Construction Materials Survey for Preparing DPR for Water Resources Project

Rajeev Kumar
Central Soil & Materials Research Station
Olof Palme Marg, Hauz Khas, New Delhi – 110016

INTRODUCTION

Thorough and systematic investigations of a project are necessary to optimize techno-economic aspects of the project. Investigations should include the study of various alternatives regarding the layout of the scheme as a whole and also details of alternatives considered for the type and location of the various features of the project. The final alternative recommended should be fully justified recording the reasons for its choice as against the others.

The surveys and investigations necessary for Irrigation and Hydroelectric projects may be of the following types:

- Topographical surveys
- Geological and Foundation Investigations
- Hydrological and Meteorological Studies
- Pre-irrigation soil survey and drainage
- Special surveys for hydroelectric projects
- Construction materials survey
- Communication facilities
- Collection of relevant data for chalking out a construction programme including coffer dam construction, and
- Hydraulic model studies

CONSTRUCTION MATERIAL SURVEY

The following data/information/reports are required before taking up construction materials survey for any project:

1. Salient features including general layout plan of the project
2. Status of investigations

    a) Reconnaissance
    b) Feasibility
    c) Pre-construction stage
    d) Construction stage, and
    e) Post-construction stage

3. Geological report

4. Map showing likely source of construction materials
5. Estimation of quantities of construction materials required
6. Copies of earlier test reports, if any.

Following are the construction materials for which construction material surveys are normally conducted to have an idea of their availability in terms of quality and quantity vis-à-vis the project requirements and also to assess the techno-economic viability of the project:

1. Aggregate (Coarse and fine)
2. Masonry stone
3. Cement
4. Pozzolana
5. Water
6. Admixture
7. Reinforcement

CONCRETE

The dams and hydroelectric projects and other structures are built with concrete. The primary advantages of using concrete are that it is durable, versatile, inexpensive and easy to produce. Concrete is a mixture of aggregate, water and a binder (usually cement), which hardens to a stone like condition. The more water used in mixing, the higher the porosity of the hardened concrete. Pores act as crack nuclei, the consequences of which are that the tensile strength and fracture toughness of concrete are usually low. To improve its usefulness, concrete must be reinforced with steel and/or its porosity reduced.

AGGREGATE

Aggregates are the important constituents in concrete. They impart body to the concrete, reduce shrinkage and effect economy. The mere fact that aggregates occupy 80% of the volume of concrete is a pointer to the impact of properties of aggregates on various properties and characteristics of concrete. In fact concrete is considered as two-phase material, i.e. paste phase and aggregate phase. This proves the importance of aggregates on concrete. Therefore, one of the major contributing factors to the quality of concrete is the quality of aggregates.

The aggregates are available in natures of the following types:

i) Stream deposits **–** These are the most economical sources of aggregate
ii) Alluvial fans
iii) Talus accumulations
iv) Wind-blown materials

The rocks for aggregate are classified as igneous, sedimentary and metamorphic rocks. The igneous and metamorphic rocks may be more suitable than sedimentary rocks.

Field Explorations for Aggregate

Such explorations are necessary to have an insight of availability of aggregates not only in terms of quality and quantity but also the economic viability by way of accessibility of the quarry, its proximity to the site etc.

For field explorations, the following points are worth mentioning:

i) It should be remembered that ideal materials are seldom available and many deficiencies can be removed by proper processing.
ii) Interpretations based on surface observations are greatly aided by an understanding of the geological conditions and processes governing the phenomenon.
iii) Selective quarrying can avoid use of objectionable parts of the deposit.
iv) Accessibility, proximity to the site and the workability of a deposit are essential considerations in evaluating its suitability.
v) The quantity of aggregate, which a deposit may yield, has to be roughly estimated and compared with the probable requirements plus allowance for wastage.
vi) Foe reconnaissance and preliminary explorations, areas may be estimated roughly by pacing. Depth and grading of the material may be judged by examining the banks of channels or other exposures.
vii) Except for an estimated deduction for waste, it may generally be assumed that a cubic metre of material in-place will produce aggregate for a cubic metre of concrete.
viii) The quantity of material likely to be available from a rock quarry has to be estimated in consultation with an Engineering Geologist.
ix) Samples from undeveloped rock formations should be typical of the deposit and cover significant variations of rock type. Outer weathered portions should be avoided and virgin rock samples should be obtained by blasting, trenching or core drilling.

