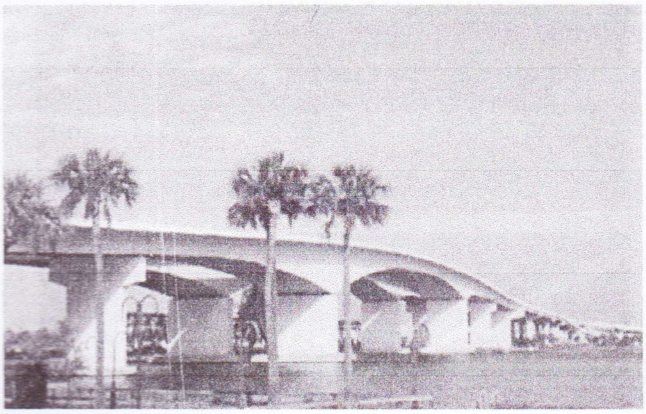


Fig. 1.7 Typical RC bridge over water which must be designed for durability

1.3 Properties of Concrete

Concrete making is not just a matter of mixing ingredients to produce a plastic mass, but good concrete has to satisfy *performance requirements* in the plastic or green state and also in the hardened state. In the plastic state the concrete should be *workable* and *free from segregation* and *bleeding*. Segregation is the separation of coarse aggregate and bleeding is the separation of cement paste from the main mass. Segregation and bleeding result in a *poor quality concrete*. In its *hardened state*, concrete should be *strong*, *durable*, and *impermeable*; and it should have minimum *dimensional changes*. Among the various properties of concrete,

its *compressive strength* is considered to be the most important and is taken as an index of its *overall quality*. Many other properties of concrete appear to be generally related to its compressive strength.

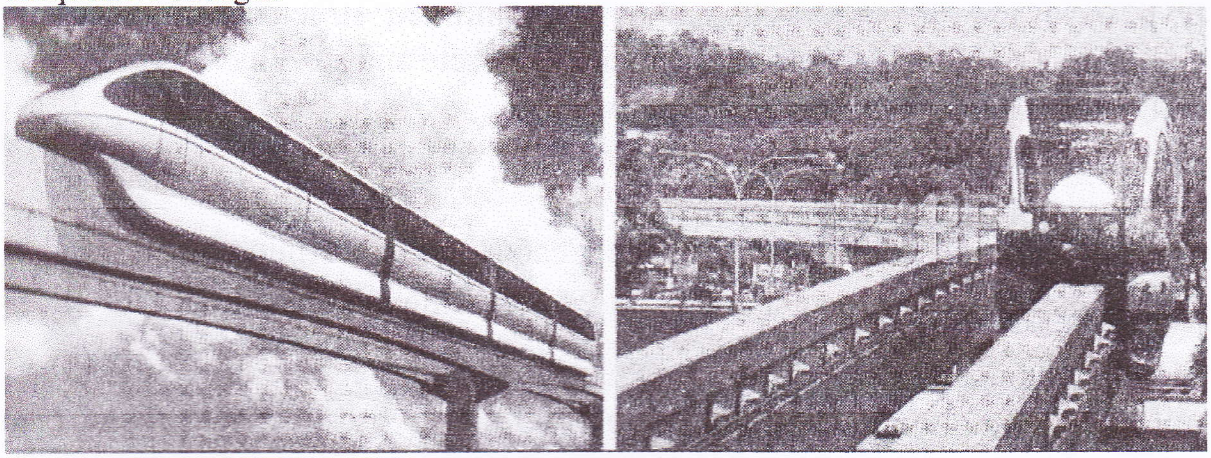


Fig. 1.8 Monorails running over RC bridges- an enjoyable means of city transport

There are generally two sets of criteria that we must consider when making concrete.

1 - Short-term requirements, while the concrete is still in the plastic state, which are *workability* and *stability*.

2 - Long-term requirements of the hardened concrete, such as *strength* and *durability*.