The following information relative to each promising deposit investigated should be collected and reported:

- Location
- Ownership
- Type of deposit, character of topography and description of vegetation
- Rough estimated volume, average depth of deposit, average overburden and ground water table with seasonal fluctuations
- Approximate percentage of coarse and fine aggregate
- Access to the deposit
- Service history of concrete made with the aggregates, if any

The chemical suitability of aggregates in concrete has to be assessed in terms of deleterious materials such as alkali silica reactive materials, organic impurities and chemical salts, all of which may jeopardize the durability of concrete, which incorporate aggregates that contain the above beyond permissible limits.

DEVELOPMENT OF QUARRY FOR AGGREGATES

Each year millions of tonnes of aggregate are mined from literally hundreds of pits and quarry locations across India. Virtually everything we build requires aggregate materials, either as an engineered soil base for stability or in the form of concrete for buildings, roads or hydraulic structures. Aggregate is used both in and under our roads, highways, streets, sidewalks, airports, railways, parking lots, sewers, foundations and in the buildings themselves. Other specialty uses include pre-cast concrete products, filtration in septic fields, backfill in underground mines, armoring 'rip-rap' which prevents erosion on shorelines and water courses. In spite of the enormous technological strides over the last century, there are still no economically viable substitutes for aggregate in the construction industry. Aggregate is a critical resource for the country, as important as water and electricity.

Aggregate consists of sorted sand, gravel and crushed stone material value largely for their physical strength characteristics when various size fractions are blended. This commodity is only available from two broad types of geologic formation.

The main source of aggregate is from outcrops of bed rock or locations where the underlying bed rock is relatively close to the surface. The rock is drilled and blasted in 'quarries' and then crushed down to a usual size. Due to the added cost of such processing, quarries are a more expansive source of aggregate than a typical gravel pit. The cost of stripping off an unconsolidated soil overlying the bed rock (called over burden) will also be a determining factor establishing the economic viability of a local bedrock location for mining purposes.

The other main source of aggregate is the gravel pits. Thousands of gravel pits have been established along the river courses. The aggregate can be readily excavated near the surface, usually by front-end loaders. Often the material is processed at the mine site by crushing any larger sized rocks and screening different particle sizes to blend a mixture with optimum support strength, or to meet a specific purpose such as concrete.

Large volumes of aggregate are required whenever we build something in India, whether it is a railway, a highway, a hydraulic structures or a city. Further more, due to the high cost of transportation, the source of aggregate is needed as close as possible to the construction site. Aggregate is characterized as a high bulk, low value commodity. The cost of transportation often exceeds the in-situ value of the mineral itself.

The primary detriment on the location of aggregate mining activity is the availability of suitable geologic sources, either as a river deposit or as near-surface bedrock outcrops. In some parts of the country, the geology is rich with such features however, in other regions there are no such local sources and aggregate must be transported at great cost to meet local construction needs.

The specific nature of the material in a mineral deposit will also affect the pattern of use. In some locations a broad spectrum of particle sizes can be found, from fine sands to coarse stone, meeting the specification for a wide range of aggregate products from concrete to river surfacing.

SOCIAL AND ENVIRONMENTAL IMPACTS

One of the major dilemmas of the quarry or mining for aggregate arises from the economic pressure to aggregate sources as close to the site/market/population as possible. Environmental standards governing the operation of pits and quarries are set out by regulation under **The Mines and Minerals Act**. The conservation of various high quality-sources of aggregate is also established as a **National or State Land Use Policy** under the planning act.

ESTIMATION OF QUANTITY

Alluvial Pits

Quantitative estimation of the sand and gravel reserves available in a given mine can be made using the data collected. The use of a mineral area can be calculated if its area extent and average thickness are known or can be estimated.

Quantity = Area x Thickness x Density

Given the area still available to be mined, as of the date of study, the same method can be used to estimate the remaining reserves. It is important to not that there quantities are only estimates. Furthermore, these values do not take into the effects of technological constraints (slope requirements, drainage etc.) and the amount of waste generated. However, to consider the technological constraints whenever they existed, the area of the actual excavation has been used in the calculation. Also silt and clay have been assumed to be the waste and have been calculated using published sieve analysis data. Whenever sieve data is not available from the considered site, it can be assumed that 80% of the total material is useable while the remaining 20% is waste.

Rock Quarries

The estimation of the original and remaining reserves is a more complicated process for a quarry site. These vary greatly with the material in question and the design of the mine itself. Whenever, the needed figures are not readily available, it can be calculated using the graphical method.

Whenever an estimate of the waste material in a quarry is not documented, it can be assumed that the percentage of waste generated by quarrying varies between 0% and 25% depending upon the physical and chemical characteristics of the material. The remaining percentage is useable as crushed stone.

Sieve Analysis Data

For most uses, consumers of rock products prefer either sand and gravel or crushed stone. These preferences stem from differences between the two commodities in their physical properties or in their price. Rigid specifications regarding hardness, particle size gradation, shape and certain chemical properties are imposed on the rock materials for much concrete construction and road building.

Quality - Specifications

Rarely is aggregate raw material at the pit or quarry site, even from the highest grade deposits; physically or chemically suited for every type of aggregate use. Therefore, every potential deposit must be tested to determine how large an area of its various components can meet the specifications for a particular type of use and what processing is required. This requires large quantities of information.

Gravel Deposits

The physical and chemical characteristics of gravel are dependent upon the age of the deposit, which also determines their topographic location. The highest quality gravel is the youngest; the least altered (soundest), the least cemented and contains the least amount of calcium carbonate in the form of interstitial caliche. These are the gravel deposits of the flood plains and the lower terraces of the major streams and their tributaries. They are source of the best quality gravel for concrete aggregate and rock material.

The moderate quality-gravel deposits, being older and more weathered, contain an abundance of unsound stones and much calcium carbonate. These are the gravel deposits of pediments (mesa tops) and upland tertiary remnants in the mountains. They are generally of poor quality for a concrete aggregate; locally useful as a source of road or sub-grade material. They are cobbly and bouldery near the mountains and pebbly to sand farther. Cemented gravel or conglomerate can be considered in this category.

Bed Rock Deposits

Bed rock derived crushed stone can be classified, in terms of their quality, as good or moderate. Good quality crushed stone may be obtained from fine grained or coarse grained igneous rocks, while moderate quality aggregate is derived from metamorphic rocks or quartzite. The fine grained igneous rocks are best suited as a source of crushed rock for road material and building stone. Its suitability for concrete aggregate may be diminished by reactive constituents. Coarse grained igneous rocks crop out widely in the mountains and are a potential source of high quality crushed rock aggregate. Moderate quality crushed stone is derived from metamorphic rocks. Foliated metamorphic rocks are generally not as good as a source of crushed rock aggregate as the igneous rocks, but some of the more gneissic rocks have been so utilized. Quartzite is also classified as a potential source of high quality crushed rock aggregate.

TESTS FOR AGGREGATE

Several tests are conducted on aggregates to assess their suitability for use in concrete.

Following are some important tests conducted on aggregates to test their suitability for concrete:

- Sieve Analysis
- Flakiness Index
- Elongation Index
- Angularity Number
- Silt and Clay Content
- Organic Impurities
- Soft Particles
- Specific Gravity
- Water Absorption
- Bulk Density
- Voids
- Bulking of Sand
- Surface Moisture in FA
- Aggregate Crushing Value
- Aggregate Impact Value
- Aggregate Abrasion Value
- Soundness
- Alkali Aggregate Reactivity
- Petrographic Examination

Sieve Analysis

This is one of the tests for determination of particle size of aggregate. Sieving successively through the sieves assesses grading pattern of a sample of coarse and fine aggregates.