Fig. 1.9 Concrete used in lining RC tunnel

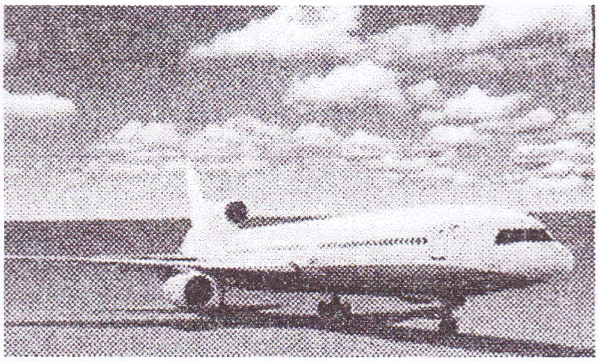


Fig. 1.10 An aero plan runway requires high strength concrete *(HSC)*

1.4 Grades of Concrete

Concrete is generally graded according to its compressive strength. The various grades of concrete are given in Table 1.2. In the designation of concrete mix, the letter M refers to the mix and the number to the specified characteristic strength of 150 mm work cubes at 28 days, expressed in *MPa (N/mm2)*. The concrete of grades M5 and M7.5 is suitable for lean concrete bases, simple foundations, foundations for masonry walls and other simple or temporary reinforced concrete constructions. These need not be designed. The concrete of grades lower than M15 is not suitable for reinforced concrete works and grades of concrete lower than M30 are not to be used in the *prestressed* concrete works.

1.5 Advantages of Concrete

Concrete as a construction material has the following advantages:

Table 1.2 Grades of Concrete

Group	Ordinary concrete			Standard concrete							High strength concrete				
Grade designation	M 10	M 15	M 20	M 25	M 30	M 35	M 40	M 45	M 50	M 55	M 60	M 65	M 70	M 75	M 80
Specified characteristic strength, at 28 days, f_{cu} MPa	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80

i. Concrete is economical in the long run as compared to other engineering materials. Except cement, it can be made from locally available coarse and fine aggregates.
ii. Concrete possesses a high compressive strength, and the corrosive and weathering effects are minimal. When properly prepared its strength is equal to that of a hard natural stone.
iii. The green or newly mixed concrete can be easily handled and molded or formed into virtually any shape or size according to specifications, see Fig. 1.2. The formwork can be reused a number of times for similar jobs resulting in economy.
iv. Concrete is strong in compression and has unlimited structural applications in combination with steel reinforcement. Concrete and steel have approximately equal coefficients of thermal expansion, see Figs. 1.4 to 1.12.
v. Concrete can even be sprayed on and filled into fine cracks for repairs.
vi. Concrete can be pumped and hence it can be laid in difficult positions also,
vii. It is durable, fire resistant and requires very little maintenance.

These advantages have resulted in extensive use of concrete in the construction of buildings, skyscrapers, Fig. 1.4, superhighways with over and under passes, Fig.1.5, bridges, Figs. 1.6 and 1.7, railways, monorails, Fig. 1.8, tunnels, Fig 1.9, runways of airfields, Fig. 1.10, water-retaining structures, docks and harbors, dams, cross drainage works, Fig. 1.11 and 1.12, bunkers and silos.

1.6 Disadvantages of Concrete

The following are the disadvantages of concrete:

i. Concrete has low tensile strength and hence cracks easily. Therefore, concrete is to be reinforced with steel bars or meshes or fibers.
ii. Fresh concrete shrinks on drying and hardened concrete expands on wetting.
iii. Provision for construction joints has to be made to avoid the development of cracks due to drying shrinkage and moisture movement.
iv. Concrete expands and contracts with the changes in temperature. Hence expansion joints have to be provided to avoid the formation of cracks due to thermal movement.
v. Concrete under sustained loading undergoes creep, resulting in the reduction of prestress in the prestressed concrete construction.
vi. Concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence and corrosion of reinforcing steel.
vii. Concrete is liable to disintegrate by alkali and sulphate attack.
viii. The lack of ductility inherent in concrete as a material is disadvantageous with respect to *earthquake resistant design*.