Flakiness Index

The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. This test is not applicable to sizes smaller than 6.3 mm.

The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.

Elongation Index

The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension. The elongation index is not applicable to sizes smaller than 6.3 mm.

The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged.

Angularity Number

One of the methods of expressing the angularity qualitatively is by a figure called Angularity Number, as suggested by Shergold. This is based on the percentage voids in the aggregate after compaction in a specified manner. The test gives a value termed the angularity number.

Silt and Clay Content

The silt and clay in fine aggregate is determined by gravimetric method.

Organic Impurities

The test is an approximate method for estimating whether organic compounds are present in the natural sand in an objectionable quantity or within the permissible limit.

Specific Gravity, Density, Voids, Absorption, Bulking and Surface Moisture in Fine Aggregate

The IS: 2386 (Part III)-1963 covers the methods of testing for above properties.

Aggregate Crushing Value

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. With aggregates of aggregate crushing value 30 of higher, the result may be anomalous and in such cases the **ten percent fines value** should be determined and used instead.

The aggregate crushing value should not be more than 45% for aggregate used for concrete other than for wearing surfaces and 30% for concrete used for wearing surfaces such as spillways, runways, roads and air field pavements.

Aggregate Impact Value

The aggregate impact value gives relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load.

The aggregate impact value should not be more than 45% for aggregate used for concrete other than for wearing surfaces and 30% for concrete used for wearing surfaces such as spillways, runways, roads and air field pavements.

Aggregate Abrasion Value

The aggregate abrasion value gives relative measure of the resistance of an aggregate to the abrasive charges. Two methods have been defined in IS: 2386 (Part IV)-1963 namely Deval abrasion testing machine and Los Angeles abrasion testing machine. However, the use of Los Angeles abrasion testing machine gives better realistic picture of the abrasion resistance of the aggregate.

Soundness

Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical condition. These physical conditions that affect the soundness of aggregate are the freezing and thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water. The aggregate, which are porous, weak and containing any undesirable extraneous matters undergo excessive volume change when subjected to the above conditions. Aggregate, which undergo more than the specified amount of volume change is said to be unsound aggregate. If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test.

Alkali Aggregate Reactivity

Alkali aggregate reactions occur between certain aggregate types and the alkali in the pore solutions of the cement paste in concrete to form a silica gel or carbonate reaction products. In the presence of free moisture, the gel will expand and manifest in cracking and differential movements in structures as well as other deleterious effects such as reduction in freeze-thaw durability and compressive and tensile strength.

Three forms of Alkali aggregate reaction generally affect hydroelectric structures:

- The alkali silica reaction ASR
- The alkali silicate/silica reaction ASSR
- The alkali carbonate reaction ACR

Petrographic Examination

Petrographic examination is the method to analyse microscopically the mineralogical composition, grain size, texture and strains. Durability of rock is dependent on the mineralogy and microscopic fabric (petrography) of the rock.

CEMENT

Cement is the glue in the most widely used composite material i.e. concrete. The cement is a dry power composed of compounds of silica, alumina, lime and iron oxide, which forms a hardened paste when mixed with water; it generally is used as a binder with aggregate to form mortar or concrete, but also may be used in its paste form as a structural material.

The following field studies are required to assess the techno-economic viability of cement:

a) Identification of factories located within reasonable distance from the project site
b) Types and quality of cements manufactured in these factories. Also the quality of materials such as limestone, calcined clay, pozzolana, flyash etc. used in manufacture
c) Output of these factories vis-à-vis requirement as per construction programme

Some cement, which suit special requirements of use or otherwise are meant for general concrete construction are as follows:

- Ordinary Portland Cement
- Rapid Hardening Portland Cement
- Extra Rapid Hardening Portland Cement
- Sulphate Resisting cement
- Granulated Blast Furnace Slag Cement
- Quick Setting Cement
- Super Sulphate Cement
- Low Heat Portland Cement
- Portland Pozzolana Cement
- Air Entraining Cement
- Hydrophobic Cement
- Masonry Cement
- Expansive Cement
- Oil Well Cement
- High Strength Ordinary Portland Cement
- Rediset Cement
- High Alumina Cement (Not used now except in refractories)

TESTS ON CEMENT

The following tests are conducted on cement to assess its suitability for use in concrete:

- Fineness
- Normal Consistency
- Setting Time (Initial and final)
- False Set
- Compressive Strength
- Heat of Hydration
- Specific Gravity

- Drying Shrinkage
- Air Content of Hydraulic Cement Mortar
- Soundness
- Los on ignition
- Chemical Composition

POZZOLANA

Factors governing selection of pozzolanic source:

- Distance from dam site
- Quality of material
- Availability of the requisite quantity as per construction programme
- Transport facilities
- Economy

Advantages of Pozzolana

Use of pozzolana in concrete results in:

- Improvement in workability
- Economy
- Protection against alkali aggregate reaction
- Reduction in heat generation, thermal volume change etc
- Reduction in bleeding
- Reduction in permeability
- Manufacture of ultra-high strength concrete using silica fume and superplasticiser

Classification of Pozzolana

The pozzolana is classified into the following classes:

a) Clays & shakes (Calcinations required)
   Example: Bhakra Dam – Calcined shale
b) Opaline materials (calcinations may or may not be required)
   Example: Diatomaceous earth, Opaline cherts & shales
c) Volcanic tuffs & pumicites (Calcinations may or may not be required)
d) Industrial Byproducts
   Example: Blast furnace slag, Flyash, Silica fume
   Rihand Dam – Flyash from Bokaro Thermal Plant

TESTS FOR POZZOLANA

Following tests are conducted on pozzolanic materials as per IS: 1727-1967 (Method of Test for Pozzolanic Materials) (First Revision) to assess their suitability:

- Chemical Analysis
- Fineness
- Soundness
- Setting Time
- Standard Consistency
- Lime Reactivity
- Compressive Strength
- Transverse Strength
- Drying shrinkage
- Permeability
- Specific Gravity and
- Moisture Content

WATER

Water is an important ingredient used in construction activity. The essential prospecting required to be done in case of water relates to assessing the quality and sufficient availability as per project requirements. Normally water that is potable is considered satisfactory for construction purpose. The water shall be clean and free from injurious amounts of oil, acid, alkali, salt, sugar, organic, inorganic, suspended matter and other substances which are deleterious to concrete or steel.

Tests normally conducted on water to assess its suitability for construction purpose are:

- pH value
- Inorganic and organic impurities
- Chemical composition
- Silt and suspended particles

ADMIXTURES

The admixtures are used in concrete to improve certain properties as per requirements of work. The admixtures are of the following types:

- Air entraining
- Accelerator
- Retarder
- Water reducing

The prospecting required to be done for admixtures based on the requirements of work or properties to be improved upon will be as follows:

- Trade name, source and the manufacturer's recommended method of use
- Typical dosage rates and possible detrimental effects of under and over-dosage
- Presence of water soluble chlorides and sulphates so as to judge likely corrosion of reinforcement or deterioration of concrete
- The average expected air content when the admixture is sued at the manufacturer's recommended rate of dosage

Prior to its actual use in concrete, the effectiveness of admixtures should be ensured by carrying out a pre-construction exercise by verifying that concrete made with admixtures when compared with identical concrete made without admixture does manifest improved physical properties as per requirements.

The admixtures will be specified as per Indian Standard IS: 9103-1979 Specification for Admixtures for Concrete.

The admixtures will be tested for:

- Product uniformity
- Performance in concrete

Tests normally conducted for product uniformity of an admixture are:

- Density
- Colour
- PH Value
- Chlorides
- Dissolved solids, and
- Suspended matter

For assessing the performance of admixture in concrete, the tests conducted are unit weight, water content, air content, setting time, bleeding, workability, strength development, volume change and durability.

REINFORCEMENT

The reinforcement in concrete may be any of the following types depending upon requirements:

- Mild Steel Bars
- Medium Tensile Steel Bars

- Hard Drawn Steel Wire
- High Strength deformed Steel Bars and Wires
- Hard Drawn Steel Wire Fabric

Tests normally conducted to assess the quality of rebar are:

- Ultimate Tensile Stress
- Yield Stress
- Proof Stress
- Percent Elongation
- Bend Test

RECENT MATERIALS DEVELOPMENTS

Research and development for new materials and improvements in existing materials are of vital importance to our Nation's infrastructure, yet Indian efforts lag far behind needs. A brief description of some of more recent developments in R&D for cement and concrete, asphalt, plastics and other synthetics follows. Potential economic and performance benefits of using these new and improved materials could not be quantified within the scope of this lecture note.

1. **Blended Cements**

Blended cements, which have been introduced within the last decade, combine Portland cements with one or more different types of byproducts, such as blast furnace slag, flyash, silica fume, etc. The addition of these particulate to portland cement can enhance its strength and increase the durability of steel containing cement composites used in dams, bridges, highways, etc. Use of these materials, however, depends on local availability.

2. **Fiber-Reinforced Concrete**

Fiber-reinforced concrete is concrete made of hydraulic cements containing fine, or fine and coarse aggregate and discontinuous discrete fibers. Some of the fibers used to reinforce concrete include steel, glass, carbon, nylon, polyethylene and polypropylene, etc. Fiber-reinforced concrete has the potential to improve the strength and durability of dams, bridges, pavements and buildings. Also, fiber-reinforced concrete has been used to stabilize rock slopes, armor jetties and line mine tunnels.

3. **Polymer Concrete**

Polymer concrete is a composite material formed by incorporating a polymer as a binder in a mixture of fine and coarse aggregate; no other cement is used. Many different polymers can be used, such as acrylics, polyesters, vinyl esters, polyurethane, styrene-butadiene, polyvinyl acetate and epoxy resin, etc. Current polymer concrete uses include patching and reconstruction of concrete structures, rehabilitation of pre-cast panels on bridges and application of thin waterproof and salt proof overlays on roads. One of the main advantages of using polymer concrete is that traffic is disrupted for shorter periods of time during construction.

4. Roller Compacted Concrete

Roller compacted concrete (RCC) requires less cement and lower quality aggregates than conventional concrete. Compaction is used to reduce pore space, thereby decreasing permeability and enhancing durability. The in-place cost of RCC is about one-third lower than that of conventional concrete. Roller compacted concrete is suitable for dams and pavements. The RCC pavement takes less time to spread than conventional concrete.

5. Corrosion

The deterioration of steel reinforced concrete bridge decks and structural steel members is a serious national problem. A major cause of the concrete is the corrosion of embedded black steel reinforcing bars by chloride ions that permeate the concrete cover. These chloride ions are derived from de-icing salts applied directly to the bridge decks or from marine environments.

New construction provides the best opportunity to [protect bridges and other structures against corrosion. These include epoxy-coated rebar, corrosion inhibitors incorporated in the steel and concrete coatings such as epoxies, polymer overlays and sealers. Epoxy-coated rebar are the most effective bridge corrosion protection, followed by corrosion inhibitors and coatings.

ANNEXURE

The relevant Indian Standards for aggregates are:

a) IS: 383-1970 Specification for Coarse and Fine Aggregates from Natural Sources for Concrete (Second Revision)
b) IS: 2430-1986 Methods for Sampling of Aggregates for Concrete (First Revision)
c) IS: 2386-1963 (Parts I to VIII) Methods of Test for Aggregates for Concrete