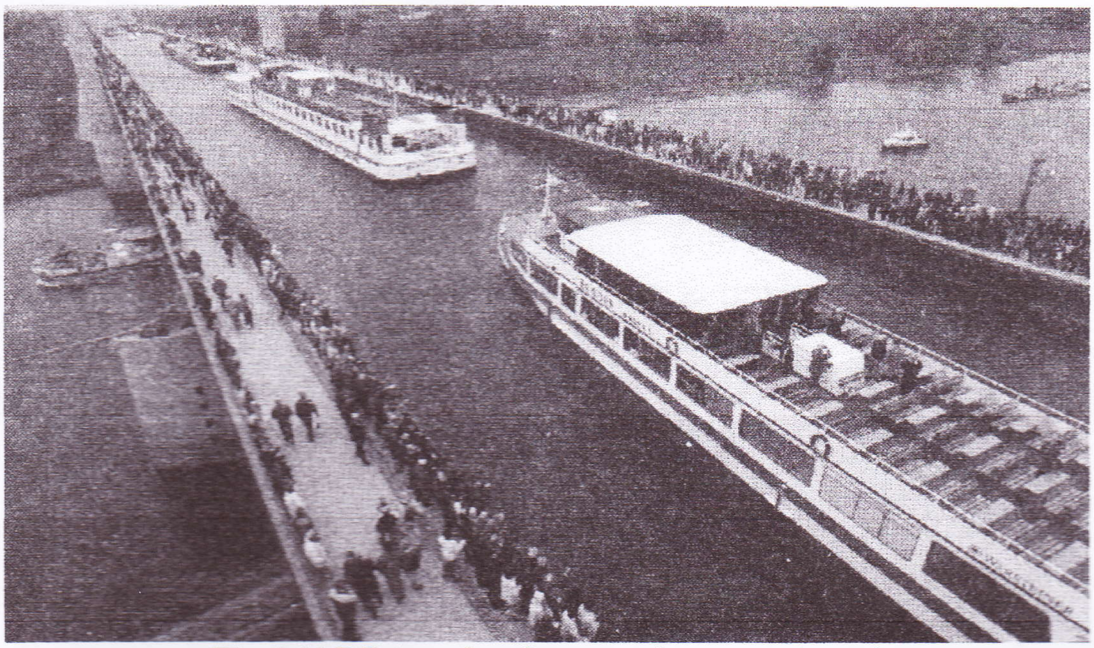


Fig. 1.11 RC Aqueduct ferry crossing water channel

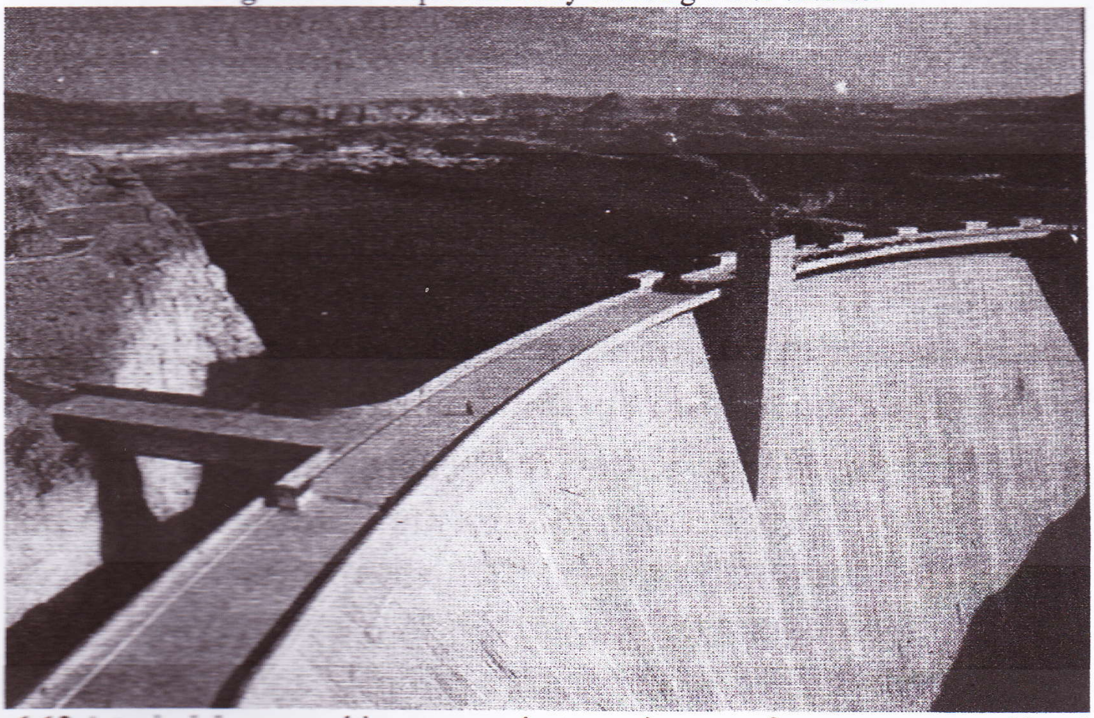


Fig. 1.12 A typical dam- a multipurpose project- requires use of mass concrete and low-heat Portland cement

1.7 References

1- Amr. E. Salama, and Gouda M. Ghanem, "Concrete Technology", Lecture notes for students of the 2nd year Civil, Civil Engineering Department, Faculty of Engineering, Mataria, Helwan University, Cairo, Egypt.

2- M. L. Gambhir, "Concrete Technology-Theory and Practice", Text book, The McGraw Hill Education Private Limited, New Delhi, Fourth Edition.

1.8 Problems

1. Draw the following with net sketches:

a. Factors affecting performance of concrete.
b. A diagrammatic sketch showing the contents of concrete, mortar, and cement paste.

2. Make a comparison between normal mixes concrete and designed mixes concrete.

3. Mark the right choice a, b, c, or d that makes the following statements correct.

- Chemical admixtures are a. types of Portland cement b. mix of fine and coarse aggregate c. ingredients in concrete other than aggregate, cement, and water d. limestone powder
- Concrete consists of a. cement and aggregate b. cement paste and aggregate c. filler and binder d. cement and water
- Mortar is a. a part of the concrete mix b. hardened cement paste c. hardened concrete d. a mix of cement and water
- Silica fume and fly ash are a. concrete constituent materials b. Supplementary cementing materials c. by-products of concrete industry d. retarders
- Supplementary cementing materials are characterized by a. their pozzolanic activity b. white color c. high permeability d. alkali reactivity
- Retarders are a. concrete constituent materials b. mineral admixtures c. limestone powder d. chemical admixtures
- Classification of concrete that specifying the proportions of constituents and their characteristics is termed a. static proportioning b. desirable properties c. strength and workability d. prescriptive specifications
- The concrete of grades M5 and M7.5 is suitable for a. highway pavement b. high strength concrete (HSC) c. lean concrete bases d. none of these choices is correct
- one of the advantages of concrete is a. its high tensile strength b. the high fire resistance compared to other construction materials c. its grey color d. its high cement content
- The lake of ductility of concrete can be improved by a. adding chemical admixtures to concrete mixes b. reinforcing concrete structural elements by reinforcing steel at the tension side c. adding fibers to concrete mixes d. both choices b, c are correct
- Workability is a. a long-term requirements of concrete b. a property of hardened concrete c. a short-term requirement of concrete d. better to be very high for all concrete mixes
- Strength and durability are a. properties of hardened concrete b. properties of fresh concrete c. very important when mixing concrete d. coarse aggregate