The relevant Indian Standards for stones are:

a) IS: 1121-1974 (Part I) Methods of test for determination of strength properties of natural building stones. Part I Compressive strength (First Revision) with amendment no. 1)
b) IS: 1121-1974 (Part II) Methods of test for determination of strength properties of natural building stones. Part II Transverse strength (First Revision)
c) IS: 1121-1974 (Part III) Methods of test for determination of strength properties of natural building stones. Part III Tensile strength (First Revision)
d) IS: 1121-1974 (Part IV) Methods of test for determination of strength properties of natural building stones. Part IV Shear strength (First Revision)
e) IS: 1122-1974 Methods of test for determination of true specific gravity of natural building stones (First Revision)
f) IS: 1124-1974 Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones (First Revision)
g) IS: 1125-1974 Method of test for determination of weathering of natural building stones (First Revision)
h) IS: 1126-1974 Method of test for determination of durability of natural building stones (First Revision)
i) IS: 1706-1972 Methods for determination of resistance to wear by abrasion of natural building stones (First Revision)
j) IS: 1127-1970 Recommendations for dimension and workmanship of natural building stones for masonry work (First Revision)
k) IS: 1706-1972 Methods for determination of resistance to wear by abrasion of natural building stones (First Revision)
l) IS: 4121-1967 Method of test for determination of water transmission rate by capillary action through natural building stones
m) IS: 4122-1967 Method of test for surface softening of natural building stones by exposure to acidic atmosphere.
n) IS: 4348-1973 Methods of test for determination of permeability of natural building stones (First Revision)
o) IS: 5218-1969 Method of test for toughness of natural building stones

The specifications of important cements are covered in the following Indian Standards:

a) IS: 269-1989 Specification for Ordinary Portland Cement 33 Grade (Fourth Revision)

b) IS: 455-1976 Specification for Portland Slag Cement (Third Revision) with amendments no. 1 to 5
c) IS: 1489-1976 Specification for Portland Pozzolana Cement (Second Revision)
d) IS: 8041-1978 Specification for Rapid Hardening Portland Cement (First Revision) with amendments no. 1 & 2
e) IS: 8112-1976 Specification for High Strength Ordinary Portland Cement (with amendments no. 1 to 4)
f) IS: 12600-1989 Specification for Low Heat Portland Cement

The methods of sampling, physical tests and chemical analysis of cements are covered in the following Indian Standards:

a) IS: 3535-1986 Methods of Sampling Hydraulic Cements (First Revision)
b) IS: 4031-1988 (Parts I to XIII) Methods of Physical Tests for Hydraulic Cement
c) IS: 4032-1985 Method of Chemical Analysis of Hydraulic Cement (First Revision)

The relevant Indian Standards for specification of flayash and calcined clay pozzolana are:

a) IS: 1344-1981 Specification for Calcined Clay Pozzolana (Second Revision)
b) IS: 3812-1981 Specification for Flyash for use as Pozzolana and Admixtures (First Revision)
c) IS: 6491-1972 Methods of Sampling Flyash

The sampling of water and conducting of physical and chemical tests will be as per the following Indian Standards:

a) IS: 456-2000 Code of Practice for Plain and Reinforced Concrete
b) IS: 3025 (Parts 3 to 24 & 26 to 28) Methods of Sampling and Test (Physical and Chemical) for Water and Waste Water

The steel bars are specified according to Indian Standards:

a) IS: 432 –1982 (Part I) Indian Standard Specification for Mild Steel and Medium Tensile Steel Bars and Hard Drawn Steel Wire for Concrete Reinforcement: Part 1 Mild Steel and Medium Tensile Steel Bars (Third Revision)
b) IS: 432 –1982 (Part II) Indian Standard Specification for Mild Steel and Medium Tensile Steel Bars and Hard Drawn Steel Wire for Concrete Reinforcement: Part 2 Hard Drawn Steel Wires (Third Revision)
c) IS: 1139–1996 Indian Standard Specification for Hot Rolled Mild Steel and Medium Tensile Steel Deformed Bars for Concrete Reinforcement
d) IS: 1566 –1982 Indian Standard Specification for Hard Drawn Steel Wire Fabric for Concrete Reinforcement (Second Revision)
e) IS: 1786–1985 Indian Standard Specification for High Strength Deformed Steel Bars and Wires for Concrete Reinforcement (Third Revision)